Science, Service, Stewardship

2022 5-Year Review: Summary & Evaluation of Snake River Spring/Summer Chinook Salmon

National Marine Fisheries Service
West Coast Region

5-Year Review: Snake River Spring/Summer Chinook Salmon

Species Reviewed	Evolutionarily Significant Unit or Distinct Population Segment
Chinook Salmon (*O. tshawytscha*)	*Snake River Spring/Summer Chinook Salmon*

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1. General Information

1.1 Introduction

Many West Coast salmon and steelhead (*Oncorhynchus sp.*) stocks have declined substantially from their historic numbers and now are at a fraction of their historical abundance. Several factors contributed to these declines, including overfishing, loss of freshwater and estuarine habitat, hydropower development, poor ocean conditions, and hatchery practices. These factors collectively led to the National Marine Fisheries Service's (NMFS) listing of 28 salmon and steelhead stocks in California, Idaho, Oregon, and Washington under the Federal Endangered Species Act (ESA).

The ESA, under section 4(c)(2), directs the Secretary of Commerce to review the listing classification of threatened and endangered species at least once every five years. A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12; 50 CFR 223.102, 224.101) is accurate (USFWS and NMFS 2006; NMFS 2020c). After completing this review, the Secretary must determine if any species should be: (1) removed from the list; (2) have its status changed from endangered to threatened; or (3) have its status changed from threatened to endangered. If, in the 5-year review, a change in classification is recommended, the recommended change will be further considered in a separate rule-making process. The most recent 5-year review analysis for West Coast salmon and steelhead occurred in 2016. This document describes the results of the 2022 5-year review for ESA-listed Snake River (SR) spring/summer Chinook salmon.

A 5-year review is:

- A summary and analysis of available information on a given species;
- The tracking of a species' progress toward recovery;
- The recording of the deliberative process used to make a recommendation on whether or not to reclassify a species; and
- A recommendation on whether reclassification of the species is indicated.

A 5-year review is not:

- A re-listing or justification of the original (or any subsequent) listing action;
- A process that requires acceleration of ongoing or planned surveys, research, or modeling;
- A petition process; or
- A rulemaking.

1.1.1 Background on Salmonid Listing Determinations

The ESA defines species to include subspecies and distinct population segments (DPS) of vertebrate species. A species may be listed as threatened or endangered. To identify taxonomically recognized species of Pacific salmon, we apply the "Policy on Applying the Definition of Species under the ESA to Pacific Salmon" (56 FR 58612). Under this policy, we identify population groups that are "evolutionarily significant units" (ESUs) within taxonomically recognized species. We consider a group of populations to be an ESU if it is substantially reproductively isolated from other populations within the taxonomically recognized species and represents an important component in the evolutionary legacy of the biological species. We consider an ESU as constituting a DPS and therefore a "species" under the ESA.

Artificial propagation programs (hatcheries) are common throughout the range of ESA-listed West Coast salmon and steelhead. Before 2005, our policy was to include in the listed ESU or DPS only those hatchery fish deemed "essential for conservation" of a species. We revised that approach in response to a court decision. On June 28, 2005, we announced a final policy addressing the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204, Hatchery Listing Policy).[1] This policy establishes criteria for including hatchery stocks in ESUs and DPSs. In addition, it: (1) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (2) requires that hatchery fish determined to be part of an ESU or DPS be included in any listing of the ESU or DPS; (3) affirms our commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (4) affirms our commitment to fulfilling trust and treaty obligations regarding the harvest of Pacific salmon and steelhead populations, consistent with the conservation and recovery of listed salmon ESUs and steelhead DPSs.

To determine whether a hatchery program is part of an ESU or DPS and therefore must be included in the listing, we consider the origins of the hatchery stock, where the hatchery fish are released, and the extent to which the hatchery stock has diverged genetically from the donor stock. We include within the ESU or DPS (and therefore within the listing) hatchery fish derived from the population in the area where they are released, and that are no more than moderately diverged from the local population.

Because the new Hatchery Listing Policy changed the way we considered hatchery fish in ESA listing determinations, we completed new status reviews and ESA listing determinations for West Coast salmon ESUs on June 28, 2005 (70 FR 37159) and for steelhead DPSs on January 5, 2006 (71 FR 834). We then reevaluated ESU and DPS status at 5-year intervals. On August 15, 2011, we published our 5-year reviews and listing determinations for 11 ESUs of Pacific salmon and 6 DPSs of steelhead from the Pacific Northwest (76 FR 50448). On May 26, 2016, we

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[1] Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead.

published our 5-year reviews and listing determinations for 17 ESUs of Pacific salmon, 10 DPSs of steelhead, and the southern DPS of eulachon *(Thaleichthys pacificus*) (81 FR 33468), including reaffirming the threatened status for SR spring/summer Chinook salmon.

1.2 Methodology Used to Complete the Review

On October 4, 2019, we announced the initiation of 5-year reviews for the 17 ESUs of salmon and 11 DPSs of steelhead in Oregon, California, Idaho, and Washington (84 FR 53117). We requested that the public submit new information on these species that has become available since our 2015-2016 5-year reviews. In response to our request, we received information from federal and state agencies, Native American Tribes (Tribes), conservation groups, fishing groups, and individuals. We considered this information and other information routinely collected by our agency during the review process.

To complete the reviews, we first asked scientists from our Northwest and Southwest Fisheries Science Centers to collect and analyze new information about ESU and DPS viability. Our scientists used the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000) to evaluate viability. The VSP concept evaluates four criteria – abundance, productivity, spatial structure, and diversity – to assess species viability. Through the application of this concept, the Science Center considered new information on the four salmon and steelhead population viability criteria. They also considered new information on ESU and DPS composition. At the end of this process, the science teams prepared reports detailing the results of their analyses (Ford 2022).

To further inform the reviews, we asked salmon management biologists from our West Coast Region familiar with hatchery programs to consider new information available since the previous listing determinations. Among other things, they looked at hatchery programs that have ended, new hatchery programs that have started, changes in the operation of existing programs, and scientific data relevant to the degree of divergence of hatchery fish from naturally spawning fish in the same area. We also consulted salmon management biologists from the West Coast Region who are familiar with habitat conditions, hydropower operations, and harvest management. These biologists identified relevant information and provided their insights on the degree to which circumstances have changed for each listed entity. Finally, we solicited information on tributary habitat conditions and limiting factors from geographically based salmon conservation partners from federal agencies, state agencies, Tribes, and non-governmental organizations.

We considered all relevant information in preparing this report. Our sources include the work of the Northwest Fisheries Science Center (Ford 2022); the reports of the regional biologists regarding hatchery programs; recovery plans for the species in question; technical reports prepared in support of recovery plans for the species in question; listing records (including the designation of critical habitat and adoption of protective regulations); recent biological opinions issued for SR spring/summer Chinook salmon; information submitted by the public and other government agencies; and the information and views provided by geographically based salmon conservation partners. The present report describes the agency's findings based on all of the information considered.

1.3 Background – Summary of Previous Reviews, Statutory and Regulatory Actions, and Recovery Planning

1.3.1 Federal Register Notice announcing initiation of this review

84 FR 53117; October 4, 2019.

1.3.2 Listing history

In 1992, NMFS listed SR spring/summer Chinook salmon as threatened (Table 1).

Table 1. Summary of the listing history under the Endangered Species Act for the SR spring/summer Chinook salmon.

Salmonid Species	ESU/DPS Name	Original Listing	Revised Listing(s)
Chinook Salmon (*O. tshawytscha*)	Snake River Spring/Summer Chinook Salmon	**FR Notice:** 57 FR 58619 **Date:** 4/22/1992 **Classification:** Threatened	**FR Notice:** 70 FR 37159 **Date:** 6/28/2005 **Classification:** Threatened

1.3.3 Associated rulemakings

The ESA requires NMFS to designate critical habitat, to the maximum extent prudent and determinable, for species it lists under the ESA. Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, that contain physical or biological features essential to conservation, that may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time of listing that are essential for the conservation of the species. We designated critical habitat for SR spring/summer Chinook salmon in 1993.

Section 9 of the ESA prohibits the take of species listed as endangered. The ESA defines take to mean harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. For threatened species, the ESA does not automatically prohibit take. Instead, it authorizes the agency to adopt regulations it deems necessary and advisable for species conservation and to apply the take prohibitions of section 9(a)(1) through ESA section 4(d). In 2000, NMFS adopted 4(d) regulations for threatened salmonids that prohibit take except in specific circumstances. On July 10, 2000, we applied these 4(d) regulations to SR spring/summer Chinook salmon (65 FR 42422).

Table 2. Summary of rulemaking for 4(d) protective regulations and critical habitat for SR spring/summer Chinook salmon.

Salmonid Species	ESU/DPS Name	4(d) Protective Regulations	Critical Habitat Designations
Chinook Salmon (*O. tshawytscha*)	Snake River Spring/Summer Chinook Salmon	**FR Notice:** 65 FR 42421 **Date:** 7/10/2000 **Revised**: 6/28/2005 (70 FR 37159)	**FR notice:** 58 FR 68543 **Date:** 12/28/1993 **Revised:** 10/25/1999 (64 FR 57399)

1.3.4 Review History

Table 3 lists the numerous scientific assessments of the status of the SR spring/summer Chinook salmon ESU. These assessments include status reviews conducted by our Northwest Fisheries Science Center and technical reports prepared to support recovery planning for these species.

Table 3. Summary of previous scientific assessments for SR spring/summer Chinook salmon.

Salmonid Species	ESU/DPS Name	Document Citation
Chinook Salmon (*O. tshawytscha*)	Snake River Spring/Summer Chinook Salmon	Ford 2022 NMFS 2016a NWFSC 2015 Ford et al. 2011 ICTRT 2007 ICTRT and Zabel 2007 Good et al. 2005 McClure et al. 2005 ICTRT 2003 Myers et al. 1998

1.3.5 Species' Recovery Priority Number at Start of 5-year Review Process

On April 30, 2019, NMFS issued new guidelines (84 FR 18243) for assigning listing and recovery priorities. Under these guidelines, we assign each species a recovery priority number ranging from 1 (high) to 11 (low). This priority number reflects the species' demographic risk (based on the listing status and species' condition in terms of its productivity, spatial distribution, diversity, abundance, and trends) and recovery potential (major threats understood, management actions exist under United States (U.S.) authority or influence to abate major threats, and certainty that actions will be effective). Additionally, if the listed species is in conflict with construction or other development projects or other forms of economic activity, then they are assigned a ‘C’ and are given a higher priority over those species that are not in conflict. Table 4 lists the recovery priority number for the SR spring/summer Chinook salmon ESU that was in effect at the time this 5-year review began (NMFS 2019b). In January 2022, NMFS issued a new report with updated recovery priority numbers. The number for SR spring/summer Chinook salmon ESU remained unchanged (NMFS 2022).

1.3.6 Recovery Plan or Outline

Table 4. Recovery Priority Number (NMFS 2019b) and Endangered Species Act Recovery Plan for SR spring/summer Chinook salmon.

Salmonid Species	ESU/DPS Name	Recovery Priority Number	Recovery Plan
Chinook Salmon (*O. tshawytscha)*	Snake River Spring/ Summer Chinook Salmon	**3C**	Title: ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon (Oncorhynchus tshawytscha) and Snake River Basin Steelhead (Oncorhynchus mykiss) https://www.fisheries.noaa.gov/resource/document/recovery-plan-snake-river-spring-summer-chinook-salmon-and-snake-river-basin **Date:** 11/30/2017 **Type:** Final

2. Review Analysis

This section reviews new information to determine whether the SR spring/summer Chinook salmon delineation remains appropriate.

2.1 Delineation of Species under the Endangered Species Act

Is the species under review a vertebrate?

ESU/DPS Name	YES	NO
Snake River Spring/Summer Chinook Salmon	X	

Is the species under review listed as an ESU/DPS?

ESU/DPS Name	YES	NO
Snake River Spring/Summer Chinook Salmon	X	

Was the ESU/DPS listed prior to 1996?

ESU/DPS Name	YES	NO	Date Listed if Prior to 1996
Snake River Spring/Summer Chinook Salmon	X		4/22/1992

Before this 5-year review, was the ESU/DPS classification reviewed to ensure it meets the 1996 ESU/DPS policy standards?

In 1991, NMFS issued a policy explaining how the agency would apply the definition of “species” in evaluating Pacific salmon stocks for listing consideration under the Endangered Species Act (ESA) (56 FR 58612). Under this policy, a group of Pacific salmon populations is considered a “species” under the ESA if it represents an “evolutionarily significant unit” (ESU) that is: (1) substantially reproductively isolated from other con-specific populations; and (2) represents an important component in the evolutionary legacy of the biological species. The 1996 joint NMFS-Fish and Wildlife Service (FWS) “distinct population segment” (DPS) policy (61 FR 4722) affirmed that a stock (or stocks) of Pacific salmon is considered a DPS if it represents an ESU of a biological species.

2.1.1 Summary of relevant new information regarding the delineation of the SR spring/summer Chinook Salmon ESU

ESU Delineation

This section summarizes information presented in Ford 2022: *Biological viability assessment update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest.*

We found no new information that would justify a change in the delineation of the Snake River spring/summer Chinook salmon ESU (Ford 2022).

Membership of Hatchery Programs

For West Coast salmon and steelhead, many of the ESU and DPS descriptions include fish originating from specific artificial propagation programs (e.g., hatcheries) that, along with their naturally produced counterparts, are included as part of the listed species. NMFS' Hatchery Listing Policy (70 FR 37204) guides our analysis of whether individual hatchery programs should be included as part of the listed species. The Hatchery Listing Policy states that hatchery programs will be considered part of an ESU/DPS if they exhibit a level of genetic divergence relative to the local natural population(s) that is not more than what occurs within the ESU/DPS.

In preparing this report, our hatchery management biologists reviewed the best available information regarding the hatchery membership of this ESU. They considered changes in hatchery programs that occurred since the last 5-year review (e.g., some have been terminated while others are new) and made recommendations about the inclusion or exclusion of specific programs. They also noted any errors and omissions in the existing descriptions of hatchery program membership. NMFS intends to address any needed changes and corrections via separate rulemaking subsequent to the completion of the 5-year review process and before any official change in hatchery membership.

In the 2016 5-year review, we defined the SR spring/summer Chinook salmon ESU as including all naturally spawned populations of spring/summer Chinook salmon originating from the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins. It was also defined as including spring/summer Chinook salmon from 11 artificial propagation programs: the Tucannon River Program; Lostine River Program; Catherine Creek Program; Lookingglass Hatchery Program; Upper Grande Ronde Program; Imnaha River Program; Big Sheep Creek Program; McCall Hatchery Program; Johnson Creek Artificial Propagation Enhancement Program; Pahsimeroi Hatchery Program; and the Sawtooth Hatchery Program (70 FR 37159).

Since 2016, four of the hatchery programs have changed in status (85 FR 81822). We: (1) added the Yankee Fork Program to the ESU because the source for these fish is the Sawtooth Hatchery Program, which is already included in the ESU; (2) added the Dollar Creek Program because the source for these fish is the McCall Hatchery Program, which is already included in the ESU, and renamed the Dollar Creek Program as the South Fork Salmon River Eggbox Program because the existing release is now classified as a separate and distinct program; (3) added the Panther Creek Program to the ESU because the source for these fish is the Pahsimeroi Hatchery Program, which is already included in the ESU; and (4) removed the Big Sheep Creek Program from the listing as a separate program, because the Big Sheep Creek Program is now considered to be a part of the listed Imnaha River Program (85 FR 81822).

The addition or removal of an artificial propagation program from an ESU does not necessarily affect the listing status of the ESU, but rather is a revision to the ESU's composition to reflect the best available scientific information as considered under our Hatchery Listing Policy. Adding an artificial propagation program to an ESU represents our determination that the artificially propagated stock is no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the ESU (70 FR 37204). We relied on the Hatchery Listing Policy in our 2020 Final Rule on Revisions to Hatchery Programs as Part of Pacific Salmon and Steelhead Species Listed under the Endangered Species Act (85 FR 81822).

2.2 Recovery Criteria

The ESA requires that NMFS develop recovery plans for each listed species unless the Secretary finds a recovery plan would not promote the conservation of the species. Recovery plans must contain, to the maximum extent practicable, objective measurable criteria for delisting the species, site-specific management actions necessary to recover the species, and time and cost estimates for implementing the recovery plan.

Evaluating a species for potential changes in ESA listing requires an explicit analysis of population or demographic parameters (the biological criteria) and also of threats under the five ESA listing factors in ESA section 4(a)(1) (listing factor [threats] criteria). Together these make up the objective, measurable criteria required under section 4(f)(1)(B).

For Pacific salmon, Technical Recovery Teams (TRTs), appointed by NMFS, define criteria to assess biological viability for each listed species. NMFS developed criteria to assess progress toward alleviating the relevant threats (listing factor criteria).

NMFS adopts the TRT's viability criteria as the biological criteria for a recovery plan, based on the best available scientific information and other considerations as appropriate. The Snake River spring/summer Chinook salmon ESU recovery plan consists of an ESU-wide plan (NMFS 2017a) and three associated geographic management unit plans (Northeast Oregon: NMFS 2017b; Idaho: NMFS 2017c; and SE Washington: SRSRB 2011). In those plans, NMFS adopted the viability criteria metrics defined by the Interior Columbia Technical Recovery Team (ICTRT) as the biological recovery criteria for the ESU (ICTRT 2007).

Biological reviews of the species continue as the recovery plan is implemented and additional information becomes available. This information, along with new scientific analyses, can increase certainty about whether the threats have been abated, whether improvements in population biological viability have occurred for spring/summer Chinook salmon, and whether linkages between threats and changes in salmon biological viability are understood. NMFS assesses these biological recovery criteria and the delisting criteria through the adaptive management program for the recovery plan during the ESA 5-Year Review (USFWS and NMFS 2006; NMFS 2020c).

2.2.1 Approved recovery plan with objective, measurable criteria

Does the species have a final, approved recovery plan containing objective, measurable criteria?

ESU/DPS Name	YES	NO
Snake River Spring/Summer Chinook Salmon	X	

2.2.2 Adequacy of recovery criteria

Based on new information considered during this review, are the recovery criteria still appropriate?

ESU/DPS Name	YES	NO
Snake River Spring/Summer Chinook Salmon	X	

Are all of the listing factors that are relevant to the species addressed in the recovery criteria?

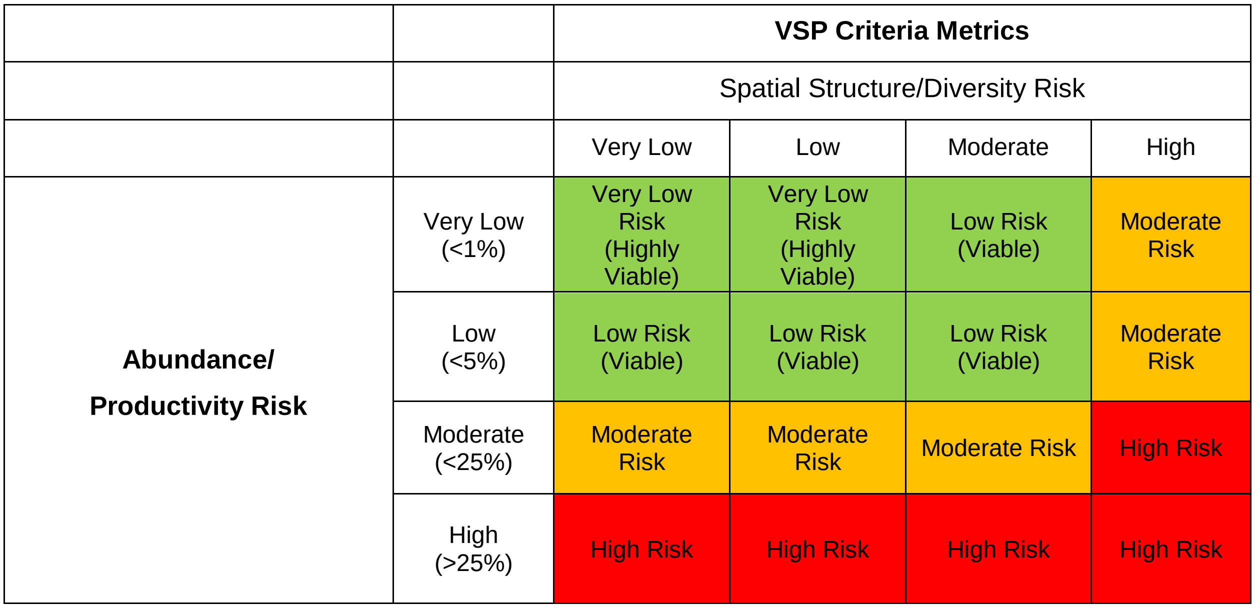
ESU/DPS Name	YES	NO
Snake River Spring/Summer Chinook Salmon	X	

2.2.3 Biological recovery criteria as they appear in the recovery plan

For the purposes of reproduction, salmon and steelhead typically exhibit a metapopulation structure (McElhany et al. 2000; Schtickzelle and Quinn 2007). Rather than interbreeding as one large aggregation, ESUs and DPSs function as a group of demographically independent populations separated by areas of unsuitable spawning habitat. For conservation and management purposes, it is important to identify the independent populations that make up an ESU or DPS.

The independent population structure and biological recovery criteria in the recovery plan for SR spring/summer Chinook salmon reflect guidance in the NMFS 2000 Technical Memorandum, NOAA NMFS-NWFSC-42, Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units (referred to as McElhany et al. 2000). McElhany et al. (2000) defined an independent population as: "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season." For our purposes, not interbreeding to a "substantial degree" means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame. Independent populations exhibit different population attributes that influence their abundance, productivity, spatial structure, and diversity. Independent populations are the units that are combined to form alternative recovery scenarios for multiple similar population groupings and ESU viability.

The viable salmonid population (VSP) concept (McElhany et al. 2000) is based on the biological parameters of abundance, productivity, spatial structure, and diversity for an independent salmonid population to have a negligible risk of extinction over a 100-year time frame. The VSP concept identifies the attributes, provides guidance for determining the conservation status of populations and larger-scale groupings of Pacific salmonids, and describes a general framework for how many and which populations within an ESU/DPS should be at a particular status for the ESU/DPS to have an acceptably low risk of extinction. The ICTRT (2007) developed combined VSP criteria metrics that describe the probability of population extinction risk in 100 years (Figure 1). NMFS color-coded the risk assessment to help readers distinguish the various risk categories.



		VSP Criteria Metrics			
		Spatial Structure/Diversity Risk			
		Very Low	Low	Moderate	High
Abundance/ Productivity Risk	Very Low (<1%)	Very Low Risk (Highly Viable)	Very Low Risk (Highly Viable)	Low Risk (Viable)	Moderate Risk
	Low (<5%)	Low Risk (Viable)	Low Risk (Viable)	Low Risk (Viable)	Moderate Risk
	Moderate (<25%)	Moderate Risk	Moderate Risk	Moderate Risk	High Risk
	High (>25%)	High Risk	High Risk	High Risk	High Risk

Figure 1. VSP Criteria Metrics.

For the purposes of recovery planning and the development of recovery criteria, the NMFS-appointed ICTRT identified independent populations for SR spring/summer Chinook salmon. then grouped them into genetically similar major population groups (MPGs) (ICTRT 2003).

The ICTRT also developed species biological viability criteria for applications at the ESU/DPS, MPG, and independent population scales (ICTRT 2007). The viability criteria are based on the VSP concept described above. Recovery scenarios outlined in the ICTRT viability criteria report (ICTRT 2007) define strategies to achieve, at a minimum, the ICTRT's biological viability criteria for each major population grouping. Accordingly, the criteria are designed "[t]o have all major population groups at viable (low risk) status with representation of all the major life history strategies present historically, and with the abundance, productivity, spatial structure, and diversity attributes required for long-term persistence." Following this guidance, recovery criteria and strategies outlined in the Snake River Spring/Summer Chinook Salmon and Steelhead Recovery Plan are targeted to achieve, at a minimum, the ICTRT biological viability criteria for each major population grouping in the ESU (SRSRB 2011; NMFS 2017a, 2017b, 2017c).

The SR spring/summer Chinook salmon ESU includes all naturally spawned populations of spring/summer Chinook salmon originating from the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins (Figure 2). The ESU includes 28 extant natural populations (plus three functionally extirpated populations and one extirpated population), which are aggregated into five MPGs based on genetic, environmental, and life-history characteristics. Historically, SR spring/summer Chinook salmon also spawned and reared in several areas that are no longer accessible, including in the Clearwater River basin and the area above Hells Canyon Dam. The following artificial propagation programs are included in the ESU; the Tucannon River Program, Lostine River Program, Catherine Creek

Program, Lookingglass Hatchery Program, Upper Grande Ronde Program, Imnaha River Program, McCall Hatchery Program, Johnson Creek Artificial Propagation Enhancement Program, Pahsimeroi Hatchery Program, Sawtooth Hatchery Program, Yankee Fork Program, South Fork Salmon River Eggbox Program, and the Panther Creek Program (85 FR 81822).

The five MPGs within the SR spring/summer Chinook salmon ESU are described in the ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon (*Oncorhynchus tshawytscha*) and Snake River Basin Steelhead (*Oncorhynchus mykiss*) (recovery plan) (NMFS 2017a), with recovery scenarios identified for each MPG. The recovery plan recognizes that, at the MPG level, there may be several alternative combinations of populations and statuses and risk ratings that could satisfy the ICTRT viability criteria.

Recovery Criteria for SR spring/summer Chinook Salmon MPGs

Lower Snake River MPG

The ICTRT criteria would call for both the Tucannon River and Asotin Creek populations to be restored to viable status, with one achieving highly viable status. The proposed MPG recovery scenario identified in the Snake River recovery plan (NMFS 2017a) is to achieve highly viable status (very low risk) for the Tucannon River population, with the focus for initial recovery efforts on improving status of the Tucannon River population, but support a reintroduction program for the extirpated Asotin Creek population.

Grande Ronde River/Imnaha River MPG

The ICTRT criteria call for a minimum of four populations (out of Catherine Creek, Upper Grande Ronde River, Minam River, Wenaha River, Lostine/Wallowa Rivers, Imnaha River, Big Sheep Creek, and Lookingglass Creek) to achieve viable status, with at least one highly viable, and the rest meeting maintained status. The proposed MPG recovery scenario identified in the Snake River recovery plan (NMFS 2017a) is to achieve viable status (low risk) for the Imnaha, Lostine/Wallowa, Minam, and Wenaha rivers and Catherine Creek populations, with at least one highly viable; achieve at least “maintained” status (moderate risk) for the Upper Grande Ronde River population; and support reintroduction programs for the Big Sheep and Lookingglass Creek populations.

South Fork Salmon River MPG

The ICTRT criteria call for two of the populations (out of the South Fork Salmon River Mainstem, Secesh River, East Fork South Fork Salmon River, and Little Salmon River) in this MPG to be restored to viable status, with at least one of these highly viable, and the rest meeting maintained status. The proposed MPG recovery scenario identified in the Snake River recovery plan (NMFS 2017a) is to achieve highly viable status for the Secesh River population; achieve at least viable status for South Fork Salmon River population; and achieve at least “maintained” status for East Fork South Fork Salmon River and Little Salmon River populations.

Middle Fork Salmon River MPG

The ICTRT criteria call for at least five of the nine populations (Big Creek, Marsh Creek, Sulphur Creek, Camas Creek, Loon Creek, Chamberlain Creek, Lower Middle Fork Salmon River, Upper Middle Fork Salmon River) in this MPG to be restored to viable status, with at least one demonstrating highly viable status. The remaining populations should achieve maintained status. The proposed MPG recovery scenario identified in the Snake River recovery plan (NMFS 2017a, 2017c) is to achieve highly viable status for the Big Creek population; achieve at least viable status for the Loon Creek, Bear Valley Creek, Marsh Creek, and Chamberlain Creek populations; and achieve at least “maintained” status for the Lower Middle Fork Salmon River, Camas Creek, Upper Middle Fork Salmon River, and Sulphur Creek populations.

Upper Salmon River MPG

The ICTRT criteria for this MPG call for at least five populations (out of Lemhi River, Valley Creek, Upper Salmon River, North Fork Salmon River, Lower Salmon River, East Fork Salmon River, Pahsimeroi River, and Panther Creek) to meet viability criteria, with at least one highly viable; the rest should be maintained. The proposed MPG recovery scenario identified in the Snake River recovery plan (NMFS 2017a) is to achieve highly viable status for the Upper Salmon River Upper Mainstem (above Redfish Lake Creek) population; achieve at least viable status for Lemhi River, Pahsimeroi River, East Fork Salmon River, and Valley Creek populations; achieve at least “maintained” status for the North Fork Salmon River, Salmon River Lower Mainstem (below Redfish Lake Creek), and Yankee Fork populations; support a reintroduction program for the Panther Creek population; and maintain and enhance current levels of natural spawning for Panther Creek.

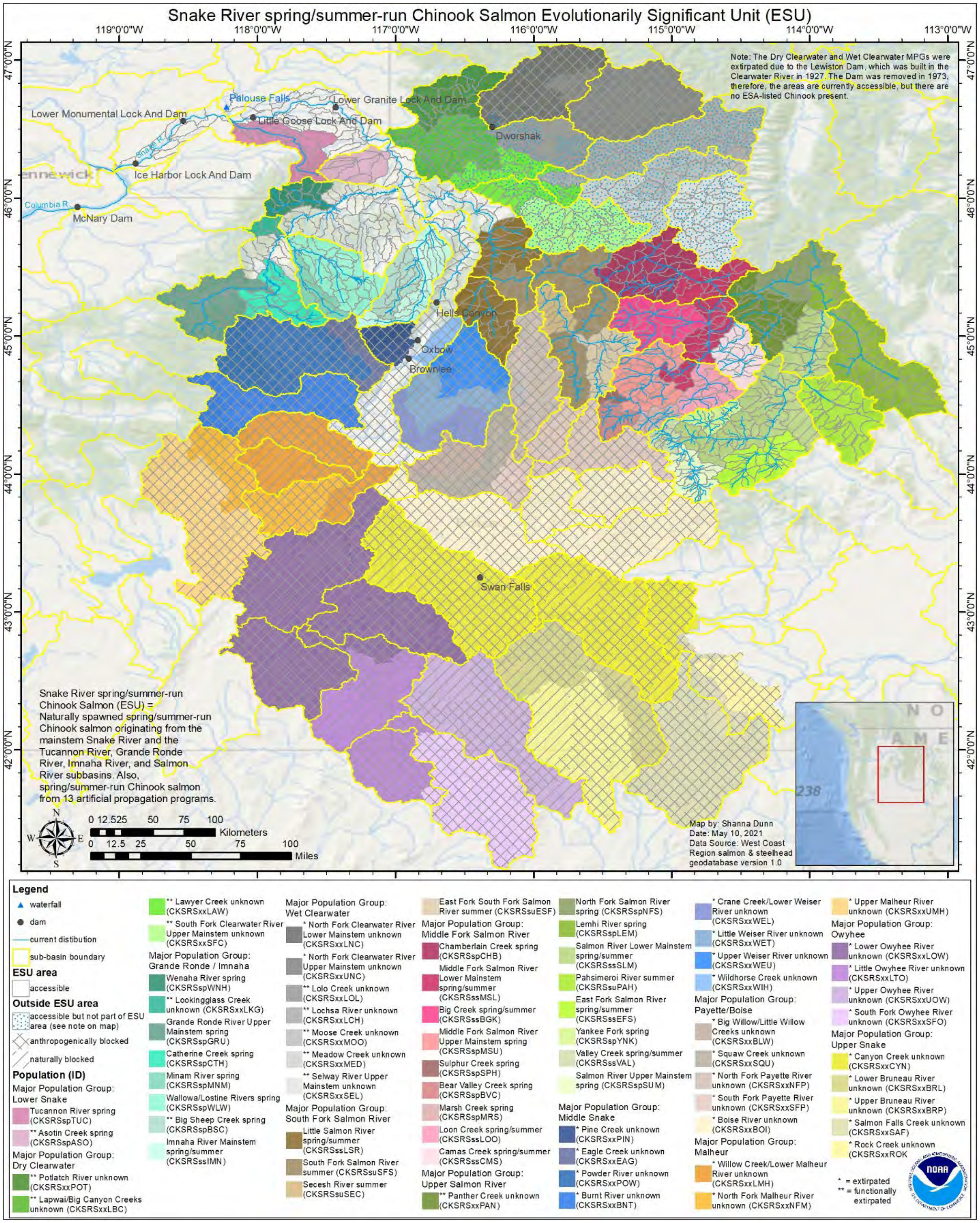


Figure 2. Snake River spring/summer Chinook salmon populations and major population groups.

2.3 Updated Information and Current Species' Status

This section summarizes information from recent assessments on the status of the SR spring/summer Chinook salmon ESU: (1) the Northwest Fisheries Science Center's biological viability assessment update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest (Ford 2022) (Subsection 2.3.1); and (2) our analysis of the current status of the ESU based on the five ESA listing factors (Subsection 2.3.2).

2.3.1 Analysis of VSP Criteria (including discussion of whether the VSP Criteria have been met)

Updated Biological Risk Summary

The majority of populations in the SR spring/summer Chinook salmon ESU remain at high overall risk, with three populations (Minam River, Bear Valley Creek, and Marsh Creek) improving to an overall rating of maintained due to an increase in abundance/productivity. However, natural-origin abundance has generally decreased from the levels reported in the prior review for most populations in this ESU, in many cases sharply. The most recent 5-year geometric mean abundance estimates for 26 out of the 27 populations are lower than the corresponding estimates for the previous 5-year period by varying degrees; the estimate for the 27th population was a slight increase from a very low abundance in the prior 5-year period (Ford 2022). The entire ESU abundance data shows a consistent and marked pattern of declining population size, with the recent 5-year abundance levels for the 27 populations declining by an average of 55 percent. Medium-term (15-year) population trends in total spawner abundance were positive over the period 1990 to 2005 for all of the population natural-origin abundance series, but are all declining over the more recent time interval (2004-2019; Table 12 and Figure 21 in Ford 2022). The consistent and sharp declines for all populations in the ESU are concerning, with the abundance levels for some populations approaching similar levels to those of the early 1990s when the ESU was listed.

No population in the ESU currently meets the Minimum Abundance Threshold (MAT) designated by the ICTRT, with nine populations under 10 percent of MAT and three populations under 5 percent MAT for recent 5-year geometric means. Populations with 5-year geometric mean abundances below 50 fish are at extremely high risk of extinction from chance fluctuations in abundance, depensatory processes, or the long-term consequences of lost genetic variation according to the ICTRT defined quasi-extinction threshold[2] (Waples 1991; ICTRT 2007; Crozier 2021). These populations include the Tucannon River, Middle Fork Salmon River lower mainstem, Camas Creek, Loon Creek, Sulphur Creek, North Fork Salmon River, Salmon River

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[2] The quasi-extinction thresholds (QET) used by the ICTRT were for purposes of population viability modeling and reaching these levels does not equate with biological extinction but rather increased concern and uncertainty about the likelihood of population persistence. QET is defined as less than 50 spawners on average for four years in a row (Waples 1991; ICTRT 2007).

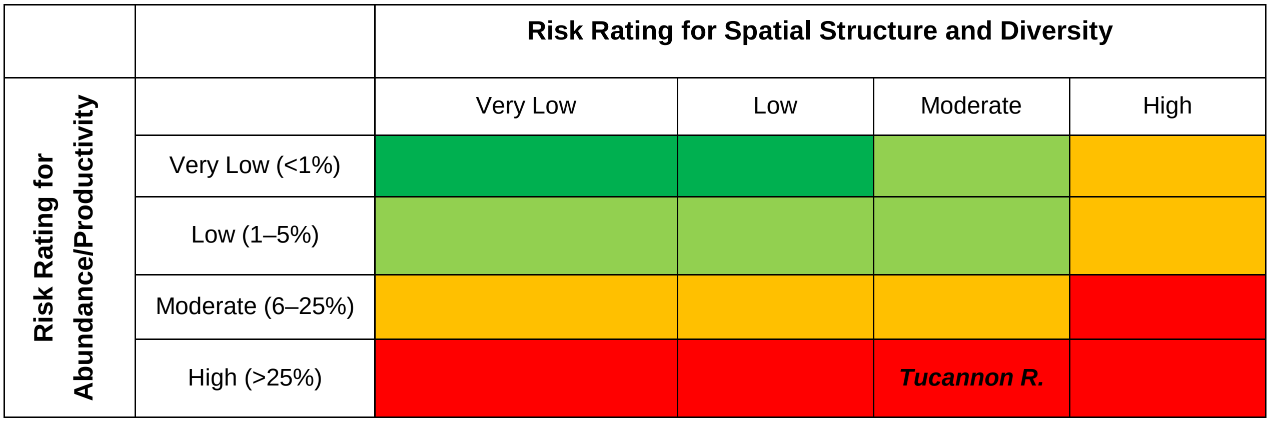
lower mainstem, and Yankee Fork populations. Productivity remained the lowest for the Grande Ronde and Lower Snake River MPGs. Relatively low ocean survivals in recent years were a major factor in recent abundance patterns.

Spatial structure and diversity ratings remain relatively unchanged from the prior reviews, with low or moderate risk levels for the majority of populations in the ESU. Four populations from three MPGs (Catherine Creek, Upper Grande Ronde River, Lemhi River, and Middle Fork Salmon River lower mainstem) remain at high risk for spatial structure loss. Three of the four extant MPGs in this ESU have populations that are undergoing active supplementation with local broodstock hatchery programs. In most cases, those programs evolved from mitigation efforts and include some form of sliding-scale management guidelines designed to maximize potential benefits in low abundance years and reduce potential negative impacts at higher spawning levels. Efforts to evaluate key assumptions and impacts are underway for several programs, but it appears likely that these programs are reducing the risk of extinction in the short term.

The description above summarizes the analysis presented in Ford (2022). In a separate status and trends analysis completed in 2021, the Washington Department of Fish and Wildlife examined adult abundance and determined that the risk level for the population in Washington with data available, the Tucannon River, is “in crisis” (Buehrens and Kendall 2021).

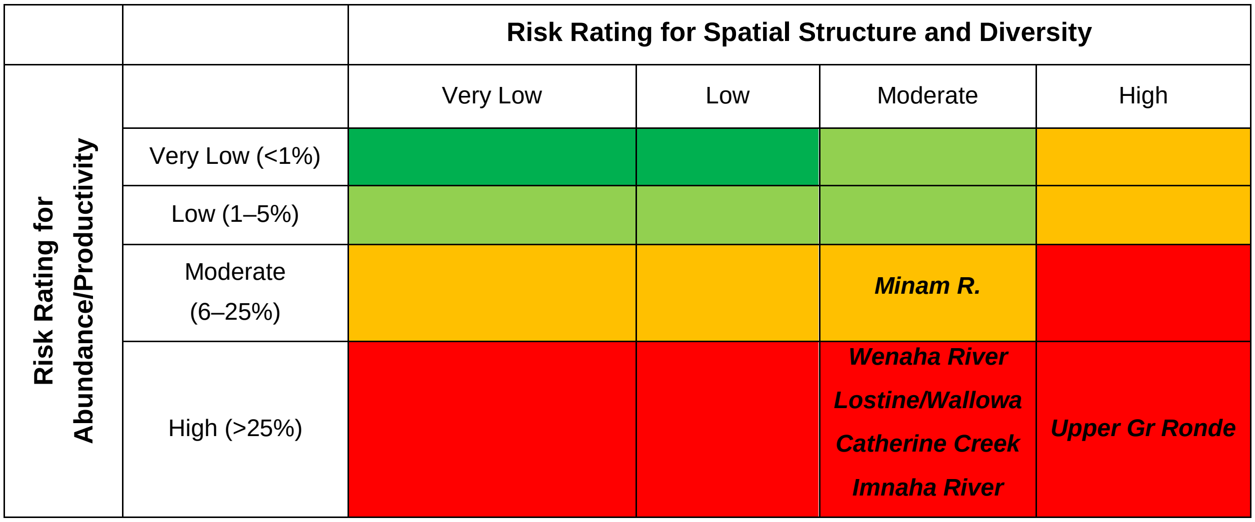
ESU Summary

Overall, the information analyzed for this 5-year review indicates cause for concern for this ESU. While there have been improvements in abundance/productivity in several populations relative to the time of listing, the majority of the populations experienced sharp declines in abundance in the recent 5-year period, primarily due to variation in ocean survival. If ocean survival rates remain low, the ESU’s viability will clearly become much more tenuous. However, if survivals improve in the near term, it is likely that the populations could increase again, similar to the pattern seen in the early 2000s after the declines in the 1990s. Overall, at this time, we conclude that this ESU continues to be at moderate-to-high risk, as supported by the population risk ratings summarized by MPG in Figure 3 through Figure 7.



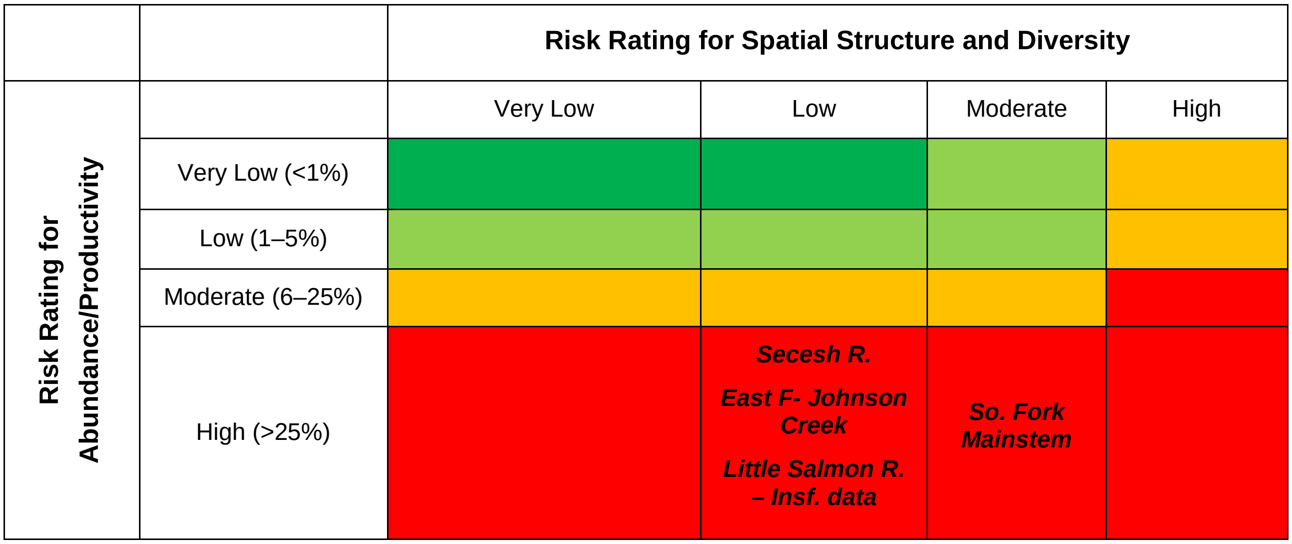
		Risk Rating for Spatial Structure and Diversity			
Risk Rating for Abundance/Productivity		Very Low	Low	Moderate	High
	Very Low (<1%)	🟩	🟩	🟢	🟧
	Low (1–5%)	🟢	🟢	🟢	🟧
	Moderate (6–25%)	🟧	🟧	🟧	🟥
	High (>25%)	🟥	🟥	🟥 ***Tucannon R.***	🟥

Figure 3. Lower Snake River MPG population risk ratings integrated across the four VSP parameters. Viability key: dark green - highly viable; light green - viable; orange - maintained; and red - high risk (does not meet viability criteria) (Ford 2022, Table 14, p. 50).



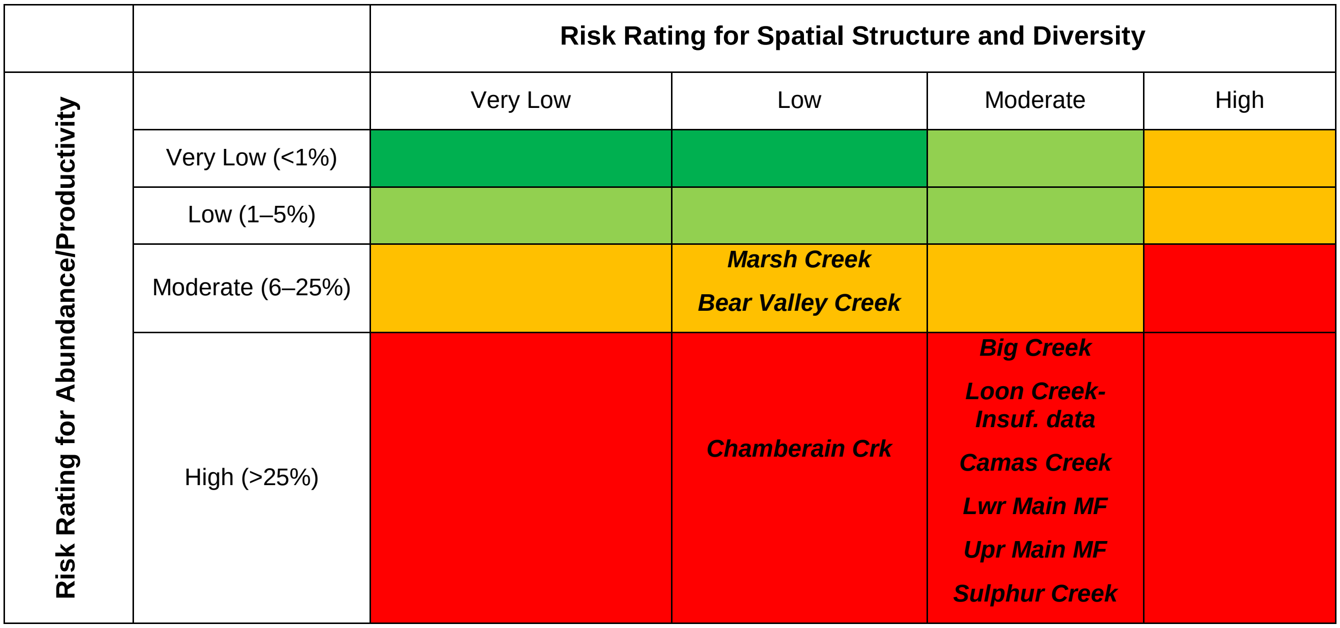
		Risk Rating for Spatial Structure and Diversity			
Risk Rating for Abundance/Productivity		Very Low	Low	Moderate	High
	Very Low (<1%)	🟩	🟩	🟢	🟧
	Low (1–5%)	🟢	🟢	🟢	🟧
	Moderate (6–25%)	🟧	🟧	🟧 ***Minam R.***	🟥
	High (>25%)	🟥	🟥	🟥 ***Wenaha River*** ***Lostine/Wallowa*** ***Catherine Creek*** ***Imnaha River***	🟥 ***Upper Gr Ronde***

Figure 4. Grand Ronde River/Imnaha River MPG population risk ratings integrated across the four VSP parameters. Viability key: dark green - highly viable; light green - viable; orange - maintained; and red - high risk (does not meet viability criteria) (Ford 2022, Table 14, p. 50).



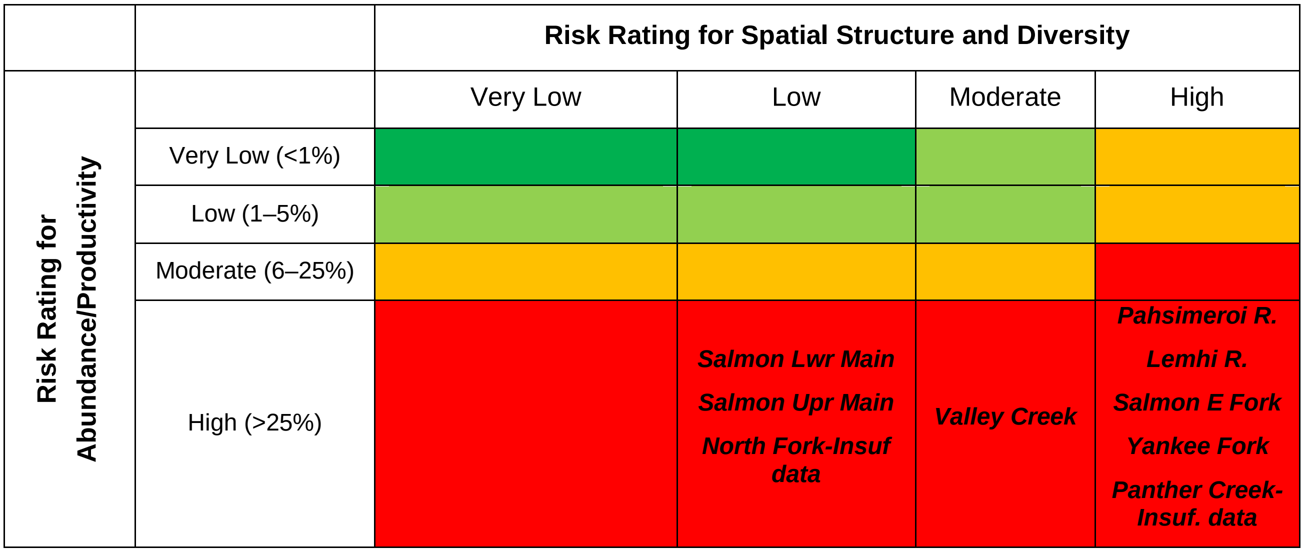
		Risk Rating for Spatial Structure and Diversity			
Risk Rating for Abundance/Productivity		Very Low	Low	Moderate	High
	Very Low (<1%)	🟩	🟩	▨	🟧
	Low (1–5%)	▨	▨	▨	🟧
	Moderate (6–25%)	🟧	🟧	🟧	🟥
	High (>25%)	🟥	🟥 ***Secesh R.*** ***East F- Johnson Creek*** ***Little Salmon R. – Insf. data***	🟥 ***So. Fork Mainstem***	🟥

Figure 5. South Fork Salmon River MPG population risk ratings integrated across the four VSP parameters. Viability key: dark green - highly viable; light green - viable; orange - maintained; and red - high risk (does not meet viability criteria) (Ford 2022, Table 14, p. 50).



		Risk Rating for Spatial Structure and Diversity			
Risk Rating for Abundance/Productivity		Very Low	Low	Moderate	High
	Very Low (<1%)	🟩	🟩	▨	🟧
	Low (1–5%)	▨	▨	▨	🟧
	Moderate (6–25%)	🟧	🟧 ***Marsh Creek*** ***Bear Valley Creek***	🟧	🟥
	High (>25%)	🟥	🟥 ***Chamberain Crk***	🟥 ***Big Creek*** ***Loon Creek- Insuf. data*** ***Camas Creek*** ***Lwr Main MF*** ***Upr Main MF*** ***Sulphur Creek***	🟥

Figure 6. Middle Fork Salmon River MPG population risk ratings integrated across the four VSP parameters. Viability key: dark green - highly viable; light green - viable; orange - maintained; and red - high risk (does not meet viability criteria) (Ford 2022, Table 14, p. 50).



		Risk Rating for Spatial Structure and Diversity			
		Very Low	Low	Moderate	High
Risk Rating for Abundance/Productivity	Very Low (<1%)	🟩	🟩	🟢	🟧
	Low (1–5%)	🟢	🟢	🟢	🟧
	Moderate (6–25%)	🟧	🟧	🟧	🟥
	High (>25%)	🟥	🟥 ***Salmon Lwr Main*** ***Salmon Upr Main*** ***North Fork-Insuf data***	🟥 ***Valley Creek***	🟥 ***Pahsimeroi R.*** ***Lemhi R.*** ***Salmon E Fork*** ***Yankee Fork*** ***Panther Creek-Insuf. data***

Figure 7. Upper Salmon River MPG population risk ratings integrated across the four VSP parameters. Viability key: dark green - highly viable; light green - viable; orange - maintained; and red - high risk (does not meet viability criteria) (Ford 2022, Table 14, p. 51).

2.3.2 Analysis of ESA Listing Factors

Section 4(a)(1) of the ESA directs us to determine whether any species is threatened or endangered because of any of the following factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or man-made factors affecting its continued existence. Section 4(b)(1)(A) requires us to make listing determinations after conducting a review of the status of the species and taking into account efforts to protect such species. Below we discuss new information relating to each of the five factors as well as efforts being made to protect the species.

Listing Factor A: Present or threatened destruction, modification or curtailment of its habitat or range

Many habitat restoration and protection actions at the federal, state, and local levels have been implemented since listing to improve degraded habitat conditions and restore fish passage. While these efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations, we do not yet have evidence demonstrating that improvements in habitat conditions have led to significant improvements in population viability under the current climate change conditions. The effectiveness of habitat restoration actions and progress toward meeting the viability criteria continue to be monitored and evaluated. Generally, it takes one to five decades to demonstrate such increases in viability.

In the 2020 Columbia River System (CRS) biological opinion (NMFS 2020a), NMFS concluded that while some degraded areas in the SR spring/summer Chinook salmon ESU are likely on an improving trend due to past habitat improvement actions and improved land-use practices, in general, tributary habitat conditions are still degraded. These degraded habitat conditions continue to negatively affect SR spring/summer Chinook salmon abundance, productivity, spatial structure, and diversity. Ongoing development and land-use activities may continue to have negative effects into the foreseeable future.

NMFS (2020a) noted that the potential exists to further improve tributary habitat capacity and productivity in this ESU, although in some areas the potential is limited or uncertain (NMFS 2016a, 2017a; BioMark ABS et al. 2019; Pess and Jordan, eds. 2019). Strong density dependence has been observed in SR spring/summer Chinook salmon populations (ISAB 2015; BioMark ABS et al. 2019; Camacho et al. 2019a, 2019b), which is counterintuitive with the historically low abundance levels for both adults and juveniles. From Camacho et al. 2019a, a list of potential explanatory hypotheses may contribute to the situation:

- a lack or reduction of marine-derived nutrients from returning adult carcasses has reduced the productivity of infertile spawning streams, thus reducing juvenile carrying capacity (Naiman et al. 2002);
- current spawners home to relatively small patches of core spawning areas effectively maintaining localized high densities even in low spawner abundances (Thurow 2000; Isaak and Thurow 2006; Hamann and Kennedy 2012);
- introduced species and hatchery-produced fish compete with and prey on young wild salmon (Levin et al. 2002; Weber and Fausch 2003);
- naturally spawning hatchery fish do not spawn as effectively as wild fish, and strays or supplementation fish may increase localized density dependence (Fleming and Gross 1993);
- reduction of off-channel habitat in spawning and rearing areas (Pollock et al. 2004);
- temperature stress related to global warming and loss of tree cover via forest fires and grazing raise water levels at critical times (Schoennagel et al. 2005);
- high adult escapements are coincidental with drought, but associated low stream flow is critical to juvenile survival in the interior Columbia basin (Arthaud et al. 2010);
- loss of life history diversity and local adaptations and temporal variation in movement in occupied habitat and regional productivity (Adkison 1995; Lichatowich and Mobrand 1995); and
- lack of historically high adult abundances, known as critical mass, to produce the full range of juvenile production and true carrying capacity. Potentiality of multiple stable states of carrying based on utilization of progressively marginal habitat as satiation of core habitat occurs.

A better understanding of the mechanism limiting tributary habitat capacity would likely improve overall population abundance and productivity.

Current Status and Trends in Habitat

Below, we summarize information on the **current status and trends in tributary habitat** conditions by MPG since the 2016 5-year review. We specifically address:

(1) population-specific key emergent or ongoing habitat concerns (threats or limiting factors) focusing on the top concerns that potentially have the biggest impact on independent population viability;

(2) population-specific geographic areas of habitat concern (e.g., independent population major/minor spawning areas) where key emergent or ongoing habitat concerns remain;

(3) population-specific key protective measures and major restoration actions taken since the 2016 5-year review that move an MPG toward achieving the recovery plan viability criteria established by the Snake River recovery plan (NMFS 2017a) as efforts that substantially address a key concern noted in **above #1 and # 2**, or that represent a noteworthy conservation strategy;

(4) key regulatory measures that are either adequate or inadequate and contribute substantially to the key tributary habitat concerns summarized above; and

(5) recommended future recovery actions over the next 5 years toward achieving population viability, including specific near-term restoration actions that would address the key concerns summarized above; projects to address monitoring and research gaps; fixes or initiatives to address inadequate regulatory mechanisms; and actions addressing priority habitat areas when sequencing priority habitat restoration actions.

The following section describes the tributary habitat for each MPG. Migration corridor habitat in the Salmon River, Snake River, and Columbia River is vitally important to this ESU. This habitat is addressed under *Listing Factor C: (Disease and Predation), Listing Factor D: (Inadequacy of Regulatory Mechanisms: Columbia River System),* and *Listing Factor E: (Other Natural or Manmade Factors).*

Lower Snake River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-Year Review

In the Lower Snake River MPG, the tributary habitat concerns reported in the 2016 5-year review (NMFS 2016a) continue to exist for the single extant Tucannon River population. The Asotin Creek population remains extirpated. Habitat concerns in the Tucannon River population include lack of stream complexity, excess sediment, low stream flows, high stream temperatures, degraded riparian conditions, reduced floodplain connectivity, and passage barriers (SRSRB 2011; NMFS 2017a).

2) Population-Specific Geographic Areas of Habitat Concern Since the 2016 5-Year Review

The population-specific geographic area of habitat concern is the Tucannon River (SRSRB 2011; NMFS 2017a).

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-Year Review

Restoration projects completed over the last 5 years include:

- For the Tucannon River population, multiple state agencies, Tribes, and other partners have added whole trees to two areas of the Tucannon River, covering ten miles of habitat. These projects reconnect the river with its floodplain, lower summer water temperatures, and create more juvenile summer and winter rearing habitat.
- In the Asotin Creek headwaters, conservation partners have installed hundreds of low-cost post-assisted log structures to restore sinuosity and reduce stream energy and hydrographic flashiness. These projects aim primarily to enhance steelhead habitat, but the projects may indirectly benefit the Asotin Creek Chinook population, which occupies the lower reaches of Asotin Creek. Chinook in habitat downstream from the projects could benefit from cooler summer water temperatures and less flashy stream flows. Further, the project provides cool water habitat for Chinook salmon as the fish move higher up in watersheds in response to climate change.

4) Key Regulatory Measures Since the 2016 5-Year Review Related to Tributary Habitat

Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last review indicates that the adequacy of regulatory mechanisms generally remains the same. Some mechanisms show the potential to improve habitat, while others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions over the Next 5 Years toward Achieving Population Viability

The greatest opportunities toward achieving population viability and advancing recovery of SR spring/summer Chinook salmon in the Lower Snake River MPG are to:

- Improve and increase summer and winter juvenile rearing habitat, especially in high potential reaches of the Tucannon River and Pataha Creek, by restoring riparian areas, reducing temperatures and substrate embeddedness, and increasing recruitment of large wood (NMFS 2017a).
- Enhance overwinter rearing habitat for juvenile Chinook salmon in the Tucannon River population. Identify the specific reaches in the lower Tucannon River occupied by juvenile Chinook salmon in winter; then increase habitat complexity and reconnect the river to its floodplain in those reaches. Restore floodplain function through the reintroduction of beavers (Pollock et al. 2017), low-tech process-based methods (Wheaton et al., eds, 2019), or Stage 0 floodplain restoration techniques where appropriate (Powers et al. 2018). Address the Tucannon Tumalum culverts and the Cottonwood Creek passage barriers.

Grande Ronde River/Imnaha River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-Year Review

Across the MPG, tributary habitat conditions range from excellent in wilderness areas to highly altered and degraded in valley bottoms and lower elevation areas due to a range of past and present land uses. Tributary habitat limiting factors across the MPG include elevated water temperatures, reduced summer flows, reduced habitat complexity and quality, lack of summer and winter rearing habitat, and impaired upstream and downstream movement of juveniles and adults. Additionally, during the outmigration from overwintering habitats to the Snake River mortalities are high, especially in the Grande Ronde Valley. Because of the collective habitat improvement and education efforts by Tribal, state, federal, municipal, non-governmental organization (NGO), and private landowner conservation partners in Northeast Oregon, instream, riparian, and upland habitat conditions in some parts of the MPG are improving (NMFS 2017b).

Significant habitat concerns exist for six of the MPG’s eight populations (Upper Grande Ronde, Catherine Creek, Wallowa/Lostine, Imnaha River, Big Sheep Creek, and Lookingglass Creek). The remaining two populations (Minam River and Wenaha River) occupy protected wilderness areas. The recovery plan (NMFS 2017b) identified the following ongoing tributary habitat concerns for the populations with the most habitat concerns:

- **Upper Grande Ronde population.** Habitat limiting factors include lack of large wood and large wood recruitment, impaired riparian conditions, channelization, loss of off-channel habitat and floodplain connectivity and function, high summer water temperatures, and low stream flows due to irrigation withdrawals.
- **Catherine Creek population.** Habitat limiting factors include lack of large wood and large wood recruitment, impaired riparian conditions, channelization, loss of off-channel habitat and floodplain connectivity, high water temperatures, and low summer stream

flows and passage barriers due to irrigation diversions. Studies by the Bureau of Reclamation show loss of habitat complexity and connectivity sufficient to support summer and winter juvenile rearing spring Chinook salmon in lower Catherine Creek, especially reaches downstream from the town of Union.

- **Lostine/Wallowa rivers population.** Habitat limiting factors include lack of large wood and large wood recruitment, impaired riparian conditions, channelization, loss of off-channel habitat and floodplain connectivity, and low stream flows due to irrigation withdrawals.

2) Population-Specific Geographic Areas of Habitat Concern since the 2016 5-Year Review

Six of the eight populations in this MPG spawn and rear in geographic areas where tributary habitat conditions are of particular concern (NMFS 2017b). Habitat conditions in the Wenaha River population area (the Wenaha-Tucannon Wilderness) are generally good and are not considered a limiting factor for SR spring/summer Chinook salmon. For the Minam River population, 90 percent of the watershed is protected by the Eagle Cap Wilderness Area. The other six populations all occupy watersheds with some areas of degraded stream habitat.

The Big Sheep Creek and Lookingglass Creek populations are considered functionally extirpated. The habitat conditions in the Imnaha River, while degraded in some areas, are not generally limiting the population’s viability (NMFS 2017b). Three populations occupy geographic areas with the most habitat concern in the MPG: Upper Grande Ronde, Catherine Creek, and Lostine/Wallowa.

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-Year Review

Tribal, state, federal, municipal, NGO, and private landowner conservation partners in Northeast Oregon have completed many habitat restoration projects in the MPG over the last 5 years. The Grande Ronde Model Watershed has facilitated local partners in the Upper Grande Ronde basin and the Wallowa River basin to analyze and prioritize habitat restoration projects through the Atlas Restoration Process (Tetra Tech, Inc. 2017; White et al. 2021). Projects include:

- **Wallowa/Lostine population.** Four projects in the Lostine River have increased summer stream flows over 12.5 miles of habitat, boosting the amount of rearing habitat available to Chinook salmon. Projects included converting flood-irrigated land to a pressurized pivot-sprinkler system. Three projects in Bear Creek restored flow to 2.5 miles of tributary habitat, increasing the amount of rearing habitat available to steelhead and Chinook salmon (GRMW 2020).
- **Catherine Creek population.** Nine projects in the Catherine Creek watershed have restored summer streamflow to more than 10 miles of habitat, increasing the rearing

habitat available to Chinook salmon. The Southern Cross project reconstructed the stream channel and restored the floodplain in one of Catherine Creek's key reaches for adult and juvenile Chinook salmon. Instream flow projects were funded through Columbia Basin Watershed Transactions Program.

- **Upper Grande Ronde population.** Conservation partners and the Wallowa-Whitman National Forest added substantial amounts of large wood to streams, increasing habitat complexity and connection of streams to their floodplains, in seven different projects on tributaries to the upper Grande Ronde River. Conservation partners completed a large-scale floodplain restoration project at Birdtrack Springs on the Grande Ronde River.

4) Key Regulatory Measures Since the 2016 5-Year Review Related to Tributary Habitat

Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last review indicates that the adequacy of regulatory mechanisms generally remains the same. Some mechanisms show the potential to improve habitat, while others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions over the Next 5 Years toward Achieving Population Viability

The greatest opportunities toward achieving population viability and advancing recovery of SR spring/summer Chinook salmon in the MPG are to:

- Continue support and development for the Atlas planning framework for the Upper Grande Ronde and Wallowa river basins to guide and prioritize habitat restoration actions (Tetra Tech, Inc., 2017; White et al. 2021). This planning framework benefits the Upper Grande Ronde, Catherine Creek, Wallowa/Lostine, Big Sheep, and Imnaha populations.
- Complete restoration actions that reduce summer stream temperatures and mitigate for climate change, including protecting instream flows through lease and acquisition, increasing hyporheic exchange and floodplain storage, reestablishing robust native riparian vegetation, and restoring floodplain function (Justice et al. 2017; Wondzell et al. 2019). Restore floodplain function through reintroduction of beavers (Pollock et al. 2017), low-tech process-based methods (Wheaton et al., eds, 2019), or Stage 0 floodplain restoration techniques where appropriate (Powers et al. 2018). These actions would benefit all of the non-wilderness populations.
- Reduce juvenile mortality during outmigration from overwintering habitats to the mainstem Snake River, especially in lower Catherine Creek and the Grande Ronde River mainstem from Catherine Creek downstream to the Wallowa River.

- Improve quantity and quality of winter rearing habitats, especially key overwintering areas in the Grande Ronde Valley. These efforts will benefit the Upper Grande Ronde and Catherine Creek populations.
- Improve summer instream flows through water lease, acquisition, and conservation—particularly for the Wallowa/Lostine, Catherine Creek, and Upper Grande Ronde populations. For the Wallowa/Lostine population, focus on increasing summer flows in the lower reaches of the Lostine River, Bear Creek, Hurricane Creek, and the upper reaches of the Wallowa River. For the Catherine Creek population, improve summer flows in the lower Catherine Creek. Continue funding projects through the Columbia Basin Watershed Transactions Program. Restore instream flow in Hurricane Creek, Bear Creek and in the Wallowa River between Wallowa Lake and Enterprise.
- Address passage barriers in all non-wilderness populations.

South Fork Salmon River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-Year Review

In the South Fork Salmon River MPG, habitat concerns exist for all four populations. The populations are South Fork Salmon River, East Fork South Fork Salmon River, Secesh River, and Little Salmon River. Habitat concerns reported in the 2016 5-year review (NMFS 2016a) and the 2017 Snake River recovery plan Idaho Management Unit of the recovery plan (NMFS 2017c) continue to exist:

- Fine sediment. Sediment levels at many monitoring sites on the Payette National Forest within the MPG are functioning appropriately, but at least two key spawning reaches in the South Fork Mainstem population continue to have elevated levels of fine sediment (Payette National Forest 2020). Rain-on-snow events in 2017 caused numerous landslides in the South Fork Salmon, Secesh, and East Fork South Fork population areas, potentially affecting Chinook salmon habitat, but the Payette National Forest has not observed subsequent spikes in sediment levels at long-term monitoring sites (Payette National Forest 2020). Sediment remains a concern for the South Fork Salmon, East Fork South Fork Salmon, and Secesh populations due to landslides and wildfires known to have delivered sediment to streams in these populations in the last 5 years (NPT 2020a).
- Temperature. High stream temperatures are a limiting factor in the South Fork Salmon, East Fork South Fork Salmon, and Little Salmon River populations (NMFS 2017c), and trends in maximum temperatures from the 1990s through 2019 are increasing in the Secesh population (Payette National Forest 2020).
- Passage barriers. Passage barriers to tributary habitat remain in the Secesh and East Fork South Fork Salmon populations (NMFS 2017c; NPT 2020a).

- Wildfires. Recent wildfires affected aquatic habitat in many areas of the MPG. Long-term photo-point monitoring of riparian areas following wildfires in the Secesh and South Fork Salmon population areas shows continued post-fire development of riparian vegetation, providing soil stability and stream shade. Photo points also reveal large wood recruitment. Quantities of large wood in stream channels have increased in many of the population areas from fire-killed trees falling directly into channels or recruitment through avalanches and landslides (Payette National Forest 2020).

2) Population-Specific Geographic Areas of Concern Since the 2016 5-Year Review

All four populations in the MPG are located in geographic areas of concern for tributary habitat conditions (NMFS 2017c).

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-Year Review

The Nez Perce Tribe and the Payette National Forest have completed many habitat restoration projects in the MPG over the last 5 years:

- Road decommissioning. In the South Fork Salmon River population, the Nez Perce Tribe and the Payette National Forest decommissioned 57 miles of road between 2016 and 2019, 15 miles of which were in riparian areas, reducing sediment delivery to streams (NPT 2020a).
- Road improvements. The Nez Perce Tribe and the Payette National Forest improved 2 miles of road in the Secesh River populationarea and over 12 miles of road in the East Fork South Fork Salmon River population area (NPT 2020a).
- Riparian plantings. The Nez Perce Tribe replanted several degraded riparian areas in the South Fork Salmon River and East Fork South Fork Salmon River population areas to improve riparian function and reduce bank erosion (NPT 2020a).
- Passage barriers. In the Little Salmon River population, the Payette National Forest replaced six culverts in the Boulder Creek subwatershed, reconnecting six miles of stream habitat (Payette National Forest 2020).

4) Key Regulatory Measures Since the 2016 5-Year Review Related to Tributary Habitat

Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last review indicates that the adequacy of regulatory mechanisms generally remains the same. Some mechanisms show the potential for some improvement, while others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions over the Next 5 Years toward Achieving Population Viability

The greatest opportunities toward achieving population viability and advancing recovery of SR spring/summer Chinook salmon in the South Fork Salmon River MPG are to:

- Reduce and prevent sediment delivery. Continue road decommissioning in the South Fork Salmon and Little Salmon populations, where the high density of roads still delivers sediment to streams. Continue appropriate road maintenance, road obliteration, road relocation, and road resurfacing in all populations in the MPG.
- Improve riparian function in selected areas. The mainstem rivers and many of the major tributaries in all populations in this MPG have roads or other human-made disturbances located within the riparian zone, and riparian function has been reduced.
- Remove or replace fish passage barriers that block access to high quality SR spring/summer Chinook salmon habitat. Anthropogenic barriers still exist in all populations in the MPG.
- Improve water quality. Reclaim abandoned mine sites, such as the Cinnabar mine site in the East Fork South Fork population, to prevent pollutants (mercury, arsenic) from entering streams.
- Plan for climate change. Improve planning for potential climate change effects by continuing to monitor stream temperature and validate fish distribution in modeled cold water refugia (Payette National Forest 2020).

Middle Fork Salmon River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-Year Review

The key habitat limiting factors affecting populations in this MPG occur in the Snake and Columbia River migration corridor, downstream of spawning and rearing tributary habitat (see *Listing Factor D: Inadequacy of Regulatory Mechanisms: Columbia River System*). For all populations in the Middle Fork Salmon River MPG, tributary habitat concerns are either non-existent or relatively small and localized. There are nine populations in this MPG: Bear Valley, Marsh Creek, Sulphur Creek, Upper Middle Fork, Lower Middle Fork, Loon Creek, Camas Creek, Big Creek, and Chamberlain Creek.

Public forestlands cover much of the Middle Fork Salmon River MPG, with large portions protected in the Frank Church-River of No Return Wilderness Area. As a result, most natal habitats for these spring/summer Chinook salmon populations remain in good to excellent condition and protected from human impacts. As described in the 2016 5-year review (NMFS 2016a) and the Snake River recovery plan Idaho Management Unit (NMFS 2017c), some small, localized areas in the MPG display degraded habitat conditions associated with roads, past mining, livestock grazing, irrigation diversions, recreation, or absence of beavers. For example, in the upper Big Creek watershed, roads and old mine sites deliver sediment to streams and water withdrawals reduce base flows, impacting the Big Creek population. Lack of beaver has reduced floodplain complexity in areas occupied by all populations.

2) Population-Specific Geographic Areas of Concern since the 2016 5-Year Review

Tributary habitat in this MPG is generally in excellent condition, protected by Forest Service management and the Frank Church-River of No Return Wilderness. Small, localized areas of degraded habitat occur in the geographic areas occupied by some populations, including the Big Creek, Bear Valley, and Camas Creek populations. However, these patches of degraded habitat are not large or severe enough to be significant concern.

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-Year Review

The key protective measure for habitat in most of these populations is maintaining the wilderness status of the Frank Church-River of No Return Wilderness. Additionally, restoration projects since 2016 have addressed limiting factors in small, localized areas of habitat degradation.

- In the headwaters of Big Creek, the Nez Perce Tribe and the Payette National Forest reduced sediment delivery to streams occupied by the Big Creek population by decommissioning 6 miles of road, 3 miles of which were in riparian areas with 12 stream crossings. They also increased road maintenance, improving 12 stream crossings and installing two bridges (NPT 2020b).
- In the headwaters of Big Creek, the Nez Perce Tribe and the Payette National Forest properly screened two water diversions, preventing impingement of juvenile Chinook salmon and other fish (NPT 2020b).

4) Key Regulatory Measures Since the 2016 5-Year Review Related to Tributary Habitat

Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last review indicates that the adequacy of regulatory mechanisms has generally remained the same. Some mechanisms show the potential to improve habitat, while others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions over the Next 5 Years toward Achieving Population Viability

The primary future habitat action in this MPG toward achieving population viability and advancing recovery is maintaining the current wilderness protection and Forest Service management of land and streams in the Middle Fork Salmon River.

Future opportunities to address small, localized areas of degraded tributary habitat include:

- Reduce and prevent sediment delivery to streams by rehabilitating abandoned mine sites and roads, such as the Dewey Mine and associated roads in the Thunder Mountain Mining District (Big Creek population).
- Improve riparian and floodplain health and function by encouraging and reestablishing beaver activity (all populations) (Pollock et al. 2017).
- Reduce impacts of water diversions for domestic, irrigation, stockwater, and hydropower purposes on instream flows in upper Big Creek by administering special use permits for water diversions on National Forest lands (Big Creek population) (Payette National Forest 2020). Apply water acquired for habitat restoration projects to mainstem Salmon River instream flow water rights.

Upper Salmon River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-Year Review

In the Upper Salmon River MPG, habitat concerns exist for all nine populations. The populations are: Lemhi River, Pahsimeroi River, North Fork Salmon River, Panther Creek, Lower Mainstem Salmon River, Upper Mainstem Salmon River, East Fork Salmon River, Yankee Fork Salmon River, and Valley Creek. Many habitat concerns reported in the 2016 5-year review (NMFS 2016a) and the Snake River recovery plan Idaho Management Unit (NMFS 2017c) continue to exist:

- Low flows. Water diversions reduce summer streamflow in all populations except the Yankee Fork. The Lemhi River and Pahsimeroi River populations are particularly impacted by low flows, with many tributaries disconnected from the mainstem rivers. Irrigation diversions significantly reduce instream flows by diverting tributaries away from the mainstem rivers. The many irrigation diversions in each watershed reduce the frequency and magnitude of peak flows and reduce the quantity available instream habitat (NMFS 2017c; Biomark ABS et al. 2019).
- Degraded riparian conditions. Riparian vegetation has been removed to accommodate agriculture or lost due to overgrazing by livestock in many areas, including in the Lemhi River, Pahsimeroi River, East Fork Salmon River, and Upper Salmon Mainstem populations (NMFS 2017c; Biomark ABS et al. 2019). Where dense riparian vegetation (primarily willow) has been lost, stream channels are commonly over-widened and homogenous, providing insufficient juvenile rearing habitat.

- Sediment. Grazing and agricultural practices, as well as the development of dirt roads and trails, have had a cumulative effect on fine sediment accumulation within many watersheds in the MPG, including the Lemhi River, Pahsimeroi River, and Upper Salmon Mainstem populations (Biomark ABS et al. 2019). Fine sediment fills interstitial spaces between gravels and cobbles, eliminating concealment cover for overwintering juvenile fish and reducing bed- and pool-scour potential through substrate embeddedness (Biomark ABS et al. 2019).
- Temperature. Summer parr are limited by high stream temperatures in most populations in the MPG, with the possible exception of the Yankee Fork and North Fork populations (NMFS 2017c; Biomark ABS et al. 2019).

Since the 2016 5-year review, juvenile overwintering habitat as emerged as a habitat concern. The Upper Salmon Subbasin Habitat Integrated Rehabilitation Assessment (IRA) identified that insufficient overwintering habitat for juvenile Chinook salmon is limiting the growth of the Lemhi River, Pahsimeroi River, and Upper Salmon Mainstem populations (Biomark ABS et al. 2019). Low-velocity and concealment habitats, necessary for successful winter rearing, are not available for pre-smolts. This is partly due to simplified stream channels and lack of floodplain complexity. Channel and floodplain alterations from roads and infrastructure are prevalent throughout several reaches in each watershed. In many instances, channel reaches have been straightened and confined to accommodate infrastructure, and large patches of floodplain have been disconnected from channel interactions. Bank armoring has prohibited natural channel migration and concentrated flow along a hydraulically smooth surface, increasing rates of bank erosion and incision farther downstream (Biomark ABS et al. 2019).

2) Population-Specific Geographic Areas of Concern since the 2016 5-Year Review

All nine populations in the MPG spawn and rear in geographic areas of concern for tributary habitat conditions (NMFS 2017c; Biomark ABS et al. 2019). Specific geographic areas of concern since the 2016 5-year review include:

- **Panther Creek watershed.** Since the 2015 5-year status assessment, the Panther Creek population has increased in importance in the MPG. Therefore, the Panther Creek watershed is an emerging geographic area of concern. The ICTRT defined the Panther Creek population as functionally extirpated in 2003 (NMFS 2017c). The Snake River recovery plan did not include the population in its initial recovery strategy for achieving a viable MPG (NMFS 2017c). However, the plan notes that as more information is gathered about spring/summer Chinook salmon spawning in Panther Creek, the Panther Creek population could become part of the MPG recovery strategy. Panther Creek has supported natural spawners since 2005. Redd counts of natural-origin spawners peaked at 131 in 2015, and in recent years have averaged around 50 redds (Conley and Denny 2019).

- **Deadwater Reach of the mainstem Salmon River.** The Deadwater Reach is a slow-water reach on the Salmon River, approximately five miles downstream from North Fork, Idaho. Recent evaluations have suggested that juvenile SR spring/summer Chinook salmon migrants suffer disproportionately higher mortality and slower travel rates, relative to upstream and downstream reaches, when migrating through this reach (Lott et al. 2020). Predation by northern pikeminnow (*Ptychocheilus oregonensis*), likely increased by slower rates of juvenile SR spring/summer Chinook salmon migrant travel, is a hypothesized factor. It is uncertain whether the Deadwater Reach is a natural feature, anthropogenic feature, or a combination of both (USACE 1984). This reach is a migration corridor for all populations in the MPG except Panther Creek.
- **Lemhi River lower mainstem.** The mainstem Lemhi River habitat downstream of Hayden Creek supports the majority of overwintering juvenile Chinook salmon in the Lemhi River. This reach has been identified as having insufficient quantity and quality of habitat and may be limiting population productivity (Biomark ABS et al. 2019).
- **Pahsimeroi River lower mainstem.** The Pahsimeroi River mainstem from Hooper Lane downstream to the river’s mouth supports all the current spawning and rearing for the Pahsimeroi River population. This reach has the largest potential for habitat improvements to lead to a population-level productivity response. The biggest concern for this reach is lack of high-quality juvenile overwintering habitat (Biomark ABS et al. 2019).
- **Upper Salmon River mainstem**. For the Upper Salmon River Mainstem population, the habitat between Alturas Lake Creek and Redfish Lake Creek in the Salmon River has the greatest geomorphic potential for habitat restoration actions to increase population productivity. This reach supports most of the population’s spawning habitat and is also likely to retain colder water under climate change scenarios due to its high elevation. Given the Upper Salmon River Mainstem population’s importance in the Snake River recovery plan (NMFS 2017c) and the reach’s potential to be a thermal refuge for the MPG as summer stream temperatures rise with a changing climate, this reach is a geographic area of concern.
- **Salmon River lower mainstem between Valley Creek and the Lemhi River.** The lower mainstem of the Salmon River, occupied by the Salmon River Lower Mainstem population, is a geographic area of concern because very little habitat restoration work is occurring in this reach, and the population has very low abundance and productivity.

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-Year Review

Conservation partners in the Upper Salmon River have completed and maintained numerous habitat restoration projects in the MPG over the last 5 years:

- **Lemhi River population.** Since 2016 conservation partners have improved summer instream flow, reconnected tributaries to the mainstem river, increased floodplain and habitat complexity, and altered grazing management to improve riparian habitat (Biomark ABS et al. 2019). The Hawley Creek project reconnected an important tributary to the Lemhi River after 100 years of agriculture-related disconnection. The Eagle Valley Ranch project, a large-scale floodplain restoration project, was implemented in an area critical to late summer/winter rearing juveniles. The Henry Project and the Lemhi Fayle Project also restored floodplain habitat, and the Big Timber 2 diversion removal provided access to 8 miles of tributary habitat. Researchers have documented adult Chinook salmon in two of five reconnected tributaries, and juvenile Chinook salmon in five reconnected tributaries (Hillman et al. 2016; Haskell et al. 2019). Overall, work in the Lemhi River basin between 2007 and 2019 has increased the summer rearing capacity for parr by 62 percent, and researchers have reported an increase in juvenile Chinook salmon productivity (Uthe et al. 2017; Haskell et al. 2019).
- **Pahsimeroi River population.** Since 2016, conservation partners have improved instream flow during the irrigation season, altered grazing management to improve riparian habitat, reconnected tributary flow to the mainstem river, and increased floodplain and habitat complexity (Biomark ABS et al. 2019). Installation of head gates, piping irrigation water, and closing ditches, coupled with the Idaho Department of Water Resources formally requiring compliance with existing water rights conditions (i.e., quantity diverted, timing of diversion, and usage of a measuring device), has resulted in perennial water in the Upper Pahsimeroi. Four additional restoration projects improved fish passage, habitat complexity, sediment transport, floodplain connectivity, and riparian health on three miles of habitat. Habitat restoration actions since 2008 effectively doubled the amount of spawning and rearing habitat available to salmon and steelhead, resulting in an increase in juvenile Chinook salmon survival and productivity (NMFS 2020a). Copeland et al. (2020) reported greatly increased spawning distribution, parr using new habitat, and increased numbers of juvenile productivity (smolts per female) following habitat restoration. The large increase in accessible stream length for Chinook salmon appeared to reduce density-dependent effects on juvenile survival (Copeland et al. 2020).
- **Panther Creek population.** Since 2016, the U.S. Forest Service and the Shoshone-Bannock Tribes have focused new efforts on stream habitat improvement in Panther Creek. The Panther Creek Riverscapes Conceptual Restoration Plan identifies mileages, reaches, and targeted restoration actions within the watershed (Hill et al. 2019). A 110-acre parcel adjacent to historically high-quality spawning habitat on Panther Creek was protected through the Land and Water Conservation Fund. Installation of a bridge on Musgrove Creek, a key tributary for Chinook salmon spawning and rearing, reconnected fish access to 7 miles of habitat.
- **Multiple Populations - Instream Flow.** Since 2016, the Idaho Water Transactions Program remained an important means of ongoing habitat restoration and protection

across the MPG. Mechanisms to improve instream flow during the irrigation season included minimum flow agreements, short-term or permanent water leases, and moving points of diversion from a flow-limited reach to a reach that has adequate water for fish. From 2016 to 2019, the Idaho Water Transactions Program protected between 29 and 41 cubic feet per second (cfs) per year (2,025 to 3,906 acre-feet per year) (IDWR 2020). These projects improved habitat for the Lemhi River, Pahsimeroi River, Upper Mainstem Salmon River, and Valley Creek populations.

- **Multiple Populations - Fish Screens.** The Idaho Department of Fish and Game maintains fish screens on at least 264 water diversions across the MPG, including 124 screens in the Lemhi, 19 in the Pahsimeroi, and 23 in the Upper Salmon Mainstem rivers, preventing entrainment of the Lemhi, Pahsimeroi, and Upper Salmon Mainstem populations in irrigation diversions (NMFS 2020b). Additional screens exist in the East Fork Salmon River, Valley Creek, North Fork, and Lower Mainstem Salmon River populations. Screens reduce diversion-related mortality for fish from every population in the MPG.
- **Yankee Fork Population.** Restoration improved floodplain connectivity, habitat complexity, increased quantity of habitat, and improved spawning substrate in key locations. Efforts since 2015 include restoring several miles of mainstem habitat historically degraded by dredge mining in the Yankee Fork.
- **East Fork Salmon River Population.** Several Federal grazing allotments were permanently closed, reducing potential impacts to spawning and rearing Chinook salmon salmon and their habitat.

4) Key Regulatory Measures Since the 2016 5-Year Review Related to Tributary Habitat

Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last 5-year review indicates that the adequacy of regulatory mechanisms has generally remained the same. Some mechanisms show the potential to improve habitat, while others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions over the Next 5 Years toward Achieving Population Viability

The greatest opportunities toward achieving population viability and advancing the recovery of Snake River spring/summer Chinook salmon in the Upper Salmon River MPG are to:

- Increase winter juvenile rearing habitat by increasing floodplain connectivity and complex habitat structure, reducing width-to-depth ratios, increasing low- to zero-velocity pool habitat with cover, providing side channel habitat, and reducing fine sediment delivery to streams – across the MPG and particularly in the Lemhi River, Pahsimeroi River, and Salmon River Upper Mainstem populations (Biomark ABS et al. 2019). As appropriate, replicate similar actions in other populations as new information identifies similar problems or based on inference from data-rich populations. Use reintroduction of beavers (Pollock et al. 2017) or low-tech process-based methods (Wheaton et al., eds, 2019) to restore floodplain function and connectivity.

- Complete Multiple Reach Assessment reports for the Upper Lemhi River basin, Lower Lemhi River basin, Lower Pahsimeroi River basin, and Upper Salmon River basin above Redfish Lake Creek to determine where habitat restoration would be most effective at increasing population viability (Biomark ABS et al. 2019).
- Increase instream flow by: (1) expanding and continuing the Idaho Water Transactions Program; (2) securing permanent water transactions for the lower Lemhi minimum flow needs, and continuing filling needs with shorter-term agreements until permanent agreements can be established; (3) seeking additional water transaction agreements for all SR spring/summer Chinook salmon populations throughout the MPG; and (4) limiting new water rights in the MPG. For aging fish screen infrastructure at water diversions, ensure ongoing funding sources continue to complete routine maintenance and necessary upgrades. Fund new fish screens when new habitat is opened up through tributary reconnection projects.
- In the lower mainstem Lemhi River (downstream of Hayden Creek), increase habitat complexity by increasing the sinuosity of the single-thread main channel while creating areas of island braiding with complex instream structure, hydraulic variability, and low-velocity areas with cover (Lemhi River population).
- In the upper mainstem Lemhi River, increase habitat complexity by creating multi-threaded channels, narrow width-to-depth ratios, stable banks, and willow-dominated riparian areas. Maintain and improve instream flow and tributary stream connections to the mainstem Lemhi River (Biomark ABS et al. 2019) (Lemhi River population).
- For the Pahsimeroi River population, maintain and improve instream flow.
- For the Pahsimeroi River population, increase habitat quantity by adding more channels within groundwater-influenced reaches that provide high-quality, complex habitat, including split flows, side channels, spring channels, and alcoves. Increase stream length by increasing sinuosity, which also increases hyporheic flow.
- For the Pahsimeroi River population, establish a robust, riparian community along the banks and floodplain, increasing shade, improving bank structure and habitat, and providing a buffer from upland and floodplain sediment sources.
- For the Pahsimeroi River population, reduce fine sediment (systemic throughout the Pahsimeroi River basin) by increasing bank stability and decreasing surface water runoff (Biomark ABS et al. 2019).

- For the Upper Mainstem Salmon River population, increase habitat complexity by creating or enhancing multi-threaded channels and increasing floodplain connection.
- For the Upper Mainstem Salmon River population, maintain and improve instream flow and tributary stream connections to the mainstem Upper Salmon River, particularly upstream of the Alturas Lake Creek confluence (Biomark ABS et al. 2019).
- For the Panther Creek population, remove fish passage barriers at road stream crossings, add large wood to streams, encourage beaver recolonization to restore floodplain connectivity, screen water diversions, and continue low-tech process-based stream habitat restoration efforts.
- For the Panther Creek population, re-evaluate the role of the Panther Creek population in the MPG recovery scenario in the Recovery Plan, considering the natural spawning that has occurred in this population since 2005 (Conley and Denny 2019).
- For the East Fork Salmon River population, maintain existing water quality and quantity and restore floodplain/riparian processes, primarily on private lands subject to historical land conversion from floodplain to agriculture.
- For the Salmon River Lower Mainstem population, restore perennial tributary connections with the Salmon River, provide thermal refugia for migrating and rearing fish, and maintain or restore floodplain connectivity and riparian processes. Reconnect tributaries to the mainstem East Fork Salmon, Lemhi, and Pahsimeroi Rivers and to the mainstem Salmon River from the North Fork Salmon River to Valley Creek.
- Improve the quantity and quality of winter rearing habitats, especially key overwintering areas in the Upper Mainstem Salmon River and the Salmon River Lower Mainstem.
- Conduct additional evaluations to identify the potential causes for low juvenile Chinook salmon survival in the mainstem Salmon River overwintering/migration corridor. Improved survival outside natal rearing areas may benefit all the MPG's populations.

Listing Factor A Conclusion

Conservation partners have implemented many tributary habitat restoration projects across the ESU since the last 5-year review. These projects have improved habitat conditions for SR spring/summer Chinook salmon spawning, rearing, and migration in many reaches. Nevertheless, widespread areas of degraded habitat persist across the basin, with simplified stream channels, disconnected floodplains, impaired instream flow, loss of cold water refugia, and other limiting factors. While it has been difficult to assess the impact of restoration projects on population viability, one recent study of the Pahsimeroi River population showed that large-scale stream restoration efforts in a watershed can have a population-scale effect, increasing juvenile freshwater productivity (Copeland et al. 2020).

Overall, site-specific restoration actions taken since the previous 5-year review are having positive effects but are not sufficient to rectify currently degraded habitat conditions. The risk to

SR spring-summer Chinook salmon populations persistence remains the same as the previous 5-year review and continues to be a significant threat to population viability and persistence.

Continued large-scale watershed and stream habitat restoration remains a key component of recovering this ESU, as described in the 2017 Snake River recovery plan (NMFS 2017a). Important considerations for tributary habitat restoration over the next 5 years include:

- Prioritize projects that improve habitat resiliency to climate change. Actions to restore riparian vegetation, stream flow, and floodplain connectivity and re-aggrade incised stream channels can ameliorate temperature increases, base flow decreases, and peak flow increases, thereby improving population resilience to certain effects of climate change (Beechie et al. 2013).

- Support and enhance local- to basin-scale frameworks to guide and prioritize habitat restoration actions and integrate a landscape perspective into decision making. Successful examples in the ESU include the Grande Ronde Atlas process and the Integrated Rehabilitation Assessment in the Upper Salmon River (Tetra Tech Inc. 2017; Biomark ABS et al. 2019; White et al. 2021). White et al. (2021) suggest that these efforts would benefit from gaining broader public support and formalizing an adaptive management strategy.

- Implement habitat restoration at a watershed scale. Roni et al. (2010) found that, for a watershed, at least 20 percent of floodplain and in-channel habitat need to be restored to see a 25 percent increase in salmon smolt production. Most watersheds occupied by this species have not yet reached that level of floodplain and habitat restoration.

- Reconnect stream channels with their floodplains. Reintroducing beaver (Pollock et al. 2017) and applying low-tech process-based methods (Wheaton et al., eds., 2019) will facilitate widespread, low-cost floodplain restoration across the ESU, increasing the productivity of freshwater habitat for Chinook salmon.

- Ensure that habitat improvement actions are implemented consistent with best practices for watershed restoration (see, e.g., Beechie et al. 2010; Hillman et al. 2016; Appendix A of NMFS 2020a).

This conclusion for Listing Factor A applies to tributary habitat for the ESU. Migration habitat conditions in the Snake River and Columbia River are crucial to the status and recovery of SR spring/summer Chinook salmon. We discuss and evaluate current migration corridor habitat conditions under *Listing Factor C: (Disease and Predation)* and *Listing Factor D: (Inadequacy of Regulatory Mechanisms: Columbia River System).*

Listing Factor B: Overutilization for commercial, recreational, scientific, or educational purposes

Harvest

Systematic improvements in fisheries management since the last 5-year review include implementation of a new *U.S. v. Oregon* Management Agreement for years 2018-2027. This agreement replaces the previous 10-year agreement. It maintains the limits and reductions in harvest impacts for the listed Snake River ESUs/DPSs that were secured in previous agreements (NMFS 2018).

Contributions of SR spring/summer Chinook salmon are considered negligible in fisheries managed by the Pacific Fishery Management Council (PFMC) (PFMC 2016, 2020), and the fisheries are not likely to jeopardize the ESU (Thom 2020). SR spring/summer Chinook salmon are encountered in fisheries in the Columbia River, the Snake River, and some tributaries. The majority of the harvest-related impacts to this ESU occur in mixed stock Columbia River fisheries. These fisheries are limited to an incidental take of 5.5 to 17 percent (depending on run size) of SR spring/summer Chinook salmon returning to the Columbia River mouth (NMFS 2018). Actual incidental take has remained the same since the last 5-year review and averaged 11.0 percent for the years 2014-2019 (TAC 2015, 2016, 2017, 2018, 2019, 2020). Estimated harvest rates for SR spring/summer Chinook salmon over the last four decades are shown in Figure 8.

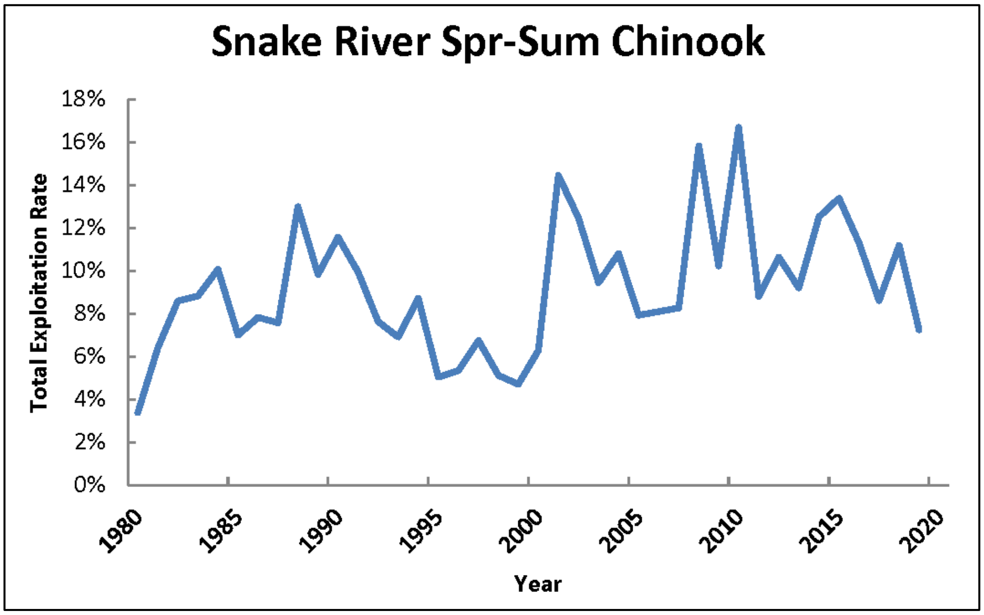


Figure 8. Total exploitation rates for Snake River spring/summer Chinook salmon in the mainstem Columbia River fisheries. Data from the Columbia River Technical Advisory Team, as presented in NWFSC (2021).

Research and Monitoring

The quantity of take authorized under ESA sections 10(a)(1)(A) and 4(d) for scientific research and monitoring for these species remains low in comparison to their abundance. Much of the work is being conducted to fulfill state and federal agency obligations under the ESA to ascertain the species' status. Authorized mortality rates associated with scientific research and monitoring are generally capped at 0.5 percent across the West Coast Region for all listed salmonid ESUs and DPSs. As a result, the mortality levels that research causes are very low throughout the region. In addition, and as with all other listed salmonids, the effects research has on the Snake River salmonids are spread over various reaches, tributaries, and areas across all of their ranges. Thus, no area or population is likely to experience a disproportionate amount of loss. Therefore, the research program as a whole has only a very small impact on overall population abundance, a similarly small impact on productivity, and no measurable effect on spatial structure or diversity for SR spring/summer Chinook salmon.

Any time we seek to issue a permit for scientific research, we consult on the effects of the proposed work on each listed species' natural- and hatchery-origin components. However, since research has never been identified as a threat or a limiting factor for any listed species, and most hatchery fish are considered excess to their species' recovery needs, examining the quantity of hatchery fish taken for scientific research would not inform our analysis of the threats to a species' recovery. Therefore, we only discuss the research-associated take of naturally produced fish in these sections.

From 2015 through 2019, researchers were approved to take a yearly average of fewer than 2,030,000 SR spring/summer Chinook salmon juveniles (<14,800 lethally). For adult salmonids during this same period, researchers were approved to take a yearly average of fewer than 9,700 SR spring/summer-run Chinook salmon (<80 lethally) (NMFS APPS database; https://apps.nmfs.noaa.gov/).

For the vast majority of scientific research actions, history has shown that researchers generally take far fewer salmonids than are authorized every year. Reporting from 2015 through 2019 indicates that over those 5 years, the average actual yearly total take for naturally produced juveniles was only 17 percent of the amount authorized. For adults, the take was less than 5 percent of the average annual amount authorized for SR spring/summer Chinook salmon. The actual lethal take was also low over the same 5-year period: average yearly lethal take of juveniles was only 9 percent, and the adults' take was less than 5 percent of the average amount authorized per year for this ESU.

The majority of the requested take for naturally produced juveniles of this ESU has primarily been (and is expected to continue to be) capture via screw traps, electrofishing units, and beach seines, with smaller numbers collected as a result of hand or dip netting, minnow traps, weirs, other seines, trawling, and hook and line sampling. Adult take has primarily been (and is expected to continue to be) capture via weirs or fish ladders, hook and line angling, and hand or dip nets, with smaller numbers getting unintentionally captured by screw traps, seining, and other methods that target juveniles (NMFS APPS database; https://apps.nmfs.noaa.gov/). Our records indicate that mortality rates for screw traps are typically less than one percent and backpack electrofishing are typically less than three percent. Unintentional mortality rates from seining, dip netting, minnow traps, weirs, and hook and line methods are also limited to no more than three percent.

The quantity of take authorized over the past 5 years has remained relatively stable for SR spring/summer Chinook salmon compared to the prior 5 years. The total amount of take authorized for naturally produced fish increased by 54 percent, and the amount of lethal take increased by 36 percent from 2015 through 2019 when compared to 2010 through 2014. However, increases in take requested and authorized have not resulted in higher amounts of take actually occurring. From 2015 through 2019, the total take reported increased by less than one percent compared to 2010 through 2014, and the lethal take that actually occurred increased by only three percent when comparing the same two time periods.

Overall, research impacts remain minimal due to the low mortality rates authorized under research permits and the fact that research is spread out geographically throughout the Snake River basin. Therefore, we conclude that the overall effect on listed populations has not changed substantially, and the risk to the species' persistence because of utilization related to scientific studies has changed little since the last 5-year review (NMFS 2016a).

Listing Factor B Conclusion

The primary fishery affecting SR spring/summer Chinook salmon is in the lower Columbia River. Incidental take of SR spring/summer Chinook salmon from Columbia River salmon fisheries has remained the same since the last 5-year review and averaged 11.0 percent of returning adults for the years 2014-2019 (TAC 2015, 2016, 2017, 2018, 2019, 2020).

Since the last 5-year review, scientific research impacts on listed SR spring/summer Chinook salmon have not changed (NMFS APPS database; [https://apps.nmfs.noaa.gov/)](https://apps.nmfs.noaa.gov/). The impact from research, monitoring, and evaluation continues to be relatively small and not a major limiting factor for this ESU.

Listing Factor C: Disease and Predation

Disease

Disease rates over the past 5 years are believed to be consistent with the previous review period. However, climate change impacts, such as increasing temperatures, are likely increasing susceptibility to diseases. For the 2016 5-year review (NMFS 2016a), we reported that the spread of a new strain (i.e., M clade) of infectious hematopoietic necrosis virus (IHNV) along the Pacific coast that may increase disease-related concerns for Snake River salmon and steelhead in the future. Since then, the M clade of IHNV has not appeared in Snake River Chinook salmon and does not appear to pose an additional risk to the ESU (Linda Rhodes, NWFSC, email sent to C. Fealko, NMFS, April 5, 2021, regarding IHNV status). SR spring/summer Chinook salmon continue to be affected by the U clade of IHNV, but this risk has not changed since the prior 5-year review.

Avian Predation

Avian predation in the lower Columbia River estuary

Piscivorous colonial waterbirds, especially terns, cormorants, and gulls, have had a significant impact on the survival of juvenile salmonids in the Columbia River. In the estuary, Caspian terns on Rice Island, an artificial dredged-material disposal island, consumed about 5.4 to 14.2 million juveniles per year in 1997 and 1998, up to 15 percent of all the smolts reaching the estuary (Roby et al. 2017). Efforts to move the tern colony closer to the ocean at East Sand Island, where they would diversify their diet to include marine forage fish, began in 1999. During the next 15 years, smolt consumption was about 59 percent less than when the colony was on Rice Island. The U.S. Army Corps of Engineers (Corps) has further reduced smolt consumption by reducing the amount of bare sand available on East Sand Island for nesting from 6 acres to 1 acre. Combined with harassment (kleptoparasitism) by bald eagles, and egg and chick predation by gulls, the number of nesting pairs has dropped from more than 10,000 in 2008 to fewer than 5,000 in 2018 and 2019 (Roby et al. 2021).

Hostetter et al. (2021) found that body size affects susceptibility to tern predation. Yearling SR spring/summer Chinook salmon are smaller than steelhead so predation rates have been relatively low. These declined with the reduction in tern colony size on East Sand Island from an average of 5.2 percent of available PIT-tagged smolts (2000 to 2007) to 2.1 percent more recently (2008 to 2018) (Roby et al. 2021).

The Corps has also reduced the size of the double-crested cormorant colony on East Sand Island, although efforts to reduce predation rates have not been successful. The pressures of lethal take and non-lethal hazing under the Corps' management plan (USACE 2015), combined with harassment by bald eagles, moved thousands of nesting pairs from the island to the Astoria-Megler Bridge. Because the colony on the bridge is 9 miles farther up-river than East Sand Island, these birds are likely to be consuming more juvenile salmonids per capita than when they were foraging farther downstream with access to marine forage fish (Lawes et al. 2021). Researchers cannot estimate predation rates for birds nesting on the bridge because PIT tags cannot be detected or recovered if they fall into the water. Although predation rates for East Sand Island cormorants on yearling SR spring/summer Chinook salmon decreased from 4.6 percent to 0.5 percent when birds moved to the bridge, they may have increased for the estuary as a whole.

Avian predation in the mainstem Columbia and Snake rivers

Juvenile SR spring/summer Chinook salmon also have been vulnerable to predation by terns nesting in the interior Columbia plateau, including islands in McNary Reservoir and the Hanford

Reach. The Corps has been successfully preventing terns from nesting on Crescent Island since 2015. However, because terns moved from this site and from Goose Island in Reclamation's Potholes Reservoir to the Blalock Islands in John Day Reservoir, predation rates on yearling SR spring/summer Chinook salmon may have increased by a small amount. To improve survival for this and other salmonids, the Corps began to raise the elevation of the reservoir during the spring smolt migration in 2020, inundating the Blalock Islands to prevent its use by terns. This operation will continue under the 2020 CRS proposed action (BPA et al. 2020).

The 2008 Federal Columbia River Power System biological opinion first required that the Action Agencies (U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and the Bonneville Power Administration) implement avian predation control measures at mainstem dams in the lower Snake and Columbia rivers. Since then, each of the CRS projects has used hazing and passive deterrence, including wire arrays crisscrossing tailraces, spike strips along the edge of the concrete, water sprinklers at juvenile bypass outfalls, pyrotechnics, propane cannons, and limited amounts of lethal take. These measures have reduced (since 2008) the number of smolts consumed by birds at the dams and will continue to be implemented, with improvements as new techniques become available.

Compensatory Mortality and Avian Predation Management

Evaluating the effectiveness of a predator control program is a two-step process: (1) estimate the magnitude of predation on a focal species; and (2) estimate the effectiveness of the control method (ISAB 2019). We must consider whether any gain in numbers of smolts overestimates the conservation benefit in terms of adult returns because of either compensatory behavior of the prey (e.g., density dependence) or another predator (e.g., removing one predator species may increase predation by another). For example, given the average 3.1 percent per year decrease in predation rates achieved by reducing the size of the tern colony on East Sand Island, and that some level of compensation is likely to occur in the ocean even in favorable ocean years, it is likely that this management measure has not led to increased adult returns for this ESU. For double-crested cormorants, reducing the colony area on East Sand Island plus hazing, egg take, and culling reduced average annual predation rates from 4.6 percent to less than 1 percent. However, in this case, predation rates on SR spring/summer Chinook salmon are likely to have increased because thousands of these birds are now foraging from the Astoria-Megler Bridge, where they are farther from the marine forage fish prey base.

Marine Mammal Predation

The four main marine mammal predators of salmonids in the eastern Pacific Ocean are California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina richardii*), and fish-eating killer whales (*Orcinus orca*).

Recent research over the past 5 years suggests that predation pressure on ESA-listed salmon and steelhead from seals, sea lions, and killer whales has been increasing in the northeastern Pacific over the past few decades (Chasco et al. 2017a, 2017b). Models developed by Chasco et al.

(2017a) estimate that consumption of Chinook salmon in the eastern Pacific Ocean by three species of seals and sea lions and fish-eating (Resident) killer whales may have increased from 5 to 31.5 million individual salmon of varying ages since the 1970s, even as fishery harvest of Chinook salmon has declined during the same time period (Marshall et al. 2016; Chasco et al. 2017a; Ohlberger 2019). This same modeling suggests that these increasing trends have continued across all regions of the northeastern Pacific over the past 5 years. The potential predation impacts of specific marine mammal predators of ESA-listed salmonids on the West Coast are discussed individually below.

Pinnipeds (Seals and Sea Lions)

The three main seal and sea lion (pinniped) predators of ESA-listed salmonids in the eastern Pacific Ocean are California sea lions, Steller sea lions, and harbor seals. With the passing of the Marine Mammal Protection Act (MMPA) in 1972, these pinniped stocks along the West Coast of the United States have steadily increased in abundance (Carretta et al. 2019).[3] With their increasing numbers and expanded geographical range, marine mammals are consuming more Pacific salmon and steelhead, and some are having an adverse impact on some ESA-listed species (Marshall et al. 2016; Chasco et al. 2017a; Thomas et al. 2017).

For the SR spring/summer Chinook salmon ESU, the highest risk from pinnipeds comes from sea lions in the lower Columbia River consuming adult Chinook salmon as they enter the river and begin their upstream migration. Predation occurs in concentrated areas, such as directly below Bonneville Dam, but also occurs at more dispersed levels throughout the lower Columbia River (Rub et al. 2019). Figure 9 shows a marked increase in the estimated numbers of California sea lions at East Mooring Basin, Astoria, Oregon, in the lower Columbia River, starting in 2013, compared to previous years. Over the past 5 years at East Mooring Basin, there were 3,834 animals in 2016, 2,345 animals in 2017, 1,030 animals in 2018, 805 animals in 2019, and 952 in 2020.[4] Both California and Stellar sea lions are present in the lower Columbia River in the spring, overlapping with the migration of the SR spring/summer Chinook salmon ESU.

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[3] The current population size of California sea lions is 257,606, within the range of its optimum sustainable population size (Carretta et al. 2019). The current population size of Steller sea lions is 71,562 (Muto et al. 2019). Muto et al. (2017) concluded that the eastern stock of Steller sea lions is likely within its optimum sustainable population range; however, NMFS has made no determination of its status relative to optimum sustainable population size.

[4] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, November 17, 2020.

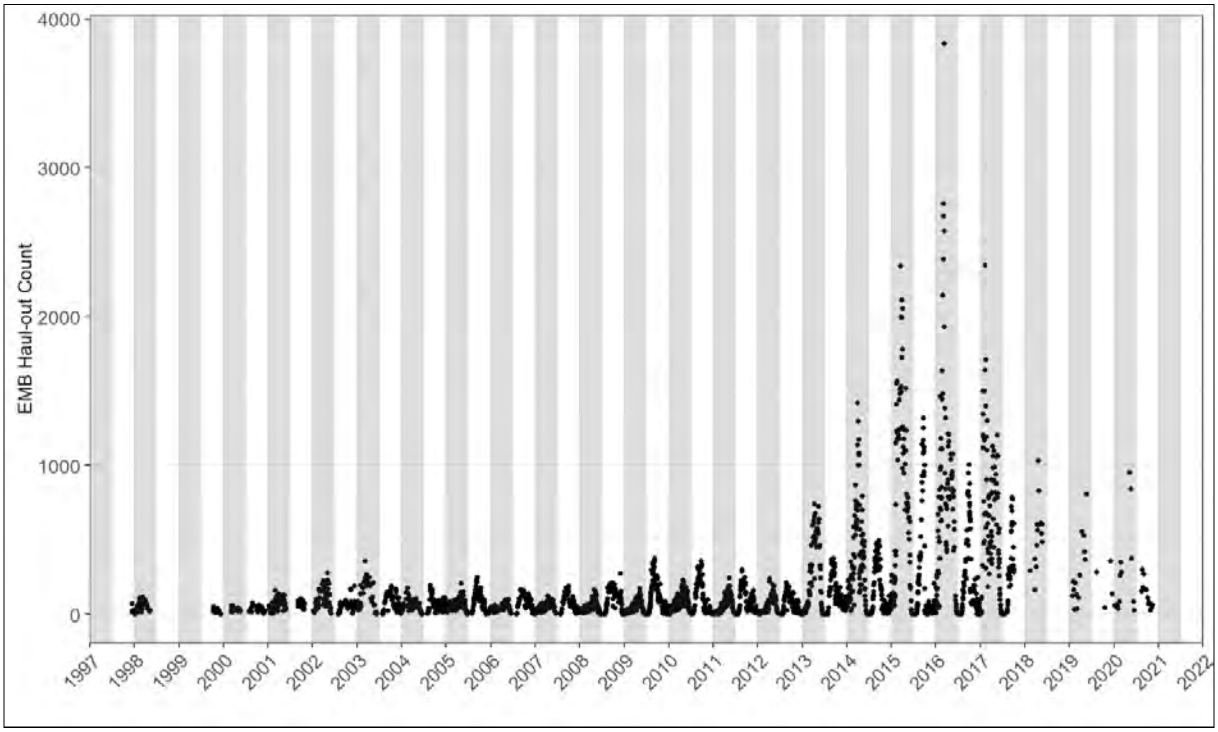

Figure 9. Estimated peak counts (spring and fall) of California sea lions in the East Mooring Basin in Astoria, Oregon, 1998 through 2020.[5]

Sea lion consumption of Chinook salmon directly below Bonneville Dam has been well studied. At Bonneville Dam, the estimated consumption of adult salmon and steelhead by both California and Steller sea lions between 2016 and 2019[6] has ranged from a low of 2,201 fish in 2019 to a high of 9,525 fish in 2016 (Tidwell et al. 2020). The percentage of salmon and steelhead runs consumed by both California and Steller sea lions at Bonneville Dam has ranged from a low of 3.0 percent in 2018 to a high of 5.8 percent in 2016 (Tidwell et al. 2020).

Although California sea lions have been the primary focus of pinniped management efforts at Bonneville Dam to date, the presence of Steller sea lions has been increasing over time, and their presence now poses a risk to salmon and steelhead recovery. At Bonneville Dam, predation in 2017, 2018, and 2019 on salmon and steelhead by Stellar sea lions exceeded that of California sea lions.

The average number of Stellar sea lions at Bonneville Dam over the past 5 years has been lower than in the previous 5-year period. The number of Stellar sea lions ranged from a high of 66 in 2018 to a low of 50 in 2019, compared to a high of 89 in 2011 and a low 65 in 2014. However, predation as a percentage of the run on Pacific salmon and steelhead stocks by Steller sea lions has been steadily increasing and was higher than that by California sea lions in 2017 (2.8 percent

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[5] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, November 17, 2020.

[6] At the time of this 5-year review, consumption data was only available through 2019.

compared to 1.9 percent), 2018 (2.3 percent compared to 0.7 percent), and 2019 (3.1 percent compared to 0.3 percent) (Tidwell et al. 2020). Furthermore, the number of individuals and residence times of Steller sea lions at Bonneville Dam have more than doubled compared to the 10-year average (Figure 10). The highest numbers of Steller sea lions tend to be during the spring, overlapping with the migration of SR spring/summer Chinook salmon (Figure 10).

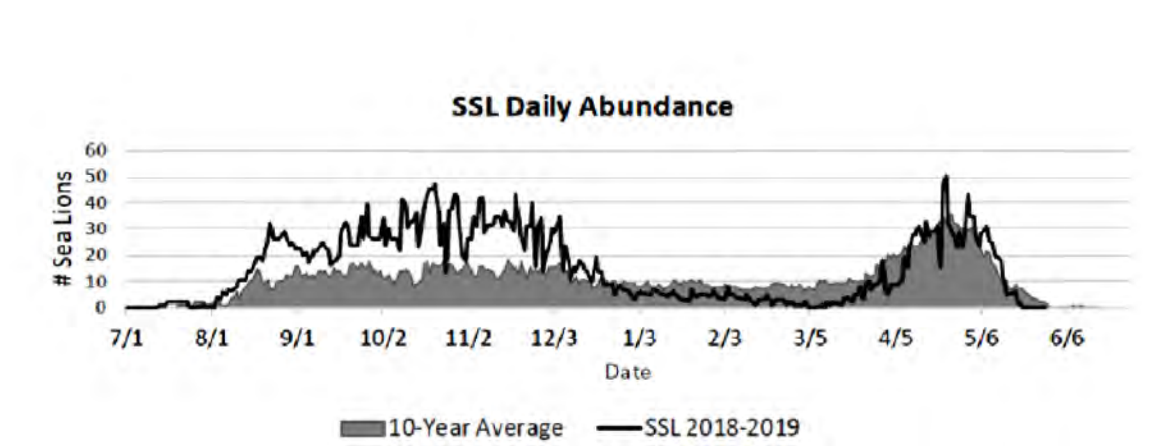

Figure 10. Maximum daily count of Steller sea lions at Bonneville Dam from 1 July 2018 through 30 June 2019 compared to the 10-year maximum daily average (Tidwell et al. 2020).

A recent study by Rub et al. (2019) suggests that the overall impact of pinniped predation on spring-run Chinook salmon occurring throughout the lower Columbia River is much higher than originally thought. Rub et al. (2019) estimated that non-harvest mortality of spring-run Chinook salmon varied from 20-44 percent between the mouth of the Columbia River and Bonneville Dam. They attributed the majority of this mortality to pinniped predation. Using these estimates and the California sea lion abundance data, Rub et al. (2019) calculated that the odds of survival for spring-run Chinook salmon decrease by 32 percent for every additional 467 sea lions present in the Columbia River.

A recent analysis by Sorel et al. (2020) looked at the effect of seasonal sea lion abundance in the Columbia River on adult spring/summer Chinook salmon survival during migrations through the lower Columbia River. Sorel et al. (2020) examined data on California sea lion abundance and adult survival in 18 populations of ESA-listed spring/summer Chinook salmon (Snake River and Upper Columbia) with different spring migration times. Of these 18 populations, earlier-migrating Chinook salmon populations experienced lower survival in association with increased exposure to higher California sea lion abundance. The authors estimated that in years with high California sea lion abundance, the nine earliest-migrating populations experienced an additional 21.1 percent mortality compared to years with baseline California sea lion abundance years, while the nine latest migrating populations experienced an additional 10.1 percent mortality. Early migrating populations in the Snake River ESU include Catherine Creek, Upper Grande Ronde, and the Minam River in the Upper Grande Ronde MPG; Marsh Creek in the Middle Fork MPG, and the Lemhi River in the Upper Salmon River MPG.

Management efforts are underway to reduce pinniped predation on Pacific salmon and steelhead in the lower Columbia River. These efforts are discussed under *Listing Factor D: (Inadequacy of Regulatory Mechanisms).*

Marine Mammal Predation Summary

Information available since the last 5-year review clearly indicates that predation by pinnipeds on Pacific salmon and steelhead continues to pose an adverse impact on the recovery of these ESA-listed fish species. Pinniped populations in Oregon and Washington have continued to increase over the past 5 years. Recent research provides evidence that adult salmonids with run timing that overlaps with increased sea lion presence, such as the SR spring/summer Chinook salmon ESU, have decreased survival rates when migrating through the lower Columbia River and estuary. While there are management efforts underway to reduce pinniped predation on Pacific salmon and steelhead in the lower Columbia River, these management efforts alone may be insufficient to reduce the severity of the risk that pinniped predation poses to the species' recovery. The SR spring/summer Chinook salmon ESU is at particularly high risk from predation by sea lions due to the overlap in timing between adult migration for this ESU and sea lion presence in the lower Columbia River.

Northern Pikeminnow Predation

A sport fishing reward program implemented in 1990 has reduced the number of Northern pikeminnow in the Columbia Basin (NMFS 2010). The program continues to meet expected targets, which may reduce predation on smolts of all salmon and steelhead species in the mainstem Columbia River. The sport reward fishery removed an average of 188,708 piscivorous pikeminnow per year during 2015 to 2019 in the Columbia and Snake rivers (Williams et al. 2015, 2016, 2017, 2018; Winter et al. 2019).

Predation of Chinook salmon smolts and pre-smolts in the mainstem Salmon River by northern pikeminnow may be a significant source of juvenile mortality in Salmon River reaches such as Deadwater Slough downstream from the North Fork confluence (Biomark ABS et al. 2019).

Aquatic Invasive Species

Non-indigenous fishes affect salmon and their ecosystems through many mechanisms. A number of studies have concluded that many established non-indigenous species (including smallmouth bass, channel catfish, and American shad) pose a threat to the recovery of ESA-listed Pacific salmon. Threats are not restricted to direct predation; non-indigenous species compete directly and indirectly for resources, significantly altering food webs and trophic structure and potentially altering evolutionary trajectories (Sanderson et al. 2009; NMFS 2010).

Listing Factor C Conclusion

The extinction risk posed to the ESU by disease, avian predation, and predation by other fish species has mainly remained the same since the last 5-year review. Disease rates over the past 5 years are consistent with the previous review period. Avian predation of Chinook salmon smolts has decreased in some areas (e.g., Caspian terns at East Sand Island) but increased in other areas (e.g., cormorants at the Astoria-Megler Bridge). Predation of Chinook salmon smolts and pre-smolts in the Salmon River by northern pikeminnow is an emerging potential concern for populations in the Upper Salmon River MPG, but not yet quantified.

New information since the last 5-year review suggests that the risk to the ESU from pinniped predation in the lower Columbia River is higher than previously understood. In addition to consuming between 2.9 to 5.9 percent of spring Chinook salmon returning to Bonneville Dam in each of the 5 years since the last 5-year review (Tidwell et al. 2020), pinnipeds also appear to be consuming large numbers of spring-run Chinook salmon throughout the lower Columbia estuary (Rub et al. 2019). Rub et al. (2019) estimated the average non-harvest mortality of adult spring Chinook salmon through the lower Columbia estuary at 20 to 44 percent annually. New management actions authorized under the Endangered Salmon Predation Prevention Act to lethally remove sea lions are expected to reduce pinniped predation on adult SR spring/summer Chinook salmon in the lower Columbia River. However, given the logistical challenges of removing sea lions and other uncertainties, the magnitude of this expected reduction in pinniped predation is uncertain.

In conclusion, the extinction risk posed to the ESU by disease, avian predation, and predation by other fish species has remained largely the same since the previous 5-year review. However, information available since the last 5-year review suggests that sea lions are consuming a large percentage of adult spring Chinook salmon migrating up the lower Columbia River (e.g., Rub et al. 2019), and that this predation by pinnipeds continues to pose a significant negative threat to the persistence of the ESU.

Recommended future actions:

- Pacific salmon and steelhead recovery partners are encouraged to develop and implement a long-term management strategy to reduce pinniped predation on Pacific salmon and steelhead in the Columbia River basin by removing, reducing, or minimizing the use of manmade haul outs used by pinnipeds in select areas, e.g., river mouths/migratory pinch points.
- Pacific salmon and steelhead recovery partners are encouraged to coordinate to expand, develop, and implement monitoring efforts in the Columbia River basin to identify pinniped predation interactions in select areas, e.g., river mouths/migratory pinch points, and quantitatively assess predation impacts by pinnipeds on Pacific salmon and steelhead stocks.

Listing Factor D: Inadequacy of Regulatory Mechanisms

Various federal, state, county and tribal regulatory mechanisms are in place to reduce habitat loss and degradation caused by human use and development, as well as reduce hydrosystem impacts, harvest and hatchery impacts, and predation.

Habitat concerns are described throughout Listing Factor A as having either a system-wide influence or more localized influence on the populations and MPGs that comprise the species. The habitat conditions across all habitat components (tributaries, mainstems, estuary, and marine) necessary to recover listed SR spring/summer Chinook salmon are influenced by a wide array of federal, state, and local regulatory mechanisms. The influence that regulatory mechanisms pose on listed salmonids and their habitat resources is largely based on the underlying ownership of the land and water resources as federal, state, or private holdings. Most of the land in the Snake River basin (about 64 percent) is managed by the U.S. Forest Service, U.S. Bureau of Land Management, and U.S. Department of Energy. The U.S. Bureau of Reclamation and other state and federal agencies and private groups manage the water resources for the basin for the many, and sometimes competing, uses.

One factor affecting habitat conditions across all land or water ownerships is climate change, the effects of which are discussed under Section 2.3.2 (*Listing Factor E: Other natural or manmade factors affecting its continued existence*). Our review of national and international regulations and agreements governing greenhouse gas emissions indicates that while the number and efficacy of such mechanisms have increased in recent years, there has not yet been a substantial deviation in global emissions from the past trend. Instead, we will need upscaling and acceleration of far-reaching, multilevel, and cross-sectoral climate mitigation to reduce future climate-related risks (IPCC 2014, 2018). These findings suggest that current regulatory mechanisms, both in the U.S. and internationally, are not currently adequate to address the rate at which climate change is negatively impacting habitat conditions for many ESA-listed salmon and steelhead.

For this 5-year review, we focus our analysis on the regulatory mechanisms that have improved conditions for SR spring/summer Chinook salmon, and on those that are still causing the most concern in terms of adequate protection for the species.

Regulatory Mechanisms Resulting in Adequate or Improved Protection

New information available since the last 5-year review indicates that the adequacy of some regulatory mechanisms has improved (or has the potential to improve) and has increased protection of SR spring/summer Chinook salmon. These include:

- Columbia River System Biological Opinion and Hydropower. NMFS completed two biological opinions, one in 2019 (NMFS 2019a) and the second in 2020 (NMFS 2020), for the Columbia River System (CRS) for the continued operations and maintenance of the hydropower system. The first opinion continued the previous proposed action with some minor changes. The proposed action analyzed in the 2020 opinion included additional salmon conservation measures, including additional spill to improve passage conditions for juvenile salmon and other measures such as those described below. The Action Agencies hypothesize that spill improvements may increase adult returns by up to 35 percent for SR spring/summer Chinook salmon. These increases are estimates only and will require validation as the program is implemented. Additional improvements in survival are possible from a revised juvenile transport program, a more focused tributary habitat improvement program, and more estuary restoration. Since the last 5-year review, increased spring spill rates have and will continue to decrease the proportion of juveniles from the Snake River that are transported downriver. This is anticipated to slightly improve adult SR Chinook salmon survival through the CRS since fish transported as juveniles have 3-10 percent lower survival than non-transported fish (Keefer et al. 2018; Crozier et al. 2020) during their upstream migrations.

  - The CRS Action Agencies are implementing an estuary habitat improvement program (the Columbia Estuary Ecosystem Restoration Program, CEERP), reconnecting the historical floodplain below Bonneville Dam to the mainstem Columbia River. From 2007 through 2019, the Action Agencies implemented 64 projects, including dike and levee breaching or lowering, tide-gate removal, and tide-gate upgrades that reconnected over 6,100 acres of historical tidal floodplain habitat to the mainstem and another 2,000 acres of floodplain lakes (Karnezis 2019; BPA et al. 2020). Floodplain habitat restoration can affect the performance of juvenile salmonids whether they move onto the floodplain or stay in the mainstem because wetlands support prey items. Thus, while most of the smolts produced by SR Chinook salmon populations may not enter a tidal wetland channel, they still derive benefits from wetland habitats. Continuing to grow during estuary transit may be part of a strategy to escape predation through larger body size during the ocean life stage.

- As part of the re-authorization process for the Hells Canyon Complex of dams (i.e., Brownlee, Oxbow, and Hells Canyon dams), the Federal Energy Regulatory Commission (FERC) has issued annual operation licenses for each project since the original 50-year licenses expired in 2005. In 2019, Oregon DEQ and Idaho DEQ issued 401 certifications for the project, an important component of a complete license application. Most notably, the 401 certifications require a substantial commitment to reduce the temperature of water exiting Hells Canyon Dam in the late summer and fall and improve water quality in the Snake River. This commitment is expected to be accomplished primarily through habitat restoration activities upstream of the Hells Canyon Complex (both in the mainstem Snake River and in several tributaries) that will address return flows from irrigation projects, narrow the channel width, and restore more normative river processes between Swan Falls Dam and the upper end of Brownlee reservoir. The Idaho Power Company amended their license application and provided FERC with a biological evaluation in 2020 that assessed the project’s impacts.

- The United States Congress (Congress) amended the MMPA in 1994 to include a new section, section 120 – Pinniped Removal Authority. This section provides an exception to the MMPA “take” moratorium and authorizes the Secretary of Commerce to authorize the intentional lethal taking of individually identifiable pinnipeds that are having a significant negative impact on the decline or recovery of salmonid fishery stocks. In

2018, Congress amended section 120(f) of the MMPA, which expanded the removal authority for removing predatory sea lions in the Columbia River and tributaries.

To address the severity of pinniped predation in the Columbia River Basin, NMFS has issued six MMPA section 120 authorizations (2008, 2011, 2012, 2016, 2018, and 2019) and one section 120(f) permit (2020). Under these authorizations, as of May 13, 2022, the states have removed (transferred and killed) 278 California sea lions and 52 Steller sea lions.

Continued management action under the MMPA is expected to reduce sea lion predation on adult salmon and steelhead in the Columbia River. Given the logistical challenges of removing sea lions and other uncertainties, the magnitude of this expected reduction in sea lion predation is uncertain.

Consistent with the Congressional intent of the Endangered Salmon Predation Prevention Act, the MMPA section 120(f) permit, NMFS encourages Eligible Entities to develop and implement a long-term management strategy to deter the future recruitment of sea lions into the MMPA 120(f) geographic area.

- Clean Water Act (CWA) – In December 2016, the United States Congress amended the CWA by adding Section 123, which requires EPA and Office and Management and Budget (OMB) to take actions related to restoration efforts in the Columbia Basin. Consequently, the U.S. Government Accountability Office (GAO) reviewed restoration efforts in the basin. In 2018, the GAO presented its report to the Committee on Transportation and Infrastructure, House of Representatives: Columbia River Basin, Additional Federal Actions Would Benefit Restoration Efforts. The report reveals that while multiple agencies had a variety of programs by which they engaged in restoration activities between 2010 and 2016, since 2016, the EPA had not yet taken steps to establish the Columbia River Basin Restoration Program, as required by the Clean Water Act Section 123. The report found that while EPA stated it had not received dedicated funding appropriated for this purpose, it actually had not yet requested funding to implement the program or identified needed resources. Also, the GAO reports that an interagency crosscut budget has not been submitted. According to OMB officials, they have had internal conversations on the approach to develop the budget but have not requested information from agencies. More recently, in 2019 the EPA developed a grants program. In September 2020 it announced the award of $2 million in 14 grants to tribal, state and local governments, non-profits, and community groups throughout the Columbia River basin.
- In December 2019, the Ninth Circuit Court of Appeals issued an opinion that the EPA must identify a temperature Total Maximum Daily Load (TMDL) for the Columbia River since neither the state of Washington nor Oregon has provided a temperature TMDL. On May 18, 2020, EPA issued for public review and comment the TMDL for temperature on the Columbia and lower Snake rivers. The TMDL addresses portions of the Columbia and lower Snake rivers that have been identified by the states of Washington and Oregon

as impaired due to temperatures that exceed those states' water quality standards. After considering comments, EPA may make modifications, as appropriate, and then transmit the TMDL to Oregon and Washington for incorporation into their current water quality management plans. Implementation of the TMDL will likely benefit SR spring/summer Chinook salmon through improved thermal conditions in the migratory corridor.

- EPA released its final Columbia River Cold Water Refuges Plan (EPA 2021) on January 7, 2021. The plan focuses on the lower 325 miles of the Columbia River from the Snake River to the ocean. Cold water refuges serve an increasingly important role to some salmon and steelhead species as the lower Columbia River has warmed over the past 50 years and will likely continue to warm in the future due to climate change. The Columbia River Cold Water Refuges Plan is a scientific document with recommendations for protecting and restoring cold water refuges. EPA issued this plan in response to consultation under section 7 of the ESA associated with its approval of Oregon’s temperature standards for the Columbia River. This plan also serves as a reference for EPA’s Columbia and Snake Rivers Temperature TMDL.
- In 2015, jeopardy biological opinions were issued for Idaho and Oregon for water quality standards for toxic substances (NMFS 2012, 2014d). These consultations called for the adoption of new water quality criteria for a number of toxic substances. Since issuance of the biological opinions, Idaho has adopted new water quality criteria for copper and selenium. Oregon has adopted new criteria for ammonia, copper, and cadmium, and EPA has promulgated new criteria for aluminum.
- In December 2016, EPA approved IDEQ’s *Upper Salmon River Subbasin Assessment and TMDL: 2016 Addendum and Five-Year Review* (IDEQ 2016). The TMDL addendum identified shade targets that were needed for the impaired streams to achieve compliance with temperature criteria. This document establishes the shade levels that land managers (i.e., private, state, and federal) should strive for through future implementation plans and actions.
- Water Quantity:
    - In December 2017, the Water Resources Commission adopted Oregon’s Integrated Water Resources Strategy, a framework for better understanding and meeting instream and out-of-stream water needs, including water quantity, water quality, and ecosystem needs. No records or reports of implementation for this strategy are more current than the 2016 monitoring strategy.[7] Thus, we have no information as to whether the targets for improvements in flows and water quality are being reached through the implementation of the new strategy.
    - In January 2018, the Washington State legislature passed the Streamflow Restoration law. This law aims to restore streamflows to levels necessary to

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[7] (https://www.oregon.gov/OWRD/programs/Planning/IWRS/Pages/default.aspx)

    support robust, healthy, and sustainable salmon populations while providing water for homes in rural Washington. The State law requires that enough water is kept in streams and rivers to protect and preserve instream resources and values such as fish, wildlife, recreation, aesthetics, water quality, and navigation. One of the most effective tools for protecting streamflows is to set instream flows, which are flow levels adopted into rule. Instream flows cover nearly half of the State of Washington's watersheds and the Columbia River. In Washington – and especially on the east side of the state – out-of-stream uses, especially irrigation, exacerbate seasonally low flows, leading to passage and temperature problems and the loss of habitat living space. Other water uses also play a contributing role, as does land use (lack of recharge arising from impervious surfaces). The Washington State Department of Ecology maintains a list of critical watersheds where instream flows are thought to be a contributing factor to "critical" or "depressed" fish status, as identified by the Washington Department of Fish and Wildlife. There are 16 basins identified as critical, affecting the following counties: Asotin, Garfield, Whitman, Columbia, Walla Walla, Benton, Yakima, Kittitas, Chelan, Pierce, King, Snohomish, Whatcom, Okanogan, and Clallam/Jefferson.

  - The Idaho Department of Water Resources (IDWR) adjudicates through the court all water rights and to which property those water rights belong. The Snake River basin adjudication was an administrative and legal process that began in 1987, and the final decree was signed in 2014 (Vonde et al. 2016). Since completion, increased administration of water rights has improved streamflow in select reaches, likely benefiting instream habitat conditions for all salmonids.
  - Federally Authorized Water Diversions – In Idaho, the U.S. Forest Service has recently completed (NMFS 2016a, 2016b, 2021) or initiated (i.e., Sawtooth National Forest) ESA section 7 consultations on the use of Federal land to convey water to private irrigation water users. Future implementation of these consultations will likely provide minor improvements, relative to baseline conditions, to water quantity and water temperature within the migratory corridor for SR Chinook salmon.

- Columbia River Harvest Management: *U.S. v. Oregon*. Pursuant to a September 1, 1983 Order of the U.S. District Court, the allocation of harvest in the Columbia River was established under the "Columbia River Fish Management Plan" and implemented in 1988 by the parties of *U.S. v. Oregon*. Since 2008, 10-year management agreements have been negotiated through *U.S. v. Oregon* (NMFS 2008a and 2018). Harvest impacts on ESA–listed species in Columbia River commercial, recreational, and treaty fisheries continue to be managed under the 2018-2027 *U.S. v. Oregon* Management Agreement (NMFS 2018). The parties to the agreement are the United States, the states of Oregon, Washington, and Idaho, and the Columbia River Treaty Tribes: Warm Springs, Yakama, Nez Perce, Umatilla, and Shoshone Bannock. The agreement sets harvest rate limits on fisheries impacting ESA-Listed species, and these harvest limits continue to be annually managed by the fisheries co-managers (TAC 2015, 2016, 2017, 2018, 2019, 2020). The current *U.S. v. Oregon* Management Agreement (2018-2027) has, on average, maintained reduced impacts of fisheries on the Snake River species (TAC 2015, 2016, 2017, 2018, 2019, 2020), and we expect that to continue with the abundance-based framework incorporated into the current regulatory regime.

Other regulatory mechanisms

At the same time, we remain concerned about the adequacy of some existing regulatory mechanisms in terms of supporting the recovery of SR spring/summer Chinook salmon. These include:

- Water rights allocation and administration issues in Oregon and Idaho, and poor implementation of jeopardy biological opinions that address flow. The lack of success in keeping water, or enough water, in streams during critical times of the year has resulted in poor survival and no opportunities for spawning, rearing, and migration in tributary streams.
- CWA – *The Navigable Waters Protection Rule: Definition of Waters of the United States*, was finalized on June 22, 2020 (85 FR 22250). This ruling will have deleterious effects on SR spring/summer Chinook salmon because the regulatory nexus has been reduced and redefined. Redefined language and increased exemptions reduce the ability to utilize the ESA and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) to avoid, minimize, and mitigate effects that impact listed species and their designated critical habitats. Additionally, in 2021, the U.S. Army Corps of Engineers finalized the re-issuance of existing Nation Wide Permits with modifications (86 FR 2744, 86 FR 73522). The modifications will allow an increase in the amount of fill and destruction of habitat for frequently used nationwide permits throughout the range of SR spring/summer Chinook salmon. Although regional conditions to the permits may address some of these issues, there has not been any indication that regional conditions will be developed or address the impacts to listed species and their designated critical habitat.
- On November 18, 2021, the EPA and Department of the Army announced the signing of a proposed rule to revise the definition of “waters of the United States” (86 FR 69372). The agencies propose to put back into place the pre-2015 definition of “waters of the United States,” updated to reflect consideration of Supreme Court decisions. This familiar approach would support a stable implementation of “water of the United States” while the agencies continue to consult with states, Tribes, local governments, and a broad array of stakeholders in implementing the water of the United States rule and future regulatory actions. Development within floodplains continues to be a regional concern. CWA 404 permit exemptions, particularly ones affecting agricultural and transportation activities, continue to promulgate degraded tributary and mainstem habitat conditions.

Incorporating measures incentivizing habitat and floodplain functional improvements could provide meaningful habitat improvements for this ESU that are not provided for in the current exemptions.

- In 2015, jeopardy biological opinions were issued for Idaho and Oregon for water quality standards for toxic substances (NMFS 2012, 2014d). These consultations called for the adoption of new water quality criteria for a number of toxic substances. Since issuance of the biological opinions, Idaho has adopted new criteria for copper and selenium. Oregon has adopted new criteria for ammonia, copper, and cadmium, and EPA has promulgated new criteria for aluminum. The reasonable and prudent alternatives calling for the adoption of new criteria for mercury and arsenic and calling for the removal of the hardness floor remain to be implemented in Idaho.
- Implementation of the 2016 addendum to the Upper Salmon River subbasin assessment and TMDL (IDEQ 2016) rests with the land managers and is voluntary. As such, there is uncertainty relative to the extent to which land management changes and restoration activities will occur along the corridors of impaired streams.
- Beaver restoration and management is recommended as a recovery action for this species (see Listing Factor A). Management authorities within this ESU need to be evaluated to determine whether changes could be made to support beaver recolonization and/or reintroduction and enhance and sustain the benefits of beaver habitat to salmon (e.g., creation of rearing habitat, decreased stream temperatures, increased channel complexity and habitat connectivity, and expanded riparian habitat).
- National Flood Insurance Program (NFIP). City, county, and state land use planning regulations remain inconsistent across the species’ range and resulting in growth and development practices that often prevent attaining desired watershed and riparian functions. Development in floodplains continues to be a regional concern as it frequently results in stream bank alteration, stream bank armoring, and stream channel alteration projects to protect private property that do not allow streams to function properly and result in degraded aquatic habitat.

  The National Flood Insurance Program (NFIP) is a federal benefits program that extends access to federal monies or other benefits, such as flood disaster funds, and subsidized flood insurance, in exchange for communities adopting local land use and development criteria consistent with federally established minimum standards. Development proceeding in compliance with NFIP minimum standards ultimately results in impacts to floodplain connectivity, flood storage/inundation, hydrology, and to habitat forming processes. Development consequences of levees, stream bank armoring, stream channel alteration projects, and floodplain fill, combine to prevent streams from functioning properly and result in degraded habitat. Most communities (counties, towns, cities) in Washington, Idaho, and Oregon are NFIP participating communities, applying the NFIP minimum standards. For this reason, it is important to note that, where it has been analyzed for effects on salmonids, floodplain development that occurs consistent with the

NFIP's minimum criteria has been found to jeopardize 18 listed species of salmon and steelhead (Chinook salmon, steelhead, chum salmon, coho salmon, sockeye salmon) (NMFS 2008b, 2016c). The Reasonable and Prudent Alternative provided in NMFS 2016c, including Columbia Basin species, has not yet been implemented.

Listing Factor D Conclusion

Based on the information noted above for regulations in the Snake River basin and the Columbia River migratory corridor, we conclude that the risk to the species' persistence because of the adequacy of existing regulatory mechanisms has remained the same. Despite improvements in the adequacy of some regulatory mechanisms within the Snake River ESU since the 2016 5-year review, there have been regulatory changes that make species preservation more challenging. In addition, programs continue that do not adequately support the persistence of SR spring/summer Chinook salmon.

Listing Factor E: Other natural or manmade factors affecting the continued existence of the species

Other natural or manmade factors affecting the continued existence of this species include:

- Climate change, including ocean conditions and marine survival;
- Rearing and migration habitat conditions in the lower Columbia River estuary; and
- Hatcheries.

Climate Change

One factor affecting the range-wide status of SR spring/summer Chinook salmon and aquatic habitat is climate change. Major ecological realignments are already occurring in response to climate change (Crozier et al. 2019). As observed by Siegel and Crozier in 2019, long-term trends in warming have continued at global, national, and regional scales. The five warmest years in the 1880 to 2019 record have all occurred since 2015, while 9 of the 10 warmest years have occurred since 2005 (Lindsey and Dahlman 2020). The year 2020 was another hot year in national and global temperatures; it was the second hottest year in the 141-year record of global land and sea measurements and capped off the warmest decade on record (http://www.ncdc.noaa.gov/sotc/global202013). Events such as the 2013-2016 marine heatwave (Jacox et al. 2018) have been attributed directly to anthropogenic warming in the annual special issue of Bulletin of the American Meteorological Society on extreme events (Herring et al. 2018). Global warming and anthropogenic loss of biodiversity represent profound threats to ecosystem functionality. These two factors are often examined in isolation, but likely have interacting effects on ecosystem function (Siegel and Crozier 2019). Conservation strategies now need to account for geographical patterns in traits sensitive to climate change, as well as climate threats to species-level diversity.

Climate change has negative implications for SR spring/summer Chinook salmon survival and recovery, and for their designated critical habitat (Climate Impacts Group 2004; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007) characterized by the ISAB as follows:

- Warmer air temperatures will result in diminished snowpack and a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.
- With a smaller snowpack, watersheds will see their runoff diminished earlier in the season, resulting in lower stream flows in June through September. Peak river flows, and river flows in general, are likely to increase during the winter due to more precipitation falling as rain rather than snow.
- Water temperatures are expected to rise, especially during the summer months when lower stream flows co-occur with warmer air temperatures. Islam et al. (2019) found that air temperature accounted for about 80 percent of the variation in stream temperatures in the Fraser River, thus tightening the link between increased air and water temperatures.

These changes will not be spatially homogenous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of important coldwater habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, earlier emergence of fry, and increased competition among species.

Impacts on Salmon

Range of effects caused by a changing climate

Climate change is predicted to cause a variety of impacts to Pacific salmon and their ecosystems (Mote et al. 2003; Crozier et al. 2008a; Martins et al. 2012; Wainwright and Weitkamp 2013; OCCRI 2019, 2021). The complex life cycles of anadromous fishes, including salmon, rely on productive freshwater, estuarine, and marine habitats for growth and survival, making them particularly vulnerable to environmental variation. Ultimately, the effects of climate change on salmon and steelhead across the Columbia Basin will be determined by the specific nature, level, and rate of change and the synergy among interconnected terrestrial/freshwater, estuarine, nearshore, and ocean environments. Climate change and anthropogenic factors continue to reduce adaptive capacity in Pacific salmon, alter life history characteristics, and simplify population structure.

The primary effects of climate change on Pacific Northwest salmon and steelhead are (Crozier 2016, 2021):

- Direct effects of increased water temperatures on fish physiology and increased susceptibility to disease.

- Temperature-induced changes to stream flow patterns can block fish migration, trap fish in dewatered sections, dewater redds, introduce non-native fish, and degrade water quality.
- Alterations to freshwater, estuarine, and marine food webs can alter the availability and timing of food resources.
- Changes in estuarine and ocean productivity can affect the abundance and productivity of fish resources.

The 2017 Snake River recovery plan (NMFS 2017a) identified the following potential effects of climate change on SR spring/summer Chinook salmon and steelhead in freshwater areas:

- Winter flooding in transient and rainfall-dominated watersheds may scour redds, reducing egg survival.
- Water temperatures during incubation may accelerate the rate of egg development and result in earlier fry emergence and dispersal, which could be either beneficial or detrimental, depending on location and prey availability.
- Reduced summer and fall flows may reduce the quality and quantity of juvenile rearing habitat, strand fish, or make fish more susceptible to predation and disease
- Reduced flows and higher temperatures in late summer and fall may decrease parr-to-smolt survival.
- Warmer temperatures will increase metabolism, which may increase or decrease juvenile growth rates and survival, depending on food availability.
- Overwintering survival may be reduced if increased flooding reduces suitable habitat.
- Timing of smolt migration may be altered due to a modified timing of the spring freshet, such that there is a mismatch with ocean conditions and predators.
- Higher temperatures while adults are holding in tributaries and migrating to spawning grounds may lead to increased prespawning mortality or reduced spawning success due to delay or increased susceptibility to disease and pathogens.
- Increases in water temperatures in Snake and Columbia River reservoirs could increase consumption rates and growth rates of predators and, hence, predation-related mortality on juvenile spring/summer Chinook salmon and steelhead.
- Lethal water temperatures (temperatures that kill fish) may occur in the mainstem migration corridor or in holding tributaries, resulting in higher mortality rates.
- If water temperatures in the lower Snake River (especially Lower Granite Dam and reservoir) warm during late summer and fall sufficiently that they cannot be maintained at a suitable level by cold-water releases from Dworshak Reservoir, then migrating adult Snake River summer Chinook salmon and steelhead could have higher rates of mortality and disease.

Effects caused by changing flows and temperatures

While all habitats used by Pacific salmon will be affected, the impacts and certainty of the change vary by habitat type. Some effects (e.g., increasing temperature) affect salmon at all life stages in all habitats. Others are habitat-specific, such as stream-flow variation in freshwater, sea-level rise in estuaries, and upwelling in the ocean. How climate change will affect each stock or population of salmon also varies widely depending on the level or extent of change, the rate of change, and the unique life history characteristics of different natural populations (Crozier et al. 2008b). A concern that affects the recovery of SR spring/summer Chinook salmon is high water temperatures in the adult migration corridor. As described above, high water temperatures in 2015 resulted in catastrophic mortalities for SR sockeye salmon during migration through the hydrosystem (Crozier et al. 2020). Conditions that lead to high water temperatures are predicted to occur more frequently in the future with climate change. Crozier's (2020) modeling suggests that during anomalously warm years like 2015, Snake River spring chinook will see 93 percent of average survival through the hydrosystem while summer Chinook salmon will experience 70 percent of normal survival, in comparison to the 8 percent of average survival for Snake River sockeye salmon. While spring Chinook salmon will not experience migration mortality as high as later migrating summer Chinook, they will be more vulnerable to prespawn mortality while holding in the higher temperatures before spawning.

Like most fishes, salmon are poikilotherms (cold-blooded animals); therefore, increasing temperatures in all habitats can have pronounced effects on their physiology, growth, and development rates (see review by Whitney et al. 2016). Increases in water temperatures beyond their thermal optima will likely be detrimental through a variety of processes, including increased metabolic rates (and therefore food demand), decreased disease resistance, increased physiological stress, and reduced reproductive success. These processes are likely to reduce the fitness of salmonids, including SR spring/summer Chinook salmon (Beechie et al. 2013; Wainwright and Weitkamp 2013; Whitney et al. 2016).

By contrast, increased temperatures at ranges well below thermal optima (i.e., when the water is cold) can increase growth and development rates. Examples of this include accelerated emergence timing during egg incubation stages, or increased growth rates during fry stages (Crozier et al. 2008a; Martins et al. 2011). Temperature is also an important behavioral cue for migration (Sykes et al. 2009), and elevated temperatures may result in earlier-than-normal migration timing. While there are situations or stocks where this acceleration in processes or behaviors is beneficial, there are others where it is detrimental (Sykes et al. 2009; Whitney et al. 2016).

How precipitation and snowpack changes will affect freshwater ecosystems largely depends on their specific characteristics and location (Crozier et al. 2008b; Martins et al. 2012). For example, within a relatively small geographic area (the Salmon River basin in Idaho), survival of some Chinook salmon populations was shown to be determined largely by temperature, while in others it was determined by flow (Crozier and Zabel 2006; Isaak et al. 2018). Certain salmon populations inhabiting regions that are already near or exceeding thermal maxima will be most affected by further increases in temperature and, perhaps, the rate of the increases, while the effects of altered flow are less clear and likely to be basin-specific (Crozier et al. 2008b; Beechie et al. 2013; Isaak et al. 2018). However, river flow is likely to become more variable in many rivers and is believed to negatively affect anadromous fish survival more than other environmental parameters (Ward et al. 2015). It is likely that this increasingly variable flow is detrimental to salmon populations in the Columbia River basin.

The effects of climate change on stream ecosystems are difficult to predict (Lynch et al. 2016). Changes in stream temperature and flow regimes are likely to lead to shifts in the distributions of native species and facilitate the establishment of exotic species. This will result in novel species interactions, including predator-prey dynamics, where juvenile native species may be either predators or prey (Lynch et al. 2016; Rehage and Blanchard 2016). It is difficult to predict how juvenile native species will fare as part of "hybrid food webs," which are constructed from native, native invaders, and exotic species (Naiman et al. 2012).

New Climate Change Information

The last 5-year review (NMFS 2016a) summarized the best available science on how climate change is predicted to impact freshwater environments, estuarine and plume environments, marine conditions and marine survival, the consequences of marine conditions, and drought management. The current best available science supports that previous analysis. The discussion below updates new information as it relates to how climate change is currently impacting and predicted to impact SR spring/summer Chinook salmon in the future.

Marine Effects

Siegel and Crozier (2020) summarized new science published in 2019 with a number of publications describing the anomalous conditions of the marine heatwave that led to an onshore and northward movement of warm stratified waters into the California Current ecosystem off of the west coast of the United States. Brodeur et al. (2019) described the community response of the plankton community composition and structure, suggesting that forage fish diets had to shift in response to food resources that are considerably less nutritionally dense. This was supported by the work of Morgan et al. (2019), who stated that it was unclear whether these observations represented an anomaly or were a permanent change in the Northern California Current.

Crozier et al. (2019) asserted in their vulnerability analysis (see below) that sea surface temperature and ocean acidification (as well as freshwater stream temperatures) were the most broadly identified climate-related stressors likely to impact populations.

Groundwater Effects

The effect of climate change on groundwater availability is likely to be uneven. Sridhar et al. (2018) coupled a surface-flow model with a ground-flow model to improve predictions of surface water availability with climate change in the Snake River basin. Combining the VIC and MODFLOW models (VIC-MF), they predicted flow for 1986-2042. Comparisons with historical data show improved performance of the combined model over the VIC model alone. Projections using RCP 4.5 and 8.5 emission scenarios suggested an increase in water table heights in downstream areas of the basin and a decrease in upstream areas. Such assessments will help stakeholders manage water supplies more sustainably. Still ultimately, less groundwater availability will likely make it more challenging for populations returning to spawn in late summer and early fall. In support of that idea, Leach and Moore (2019) found that groundwater may only make streams resistant to change in the short term as groundwater sources will be impacted on longer time scales.

Freshwater Effects

As described in Siegel and Crozier (2019), Isaak et al. (2018) examined recent trends in stream temperature across the western United States using a large regional dataset. Stream warming trends paralleled changes in air temperature and were pervasive during the low-water warm seasons of 1996-2015 (0.18-0.35°C/decade) and 1976-2015 (0.14-0.27°C/decade). Their results show how continued warming will likely affect the cumulative temperature exposure of migrating salmon. Isaak et al. (2018) concluded that most stream habitats will likely remain suitable for salmonids in the near future, with some becoming too warm.

Streams with intact riparian corridors that lie in mountainous terrain are likely to be more resilient to changes in air temperature. These areas may provide refuge from climate change for a number of species, including Pacific salmon. Krosby et al. (2018) identified potential stream refugia throughout the Pacific Northwest based on a suite of features thought to reflect the ability of streams to serve as such refuges. Analyzed features include large temperature gradients, high canopy cover, large relative stream width, low exposure to solar radiation, and low levels of human modification. They created an index of refuge potential for all streams in the region, with mountain area streams scoring highest. Flat lowland areas, which commonly contain migration corridors, were generally scored lowest, and thus were prioritized for conservation and restoration. These low-lying habitats provide important juvenile rearing habitat, thus their continued value (without restoration) as rearing habitat in the near term is a concern.

Siegel and Crozier (2019) point out concern that for some salmon populations, climate change may drive mismatches between juvenile arrival timing and prey availability in the marine environment. However, phenological diversity can contribute to metapopulation-level resilience by reducing the risk of a complete mismatch. Carr-Harris et al. (2018) explored phenological diversity of marine migration timing in relation to zooplankton prey for sockeye salmon from the Skeena River of Canada. They found that sockeye migrated over a period of more than 50 days. Populations from higher elevation and further inland streams arrived in the estuary later, and different populations encountered distinct prey fields. They recommended that managers maintain and augment such life-history diversity. SR spring/summer Chinook salmon exhibit some phenological diversity, but it is not known whether it is enough to buffer the effects of climate change.

A concern that affects the recovery of SR spring/summer Chinook salmon is high water temperatures in the adult migration corridor. As described above, high water temperatures in 2015 resulted in catastrophic pre-spawning mortalities for SR sockeye salmon. Crozier et al. suggested that SR spring/summer Chinook salmon could have post-migration difficulty finding deep, cool pools in which to hold prior to spawning. Spring Chinook salmon are expected to advance their migration timing and migrate faster in response to higher temperatures, increasing the total holding period. Conditions that lead to high water temperatures are predicted to occur more frequently in the future with climate change. Anttila et al. (2019) suggest that migration conditions act as a strong selective force on cardiace capacity in sockeye salmon populations, as measured by sacrco(endo)plasmic reticulum Ca2+-ATPase activity (SERCA). They found that SERCA differs considerably across populations and related these differences to the adult migratory experience of populations, with those that migrated to high elevations (such as SR spring/summer Chinook salmon) and experiencing higher temperatures have larger capacities.

Marine Survival

Variation in marine productivity and prey quality can greatly impact the marine survival of salmon populations. The specific ocean habitat use of different salmon populations is poorly defined. Recent work by Espinasse et al. (2019) used carbon and nitrogen stable isotopes derived from an extensive time-series of salmon scales to examine aspects of the marine environment used by Rivers Inlet (British Columbia) sockeye salmon. The authors were able to identify likely rearing areas before sampling. This work and other research cited in Siegel and Crozier (2020) are improving our understanding of how marine productivity impacts salmon growth and survival, particularly during the early marine period.

Siegel and Crozier (2019) observe that changes in marine temperature are likely to have a number of physiological consequences on fishes themselves. For example, in a study of small planktivorous fish, Gliwicz et al. (2018) found that higher ambient temperatures increased the distance at which fish reacted to prey. Numerous fish species (including many tuna and sharks) demonstrate regional endothermy, which in many cases augments eyesight by warming the retinas. However, Gliwicz et al. (2018) suggest that ambient temperatures can similarly affect fish that do not demonstrate this trait. Climate change is likely to reduce the availability of biologically essential omega-3 fatty acids produced by phytoplankton in marine ecosystems. Loss of these lipids may induce cascading trophic effects, with distinct impacts on different species depending on compensatory mechanisms (Gourtay et al. 2018). Reproduction rates of many marine fish species are also likely to be altered with temperature (Veilleux et al. 2018). The ecological consequences of these effects and their interactions add complexity to predictions of climate change impacts in marine ecosystems.

Crozier et al. (2021) recently published results from a study looking at how climate change would affect survival across the entire life cycle of eight populations of SR spring/summer Chinook salmon. This study used multiple global emission scenarios to predict changes in ocean conditions. They found relative resilience in freshwater stages for these eight populations. The dominant driver toward extinction was rising sea surface temperatures (SST), which tracked an almost 90 percent decline by 2060 in survival in the marine life stage.[8] The modeled carryover effects of changes in timing are likely to be adaptive, but inadequate as compensation for large declines in marine survival.

Further, Crozier et al. (2021) results indicate that as one symptom of a changing ocean, rising SST puts all of the study populations at high risk of extinction, despite actions within the hydrosystem to speed juvenile travel and increase in-river survival. In nearly all simulations, small populations had minimal demographic buffers against declining marine survival rates and quickly dropped below the quasi-extinction threshold. Threats to the larger study populations caused even greater concern because the modeled eight populations are the remaining strongholds, which provide genetic and demographic resilience for the SR spring/summer Chinook salmon ESU as a whole. While these dramatic declines are not predicted to occur over the next 5 years, they do support an increasing concern about whether enough resilience can be gained in other parts of their life cycle (e.g., production and survival in freshwater habitats) to mitigate for future climate-caused losses in marine habitats.

Climate Vulnerability Assessment

Crozier et al. (2019) recently completed a climate vulnerability assessment for Pacific salmon and steelhead, including SR spring/summer Chinook salmon (Figure 11). The assessment was based on three components of vulnerability: (1) biological sensitivity, which is a function of individual species characteristics; (2) climate exposure, which is a function of geographical location and projected future climate conditions; and (3) adaptive capacity, which describes the ability of a DPS to adapt to rapidly changing environmental conditions. Objectives were to characterize the relative degree of threat posed by each component of vulnerability across DPSs

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[8] There are two main caveats to these modeled projections. First, the Northeast Pacific might not warm at the rate modeled, despite rising levels of atmospheric CO_2. Over the past century, global mean temperature has been a weaker determinant of SST than internal variability in the climate system, represented by strong changes in sea-level pressure and natural variability in ocean circulation. How long this situation will continue is difficult to predict. Nonetheless, with the entire ocean warming at all depths, this signal will inevitably reach coastal waters.

A second possibility is that the Northeast Pacific will warm as modeled, but with some sort of ecological surprise that will reverse the historical relationship between SST and salmon survival. Ocean temperature does not limit salmon through a direct physiological response, but rather through a combination of bottom-up and top-down trophic processes, which jointly regulate salmon growth and survival and which explain the non-stationarity of statistical correlations. Although warm conditions have been associated with lower-quality prey and more warm-water predators, it is possible that novel communities will arise with different responses to temperature, or that salmon will adapt to an altered food web in a positive manner.

and to describe landscape-level patterns in specific threats and cumulative vulnerability at the DPS level. Refer to Crozier et al. (2019) for more information on their methodology to calculate climate vulnerability for each DPS.

Crozier et al. (2019) concluded that SR spring/summer Chinook salmon has a high risk of overall climate vulnerability based on its high risk for biological sensitivity, very high risk for climate exposure, and high capacity to adapt. Life-stage sensitivity attributes for this ESU were scored very high for the adult freshwater stage, which essentially caused the very high score in cumulative life-cycle effects. This species has been closely studied as a threatened and indicator species and is the subject of life-cycle modeling under climate change conditions. Negative effects of high temperatures encountered during the adult and juvenile freshwater stages have been documented (Crozier and Zabel 2006; Crozier et al. 2017a, 2017b). Estimated extinction risk under climate change scenarios is significantly higher than under the historical climate regime (Crozier and Zabel 2013).

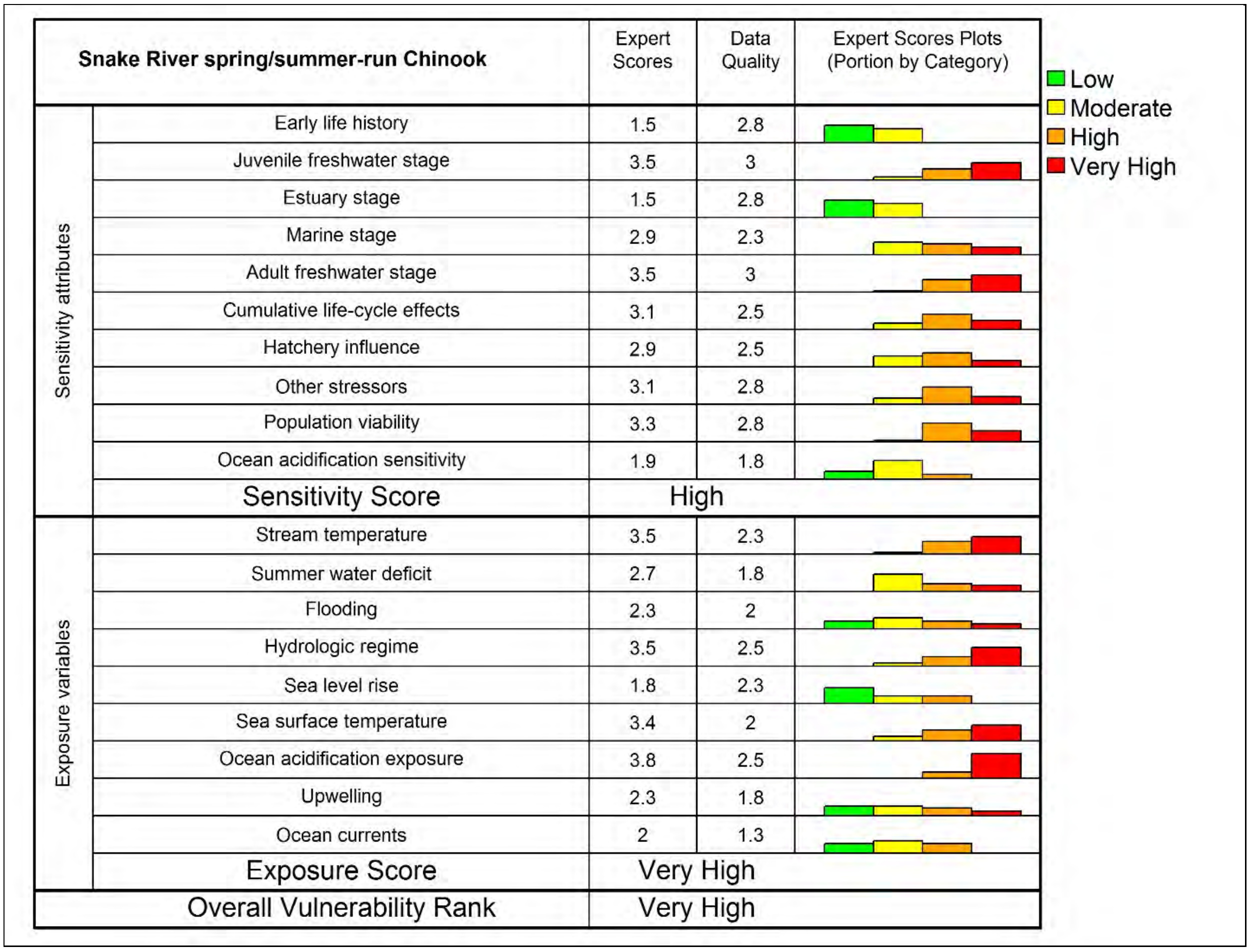
Populations within this ESU that migrate later are called summer-run fish. Examples are the Pahsimeroi and South Fork Salmon River populations, which encounter stressful temperatures during the adult migration. However, both spring- and summer-run populations are at risk for prespawn mortality while holding in tributary habitats during peak summer temperatures (Bowerman et al. 2016). This ESU was ranked very high risk for the adult freshwater stage. Because juveniles spend a full year in fresh water, they can experience negative effects on survival from warm summer temperatures and low flows (Crozier and Zabel 2006; Crozier et al. 2008b). Juvenile survival during the smolt migration depends strongly on rapid flows from snowmelt (Zabel et al. 2008; Faulkner et al. 2018). Thus, sensitivity in the juvenile freshwater stage was ranked high risk. The Interior Columbia recovery domain is likely to lose a substantial portion of snowpack, so this ESU was ranked very high for hydrologic regime shift.

Furthermore, exposure to stream temperature change ranked very high, elevating vulnerability to very high in both the juvenile and adult freshwater stages. A vast majority of populations in this ESU exhibit the yearling life history strategy. Therefore, loss of this rearing strategy would mean loss of a significant characteristic of this ESU, a threat reflected in the high score for cumulative life-cycle effects. Carryover effects between life stages also increased the cumulative life-cycle effects risk, as discussed below.

SR spring/summer Chinook salmon sensitivity was ranked moderate at the marine stage, although some scorers considered the marine mortality risk to be high. Marine survival for this ESU is lower during warm phases of the Pacific Decadal Oscillation, and rising sea surface temperature will likely have impacts similar to the warm ocean conditions related with both warm phases of the PDO and low adult survival (Zabel et al. 2006; Crozier et al. 2008b). On the other hand, while the smolt migration is slower in low snowpack years, earlier smolt migration timing might benefit this DPS in relation to ocean upwelling. At present, much of the population enters the ocean later than the optimal period for survival (Scheuerell et al. 2009). SR spring/summer Chinook salmon have a relatively short estuary rearing period (Weitkamp et al.

2012, 2015), which resulted in low risk scores for estuary stage and sea-level rise. Observations suggest that longer freshwater rearing produces larger smolts, which then spend less time in the estuary. Of primary concern in the cumulative life-cycle effects attribute is loss of unique life history types, including the spring/summer adult run type and the yearling juvenile life history strategy. Cumulative effects from shifts in successive life stages may reduce survival in subsequent life stages. For example, earlier migration timing at the juvenile freshwater stage may mean fish are smaller at ocean entry and less likely to encounter favorable ocean feeding conditions. Such a timing alteration could reduce early marine survival (Crozier et al. 2008a). Thus, sensitivity of this ESU was considered high for cumulative life-cycle effects.

Overall Snake River spring/summer Chinook salmon scored high in adaptive capacity (Crozier et al. 2019), partially from complex terrain that includes snow-cooled streams. However, the Interior Columbia ESUs face the largest percentage loss of snow-dominated habitat, potentially causing a net contraction in life history variability. This ESU may have sufficient adaptive capacity to increase the production of subyearling smolts, or for yearling smolts to migrate earlier in spring. Adults may have some flexibility in migration timing to avoid high stream temperatures in the migration corridor, but Crozier et al. 2020 suggests that it will not be sufficient. This would likely have a differential impact on different populations, which could ultimately reduce diversity in the basin. Early migrating adults in this ESU will still need to hold for extended periods before spawning, increasing their exposure to high stream temperatures and risk from harvest and disease. Energetic costs during the holding period might limit adaptive capacity in the adult stage. Very low abundance levels, such as seen at quasi-extinction thresholds, will inhibit adaptive capacity.



Snake River spring/summer-run Chinook		Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Early life history	1.5	2.8	
	Juvenile freshwater stage	3.5	3	
	Estuary stage	1.5	2.8	
	Marine stage	2.9	2.3	
	Adult freshwater stage	3.5	3	
	Cumulative life-cycle effects	3.1	2.5	
	Hatchery influence	2.9	2.5	
	Other stressors	3.1	2.8	
	Population viability	3.3	2.8	
	Ocean acidification sensitivity	1.9	1.8	
	Sensitivity Score	High		
Exposure variables	Stream temperature	3.5	2.3	
	Summer water deficit	2.7	1.8	
	Flooding	2.3	2	
	Hydrologic regime	3.5	2.5	
	Sea level rise	1.8	2.3	
	Sea surface temperature	3.4	2	
	Ocean acidification exposure	3.8	2.5	
	Upwelling	2.3	1.8	
	Ocean currents	2	1.3	
	Exposure Score	Very High		
Overall Vulnerability Rank		Very High		

Figure 11. SR spring/summer Chinook salmon Climate Effects Exposure and Vulnerability (Crozier et al. 2019).

Lower Columbia River Estuary Modifications

The lower Columbia River estuary provides important migratory habitat for juvenile SR spring/summer Chinook salmon. Since the late 1800s, about 70 percent of the vegetated tidal wetlands of the Columbia River estuary have been lost to diking, filling, and bank hardening, combined with flow regulation and other modifications (Kukulka and Jay 2003; Bottom et al. 2005; Marcoe and Pilson 2017; Brophy et al. 2019). Disconnection of tidal wetlands and floodplains has reduced the production of wetland macrodetritus supporting the food web (Simenstad et al. 1990; Maier and Simenstad 2009), both for small Chinook salmon and chum salmon that rear in shallow water and for larger juveniles, such as yearling SR spring/summer Chinook salmon, which migrate in the mainstem (PNNL and NMFS 2020).

Restoration actions in the estuary have improved habitat quality and fish access to floodplain forests and wetlands. From 2007 through 2019, the Bonneville Power Administration and Corps implemented 64 projects that included dike and levee breaching or lowering, tide-gate removal, and tide-gate upgrades. These have reconnected over 6,100 acres of the historical floodplain to the mainstem Columbia River and another 2,000 acres of floodplain lakes (Karnezis 2019; BPA et al. 2020). This represents more than a 2.5 percent net increase in the connectivity of habitats that produce prey used by yearling Chinook salmon (Johnson et al. 2018). In addition to this extensive reconnection effort, the Bonneville Power Administration and Corps have acquired conservation easements to protect about 2,500 acres of currently functioning floodplain habitat from development. Numerous other project sponsors have completed floodplain protection and restoration projects in the lower Columbia River. While these efforts likely provide survival benefits for yearling Chinook salmon, the improvements have not been at a scale where we would expect measurable survival improvements.

Hatchery Effects

The effects of hatchery fish on the status of an ESU depends upon which of the four key attributes – abundance, productivity, spatial structure, and diversity – are currently limiting the ESU, and how the hatchery fish within the ESU affect each of the attributes (70 FR 37204). Hatchery programs can provide short-term demographic benefits, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of the risk depend on the status of affected populations and on specific practices in the hatchery program.

Hatchery managers have continued to implement and monitor changes in hatchery management since the last 5-year review for the hatchery programs within this ESU. Currently, there are 18 spring/summer Chinook salmon hatchery programs in the Snake River basin, 13 of which are ESA-listed (Table 7). Most of these programs are integrated with the natural populations and release hatchery fish into rivers with ESA-listed natural-origin SR spring/summer Chinook salmon. SR spring/summer Chinook salmon hatchery program production levels have remained stable since the most recent 5-year review (NMFS 2016a). Many captive broodstock programs initiated during the 1990s to conserve SR spring/summer Chinook salmon genetic resources were terminated after the status of these fish improved.

Over the years, hatchery programs that supplement natural-origin populations in the Snake River have made improvements to their hatchery programs. In particular, program managers have better integrated natural-origin fish into their broodstock. Integration of hatchery programs is typically done using sliding scales sensitive to population abundance, by adjusting the pHOS and pNOB (percent hatchery origin fish on spawning grounds, and percent natural-origin fish in hatchery broodstock, respectively). Under the sliding scales, the programs allow some hatchery-origin fish to spawn in the wild at all abundance levels but reduce the proportions of hatchery-origin spawners as natural-origin abundance increases. In addition, the proportion of natural-origin fish used in broodstock increases as abundance increases, as determined by the sliding scales. This strategy attempts to balance the risk of extinction (low natural-origin abundance) with the risk of hatchery influence.

Similarly, segregated hatchery programs, which only use hatchery-origin broodstock, have improved release and collection strategies to reduce straying. This reduction in straying has reduced the potential for these segregated programs to impact naturally spawning Chinook salmon.

In addition to risks of hatchery influence, there is potential for competition and predation when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas and migratory corridors. Because hatchery fish released are likely to affect natural-origin fish as they emigrate, they can affect the productivity VSP parameter of the natural population.

The following subsections provide additional information on hatchery programs by location.

Clearwater River

Four non-ESA-listed hatchery programs operate in the Clearwater River basin: Kooskia spring Chinook, Clearwater Fish Hatchery spring/summer Chinook salmon, Nez Perce Tribal Hatchery spring/summer Chinook salmon, and Dworshak spring Chinook salmon programs. Chinook salmon in the Clearwater River are not part of the listed SR spring/summer Chinook salmon ESU, and critical habitat for the ESU was not designated in the Clearwater River basin. The hatcheries in the Clearwater basin are operated as segregated programs and focus on keeping hatchery fish separate from natural-origin populations. NMFS completed a consultation on these programs in 2017 and determined that the programs are not likely to appreciably reduce the likelihood of survival and recovery of the SR spring/summer Chinook salmon ESU (NMFS 2017d). These hatchery programs have implemented new strategies to limit straying of program fish into areas where ESA-listed fish are present (NMFS 2017d). Straying effects and population-level pHOS values of all programs do not constitute a serious threat to the SR spring/summer Chinook salmon ESU. They are considered negligible since all of the population level pHOS values from the proposed programs are below 0.05.

South Fork Salmon River

Five hatchery programs operate in the South Fork Salmon River basin: three integrated programs and two segregated programs. NMFS completed a consultation on these programs in 2019 and determined that the programs are not likely to appreciably reduce the likelihood of survival and recovery of the SR spring/summer Chinook salmon ESU (NMFS 2019a). PNI (percent natural influence) and pHOS targets have been defined for these programs. The hatchery programs are: South Fork Salmon River summer Chinook, South Fork Chinook Egg Box Project summer Chinook salmon, Johnson Creek Artificial Propagation and Enhancement Project summer Chinook salmon, Rapid River spring Chinook salmon, and Hells Canyon spring Chinook salmon programs. Straying effects and population-level pHOS values of all programs do not constitute a serious threat to the Snake River spring/summer Chinook salmon ESU and are considered negligible since all of the population level pHOS values from the proposed programs are below 0.05. Furthermore, the hatchery operators have adopted sliding scales with PNI values that are expected to be over 0.67 for the South Fork Salmon River summer Chinook salmon hatchery program, the South Fork Chinook Salmon Eggbox Program (since it uses eggs from the McCall hatchery program), and the Johnson Creek Artificial Propagation Enhancement programs.

The South Fork Salmon River summer Chinook salmon hatchery program, operated at the McCall Fish Hatchery, has two components (segregated and integrated), with a recently implemented genetic relationship between them. A sliding scale is used to manage the level of integration between the hatchery and natural populations for the integrated component, and a percentage of returning fish from the integrated component will be used as broodstock in the segregated component. This type of genetic linkage is sometimes referred to as a “stepping stone” system (HSRG 2014). Initial analysis by NMFS shows that these linked programs pose considerably less risk of hatchery-influenced selection than solely segregated programs because they maintain a genetic linkage with the naturally spawning population (Busack 2015).

The South Fork Salmon River summer Chinook salmon hatchery program also contributes eyed eggs to the South Fork Chinook salmon egg box program, meaning that segregated hatchery fish produced in the egg box program are also genetically linked to a naturally spawning population. As noted above, genetically linked programs are considered to pose less risk of hatchery-influenced selection than segregated programs (Busack 2015). According to the 2019 Biological Opinion, the South Fork Salmon River population has shown a substantial improvement in PNI since the integrated hatchery-origin returns were incorporated into broodstock from 0.25 to 0.63 (NMFS 2019a). Unfortunately, poor ocean conditions have contributed to low SARs in recent years. Therefore, it will likely take more time to determine the success of the sliding-scale PNI management scenarios.

The Johnson Creek Artificial Propagation Enhancement (JCAPE) (East Fork, South Fork Salmon River) program has always used 100 percent natural-origin fish in its broodstock, so it maintains a strong link to the natural-origin population. Since this program exclusively uses natural-origin fish for broodstock, the PNI is consistently over the recommended 67 percent (NMFS 2019a) and will continue to be in the future.

The Rapid River (Little Salmon/South Fork Salmon River) and Hells Canyon programs (Upper Snake River) are segregated programs that produce fish for harvest purposes. As described in the most recent biological opinion, these programs have developed new strategies to limit straying and ecological interactions between hatchery and ESA-listed natural-origin fish (NMFS 2019a).

Upper Salmon River

There are four hatchery programs in the upper Salmon River basin, all integrated with the natural-origin populations. The programs are; Upper Salmon River spring Chinook salmon (Sawtooth), Yankee Fork spring Chinook salmon, Pahsimeroi summer Chinook salmon, Panther Creek summer Chinook salmon programs.

The Upper Salmon River spring Chinook salmon (Sawtooth) hatchery program operates similarly to the South Fork Salmon River program described above, with both an integrated and a segregated component. A sliding scale is used to manage the level of integration between the hatchery and natural populations for the integrated component, and a percentage of returning fish from the integrated component will be used as broodstock in the segregated component. PNI management targets have been identified for this program to be implemented depending on the number of natural-origin and hatchery-origin adult returns. According to the newest Biological Opinion, operators have adopted a sliding scale that has a future PNI value that is expected to be over 0.67, before the population reaches the minimum abundance threshold. The weir on the Upper Salmon River is highly efficient (>90 percent). This commitment to achieve PNI and pHOS values in the sliding scale is an improvement in diversity from previous operations. Because the sliding scale depends on natural-origin returns, at low abundance, the PNI will be between 0.5 and 0.67 in most years (NMFS 2017e).

The Yankee Fork program is related to the Sawtooth program, as broodstock from the Sawtooth program are being used to jump start the Yankee Fork program. Over time, broodstock will be collected solely in Yankee Fork, and a sliding scale will be used to manage the level of integration between the hatchery and natural populations. PNI management targets have been identified for this program to be implemented depending on the number of NOR and HOR escapement. The operators have adopted a sliding scale that has future expected PNI values over 0.5, which will maintain natural influence of the population. In addition, the operators have agreed to a target PNI over 0.67 (or 67 percent) after the population reaches minimum abundance threshold (NMFS 2017e).

The Pahsimeroi program has both an integrated and segregated component. A sliding scale is used to manage the level of integration between the hatchery and natural populations for the integrated component, and a percentage of returning fish from the integrated component will be used as broodstock in the segregated component. PNI management targets have been identified for this program to be implemented depending on the number of NOR and HOR escapement. According to the newest Biological Opinion, operators have adopted a sliding scale that has a future PNI value that is expected to be over 0.67, before the population reaches the minimum abundance threshold. The weir on the Upper Salmon River is highly efficient (>90 percent). This commitment to achieve PNI and pHOS values in the sliding scale is an improvement in diversity from previous operations. We expect the future PNI values in most years to exceed 0.67 (NMFS 2017e).

The Panther Creek program is related to the Pahsimeroi program, as broodstock from the Pahsimeroi program are being used to jump start the Panther Creek program. Over time, broodstock will be collected solely in Panther Creek, and a sliding scale will be used to manage the level of integration between the hatchery and natural populations. PNI management targets have been identified for this program to be implemented depending on the number of NOR and HOR escapement. Even though it is not mandatory, the operators have adopted a sliding scale that has future expected PNI values over 0.5, which will maintain natural influence of the population (NMFS 2017e).

NMFS completed a consultation on these programs in 2017 and determined that the programs are not likely to appreciably reduce the likelihood of survival and recovery of the SR spring/summer Chinook salmon ESU (NMFS 2017e). Straying effects and population-level pHOS values of all programs do not constitute a serious threat to the SR spring/summer Chinook salmon ESU and are considered negligible since all of the population level pHOS values from the proposed programs are below 0.05.

Grande Ronde/Imnaha Rivers and Lower Snake River

Six hatchery programs operate in the Grande Ronde/Imnaha and lower Snake River basins. All six programs are integrated with, and intended to supplement, natural-origin populations. Sliding scales are used to manage the level of integration between the hatchery and natural populations for the integrated component. NMFS completed a consultation on these programs in 2016 and determined that the programs are not likely to appreciably reduce the likelihood of survival and recovery of the SR spring/summer Chinook salmon ESU (NMFS 2016b). The programs are; Catherine Creek spring/summer Chinook salmon, Lookingglass Creek spring Chinook salmon, Lostine spring/summer Chinook salmon, Upper Grande Ronde spring/summer Chinook salmon, Imnaha River spring/summer Chinook salmon, Tucannon River Endemic spring Chinook salmon programs.

Table 5. ESA Status of hatchery programs within the Snake River spring/summer Chinook salmon ESU.

Program Stock Origin	Program	Run	Watershed Location of Release (State)	Currently Listed?
Tucannon	Tucannon River	Spr/Sum	Tucannon River (WA)	Yes
Lostine	Lostine River	Spr/Sum	Lostine River (OR)	Yes
Catherine Creek	Catherine Creek	Spr/Sum	Catherine Creek (OR)	Yes
Lookingglass	Lookingglass Hatchery Reintroduction	Spr/Sum	Lookingglass Creek (OR)	Yes
Upper Grande Ronde	Upper Grande Ronde	Spr/Sum	Upper Grande Ronde (OR)	Yes
Imnaha	Imnaha River	Spr/Sum	Imnaha River (OR)	Yes
SF Salmon	McCall Hatchery	Summer	SF Salmon River (ID)	Yes
	South Fork Salmon River Eggbox	Spring	SF Salmon River (ID)	Yes
Johnson Creek	Johnson Creek Artificial Propagation Enhancement	Summer	EF/SF Salmon River (ID)	Yes
Pahsimeroi	Pahsimeroi Hatchery	Summer	Salmon River (ID)	Yes
	Panther Creek	Summer	Salmon River (ID)	Yes
Sawtooth	Sawtooth Hatchery	Spring	Upper Mainstem Salmon River (ID)	Yes
Sawtooth/ Pahsimeroi	Yankee Fork	Spring	Yankee Fork (ID)	Yes
Rapid River	Rapid River Hatchery	Spring	Little Salmon River (ID)	No

Program Stock Origin	Program	Run	Watershed Location of Release (State)	Currently Listed?
Dworshak stock/ Clearwater River	Dworshak NFH	Spring	NF Clearwater River (ID)	No
	Kooskia	Spring	Mainstem Clearwater River(ID)	No
	Clearwater Hatchery	Spring	Mainstem Clearwater River (ID)	No
	Nez Perce Tribal Hatchery	Spring	Mainstem Clearwater River (ID)	No

Listing Factor E Conclusions

Climate Change

SR spring/summer Chinook salmon has a high risk of overall climate vulnerability based on its high risk for biological sensitivity, very high risk for climate exposure, and high capacity to adapt. Life-stage sensitivity attributes for this ESU were scored very high for the adult freshwater stage, which essentially caused the very high score in cumulative life-cycle effects. The high overall sensitivity rank of this ESU stemmed largely from its migration characteristics. Negative effects of high temperatures encountered during the adult and juvenile freshwater stages have been documented, and estimated extinction risk under climate change scenarios is significantly higher than under the historical climate regime. Recent work evaluated climate impacts at all life stages of eight populations of SR spring/summer Chinook salmon and modeled future trajectories forced by global climate model projections. Populations rapidly declined in response to increasing sea surface temperatures and other factors across diverse model assumptions and climate scenarios. The high adaptive capacity scored in Crozier et al. 2019 was insufficient when modeled in Crozier et al. 2021 with the current RCP (representative concentration pathways) 4.5 and 8.5. These models predicted climate impacts were most dramatic in the marine stage, where survival was reduced by 83-90 percent by 2060 (Crozier et al. 2021). This occurred even when modeling shifts in migration timing, with smolts arriving at Bonneville Dam about 6.5 days earlier and actions within the hydrosystem to speed juvenile travel to allow an earlier initiation of the marine stage, which generally improves marine survival. While the smaller populations had minimal demographic buffers and quickly dropped below the quasi-extinction threshold in nearly all simulations, the drop in larger populations is even more concerning as they provide genetic and demographic resilience for the ESU as a whole (Crozier et al. 2021).

Hatchery Effects

In general, hatchery programs can provide short-term demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of risk depend on the status of affected populations and on specific practices in the hatchery program. Hatchery programs can affect naturally produced populations of salmon and steelhead in a variety of ways, including competition (for spawning sites and food) and predation effects, disease effects, genetic effects (e.g., outbreeding depression, hatchery-influenced selection), broodstock collection effects (e.g., to population diversity), and facility effects (e.g., water withdrawals, effluent discharge) (NMFS 2018).

The hatchery programs that affect the Snake River spring-run Chinook salmon ESU have changed over time, and these changes have likely reduced adverse effects on ESA-listed species. Over the years, hatchery programs that supplement natural-origin populations in the Snake River have improved their hatchery programs. In particular, program managers have better integrated natural-origin fish into their broodstock and limited the number of hatchery-origin spawners, when appropriate. Integration of hatchery programs is typically done using sliding scales sensitive to population abundance. Under the sliding scales, the programs allow some hatchery-origin fish to spawn in the wild at all abundance levels but reduce the proportions of hatchery-origin spawners as natural-origin abundance increases. In addition, the proportion of natural-origin fish used in broodstock increases as abundance increases, as determined by the sliding scales. This strategy attempts to balance the risk of extinction (low natural-origin abundance) with the risk of hatchery influence.

Similarly, hatchery programs that are segregated from the natural-origin population have improved release and collection strategies to reduce straying. This reduction in straying has reduced the potential for these segregated programs to impact naturally spawning Chinook salmon.

Recommended Future Actions

At this time, we are unable to mitigate for the effects of reduced ocean survival within the marine environment. Thus, efforts to improve productivity and survival in freshwater habitats could affect marine survival in these populations as well as increase the resilience of populations during all life stages. These include:

- Throughout salmon watersheds, improving and expanding access to rearing habitat should increase smolt abundance and body condition, resulting in improved population viability. Intrinsic habitat potential is negatively correlated with present levels of disturbance, so restoring all critical habitat could yield substantial benefits. Specifically, the lower-elevation habitat that was historically highly productive has been preferentially lost; and
- Improving individual fish growth by reducing contaminant loads, increasing floodplain habitat, and increasing habitat complexity, in general, could boost population productivity.

2.4 Synthesis

The ESA defines an endangered species as one that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as one that is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. Under ESA section 4(c)(2), we must review the listing classification of all listed species at least once every 5 years. While conducting these reviews, we apply the provisions of ESA section 4(a)(1) and NMFS' implementing regulations at 50 CFR part 424.

To determine if a reclassification is warranted, we review the status of the species and evaluate the five threat factors, as identified in ESA section 4(a)(1): (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or man-made factors affecting a species' continued existence. We then make a determination based solely on the best available scientific and commercial information, taking into account efforts by states and foreign governments to protect the species.

We conclude:

Updated Biological Risk Summary: Our Northwest Fisheries Science Center completed an updated viability assessment for the ESU (Ford 2022). In summary, while there have been improvements in abundance/productivity in several populations relative to the time of listing, the majority of populations experienced sharp declines in abundance in the recent 5-year period, primarily due to variation in ocean survival, and declines for all populations in the 15-year trends.

In addition, we examined how threats associated with the five listing factors have changed in the last 5 years:

- *Listing Factor A (Habitat)*: Conservation partners have implemented many tributary habitat restoration projects across the ESU since the last 5-year review, improving habitat conditions for spring/summer Chinook salmon spawning, rearing, and migration in many reaches. However, widespread areas of degraded habitat persist across the basin, with simplified stream channels, disconnected floodplains, impaired instream flow, loss of cold water refugia, conditions increasingly favoring non-native predator fish, and other limiting factors (NMFS 2020). The risk to the species persistence due to habitat degradation remain relatively unchanged since the last review and continues to be a threat to the persistence of this ESU.
- *Listing Factor B (Overutilization)*: The risk to the species' persistence because of overutilization remains essentially unchanged since the 2016 5-year review.

- *Listing Factor C (Disease and Predation*): The extinction risk posed to the ESU by disease, avian predation, and predation by other fish species has remained largely the same since the last 5-year review. Information available since the last 5-year review suggests that sea lions are consuming a large percentage of adult spring Chinook salmon migrating through the lower Columbia River (e.g., Rub et al. 2019) and that predation by pinnipeds continues to pose a significant negative threat to the persistence of this ESU.
- *Listing Factor D (Regulatory Mechanisms)*: New information available since the last 5-year review indicates that the adequacy of a number of regulatory mechanisms has remained the same. Some mechanisms show the potential for some improvement, while others made it more challenging to protect and recover our species.
- *Listing Factor E (Other Natural and Manmade Factors)*: SR spring/summer Chinook salmon are highly vulnerable to the effects of climate change. Threats include increases in stream temperature, changes to freshwater hydrologic regime, sea surface temperature and ocean acidification. Recent life-cycle modeling for this species suggested relative resilience in freshwater life stages, with the dominant driver toward extinction being rising sea surface temperature, associated with a 90 percent decline in survival in the marine life stage by 2060. With climate change and a warming ocean, we expect to see unfavorable ocean conditions and low marine survival more frequently in the future. The hatchery programs that affect the Snake River spring-run Chinook salmon ESU have changed over time, and these changes have likely reduced adverse effects on ESA-listed species.

Overall, the information analyzed for this 5-year review indicates an increased level of concern in the risk status for SR spring/summer Chinook salmon. The basis for this concern includes: (1) The combination of short and medium-term declining population trends across the ESU; (2) no populations current abundances meeting MAT and almost half the populations less than 10 percent of their MAT; (3) climate change modeling indicating all smaller populations and most larger populations will meet QET within 1-4 decades with all current climate scenarios due to predicted negative impacts of climate change on all life stages; (4) potential for continued low marine survival due to higher SST and ocean acidification; and (5) high levels of predation on returning adults by pinnipeds in the lower Columbia River. We recommend maintaining the current classification of Threatened but recommend closely monitoring abundance and productivity statistics during the next 5-year period and initiating a new status review if warranted prior to the next 5-year review.

2.4.1 Snake River Spring/Summer Chinook Salmon Delineation and Hatchery Membership

The Northwest Fisheries Science Center’s review (Ford 2022) found that no new information had become available that would justify a change in the delineation of the Snake River spring/summer Chinook salmon ESU.

The West Coast Regional Office’s review of new information since the previous 2016 5-year review regarding the ESU membership status of various hatchery programs indicates no changes in the Snake River spring/summer Chinook salmon membership are warranted.

2.4.2 ESU/DPS Viability and Statutory Listing Factors

- The information presented in the Northwest Fisheries Science Center’s review of updated information (Ford 2022) indicates that the biological risk category for the majority of SR spring/summer Chinook salmon remained high with three populations improving slightly to moderate since the time of the last status review (NMFS 2016a).
- Our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the SR spring/summer Chinook salmon’s persistence has increased since our previous 5-year review.

3. Results

3.1 Classification

Listing status:

Based on the information identified above, we recommend that the SR spring/summer Chinook salmon ESU maintain its current classification as a threatened species. However, we are very concerned about current trends in abundance and productivity. Because of that concern, we have recommended specific actions be implemented over the next 5 years. Those recommendations are made within the discussion of each listing factor (Section 2) and also summarized below in Section 4. The recommendations are actions that can be taken at the population, MPG, and ESU levels. Furthermore, we will continue to evaluate the risk to the ESU over the next 5 years, with the potential to initiate a status review prior to the standard 5-year review period.

ESU/DPS Delineation:

The Northwest Fisheries Science Center's review (Ford 2022) found that no new information has become available that would justify a change in delineation for the SR spring/summer Chinook salmon ESU.

Hatchery Membership:

For the SR spring/summer Chinook salmon ESU, we do not recommend any changes to the hatchery program membership.

3.2 New Recovery Priority Number

Since the previous 2016 5-year review, NMFS revised the recovery priority number guidelines and twice evaluated the numbers (NMFS 2019b, 2022). Table 4 indicates the number in place for the SR spring/summer Chinook salmon ESU at the beginning of the current review (3C). In January 2022, the number remained unchanged.

As part of this 5-year review, we reevaluated the number based on the best available information, including the new viability assessment (Ford 2022), and concluded that the current recovery priority number remains 3C.

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4. Recommendations for Future Actions

In our review of the listing factors, we identified several actions critical to improving the status of the SR spring/summer Chinook salmon ESU. These include implementing the 2017 Snake River recovery plan (NMFS 2017a), the *U.S. v. Oregon* (in-river harvest) Management Agreement for 2018-2027 and 2018 biological opinion, the 2020 Columbia River System biological opinion (NMFS 2020a), and biological opinions on hatchery operations within the ESU (NMFS 2016b, 2017d, 2019).

The greatest opportunities to advance recovery are to:

- Prioritize tributary habitat projects that improve habitat resiliency to climate change. Actions to restore riparian vegetation, streamflow, and floodplain connectivity and re-aggrade incised stream channels can ameliorate temperature increases, base flow decreases, and peak flow increases, thereby improving population resilience to some effects of climate change (Beechie et al. 2013).
- Support and enhance local- to basin-scale frameworks to guide and prioritize tributary habitat restoration actions and integrate a landscape perspective into decision making. Successful examples in the ESU include the Grande Ronde Atlas process and the Integrated Rehabilitation Assessment in the Upper Salmon River (Tetra Tech Inc. 2017; Biomark ABS et al. 2019; White et al. 2021).
- Implement habitat restoration at a watershed scale. Roni et al. (2010) found that, for a watershed, at least 20 percent of floodplain and in-channel habitat need to be restored to see a 25 percent increase in salmon smolt production. Most watersheds occupied by this species have not yet reached that level of floodplain and habitat restoration.
- Reconnect stream channels with their floodplains. Reintroducing beaver (Pollock et al. 2017) and applying low-tech process-based methods (Wheaton et al., eds, 2019) will facilitate widespread, low-cost floodplain restoration across the ESU, increasing the productivity of freshwater habitat for Chinook salmon.
- Ensure that habitat improvement actions are implemented consistent with best practices for watershed restoration (e.g., Beechie et al. 2010; Hillman et al. 2016; Appendix A of NMFS 2020).
- Develop and implement long-term management strategies to reduce pinniped predation on adult SR spring/summer run Chinook salmon returning to the lower Columbia River.

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5. References

5.1 Federal Register Notices

November 20, 1991 (56 FR 58612). Notice of Policy: Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon.

February 7, 1996 (61 FR 4722). Notice of Policy: Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act.

July 10, 2000 (65 FR 42421). Endangered and Threatened Species; Final Rule Governing Take of 14 Threatened Salmon and Steelhead Evolutionarily Significant Units (ESUs).

June 28, 2005 (70 FR 37159). Final Rule: Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs.

June 28, 2005 (70 FR 37204). Final Policy: Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead.

January 5, 2006 (71 FR 834). Final Rule: Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead.

August 15, 2011 (76 FR 50448). Notice of availability of 5-year reviews: Endangered and Threatened Species; 5-Year Reviews for 17 Evolutionarily Significant Units and Distinct Population Segments of Pacific Salmon and Steelhead.

May 26, 2016 (81 FR 33468). Notice of Availability of 5-year Reviews Endangered and Threatened Species; 5-Year Reviews for 28 Listed Species of Pacific Salmon, Steelhead, and Eulachon.

April 30, 2019 (84 FR 18243). Notice of Final Guidelines: Endangered and Threatened Species; Listing and Recovery Priority Guidelines.

October 4, 2019 (84 FR 53117). Notice of Initiation of 5-year Reviews: Endangered and Threatened Species; Initiation of 5-Year Reviews for 28 Listed Species of Pacific Salmon and Steelhead.

April 21, 2020 (85 FR 22250). Final rule. The Navigable Waters Protection Rule: Definition of “Waters of the United States.”

December 17, 2020 (85 FR 81822). Revisions to Hatchery Programs Included as Part of Pacific Salmon and Steelhead Species Listed Under the Endangered Species Act.

January 13, 2021. (86 FR 2744). Final Rule: Reissuance and Modification of Nationwide Permits.

December 7, 2021 (86 FR 69372). Proposed rule. Revised Definition of "Waters of the United States."

December 27, 2021 (86 FR 73522). Final rule. Army Corps of Engineers. Reissuance and Modification of Nationwide Permits.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Oncorhynchus tshawytscha: Snake River S

Current Classification: Threatened

Recommendation resulting from the 5-Year Review

☐ Downlist to Threatened
☐ Uplist to Endangered
☐ Delist
☒ No change is needed

Review Conducted By (Name and Office):

West Coast Region Snake River Spring-Summer Chinook Salmon ESU Evaluation Team

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

Approve Korie Ann Schaffer Date: 06/30/2022
For Scott M. Rumsey, Ph.D., Acting Regional Administrator

Cooperating Regional Administrator, NOAA Fisheries

☐ Concur ☐ Do Not Concur ☒ N/A

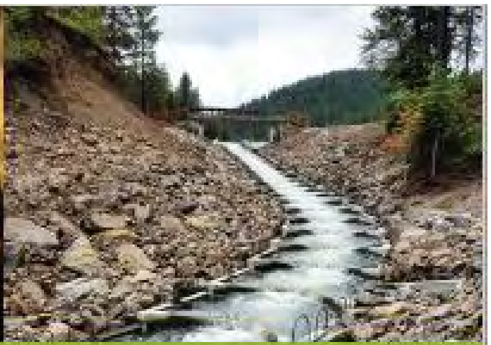
Signature____ Date: _______

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

☒ Concur ☐ Do Not Concur

Signature____ Date: _______



NOAA Fisheries WCR Anadromous Salmonid Design Manual - NMFS 2022

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NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual

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Acknowledgments

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Acronyms and Abbreviations

Symbol or Acronym	Term or Title
°C	degrees Celsius
°F	degrees Fahrenheit
ASP	Alaska steeppass
AWS	auxiliary water system or auxiliary water supply system
BOR	U.S. Bureau of Reclamation
ft^3/s	cubic feet per second
EDF	energy dissipation factor
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FERL	Fisheries-Engineering Research Laboratory
FPA	Federal Power Act
ft^2	square foot
ft^3	cubic foot
ft/s	foot per second
$ft\text{-}lb/ft^3/s$	foot pounds per cubic foot of flow per second
GCF	grade control fishway
gpm	gallon per minute
HDM	Hydraulic Design Method
HGMP	Hatchery and Genetic Management Plan
lb	pound
LSSS	Low Slope Stream Simulation
MSA	Magnuson-Stevens Fishery Conservation and Management Act
mm	millimeter
NMFS	National Marine Fisheries Service

Symbol or Acronym	Term or Title
NOAA	National Oceanic and Atmospheric Administration
O&M	operations and maintenance
PIT	passive integrated transponder
R/D	ratio of radius of curvature to pipe diameter
SSD	Stream Simulation Design
USACE	U.S. Army Corps of Engineers
VFD	variable frequency drive
WCR	West Coast Region

1 Introduction

The Environmental Service Branches provide technical and engineering assistance to National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) West Coast Region (WCR) fisheries biologists. NMFS also plays a supportive and advisory role in the management of living marine resources in the areas under state jurisdiction. This document is intended to assist with improving conditions for salmonids that must migrate past barriers to complete their life cycle. Effective Fish passage requires the integration of numerous scientific and engineering disciplines including, but not limited to, fish behavior, ichthyomechanics, hydraulics, hydrology, fluvial geomorphology and engineering. Installing a fish passage structure does not constitute providing satisfactory fish passage unless all of the above components are adequately factored into the design.

This document is intended to: provide internal assistance to NMFS biologists in designing effective fish passage; encourage consistency across the WCR region; while supporting the implementation of NMFS's statutory authorities related to the conservation and protection of marine resources; and provide technical assistance to project proponents.

The efficacy of any fish passage structure, device, facility, operation, or measure is highly dependent on local hydrology, target species and life stage, obstacle orientation relative to the stream, facility operation, and many other site-specific considerations. While the information provided herein will apply to many structures, it should be regarded as general guidance for the design, operation, and maintenance of fishways throughout the WCR. The criteria described in this document are not universally applicable and should not replace site-specific recommendations.

This document provides general guidance and is not intended as an alternative to active consultation with NMFS biologists and engineers. Application of these criteria in the absence of consultation does not imply approval by NMFS. This document provides criteria and additional guidelines for the design and operation of facilities at barriers to fish migration and water intakes in California, Washington, Oregon, and Idaho. The facilities are designed to create safe passage routes for adult and juvenile salmonids in rivers and streams and through reservoirs, restore habitat connectivity within watersheds, and enhance salmonid population productivity. NMFS's manual for fish passage facility design is meant to help NMFS staff advise project applicants on the engineering design of future fish passage projects and modifications to existing projects. The criteria are based on decades of experience developing, testing, operating fish passage systems and relies on the best available scientific information.

The WCR has developed a flow chart for how to use their various fish passage guidance documents (Figure 1). Prior to designing a fish passage facility, NMFS recommends the project proponent familiarize themselves with the "NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change" (Improving Resilience) guidance document. The Improving Resilience document outlines how to incorporate projected future flows the facility may experience over the life of the project and should be the starting point for the design process.

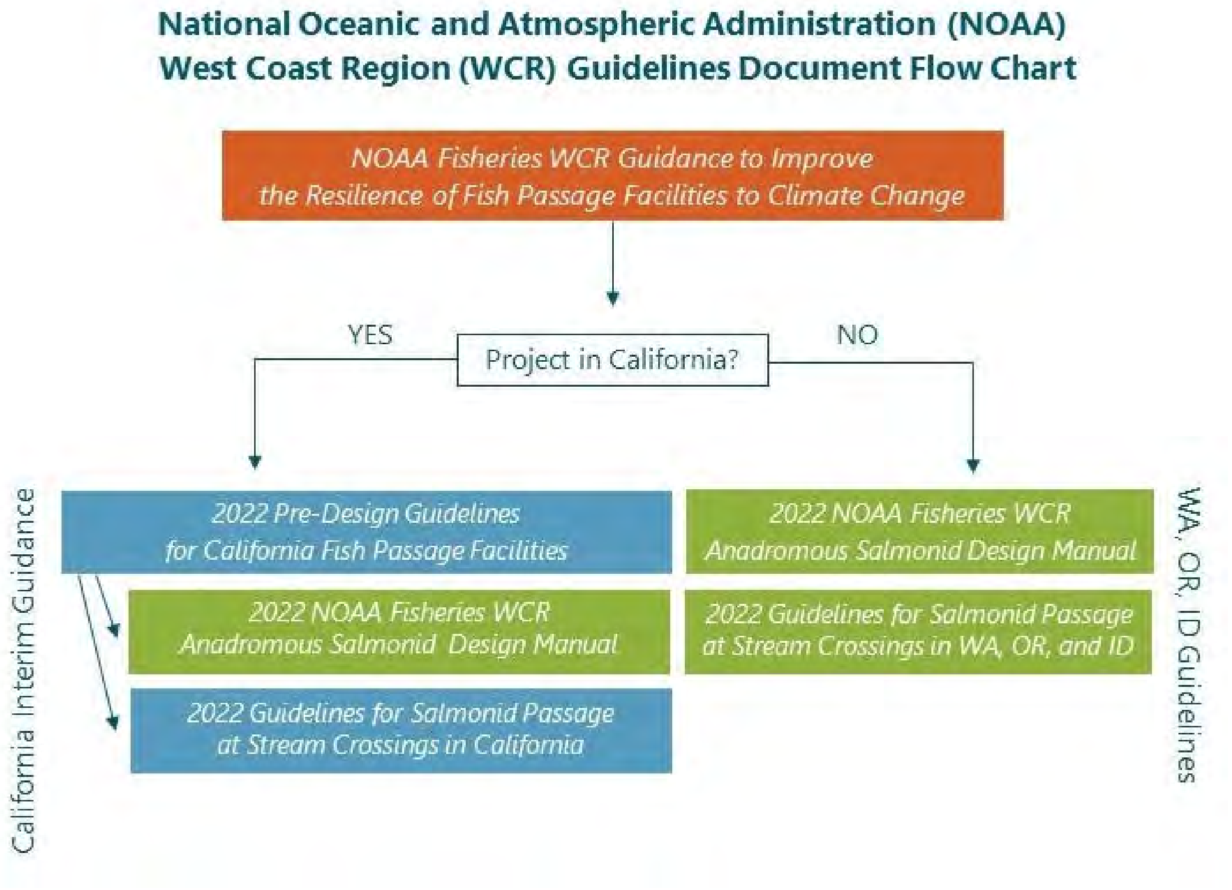

Figure 1-1. West Coast Region Fish Passage Guideline Flow Chart

In 2013, the Northwest and Southwest regions of the National Oceanic and Atmospheric Administration's (NOAA) NMFS were merged to form the WCR. This document is the first step in integrating fish passage design criteria and guidelines of the two former regions. This document, *NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Guidelines* supersedes the following documents:

- Northwest Region's *Anadromous Salmonid Passage Facility Design*, dated July 2011
- Southwest Region's *Fish Screening Criteria for Anadromous Salmonids*, dated January 1997
- Southwest Region's Experimental Fish Guidance Position Statement, dated January 1994
- Southwest Region's Water Drafting Specifications, dated August 2001

This document provides criteria and guidance for passage of anadromous salmonids only. For additional passage guidance concerning non-salmonids, refer to applicable state and federal entities.

This document contains introductory chapters, technical chapters, and appendices. The introductory chapters (Chapters 1 and 2) provide the statutory and biological background for the requirement to provide safe, timely, and effective passage of salmonids around barriers and definitions of key terms. The technical chapters (Chapters 3 through 10) present design criteria and guidelines that result in hydraulic conditions salmonid fish require to successfully pass barriers and minimize effects to salmonid populations, along with the scientific basis for criteria for which applicable references are available. The appendices provide information on aspects of fish passage facility design that are under development and may change over time after additional testing. Additionally, the appendices contain background information that was removed from the technical chapters to make the chapters more streamlined, but still needs to be available to the reader because the information is informative and relevant.

Throughout the chapters all criteria are italicized to be easily identifiable. In addition, chapter and appendix sections are cross-referenced where applicable. For example, the chapter on screens may direct the reader to the chapter on design flows so a reader interested in screens will understand that additional information is available in another chapter.

NMFS has separated these fish passage engineering guidelines into two volumes. This first volume entitled *NOAA Fisheries West Coast Region Anadromous Salmonid Passage Design Manual* provides design guidance for structural fish passage, protection, and exclusion projects not associated with river or stream crossings. This first volume represents guidelines that are based on decades of research, monitoring, and NMFS’ experience with these types of passage systems. NMFS considers material in this volume to be in a mature state and does not anticipate it will change significantly over time.

The guidance in Chapter 4 of this volume applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat in those states. Due to significantly different hydrologic conditions in California and those conditions impact on life history of NMFS trust species, project proponents should work with NMFS engineering staff to determine the appropriate design flows following the 2022 Pre-Design Guidelines for California Fish Passage Facilities.

The second volume, entitled *Guidelines for Salmonid Passage at Stream Crossings in Oregon, Washington, and Idaho* (NMFS 2022b) represents a growing body of work relating to fish passage at stream crossings that NMFS expects will expand significantly in the future. Separating these guidelines into two volumes will allow NMFS to refine and expand this additional volume in the near future as new information becomes available, without having to reopen and modify the entire guidelines document. NMFS 2022b includes introduction matter as well as two technical chapters relating to stream crossings and grade control fishways.

The guidance in Chapters 3 and 4 of NMFS 2022b applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat. Given significantly different hydrologic conditions, stream crossing projects in California should refer to: *Guidelines for Salmonid Passage at Stream Crossings in California* (NMFS 2019, addendum).

These criteria and guidelines were developed based on 60 years of agency experience in creating successful fish facility designs and have been further refined through a collaborative process with regional fish facility design experts. The criteria and guidelines in Volume 2 address more emerging fields of fish passage engineering and stream restoration. The criteria and rationale provided will be revised as needed if new information suggests that updated criteria would further improve passage conditions for fish.

1.1 Statutory Background

NMFS is mandated by U.S. Congress to manage, conserve, and protect living marine resources within the U.S. Exclusive Economic Zone. NMFS is authorized to conduct these actions under the Federal Power Act (FPA; administered by the Federal Energy Regulatory Commission [FERC]), the Fish and Wildlife Coordination Act (administered by the U.S. Fish and Wildlife Service), the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSA). This document provides criteria and technical assistance to project proponents on the design of fish passage facilities in order to provide safe, timely, and effective fish passage, consistent with NMFS responsibilities under the ESA, FPA, and MSA.

The requirement of safe, timely and effective passage derives from the unofficial but reliable definition of a fishway presented by Congress in a report related to the Energy Policy Act of 1992. The definition of "safe and timely passage" was expanded to include both passage structures and operations "necessary to ensure the effectiveness" of such structures. None of the terms "safe," "timely," or "effective" are further defined. However, in practice NMFS typically includes provisions which give these terms meaning. Regarding "safe" passage, NMFS requires licensees to design and operate their fishways so that they minimize the occurrence of injury or mortality experienced by fish while attempting to utilize the fishway. Regarding "timely" passage, a fishway prescription may include provisions for reducing the time in which a fish utilizing the fishway is subjected to stressful interactions, such as time spent in a trap or in transit, or a requirement for flows which will attract fish to a passage facility. Regarding "effective" passage, NMFS typically includes provisions requiring the operator to ensure that its facility succeeds in passing as close to 100% of the fish attempting to migrate through the system as possible.

Following these criteria will likely streamline processes, improve certainty, and improve the likelihood of success. NMFS also provides support and advice to states regarding the management of living marine resources in areas under state jurisdiction. This includes salmon (*Oncorhynchus spp.*) and steelhead (*O. mykiss*) due to their economic, cultural, recreational, and symbolic importance to society (NRC 1996).

NMFS pursues fish passage to contribute to its fishery management and ESA recovery goals. In reviewing, planning, designing, and implementing fish passage facilities, NMFS engineers will coordinate with NMFS biologists to make sure the particular target species, population numbers, migration timing and recovery goals are met.

1.2 Biological Background

Fish species within the family Salmonidae spawn in fresh water. Some species spend their entire lives in fresh water. Others spend a portion of their lives in marine waters where they grow and become sexually mature before returning to fresh water to spawn (Quinn 2005). The life history pattern that involves marine residence is known as anadromy, and salmonid species that display this pattern are referred to as anadromous salmonids.

NMFS has identified several key parameters that are used to judge the overall status and viability of salmon and steelhead populations. These include abundance, genetic diversity and life history diversity, productivity, and spatial structure (McElhany et al. 2000). NMFS considers a population to be viable if over a 100-year timeframe it can withstand threats and the risk of extinction from demographic variation, local environmental variation, and genetic diversity changes (McElhany et al. 2000). For examples of how these population parameters are used in viability assessments and recovery planning, see Lindley et al. (2007) and NMFS (2014). NMFS assesses any effects of barriers to migration and water intake structures on anadromous salmonids in the context of these parameters and overall population viability. The viability parameters are briefly described as follows:

Abundance. This is a commonly used species conservation and management parameter that refers to the number of organisms in a population.

Genetic diversity and life history diversity. Diversity refers to the distribution of traits within and among populations, which range in scale from DNA sequence variation at single genes to complex life history traits (McElhany et al. 2000). Genetic diversity and life history diversity are interrelated; thus, this parameter is not as straightforward as abundance. For example, a unique characteristic of anadromous salmonids is their high degree of fidelity to natal streams or rivers (Quinn 2005), which is a genotypic trait. This trait in turn facilitates local adaptations that result in phenotypic expressions of highly variable life history patterns (Taylor 1991; Waples 1991).

Life history diversity is often cited as a crucial component of salmonid population resiliency. This is based on evidence that maintaining multiple and diverse salmon stocks that fluctuate independently of each other reduces extinction risk and long-term variation in regional abundances (Roff 1992; Hanski 1998; Hilborn et al. 2003). Schindler et al. (2010) describe this as the portfolio effect, where risk is spread across multiple stocks. Preserving and restoring life history diversity is an integral goal of many salmonid conservation programs (Ruckelshaus et al. 2002). In addition, it is increasingly recognized that strengthening a population's resilience to environmental variability, including climate change, will require expanding habitat opportunities to allow a population to express and maintain its full suite of life history strategies (Bottom et al. 2011).

Productivity. Productivity represents the ability of a population to grow when conditions are suitable, which is essential to conservation success. In the absence of density-dependent factors, productivity is a measure of a population's ability to survive to reproduce and its reproductive success (McElhany et al. 2000). Populations that are below cohort replacement rate or have limited ability to respond to favorable environmental conditions are less viable and at higher risk of extinction.

Spatial structure. This parameter refers to the geographic distribution of individuals in a population or populations. A population's spatial structure comprises the geographic distribution of individuals and the processes that generate that distribution (McElhany et al. 2000). The structure of a population depends on the quality of habitat available to the population, how the habitat is configured spatially, the dynamics of the habitat, and the dispersal characteristics of individuals in the population among the available habitats (McElhany et al. 2000).

The viability of salmonid populations can change over time, and NMFS considers the potential for this to occur when reviewing fish passage designs. Changes in population viability could occur from multiple factors, including the following:

- Terminating or adding new hatchery supplementation programs
- Recolonization of historical habitats after removal of a migration barrier
- Increased partitioning of the spatial structure of a population due to new barriers being installed and loss of access to habitat
- Habitat degradation and restoration
- Shifts in river hydrology and water temperature due to climate change
- Disasters (fires, landslides, etc.)
- Changes in water management

1.3 Migration Barriers

Anthropogenic barriers include, but are not limited to, hydroelectric dams, water storage projects, irrigation diversions, water withdrawals, and tide gates. Dams can have significant effects on the structure and function of river ecosystems (Ward and Stanford 1979), and change in flow regulation is considered one of the most pervasive changes to rivers worldwide (Stanford et al. 1996). The effects of restricted access to migrating fish caused by dams and weirs have been broadly implicated in population declines of freshwater species around the world (Northcote 1998).

Dams can block access to habitat, eliminate habitat in the footprint of a dam and reservoir, affect the amount and timing of water flow, and result in mortality during passage (Ruckelshaus et al. 2002). Columbia River dams have blocked access to nearly 40% of the habitat historically available to salmon (NRC 1996). Construction of Hells Canyon Dam resulted in the loss of 90% of the historical spawning habitat of fall-run Chinook salmon (*O. tshawytscha*) in the Snake River, Idaho (McClure et al. 2001). In California, approximately 95% of Chinook salmon spawning habitat has been lost or is no longer accessible (Yoshiyama et al. 1996). Smaller water diversions can block access to habitats as well as cause mortality from entrainment at unscreened (or improperly screened) diversions and predation above or below the diversion. Another example, is the substantial amount of historical spawning and rearing steelhead habitat rendered unavailable in the Santa Clara River (due to the construction of dams). Santa Felicia Dam blocks 95% of the steelhead habitat within the Piru Creek watershed; more than 30 miles of stream lies between Santa Felicia Dam and Pyramid Dam (NMFS 2006 and references therein).

Dams blocking passage of steelhead to upstream habitats constitute an obstruction within a freshwater migration corridor for the species and, therefore, an impact to steelhead habitat.

In summary, some anadromous salmonid populations migrate hundreds of miles in fresh water, and barriers in their migration corridors can affect population viability (Ruckelshaus et al. 2002). This includes barriers that are complete blockages as well as barriers that are partial blockages due to localized hydraulic conditions or poorly functioning passage facilities. NMFS is responsible for evaluating the degree to which barriers affect anadromous salmonid populations and providing guidance on how to resolve any migration effects.

1.4 Design Process

Resolving effects on salmonid migrations from barriers involves the integration of information on fish behavior and physiology, biomechanics, hydraulic and hydrologic conditions, and civil engineering. Simply installing a fish passage structure does not constitute providing satisfactory fish passage. A successful design requires that information on each of these components be factored into the design.

Instances can also occur where a fish passage facility may not be a feasible solution for correcting a passage impediment due to biological, societal, or economic constraints. In these situations, removal of the impediment or altering project operations may be a suitable surrogate in lieu of constructing fish passage facilities (Clay 1995).

When determining whether NMFS will promote or prescribe solutions to fish passage issues, NMFS will rely on a collaborative approach that considers the views of other fisheries resource agencies, Native American tribes, non-governmental organizations, citizen groups, and other governmental agencies. The approach strives to consider fish passage objectives developed by other parties (e.g., well-placed stakeholder groups) to support fisheries restoration and habitat enhancement actions identified in conservation plans.

This document addresses design features that may provide for to the safe, timely, and effective passage of fish. It is the responsibility of the design engineer to ensure that other design requirements are met such as the structural integrity of the facility and public safety.

This document provides specific fish passage facility design criteria and technical assistance for actions within the WCR pertaining to the various authorities of NMFS. When reviewing fish passage proposals by project proponents, NMFS will apply the criteria to major upgrades to existing facilities and the design of new fish passage facilities to the extent practicable. Existing facilities that are not compliant with this document may have to be modified using the criteria identified herein if fish passage problems are observed at these facilities. If the project is unable to meet the criteria, then the project proponent should continue to work with NOAA staff in developing a recommended solution that would best attain fish passage goals for the project.

1.5 Experimental Technologies

Experimental technologies include devices or systems that have demonstrated some potential for protecting or passing fish, but for which adequate scientific evidence has not been collected to verify effectiveness and gain agency acceptance or to be considered for general application (AFS 2000). Experimental technologies are new, innovative and unproven technologies that could be broadly applied, rather than deviations from criteria applying to a single site.

NMFS considers experimental technologies to include designs with major departures from conventional fish passage technologies as covered in this document. Experimental technologies may also include application of proven techniques to unusual environmental conditions or facility operations. Site specific deviations from criteria may not rise to the level of experimental designs, but rather warrant a conversation between the applicant and appropriate NMFS staff.

Proponents of experimental fish passage designs should provide NMFS with a sound biological or scientific basis to support the proposed design. This may include the following proof-of-concept steps as appropriate:

- A demonstrated, favorable fish behavioral response in a laboratory setting
- An acceptable plan for evaluating the prototype installation
- An acceptable alternate fish passage design developed concurrently with the unproven fish passage design that satisfies the criteria listed herein, should the prototype not perform as anticipated nor adequately protect fish

Appendix C (Experimental Technologies) provides additional information on the NMFS approval process for unproven fish passage technologies.

1.6 Temporary and Interim Passage

Where construction and/or modifications to artificial impediments (e.g., dams), natural impediments (rockslides, other natural issues) or upstream passage facilities are planned, upstream and downstream passage may be adversely impacted or interrupted. If possible, these activities should be scheduled for periods when migrating fish are not present, as specified in the in-water work period allowable for construction of facilities in streams. However, this may not always be possible or advisable. In these cases, an interim fish passage plan should be prepared and submitted to NMFS for review, in advance of work in the field.

In the interim plan, upstream and downstream fish passage should be provided for any adult or juvenile fish likely to be present in the action area during construction, unless passage did not exist before construction or where the stream reach is naturally dry at the time of construction. Methods for work area isolation and dewatering, as necessary, should be determined in consultation with NMFS.

Design criteria listed elsewhere in this document also apply to the interim passage plan. Where this is not possible, project owners should seek NMFS review of alternate interim fish passage design criteria, and a final interim passage plan. Coordination with NMFS ahead of time is advised to determine appropriate work windows and other recommended alternatives or both.

1.7 Section 7 Consultation under the Endangered Species Act

This fish passage manual can be useful during ESA Section 7(a)(2) and Essential Fish Habitat (EFH) consultations. Incorporating the criteria within this document will help project proponents design projects that provide fish passage in a variety of situations. During the design process project developers can incorporate criteria within this document and work with NMFS engineers and biologists to ensure their projects meet these fish passage criteria. While this document provides substantial criteria related to fish passage, there are aspects of project design that are beyond the scope of this document. For instance, this manual does not identify or endorse specific construction best management practices. Project developers should coordinate with NMFS on project elements that fall outside the scope of this document.

This manual can also be used to achieve regulatory streamlining by aiding in the development of programmatic ESA and EFH consultations on activities involving fish passage. By incorporating these criteria into programmatic actions, action agencies and other stakeholders can help ensure their actions provide fish passage and appropriate conservation for protected resources, while streamlining the regulatory process.

1.8 Additional Information

Additional information on fish passage is available at the WCR website: http://www.westcoast.fisheries.noaa.gov/. Questions regarding this document and requests for assistance from NMFS fish passage specialists can be directed to the following offices:

For Washington, Oregon, and Idaho:

NOAA Fisheries West Coast Region
Environmental Services Branch
1201 Northeast Lloyd Boulevard, Suite 1100
Portland, Oregon 97232

503-230-5400

For California:

NOAA Fisheries West Coast Region
Environmental Services Branch
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404

707-387-0737

2 Definition of Terms

Anadromous **–** pertaining to a fish species that displays the life history pattern known as anadromy in which adults spawn in fresh water and juveniles migrate to sea to grow to their final size and then return to fresh water to spawn (Quinn 2005).

Active screens **–** juvenile fish screens equipped with efficient mechanical cleaning capability that are automatically cleaned as frequently as necessary to keep the screens free of any debris that may restrict flow through the screen area. NMFS requires active screen designs in most cases.

Applicant **–** a person or entity that proposes to design, modify, or construct a fish passage facility at an existing or new barrier, water diversion, or water conveyance that NMFS will review under its authorities identified in Chapter 1.

Approach velocity **–** the vector component of canal velocity that is normal (perpendicular) to, and immediately upstream of, the screen surface. Approach velocity is calculated based upon the submerged area of the screen for conical screens, all cylindrical screens (torpedo, T-screen, and end-of-pipe or hose screens) where submergence and clearance criteria are met, and inclined screens where angle and submergence requirements are met. For rotary drum screens, approach velocity is the vector component of canal flow velocity that is normal to, and immediately upstream of, the vertical projection of the screen surface.

Approach velocity is a design parameter that is used to calculate the minimum amount of effective screen area required to protect fish. The amount of effective screen area required to meet screen performance criteria is calculated by dividing the maximum diversion flow by the approach velocity. Approach velocity can be measured in the field with precise flow measurement equipment, and average operating approach velocity can be calculated by dividing the measured screen flow by the effective screen area. Approach velocity should be measured as close to the boundary layer of turbulence generated by the screen face as is physically possible. Chapter 8 provides a more detailed discussion of approach velocity.

Apron **–** a flat or slightly inclined slab of concrete below a flow control structure that provides erosion protection and produces hydraulic characteristics suitable for energy dissipation or, in some cases, fish exclusion.

Attraction flow **–** flow that emanates from a fishway entrance with sufficient velocity and quantity, and in the proper location and direction, to attract upstream migrants into the fishway entrance. Attraction flow consists of gravity flow from the fish ladder and any auxiliary water system (AWS) flow added at points within the lower fish ladder.

Auxiliary water system or auxiliary water supply system (AWS) **–** a hydraulic system that augments fish ladder flow at various points in a passage facility for upstream migrating fish. Large amounts of auxiliary water flow are typically added near the fishway entrance pool to increase the amount of attraction flow emanating from the fishway entrance and the attractiveness of the entrance to fish.

Backwash **–** a system that removes debris from dewatering screens by using pressurized flow against the screen surface in the opposite direction of the approach flow.

Backwater **–** a condition whereby a hydraulic drop is influenced or controlled by a water surface control feature located downstream of the hydraulic drop.

Baffles **–** physical structures placed in the water flow path designed to dissipate energy or redirect flow to achieve more uniform flow conditions.

Bankfull flow**–** the bank height when a stream or river channel is inundated under a flow that occurs at the 1.2-year to 1.5-year average flood recurrence interval. Bankfull height may be estimated by morphological features in the channel such as: 1) a topographic break from a vertical bank to a flat floodplain or from a steep to a gentle slope; 2) a change in vegetation from bare ground to grass, moss to grass, grass to sage, grass to trees, or no trees to trees; 3) a textural change of depositional sediment; 4) the elevation below which no fine debris (e.g., needles, leaves, cones, seeds) occurs; and 5) a textural change of fine sediment deposits (matrix material) between cobbles or rocks.

Bedload **–** sand, silt, gravel, soil, and rock debris transported by moving water on or near the streambed.

Bifurcation (trifurcation) pools **–** pools in a fish ladder below which the fish ladder (and flow) is divided into two or three separate routes.

Brail **–** a device that is moved upward (vertically) through a water column to crowd fish into an area for collection.

Bypass flow **–** in the context of dewatering screen design, the portion of diverted flow that is specifically used to return fish to the river.

Bypass reach **–** the portion of the river between the point of flow diversion and where bypassed flow and fish are returned to the river.

Bypass entrance **–** an unscreened opening in a facility that fish can enter, and after which are conveyed in flow to a sampling facility or back to the stream or river. The number and locations of entrances at a facility can range from one to several and are discussed in Chapter 8.

Bypass system **–** the component of a downstream fish passage facility that conveys (transports) fish from the diverted flow back into the body of water from which they originated. Bypass systems typically consist of entrance, conveyance (flume or pipe), and outfall structures.

Canal velocity **–** the water particle speed (feet per second) in a canal flowing parallel to the streambank.

Channel bed width **–** the width of the streambed under bankfull channel conditions.

Conceptual design **–** an initial design concept based on the site conditions and biological needs of the species intended for passage, also sometimes referred to as preliminary design or functional design. This is the first phase in the design process of a fish passage facility and is discussed in Chapter 3.

Crowder **–** a combination of static or mobile panels installed in a fishway, raceway, or holding pool for the purpose of moving fish into a specific area for sampling, counting, broodstock collection, or other purposes. Crowder panels are usually porous and constructed of perforated plate or picket bars. The panels can also be fabricated using solid, non-porous materials. Also, see the definition for picket leads in this chapter.

Diffuser **–** a system of hydraulic components arranged to control water flow rate and convert high-velocity, high-pressure, non-uniform flow into low-energy, uniform flow. A diffuser also includes one or more panels of narrowly spaced horizontal or vertical bars to prevent fish from passing through the bars and entering the area upstream of the panels.

Distribution flume **–** a channel used to route fish to various points in a fish trapping system.

Effective screen area **–** the total wetted screen area minus the area occluded by major structural elements.

End of pipe screen **–** juvenile fish screening devices attached directly to the intake of a diversion pipe.

Entrainment **–** the diversion of fish into an unsafe area or passage route.

Exclusion barriers **–** facilities that prevent upstream migrants from continuing to migrate upstream. These are typically used to prevent fish from entering areas that have no egress route or may result in fish being injured.

Exit control section **–** the upper portion of an upstream passage facility that provides suitable passage conditions to accommodate varying forebay water levels. Water level fluctuation is accommodated by adjusting the pool geometry and weir design, and by adding or removing flow at specific locations.

False weir **–** a specialized floor diffuser used to introduce water at the top of a fishway or entrance to a distribution flume for the purpose of attracting and encouraging fish to move into a specific area. The device usually creates a strong upwelling flow that cascades over a weir. Fish are attracted to the cascading flow and swim through the upwelling into a distribution flume.

Fish ladder **–** the structural component of an upstream fish passage facility (or fishway) that allows fish to move over a barrier by dissipating the potential energy caused by the head differential that results from a barrier being placed in a waterway. The ladder dissipates energy using a series of discrete pools, a series of baffled chutes and resting pools, or uniformly with a single baffled chute placed between an entrance pool and an exit pool.

Fish lift **–** a mechanical component of an upstream passage system that provides fish passage by lifting fish in a water-filled hopper or other lifting device into a conveyance structure that delivers upstream migrants past the impediment.

Fish lock – a mechanical and hydraulic component of an upstream passage facility that raises fish over a dam by attracting or crowding fish into a chamber, closing access to the chamber, and filling the chamber until the water surface in the lock chamber reaches (or comes sufficiently close to) the reservoir forebay level. Once at this water surface elevation, a gate to the chamber is opened, allowing fish to swim into the reservoir above the dam (Clay 1995). Fish locks can also be used as part of a trap and haul system to lift fish from the river level to a higher elevation for sorting, or transportation, or both.

Fish passage season – the range of dates that characterize when juvenile or adult life stages of a species will arrive at a specific location during their downstream or upstream migration. The locations could include, for example, a dam or an existing or proposed fishway.

Fish weir (also called picket weir, picket lead, or fish fence) – a device with closely spaced pickets or bars that allows water flow to pass, but precludes fish from migrating farther upstream. This term is normally applied to the device used to guide adult fish into a trap or counting window. This device is not a weir in the hydraulic sense.

Fishway – the suite of facilities, structures, devices, measures, and project operations that constitute and are essential to the success of an upstream or downstream fish passage system. The suite provides a water passage route around or through an obstruction that is designed to dissipate the energy in such a manner that enables fish to ascend the obstruction without undue stress (Clay 1995).

Fishway entrance – the component of an upstream passage facility that discharges attraction flow into the tailrace of a barrier and that upstream migrating fish use to enter the facility.

Fishway entrance pool – the pool immediately upstream of the fishway entrance(s) where fish ladder flow combines with AWS flow to form the attraction flow.

Fishway exit – the component of an upstream fish passage facility where flow from the forebay of the dam or barrier enters the fishway, and where fish exit the ladder and enter the forebay upstream of the dam.

Fishway weir – the partition that divides two pools in a fishway and passes flow between adjacent pools.

Flood frequency – the probable frequency that a streamflow will recur based on historical flow records. For example, a 100-year flood event refers to a flood flow magnitude that is likely to occur on average once every 100 years or has a 1% chance of being exceeded in any given year. Although calculating possible flood recurrence is often based on historical records, there is no guarantee that a 100-year flood will occur within the 100-year period, or not occur several times within that period.

Floodplain – the area adjacent to a stream that is inundated during periods of flow that exceed the channel capacity the stream has established over time.

Flow control structure – a structure in a water conveyance designed to maintain flow in a predictable fashion.

Flow duration exceedance curve – the plot of the relationship between the magnitude of daily flow and the percentage of time during a specific period that flow is likely to be equaled or exceeded. Flow exceedance curves may use flow data from an entire year or part of a year. For example, the 1% annual exceedance flow is the flow level exceeded 1% of the time within the entire year (i.e., 3.6 days on average), whereas the 1% exceedance flow for the fish migration window is the flow level exceeded 1% of the time during the fish passage season for a particular species and location. Exceedance values are usually derived using daily average flow data.

Forebay – the waterbody located immediately upstream of a dam that results from the dam impounding river flow behind the structure.

Freeboard – the height of a structure that extends above the maximum water surface elevation.

Fry – a juvenile salmonid with an absorbed egg sac that is less than 60 millimeters in total length (as defined for the purposes of this document). An embryo develops within an egg until it hatches. The hatchling (alevins) feeds off the large external yoke sac for nourishment, grows, and emerges from the spawning gravel as a fry when it can feed on its own (Quinn 2005).

Functional design – an initial design concept based on the site conditions and biological needs of the species intended for passage. This is also sometimes referred to as preliminary design or conceptual design. Also, see the definition for conceptual design in this chapter. The functional design commonly includes the general layout, interior dimensions, and specifications covering the hydraulic features of the fishway (Clay 1995).

Hatchery supplementation – hatchery programs designed for hatchery-origin fish to spawn in the wild and make a contribution to the conservation of a species or population (HSRG 2009).

Head loss – the irreversible reduction in total head (total energy per unit weight) of water as it flows through conduits, open channels, spillways, turbines, and other hydraulic structures. Total head is the sum of elevation head, pressure head, and velocity head. Head is described in units of length, usually in feet or meters.

Hopper – a device used to lift fish in water from a collection or holding area for release upstream of a barrier or into a transportation truck.

Hydraulic drop – the difference in total head between an upstream water surface and a downstream water surface. It includes the sums of the elevation head, pressure head, and velocity head at the upstream and downstream water surface locations. Also, see the definition for head loss in this chapter.

For fishway entrances and fishway weirs, the differences in velocity head and pressure head are usually negligible, and only water surface elevation differences are considered when estimating hydraulic drop across the structure.

Impingement – the condition where a fish comes in contact with the surface of a dewatering screen and remains on the screen. This occurs when the approach flow velocity immediately upstream of the screen exceeds the swimming capability of a fish given its size and condition. Impingement can injure a fish, and prolonged contact with a screen surface or bar rack can result in mortality. One objective of NMFS' approach velocity criterion is to eliminate the possibility for healthy salmonid fry or larger fish to become impinged on a screen surface or bar rack.

Infiltration gallery – a facility used to withdraw surface water from beneath the streambed.

Intermediate bypass entrance – a bypass entrance installed upstream of the main bypass entrance. Also, see the definition of bypass entrance in this chapter. Chapter 8 provides guidelines on the number of bypass entrances needed in a bypass facility and their location.

Invert – the lowest inside surface of a culvert or flume.

Kelts – an adult steelhead that survived spawning and is migrating downstream (Quinn 2005).

Off-ladder trap – a facility or system for capturing fish located adjacent to a fish ladder in a flow route that is separate from the normal fish ladder route. This system allows fish to pass a barrier via the ladder or be routed into the trap, depending on the management objectives for the species or population at the facility.

Minimum effective screen area – the maximum screen flow divided by the allowable approach velocity.

Passive screens – juvenile fish screens that do not have an automated mechanical cleaning system.

Picket leads or pickets – a set of narrowly spaced vertical or inclined flat bars or slender circular cylinders designed to exclude fish from a specific route of passage. Picket leads are similar to diffusers, but picket leads generally lack the ability to control the flow rate or significantly alter the flow distribution. Also, see the definitions of a fish weir and crowder in this chapter.

PIT-tag detector – a device used to scan fish for the presence of a passive integrated transponder (PIT) tag implanted in the fish. While passing through the detector, PIT tags transmit a unique identifying number that can be read at a short distance, depending on the tag size, type, and antenna design. These passive tags operate in the radio frequency range and are inductively charged and read by the detector. They do not have a battery and can remain operational for decades.

Plunging flow – flow over a weir that falls into a receiving pool where the water surface elevation of the receiving pool is lower than that of the weir crest elevation. Surface flow in the receiving pool is typically in the upstream direction, downstream from the point of entry into the receiving pool. Also, see the definition for streaming flow in this chapter.

***Porosity* –** the percent open area of a mesh, screen, rack, or other flow area relative to the entire gross area.

***Positive exclusion* –** a means of excluding fish by providing a barrier the fish cannot physically pass through.

***Preliminary design* –** an initial design concept based on the site conditions and biological needs of the species intended for passage. This is also sometimes referred to as a functional design or conceptual design. Also, see the definition for conceptual design in this chapter.

***Ramping rates* –** the rate at which the water surface level at a specific point in a river is artificially altered (either increased or decreased) over a specific time period as a result of changes in the regulation of flow upstream. The rate is typically measured and stated as the change in vertical inches per hour.

***Rating curve* –** graphed data depicting the relationship between water surface elevation and streamflow.

***Redd* –** the nest a female salmonid excavates, deposits embryos into, and immediately buries with gravel substrate. Redds can be located in streams, rivers, or lake beaches. The locations selected vary with populations and species (Quinn 2005).

***Rotary drum fish screen* –** a horizontally oriented cylinder (drum) constructed of fish screen material. Rotary drum screens include an active cleaning method and at least one fish bypass route. The drum rotates on its horizontal axis during each cleaning cycle. Debris deposited on the upstream surface of the drum is lifted by the rotating drum and washed off the downstream surface of the drum by the flow passing through the drum. Fish are guided to a bypass entrance upstream of one end of the screen array.

***Screen material* –** the material that provides physical exclusion to reduce the probability of entraining fish into diverted flow. Examples of screen material include perforated plate, bar screen, and woven wire mesh.

***Scour* –** erosion of streambed material resulting in the temporary or permanent lowering of the streambed profile.

***Soffit* –** the inside top of culvert or underside of a bridge.

***Smolt* –** a juvenile salmonid that has completed its freshwater rearing cycle and initiated a downstream migration to reach a marine environment. To prepare for seawater, the freshwater life stage (parr) undergoes a physiological and osmoregulatory transition and begins its downstream migration. Fish in this transitional stage between fresh water and marine rearing that are actively migrating downstream are termed smolts (Quinn 2005).

***Streaming flow* –** flow over a weir that falls into a receiving pool and where the water surface elevation of the receiving pool is above the weir crest elevation. In these situations, surface flow in the receiving pool is typically in the downstream direction and away from the point where flow enters the receiving pool.

Sweeping velocity – the vector component of water particle speed that is measured parallel to, and immediately upstream of, the screen surface.

Tailrace – the portion of the water channel below a dam that conveys turbine and spillway discharge downstream from the dam.

Tailwater – the body of water immediately downstream of a dam or other in-stream structure.

Total project head – the difference in water surface elevation from upstream to downstream (or from the headwater to the tailwater) of a barrier such as a dam or weir. Normally, total project head encompasses a range of values based on streamflow and the operation of flow control devices.

Thalweg – the streamflow path following the deepest parts (i.e., the lowest elevation) of a stream channel.

Tide gate – a mechanical device that allows flow to pass in one direction but not in the opposite direction. Tide gates are often used as part of a levee or dike system to allow streamflow into a bay or estuary during ebb tides and prevent the flow of saltwater to pass in the opposite direction and enter the area upstream of the levee or dike during flood tides.

Training wall – a physical structure designed to direct flow to a specific location or in a specific direction.

Transport channel – a hydraulic conveyance designed to allow fish to swim between different sections of a fish passage facility.

Transport velocity – the velocity of the flow within a transport channel of a fishway.

Trap and haul – the collection, loading, and transportation of adult fish from a collection site at or below a barrier to a release point located upstream from the barrier or at another location, and juvenile fish from a collection site at or above a barrier to a release point located downstream from the barrier or at another location.

Trash rack – a rack of vertical bars with spacing designed to catch debris and preclude it from entering the fishway or other hydraulic structure but allows fish to pass through the openings between bars. Trash racks are also referred to as a grizzly.

Trash rack, coarse – a rack of widely spaced vertical bars designed to catch large debris and preclude it from entering a fishway, while providing sufficient openings between the bars to allow adult fish to exit the fishway.

Trash rack, fine – a rack of narrowly spaced vertical bars designed to catch both small and large debris and reduce or eliminate the entry of fish into the intake of an AWS.

Turbine intake screens – partial flow screens positioned within the upper portion of a turbine intake that guide fish entering the turbine into a collection system for transport or bypass back to the river. Turbine intake screens are installed at most mainstem Columbia and Snake River dams operated by the U.S. Army Corps of Engineers (USACE; Appendix G).

Upstream fish passage **–** fish passage relating to the upstream migration of adult and juvenile fish.

Upstream passage facility **–** a fishway system designed to pass fish upstream of a passage impediment, either by volitional passage (i.e., under their own swimming capability) or non-volitional passage (i.e., via a lift or transport vehicle).

Vee screens **–** a pair of vertically oriented juvenile fish screens installed in a vee configuration (i.e., positioned symmetrically about a centerline), and where the bypass entrance is located at the apex of the two screens. Vee screens are also referred to as chevron screens.

Velocity head, $\boldsymbol{h_v}$ **–** the kinetic energy per unit weight of fluid due to its velocity; h_v has the units of length (usually in feet or meters) and is calculated as shown in the following equation:

$$h_v = v^2/2g$$

where:

v = velocity of the fluid (feet per second, meters per second)
g = acceleration due to gravity (32.2 feet per second^2, 9.81 meters per second^2)

Vertical barrier screens **–** screens located between the bulkhead (upstream) and operating (downstream) gate slots at mainstem dams on the Columbia and Snake rivers operated by the USACE. The screens keep fish diverted into the bulkhead slot by turbine intake screens from passing back into the turbine through the operating slot. Fish retained in the bulkhead gate slot by the vertical barrier screen enter a specially designed juvenile fish bypass system through orifices. (Figure G-4 in Appendix G.)

Volitional passage **–** fish passage whereby fish transit a passage facility under their own swimming capability, using timing and behavior they choose, and under all naturally passable flows. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish pass through the facility without the aid of any apparatus, structure, or device (i.e., they are not trapped, mechanically lifted or pumped, or transported).

Wasteway **–** a conveyance that returns excess water originally diverted from an upstream location back to the stream or channel from which it was diverted.

Weir **–** a low wall or dam built across the width of a river that pools water behind it while allowing water to flow steadily over the top of the structure.

3 Design Development

3.1 Introduction

Chapter 3 describes the general process NMFS follows and the types of information required during project design. Fish passage project designs subject to NMFS engineering review are typically developed in two major phases. The major phases are the preliminary design (Section 3.2.1), also referred to as the functional or conceptual design, and the final design (Section 3.2.2), which results in the development of detailed plans and specifications.

A review by NMFS of an applicant's fish passage facility designs will be conducted in the context of whether they meet the recommended criteria and technical assistance listed in this document.

Fish passage facilities refer to physical structures, facilities, or devices used to provide safe, timely, and effective passage for all life stages of fish as identified in Section 1.1 of this document. During its review, NMFS will consider site-specific information, including site limitations, biological information, and operations and maintenance (O&M) information provided by the applicant. Although the submittal of all information discussed in Chapter 3 may not be required in writing, the applicant should be prepared to describe how the biological and site information was included in the development of the project design.

3.2 Design Process

Both the preliminary and final designs should be developed in cooperation and interaction with WCR biological staff from effected Branch and engineering staff from the Environmental Services Branch.

To facilitate an iterative, interactive, and cooperative process, project applicants are encouraged to initiate coordination with NMFS early in the development of the preliminary design. Early and frequent interactions can aid in a smooth review process. NMFS' preference is to work with applicants in developing alternatives that comply with ESA. In general, NMFS cannot complete a project review of design plans that are submitted without the supporting information (listed in Section 3.3).

Project applicants should consult with NMFS on all phases of a design. Section 3.2.2 provides the minimum information needed for NMFS review. Large, complex projects will likely have multiple iterations within each of the two major design phases. As multiple design iterations are developed, each iteration should be made available to NMFS for review.

3.2.1 Preliminary Design

Depending on the size and complexity of the project, NMFS typically requests that it be allowed to review and provide comments on the 30%, 60%, and 90% design iterations of the preliminary design. Due to the nature of the review process, such as applications for a FERC license and ESA consultation, a preliminary design should be developed in cooperation and interaction with biological and engineering staff from the NMFS WCR. The preliminary design should be complete and to allow the application or engineering review to move forward.

The preliminary design establishes a preferred alternative based on comprehensive evaluations of the key elements of the design. This first phase in the design of a fish passage facility includes the following steps. Project proponents should:

1. Engage with project stakeholders and ascertain their operational requirements.
2. Identify and prioritize project objectives and the associated functional requirements.
3. Assemble the design criteria of the federal, state, and tribal fish resource agencies.
4. Collect pertinent biological, hydrological, and engineering information.
5. Develop appropriately scoped geomorphic assessments for the project.
6. Define project reliability and backup or contingency parameters.
7. Develop a process for evaluating and ranking alternative designs and operations.
8. Generate alternative designs and select the preferred alternative.
9. Develop initial layout drawings and models as needed to describe the facility.
10. Describe the operational requirements of the major facility sub-components

The preliminary design results in a facilities layout that includes section drawings and the identification of component sizes and water flow rates for the primary project features. Cost estimates are also included in the preliminary design. Completion of the preliminary design commonly results in a document that may be used for budgetary and planning purposes and for soliciting (and subsequently collating) design review comments provided by other reviewing entities. The preliminary design is usually considered to be at the 20% to 30% completion stage of the design process. The preliminary design may include the following sub-phases of design work:

- Reconnaissance study: Typically, this study investigates the optimal design and construction specific to each site. The study usually occurs early in the preliminary design process.
- Conceptual alternatives study: This study lists the types of facilities that may be appropriate for accomplishing the fish passage objectives at a selected site. It does not entail much on-site investigation. Its purpose is to develop a narrowed list of alternatives that merit additional assessment.
- Feasibility study: This study includes an incrementally greater amount of development of each design concept (including a preliminary cost estimate) than does the conceptual alternatives study. It enables the most-preferred alternative to be identified.

3.2.2 Detailed or Final Design

The final design should be based on the preliminary design that NMFS reviewed. Any significant deviation from the accepted preliminary design will trigger a new review. Once the detailed design process commences, NMFS should have the opportunity to review and provide *comments on the designs developed at the 30%, 60%, 90%, and 100% stages, or near each of these stages.*

The details of the final design phase uses the preliminary design as a springboard for beginning the final design and specifications in preparation for the bid solicitation (or negotiation) process. NMFS reviews usually provide refinements in the detailed design that will lead to O&M and fish safety benefits. Electronic drawings are the preferred review medium, though NMFS may request scaled 11-by-17-inch paper drawings in addition to electronic media.

3.2.3 Smaller Projects

For smaller projects where the review process may involve only one or two steps, each submittal to NMFS should include enough information about the project to ensure that the reviewing engineer is able to discern the goals of the project, any biological and physical constraints of the project, and how the proposed design intends to meet the goals of the project given constraints that were identified.

3.2.4 Review Timelines

NMFS should be allowed at least 30 days to review and comment on each stage of the design process (30%, 60%, 90%, and 100%).

Although NMFS may waive or voluntarily shorten a review period for a specific stage, project applicants should develop their design schedules using the standard 30-day review period for each stage of the design.

3.3 Information Requirements

The design of all fish passage facilities should be developed based on a synthesis of the required site and biological information listed below, with a clear understanding of how the facility will be operated and maintained. The following project information is needed for, and should be provided with, the preliminary design. In some cases, NMFS may need additional information not listed herein.

3.3.1 Functional Requirements

The project design should describe the functional requirements of the proposed fish passage facilities as related to all anticipated project operations and streamflows. The design should describe the expected median, maximum, and minimum monthly diverted flow rates and any special operations (e.g., the use of flash boards) that modify forebay or tailrace water surface elevations.

3.3.2 Site and Physical Information

The following physical information should be provided and used in developing the project design.

3.3.2.1 Plans

Design submittals should include visual representations of various project features. These plans may include any or all of the following:

- Site plan drawings: Showing the location and layout of the proposed fish passage facility relative to existing project facility features
- Surveys: Topographic and bathymetric surveys, particularly where they might influence locating fishway entrances and exits and personnel access to the site
- Additional drawings: Drawings of existing facilities illustrating longitudinal profile, elevations, and plan views, including details showing the intake configuration, location, and capacity of the project's hydraulic features
- Project Location Map including nearby town and north arrow along with Latitude and Longitude
- Temporary passage facility drawings: Drawings demonstrating plans for temporary or interim passage during construction of the primary facility. These temporary facilities should provide passage at a level no worse than existed prior to commencing construction on primary facility.

3.3.2.2 Hydrology

Design submittals should include information on the hydrology of the basin—including daily and monthly streamflow data and flow duration exceedance curves at the proposed site for a fish passage facility—based on the entire period of available records, which may be modified based upon site specific issues as approved by NMFS staff.

If stream gage data are unavailable for a proposed facility location (or if records exist for only a brief period of time), flow records may be generated using synthetic methods to develop the necessary basin hydrology information, which is used to develop the high and low fish passage design flows for the project (Chapter 4).

3.3.2.3 Project operations and basic information

Information on project operations that may affect fish migration should be provided.

Project information is key to understanding basic design parameters for fish passage (both for baseline conditions and for future fish passage changes). This could include information on powerhouse flow capacity, periods of powerhouse operation, turbine sequencing, debris management, flashboard or crest gate operation, flood or waster gate operation staffing levels, planned outages, pulse flows, project forebay and tailwater rating curves that encompass the entire operational range of the project, water temperature etc.

3.3.2.4 Morphology

Information on the stream or river channel at the site of the fish passage project should be provided, and includes but is not limited to the following:

- *Determine the potential for channel degradation, aggregation/subsidence, or channel migration, which may alter stream channel geometry and compromise fishway performance (if the fish passage facility is proposed at a new or modified diversion).*
- *Describe whether the stream channel is stable, conditionally stable, or unstable.*
- *Identify the overall geomorphology of the channel (e.g., straight, meandering, or braided).*
- *Provide the rate of lateral channel migration and change in stream gradient that has occurred during the last decade if migration is evident or likely to occur in the future using aerial photography, anecdotal information, or physical monitoring.*
- *Describe the effect the proposed fish passage facility may have on the existing stream alignment and gradient.*
- *Describe the potential for future channel modification to occur; this could be from construction of the facility or natural channel processes (i.e., instability).*
- *Describe the substrate of the channel and provide the D50.*

3.3.2.5 Sediment and debris

Any sediment and debris conditions that may influence the design of the fish passage facility or present potentially significant problems should be described.

3.3.3 Biological Information

Section 3.3.3 outlines miscellaneous information that should be provided and used in developing the project design. Contact the NMFS biologist in your area to determine which of the following is needed for the project.

3.3.3.1 Salmonid biological information

The following biological information should be provided for site specific conditions:

- Salmonid species present in the basin that are affected by the project, or are expected to be in the basin in the future
- Approximate abundance of each salmonid species and run (e.g., winter, spring, summer, fall, and late fall)
- Various life stages present, or expected to be present, in the future and their migration timing (fish passage season)
- Location and timing of spawning in the basin
- Location and timing of juvenile downstream migration

3.3.3.2 Non-salmonid passage

Information on any non-salmonid species (and life stages) present at the proposed fish passage site should be provided to address passage requirements for these species.

3.3.3.3 Predation risk

Information on predatory species that may be present at the proposed site should be provided along with information on conditions that favor or help to prevent their preying on salmonids. Information should include, but is not limited to, species type, life stage, spawning ground, and location of predator habitat.

3.3.3.4 Fish behavior characteristics

Any known fish behavioral traits of salmonid or non-salmonid passage that might affect the design of the facility should be provided.[1]

3.3.3.5 Additional research needs

Any uncertainty associated with how migrating fish approach the site where a new facility is being considered should be identified through directed studies, including routes fish may use when approaching the site. For more information related to large projects, see Appendix G.

3.3.3.6 Streamflow requirements

The minimum streamflow required to allow migration around the impediment during low water periods (See Design Flow Range in Chapter 4).

3.3.3.7 Poaching risk

The degree of poaching or illegal trespass activity in the immediate area of the proposed facility should be identified, along with any security measures needed to reduce or eliminate illegal activity.

3.3.3.8 Water quality

Water quality factors that may affect fish passage at the site should be described. For example, fish may not migrate if water temperature and quality are marginal and may instead seek coldwater refugia (e.g., deep pools fed by groundwater) or holding zones where dissolved oxygen levels are higher than surrounding reaches until water quality conditions improve. Water temperature issues are important considerations that can effect design. Therefore, it is also important to document other temperature issues (eg. reservoir stratification, or effluent releases in the project area, among other issues).

3.3.4 Operations and Maintenance Information

In order to provide a degree of certainty that necessary maintenance will be funded and performed, the following O&M information should be provided for in development of the preliminary design.

Historically, many fish passage facilities have been built and have subsequently fallen into disrepair due to improper operations or lack of maintenance or funding. New project designs

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[1] For example, most salmonid species pass readily over a fishway weir with either plunging or streaming flow. However, pink and chum salmon have a strong preference for streaming flow conditions and may reject plunging flow. Therefore, if pink or chum salmon are in the basin, this needs to be identified. Similarly, American shad prefer streaming flow conditions and generally reject both plunging flow and orifice passage.

should consider the need for proper operations and long-term maintenance. Start up, daily, and yearly maintenance procedures, daily logs, and annual reports should be considered in the design development and included as part of the O&M plan.

3.3.4.1 Maintenance funding

The O&M plan should identify the party responsible for funding the O&M of the proposed facility.

3.3.4.2 Operating and maintaining entity

The O&M plan should identify the party responsible for operating the facility and carrying out maintenance actions.

3.3.4.3 Facility shutdown

The O&M plan should describe maintenance actions that will require the facility to be taken out of service and the timeline for these actions.

3.3.4.4 Schedule of operations

The O&M plan should identify the proposed schedule of operations for intermittently operated facilities, such as weirs or traps, and the accompanying plans for salvaging fish from these facilities after they are operational. This should include plans for how the facility will be dewatered and how salvaged fish will be returned to the stream or river.

4 Design Flow Range

Prior to determining the fish passage design flows, the steps in the 2022 NOAA Fisheries WCR Guidance to Improve the Resilience of Fish Passage Facilities to Climate Change should be followed to determine what if any climate impacts should be considered and included in the design. The guidance in Chapter 4 applies to projects located in Washington, Oregon, and Idaho over the range of anadromous salmonid habitat. Due to significantly different hydrologic conditions in California, project proponents should work with NMFS engineering staff to determine the appropriate design flows for site conditions.

4.1 Introduction

A fishway design and facility must allow for the safe, timely, and efficient passage of fish within a specific range of streamflow. The design streamflow range is bracketed by the designated fish passage design low flow and high flow described in Sections 4.2 and 4.3.

Within the design streamflow range, a fish passage facility should operate within its specific design criteria. Outside of the design streamflow range, fish should either not be present, not be actively migrating, or should be able to pass safely without need of a fish passage facility.

Site-specific information is critical to determining the design time period and river flows for the passage facility—local hydrology may require that the design streamflow range be modified for a particular site.

4.2 Design Low Flow for Fish Passage

Design low flow for fishways is the average daily streamflow that is exceeded 95% of the time during periods when migrating fish are normally present at the site.

This is determined by summarizing the previous 25 years of mean daily streamflow occurring during the fish passage season, or by an appropriate artificial streamflow duration methodology (if streamflow records are not available). Shorter data sets of streamflow records may be useable if they encompass a broad range of flow conditions. The fish passage design low flow is the lowest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.3 Design High Flow for Fish Passage

Design high flow for fishways is the average daily streamflow that is exceeded 5% of the time during periods when migrating fish are normally present at the site.

This is determined by summarizing the previous 25 years of mean daily streamflow occurring during the fish passage season, or by an appropriate artificial streamflow duration methodology (if streamflow records are not available). Shorter data sets of streamflow records may be used if they encompass a broad range of flow conditions. The fish passage design high flow is the highest streamflow for which migrants are expected to be present, migrating, and dependent on the proposed facility for safe passage.

4.4 Fish Passage Design for Flood Flows

The general fishway design should have sufficient river freeboard to minimize overtopping by 50-year flood flows.

Above a 50-year flow event, fishway operations may include shutdown of the facility to allow the facility to quickly return to proper operation when the river drops to within the range of fish passage design flows. Other mechanisms to protect fishway operations after floods will be considered on a case-by-case basis. A fishway should never be inoperable due to high river flows for a period greater than 7 days during the migration period for any anadromous salmonid species. In addition, the fish passage facility should be of sufficient structural integrity to withstand the maximum expected flow. It is beyond the scope of this document to specify structural criteria for this purpose. If the fish passage facility cannot be maintained, the diversion structure should not operate, and the impediment should be removed.

5 Upstream Adult Fish Passage Systems

5.1 Introduction

Chapter 5 provides criteria and guidelines for designing upstream adult fish passage facilities as well as selecting appropriate ladder types for specific site conditions. These criteria and guidelines apply to adult upstream fish passage facilities in moderately sized streams. Where applicable, supplementary criteria for facilities located in small streams will be noted. Chapter 5 does not address fish passage systems, such as fish locks and mechanical lifts, which may provide passage over barriers or be used as part of a trap and haul system. Fish lifting devices are covered in Section 7.6.

Chapter 5 also discusses upstream passage impediments, which are artificial or natural structural features or project operations that cause adult or juvenile fish to be injured, killed, blocked, or delayed in their upstream migration to a greater degree than in an unobstructed river setting. These impediments can present total or partial fish passage blockages. Artificial upstream passage impediments require approved structural and operational measures to mitigate, to the maximum extent practicable, for adverse impacts to upstream fish passage. These impediments require a fish passage design based on conservative criteria because the natural complexity of streams and rivers that usually provide passage opportunities has been substantially altered. The criteria in this chapter also apply to natural barriers, when passage over the barrier is desired and consistent with watershed, subbasin, or recovery plans.

Examples of passage impediments include, but are not limited to, the following:

- Permanent or intermittent dams
- Hydraulic drops over artificial instream structures[2] in excess of 1.5 feet
- Weirs, aprons, hydraulic jumps, or other hydraulic features that produce depths of less than 10 inches, or flow velocity greater than 12 feet per second (ft/s) for more than 90% of the stream channel cross section
- Conditions that create false attraction, including the following:
    - Project operations or features that lead upstream migrants into impassable routes
    - Discharges that may be detected and entered by fish with no certain means of continuing their migration (e.g., poorly designed spillways, cross-basin water transfers, canal wasteways, or unscreened diversions) or have the potential to result in mortality or injury (e.g., turbine draft tubes, shallow aprons, and flow discharges)
- Insufficient flow, which includes the following:
    - Diffused or braided flow that impedes approach to the impediment

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[2] This is based on the *Fisheries Handbook of Engineering Requirements and Biological Criteria* (Bell 1991), which recommends using fishways for head differences as low as 2 feet.

  - Insufficient flow in a bypass reach, such that fish cannot enter or are not stimulated to enter the reach and move upstream; bypass reaches are commonly located adjacent to a powerhouse or wasteway return
  - Water diversions that reduce instream flow

- Poorly designed headcut control or bank stabilization measures that create poor upstream passage conditions such as those listed above
- Degraded water quality in a bypass reach, relative to the water quality downstream of the confluence of bypass reach and flow return discharges (e.g., at the confluence of a hydroelectric project tailrace and bypass reach)
- Ramping rates in streams or in bypass reaches that delay or strand fish
- Upstream passage facilities that do not satisfy the criteria and guidelines described in Chapter 5

The typical components of an upstream adult fish passage system are shown in Figure 5-1.

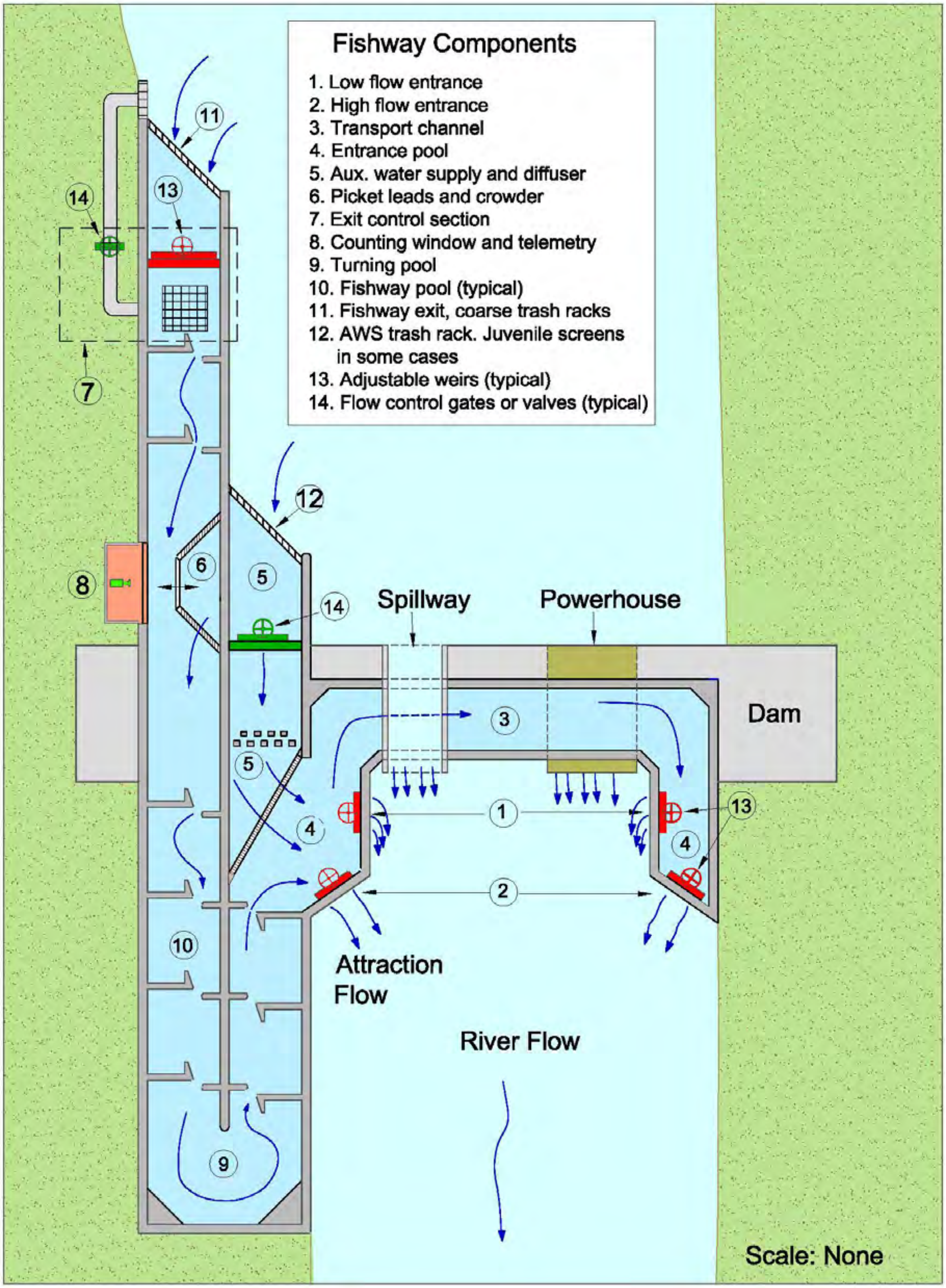

Figure 5-1. Components of vertical slot fishway for upstream passage

5.1.1 Passage Alternatives: Volitional and Non-volitional

Volitional passage is preferred for passage facilities over non-volitional passage. Non-volitional systems may be considered where volitional passage facilities are not feasible due to significant engineering constraints or biological limiting conditions.

NMFS typically prefers volitional fish passage as these systems afford passage opportunities for migrating fish at all times, and fish can transit a passage facility under their own swimming capability, using timing and behavior they choose, and under all naturally passable flows. Volitional passage means fish can enter, traverse, and exit a passage facility under their own power, instinct, and swimming capability. The fish migrate through a volitional passage facility without the aid of any mechanical apparatus, structure, or device.

Volitional passage systems at dams usually consist of hydraulically engineered fish ladders that use one of the designs described in this manual. Under certain site conditions, a volitional passage system for a dam of low or moderate height may be designed as a nature-like channel; or it may be a hybrid design that incorporates features of both nature-like and traditional designs. Volitional systems for applications other than dams generally seek to emulate nature-like conditions with stream simulation techniques.

There are some situations where a volitional passage system is infeasible due to biological factors, engineering constraints, fish management objectives, or other project-specific limitations. In these instances~~,~~ non-volitional systems may be appropriately considered to meet fisheries management goals and objectives, provided they are designed, constructed, and operated following the guidance in chapter 7 of this Manual.

Non-volitional systems, due to long term operations and maintenance requirements, can have higher total life-cycle costs when compared to fish ladders. Project proponents should carefully weigh the pros and cons of the different alternative modes of passage to select the most appropriate design that will consistently accomplish the project’s fish passage goals. There may be instances where the inability of a project proponent to consistently and correctly operate and maintain a proposed collection and transport system represents an unacceptable risk to the managed fish species.

Although site specific challenges exist, non-volitional designs can be a viable management tool that provides Pacific salmonids access to some historic habitats, including cold-water sites that will be increasingly important given climate projections.

5.1.2 Passage of Other Species

Where appropriate, upstream adult fish passage systems should incorporate passage requirements for other species (e.g., shad, sturgeon, Pacific lamprey, and suckers) that may use the system, provided that the changes do not compromise the passage of target species (salmonids).

Failure to account for the passage requirements of other species may create a biological blockage in the ladder that could delay or compromise the passage of the target species. For example, if American shad (*Alosa sapidissima*) cannot pass a fishway, the numbers of shad in the fishway may build up to the point where other fish do not enter or move through the fishway.

5.1.3 Temperature Considerations

In certain cases, water temperature control may be a critical factor for fish ladder designs, particularly at high head dams. Some reservoirs or head ponds may become thermally-stratified at some point during the fish passage season, resulting in a potential temperature mismatch between the fish ladder's discharge and the dam's other tailwater or tailrace discharges. Also, during summer seasons, water temperature may increase as water passes through long fish ladders whose exterior concrete surfaces are exposed to solar energy for a considerable period of time. Such temperature mismatch situations may cause salmonids (or other species) to reject the fish passage route. To the degree these conditions exist, artificial temperature modulation at fishways and ladders may be necessary (Caudill et al. 2013).

5.2 Fishway Entrance

5.2.1 Description and Purpose

A fishway entrance is a gate or slot through which fishway attraction flow is discharged in a manner that encourages and allows adult fish to enter the upstream passage facility. The fishway entrance is often the most difficult (Bates 1992)—yet most critical—component to design for an upstream passage system, particularly at dams (Clay 1995). Fishway entrances should be placed to ensure that fish are attracted to and enter the best passage routes past the passage impediment throughout the entire design flow range. The most important aspects of fishway entrance design are as follows:

- Location of the entrance
- Pattern and amount of flow from the entrance
- Approach channel immediately downstream of the entrance
- Flexibility in adjusting entrance flow to accommodate variations in tailrace elevation, stream or river flow, and project operations

5.2.2 Specific Criteria and Guidelines – Fishway Entrance

5.2.2.1 Configuration and operation

Unless otherwise approved by NMFS, at sites where the entrances are located in deeper water, fishway entrances should be equipped with downward-opening slide gates or adjustable weir gates that rise and fall with the tailwater elevation. At locations where the tailwater is not deep, orifice entrances or downward-closing slide gates (which create an orifice entrance) may be used. The entrance gate should be able to completely close off the entrance when not in use. Gate stems or other adjustment mechanisms should not be placed in any fish migration pathway. Fishway entrance gates operating in an orifice configuration should not be closed to an opening height less than 12-inches except when fully closed.

The fishway entrance gate configuration and its operation may vary based on site-specific project operations and streamflow characteristics. Entrance gates are usually operated in either a fully open or fully closed position, with the operation of the entrance being dependent on tailrace flow characteristics. Sites with limited tailwater fluctuation may not require an entrance gate to regulate the entrance head, while other sites may maintain proper entrance head by regulating auxiliary water flow through a fixed-geometry entrance gate.

5.2.2.2 Location

Fishway entrances should be located at points where fish can easily locate the attraction flow and enter the fishway. When choosing an entrance location, high-velocity and turbulent zones in a powerhouse or spillway tailrace should be avoided in favor of relatively tranquil zones adjacent to these areas. A site-specific assessment must be conducted to determine entrance location and entrance jet orientation. A physical hydraulic model is often the best tool for determining this information (Bell 1991).

The fishway entrance should be located as far upstream as possible since fish will seek the farthest upstream point (Bell 1991). This is especially the case with low flow entrances. This guideline is subject to adjustment by NMFS based on site-specific constraints that include the configuration of the project, flow level, and flow patterns associated with powerhouse or facility operations and spill discharge in relation to site conditions.

Some fishway entrances at a project should be located on the shoreline (Bell 1991). This is because fish orient to shorelines when migrating upstream. Locating an entrance on the shoreline takes advantage of this behavior, where the shoreline serves to lead fish to the entrance.

One of the most significant design decisions for a fishway entrance is its location (WDFW 2000). Turbulence can be a barrier to fish passage because velocities, turbulence, upwells, reverse currents, and aeration can affect attraction and access to fishways (WDFW 2000). At locations where the tailrace is wide, shallow, and turbulent, excavation to create a deeper, less-turbulent holding zone adjacent to the fishway entrance(s) may be necessary. Therefore, it is important to fully characterize and understand flow patterns when locating a fishway entrance at a site.

5.2.2.3 Additional entrances

If the site has multiple zones where fish accumulate, each zone should have a minimum of one fishway entrance. For long powerhouses or dams, additional entrances may be required. Multiple entrances are usually required at sites where the high and low design flows create different tailwater conditions. All entrances should meet the requirements of Section 5.2.

Since tailrace hydraulic conditions usually change with project operations and hydrologic events, it is often necessary to provide two or more fishway entrances to accommodate the differences between high- and low-flow river conditions (often referred to as high- and low-flow entrances). When switching between high- and low-flow conditions, it is often necessary to close some entrances that are operating poorly or those the fish can no longer access, and open others where fish are congregating and holding. These features should be designed so that entrance changes can be performed simply, swiftly, and easily.

5.2.2.4 Attraction flow

Additional attraction flow from the fishway entrance is needed to extend the area of intensity of velocity of the outflow (from the entrance) to increase fish attraction into the entrance (Clay 1995). Attraction flow from the fishway entrance should be between 5% and 10% of the fish passage high design flow (Chapter 4). For smaller streams, NMFS may conclude that attraction flows up to 100% of streamflow may be required.

Larinier et al. (2002) conclude that a major cause of poor fishway performance is a lack of adequate attraction flow. At dams, the entrance flow for fish attraction should be sufficient to compete with spillway or powerhouse discharge flow (Bates 1992). Generally speaking, the higher the percentages of total river flow used for attraction into the fishway, the more effective the facility will be in providing upstream passage. The proportion of attraction flow needed is based on extensive research and results of laboratory studies.[3] The proportion selected should be sufficient to allow fish to both find and want to enter fishway entrances.

Under conditions where ladder entrances are optimally situated near the impediment and fish are naturally led to an entrance, an attraction flow of 5% of the fish passage design flow is used. However, some situations may require that more than 10% of the passage high design flow be used. For example, if a site features obscure approach routes to the passage facility or if entrances are located in a less than optimal location, a higher proportion of the design flow is needed as attraction flow. Additionally, facilities with multiple entrances may require more attraction flow (not to exceed a total of 10% of the fish passage design flow).

Powerhouse and spillway flows are not considered part of the proportion of project flow used for fishway attraction. Powerhouse and spillway flows should be shaped, and turbine unit and spill gate operation prioritized, to create tailrace conditions that naturally lead to and allow fish to rapidly locate the fishway entrances (Bell 1991).

5.2.2.5 Hydraulic drop

The fishway entrance hydraulic drop (also called entrance head) should be maintained between 1 and 1.5 feet, depending on the species present at the site, and designed to operate from 0.5 to 2 feet of hydraulic drop (USFWS 1960; Junge and Carnegie 1972).

A range of 1 to 1.5 feet is considered a normal operating range that helps establish streaming flow conditions (Bates 1992). Gauley et al. (1966) found in laboratory studies that Chinook salmon and steelhead made significantly faster ascents up an experimental ladder with orifice flow and flow over a weir when head on the weir was increased from 0.95 to 1.2 feet.

The hydraulic drop criterion is based in part on results of laboratory studies where an increasing number of Chinook and sockeye salmon and steelhead failed to enter all entrances tested when head was increased from 2 to 3 feet. Pink and chum salmon have more specific

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[3] For example, Weaver (1963) conducted a study wherein he provided salmon and steelhead with a choice of entering adjacent channels of the same width but different velocities; a higher proportion chose to enter the channel with higher velocity.

requirements. Fish from these species can easily swim through an entrance with 1.5 feet or more of head differential, but they will not jump even a portion of that height (Bates 1992).

5.2.2.6 Dimensions

For larger streams, the minimum fishway entrance width should be 4 feet, and the entrance depth should be at least 6 feet, although the shape of the entrance is dependent on attraction flow requirements and should be shaped to accommodate site conditions.

For smaller streams, the ladder entrances should be as large as possible, consistent with available fishway entrance flow, to maximize fish attraction and minimize plugging by debris. The minimum size for an orifice-style entrance should be 1.5 feet by 1.5 feet. The minimum width for a vertical slot-style entrance should be 1.25 feet if large Chinook salmon are present and 1 foot otherwise, and the depth (i.e., bottom of the slot to the tailwater level) should be at least 2 times the slot width.

In general, the dimensions of the fishway entrance should create a compact, strong attraction flow jet that projects out of the entrance a significant distance into the tailrace.

For identical water velocities, attraction jets created by entrances that are small, narrow, and deep, or are wide and shallow, do not project as far into the tailrace as does a compact entrance (Section 5.2.2.8; also, see requirements for mainstem Columbia and Snake rivers in Appendix G). The entrance width criterion is based partly on results of laboratory studies where Chinook salmon and steelhead preferred 3.9-foot-wide entrances over 1.5-foot-wide entrances under a constant velocity condition of 8 ft/s and lighted conditions. However, under dark conditions, all of these species preferred the wider opening, and coho salmon preferred the wider opening under both lighted and dark conditions (Weaver et al. 1976).

For ladder entrances at facilities located in small streams, orifice size is based on the minimum orifice size for an Ice Harbor-style ladder (Section 5.5.3.3). For a slot-style entrance at a facility in a small stream, the slot width is based on the minimum slot widths for vertical slot ladders (Section 5.5.2.1.1), and the minimum depth is based on the square area of a 1.5-foot by 1.5-foot orifice. For example, the criterion above states that slot depth (the depth from the bottom of the vertical slot-style entrance to the tailwater water surface elevation) should be double the slot width, and the minimum width should be 1.25 feet if large Chinook salmon are present and 1 foot otherwise. Therefore, when sizing a 1-foot-wide slot, the design should submerge the slot 2 feet, which is close to the 2.25 square foot (ft^2) open area of a 1.5-feet by 1.5-feet orifice.

5.2.2.7 Types of entrances

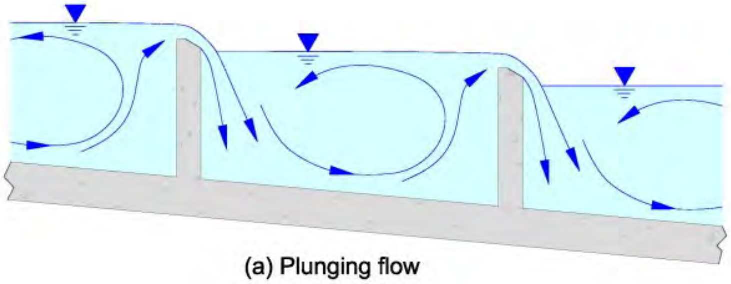
Fishway entrances may be adjustable submerged weirs, vertical slots, orifices, or other shapes, provided that the requirements specified in Section 5.2.2 are achieved.

Care should be taken to select a fishway entrance that generates a good attraction jet and is passable by all species of interest (Junge and Carnegie 1972). For example, American shad typically refuse to pass through orifices. Therefore, at sites where American shad are present, orifice entrances should be avoided, and surface routes in fishways are required (Larinier et al. 2002). This is true of all species in the genus *Alosa*. Also, American shad orient to walls when migrating through fishways and can be trapped in corners if no surface-oriented route is available (Junge and Carnegie 1972; Bell 1991; WDFW 2000).

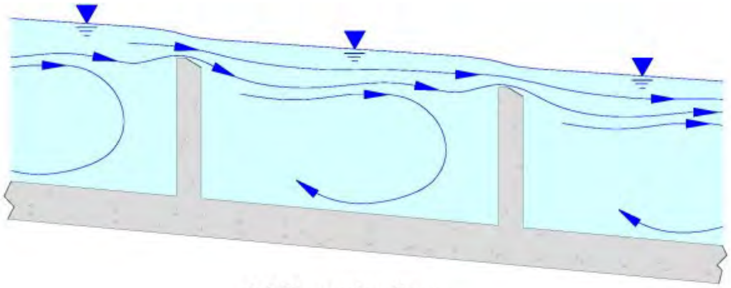
5.2.2.8 Flow conditions

The fishway entrance should create either streaming flow or hydraulic conditions similar to a submerged jet.

The desired flow condition for entrance weir and slot discharge jet hydraulics is streaming flow (WDFW 2000). A streaming flow is an intact plume of water moving almost horizontal near the water surface or at the elevation of an orifice entrance. In contrast, plunging flow drops vertically over an entrance sill or weir and then upwells downstream a few feet from an entrance. Plunging flow sets up a hydraulic roll where surface flow is moving in an upstream direction toward the entrance (Figure 5-2). This induces fish to jump at the flow, which may cause injuries, and it presents hydraulic conditions that some species may not be able to pass or may refuse to pass. This includes American shad and pink and chum salmon. Plunging flow also directs the attraction jet downward toward the stream bottom rather than across the tailrace. Streaming flow may be accomplished by placing the entrance weir (or invert of the slot) elevation such that flow over the weir falls into a receiving pool with a water surface elevation above the weir crest elevation (Katopodis 1992).



(a) Plunging flow



(a) Streaming flow

Figure 5-2. Plunging (a) and streaming (b) flows in pool and weir style of fishways

5.2.2.9 Orientation

Generally, low-flow entrances should be oriented nearly perpendicular to the streamflow (Figure 5-1; Bates 1992). High-flow entrances should be oriented to be more parallel to streamflow or at an angle away from the shoreline (Figure 5-1). A site-specific assessment should be conducted to determine entrance location and entrance jet orientation.

Low-flow entrances are designed to be used by fish during periods when flow conditions approach the low design flow. They are generally the entrances furthest upstream and closest to the passage barrier. High-flow entrances are designed for use during periods when flow conditions approach the high design flow. Bates (1992) suggests that high-flow entrances be placed at a 30-degree angle to the high-flow streamline, ideally along the edge of a high-flow hydraulic barrier. In general, high-flow entrances are located slightly downstream from the barrier at a point in the tailrace where the turbulence from the barrier under high flow conditions has just dissipated. A physical hydraulic model is often the best tool for determining this information; this model is used to test various design alternatives that favor fish passage (Bell 1991).

5.2.2.10 Staff gages

The fishway entrance design should include staff gages to allow for a simple determination of whether the entrance head criterion (Section 5.2.2.5) is met. Staff gages should be located in the entrance pool and in the tailwater just outside of the fishway entrance in an area visible from an easy point of access. Gages should be readily accessible to facilitate in-season cleaning.

Staff gages are important tools for determining whether a fish ladder entrance is meeting criteria. Care should be taken when locating staff gages to avoid placement in turbulent areas and locations where flow is accelerating toward a fishway entrance.

5.2.2.11 Entrance pools

The fishway entrance pool should be designed to combine ladder flow with auxiliary water system (AWS; also known as auxiliary water supply system) flow in a manner that encourages fish to move from the entrances in an upstream direction and optimizes the attraction of fish to lower fishway weirs.

The fishway entrance pool is at the lowest elevation of the upstream passage system. It discharges flow into the tailrace through the entrance gates to attract upstream migrants. In many fish ladder systems, the entrance pool is the largest and most important pool in terms of providing proper guidance of fish from the entrance to the ladder section of the upstream passage facility. Ladder flow and AWS flow through diffuser gratings are combined in the pool to form the entrance attraction flow (Section 5.3, Figure 5-1).

Attraction to the lower fishway weirs may be optimized by the following:

- Shaping the entrance pool to create a natural funnel leading fish to the ladder weirs
- Angling vertical AWS diffusers toward the ladder weirs
- Locating the jet from the ladder weir adjacent to the upstream terminus of the vertical AWS diffusers

The pool geometry will normally influence the location of attraction flow diffusers.

5.2.2.12 Transport velocity

Transport velocities between the fishway entrance and first fishway weir, fishway channels, and over-submerged fishway weirs should be consistent with the guidance found in section 5.4.2.1.

Gauley et al. (1966) reported that Chinook and sockeye salmon and steelhead passage times did not differ significantly between water velocities of 1 and 4 ft/s in an experimental 270-foot-long transportation channel. However, Weaver (1963) reported that Chinook salmon moved progressively slower in a test flume as velocities increased from 2 to 8 ft/s.

Note that as tailwater level rises and the lower fishway weirs become submerged, it becomes necessary to increase the flow in this area of the ladder to meet the transport velocity criterion (Bell 1991).

An AWS can be used to supply additional water through wall or floor diffusers. Care should be taken to design the fishway weirs that will be submerged to accommodate the additional flow in the ladder so that other fish passage (or hydraulic) criteria are not exceeded. The transport channel velocity guidelines do not apply to individual ladder pools since these are governed by design criteria specific to these pools.

5.3 Auxiliary Water Systems

5.3.1 Description and Purpose

An AWS should be used to supply additional water to the fishway when the required attraction flow (as specified in Section 5.2.2.4) is greater than ladder flow.

Auxiliary water is often required at fishways to provide additional attraction flow from the entrance pool to fishway entrances (Bell 1991). Adding AWS flow is based on the concept that fish migrating upstream are attracted by flow velocity of certain magnitudes, which the fish swim against to continue their migration upstream (Clay 1995). Auxiliary water can also be supplied through an AWS to areas between fishway weirs that are partially submerged by high tailwater elevations and fail to meet the flow velocity criterion, as discussed in Section 5.2.2.12. In addition, an AWS can be used to provide additional flows to various transition pools in the ladder such as bifurcation or trifurcation pools, multiple entrances, pools in fish trapping facilities, exit control sections, and counting station pools.

5.3.1.1 AWS supply source

The source of water for the AWS flow should be of the same quality (e.g., temperature, turbidity, and water chemistry) as the flow in the ladder (i.e., the receiving water).

The AWS flow is usually routed from the forebay to the ladder via gravity, but water quality may vary from the ladder flow depending on the location of the AWS intake. The AWS flow can also be pumped from the tailrace or delivered via a combination of gravity and pumped sources. Differences in the water sources could cause fish to reject the ladder.

5.3.2 Specific Criteria and Guidelines – AWS Fine Trash Racks

5.3.2.1 Bar spacing

A fine trash rack should be provided at the AWS intake with clear space between the vertical flat bars of 0.875 inch or less.

The purpose of an AWS fine trash rack is to stop debris from entering the AWS, which might plug the upstream side of the diffuser panel. Since the normal, clear opening between bars on the diffuser panels is 1 inch (Section 5.3.7), the AWS fine trash rack should be 0.875 inch or less. At sites where Pacific lamprey may be present and diffusers with 0.75-inch clear openings are used (Section 5.3.7), the AWS fine trash rack should have a maximum clear opening of 0.625 inch or less.

5.3.2.2 Velocity

Maximum velocity through the AWS fine trash rack should be less than 1 ft/s, as calculated by dividing the maximum flow by the submerged area of the fine trash rack.

5.3.2.3 Cleaning consideration

The support structure for the fine trash rack should not interfere with cleaning requirements and should provide access for debris raking and removal.

5.3.2.4 Slope

The fine trash rack should be installed at a 1H:5V (horizontal:vertical) or flatter slope for ease of cleaning. The fine trash rack design should accommodate maintenance requirements by considering access for personnel, travel clearances for manual or automated raking, and removal of debris.

5.3.2.5 Staff gages and head differential

Staff gages should be installed to indicate head differential across the AWS intake fine trash rack and should be located to facilitate observation and in-season cleaning. Head differential across the AWS intake fine trash rack should not exceed 0.3 foot in order to facilitate cleaning, minimize velocity hot spots, and maintain hydraulic efficiency in gravity and pumped systems.

Staff gages are used for determining whether the head across a trash rack is within criteria or not. Care should be taken when locating staff gages so that they can be easily read by personnel.

5.3.2.6 Structural integrity

AWS intake fine trash racks should be of sufficient structural integrity to avoid the permanent deformation associated with maximum occlusion.

5.3.3 Specific Criteria and Guidelines – AWS Screens

In instances where the AWS poses a risk to the passage of juvenile salmonids because of its design involving high head and convoluted flow paths, the AWS intake should be screened to the standards specified in Chapter 8 to prevent juvenile salmonids from entering the AWS.

Trip gates, pressure relief valves, or other alternate intakes to the AWS may be included in the design to ensure that AWS flow targets are achieved if screen reliability is uncertain under high river flow conditions. Debris and sediment issues may preclude the use of juvenile fish screen criteria for AWS intakes at certain sites. Passage risk through an AWS will be assessed by NMFS on a site-specific basis to determine whether screening of the AWS is warranted and how to provide the highest reliability possible.

5.3.4 Specific Criteria and Guidelines – AWS Flow Control

The AWS should have a flow control device located sufficiently far away from the AWS intake to ensure the flow at the AWS fine trash rack or screen is uniformly distributed. To facilitate cleaning, the flow control system should allow flow to be easily shut off for maintenance and then restarted (and reset) to proper operating conditions.

The flow control device may consist of a control gate, pump control, turbine intake flow control, or other flow control systems located sufficiently far away from the AWS intake to ensure uniform flow distribution at the AWS fine trash rack for all AWS flows. Flow control is necessary to ensure that the correct quantity of AWS flow is discharged at the appropriate location during a full range of forebay and tailwater levels.

5.3.5 Specific Criteria and Guidelines – AWS Excess Energy Dissipation

Excess energy should be dissipated from AWS flow prior to passage through diffusers.

Dissipation of excess energy is necessary to minimize surging and induce relatively uniform velocity distribution at the diffusers because surging and non-uniform velocities may cause adult fish jumping and associated injuries or excess migration delay. The introduction of highly turbulent or aerated water will discourage fish from entering or passing through a fishway and possibly result in fish delay or injury (Clay 1995). Examples of methods to dissipate excess AWS flow energy include the following:

- Routing flow into a fishway pool with adequate volume (Section 5.3.6.2)
- Passing AWS flow through a turbine
- Passing AWS flow through a series of valves, weirs, or orifices
- Passing AWS flow through a pipeline with concentric rings or other hydraulic transitions designed to induce head loss

All of these dissipation systems require that AWS flow passes through a baffle system that has a porosity of less than 40% to reduce surging through fishway entrance pool diffusers. Adjustable baffles may be required in some systems to properly balance flow across the diffuser.

Figure 5-3 provides a schematic of a fishway AWS diffuser system showing the components needed, and their shape and arrangement, to control water flow rate and convert high-velocity, high-pressure, non-uniform flow into low-energy uniform flow.

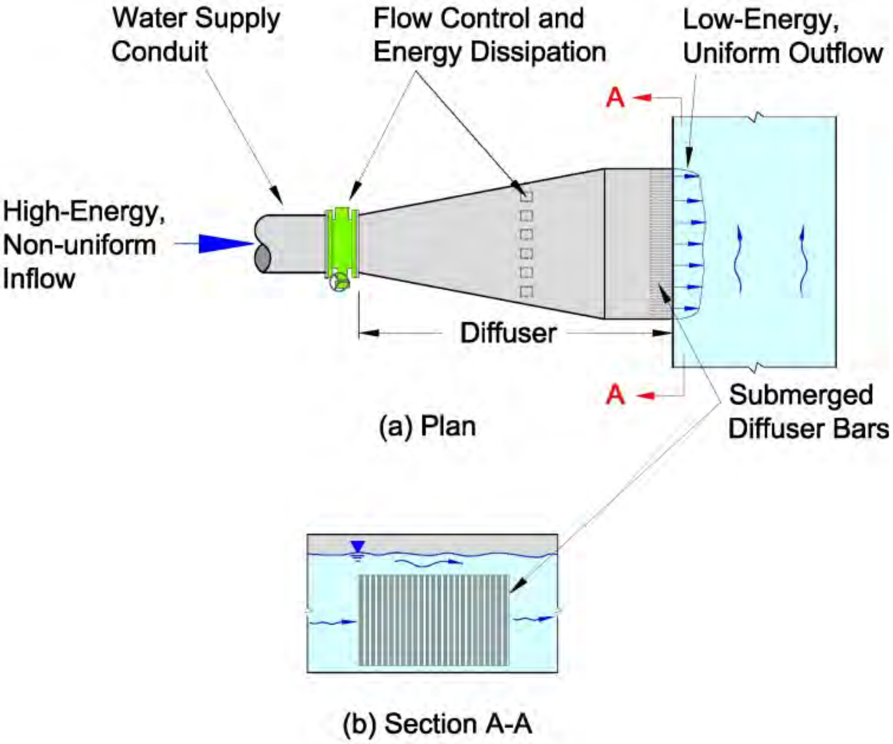


Figure 5-2. Schematic of a fishway AWS diffuser system in plan (a) and section (b) views

5.3.5.1 Energy dissipation pool volume

An energy dissipation pool in an AWS should have a minimum water volume established by the formula shown in Equation 5-1.

$$V = \frac{(\gamma)(Q)(H)}{16\ ft{-}lb\ /ft^3/s} \tag{5-1}$$

where:

V = pool volume in cubic feet (ft^3)
γ = specific weight of water, 64.2 pounds (lb) per ft^3
Q = AWS flow, in ft^3/s
H = energy head of pool-to-pool flow, in feet drop into the AWS pool

Note that the pool volumes required for AWS pools are smaller than those required for fishway pools. This is due to the need to provide resting areas in fishway pools and because AWS systems require additional elements (e.g., diffusers and valves) to dissipate energy and are not pathways for upstream fish passage.

5.3.6 Specific Criteria and Guidelines – AWS Diffusers

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bell 1991; Bates 1992). For adult salmonid passage, the maximum clear spacing between bars is 1 inch between diffusers bars. At sites where adult Pacific lamprey may be present, diffusers should have a maximum 0.75-inch clear spacing between bars.

Wall diffusers should consist of non-corrosive, vertically oriented diffuser panels of vertically oriented flat bar stock. Similarly, floor diffusers should consist of non-corrosive, horizontally oriented diffuser panels of horizontally oriented flat bar stock. Orientation of flat bar stock should maximize the open area of the diffuser panel. If a smaller species or life stage of fish is present, smaller clear spacing between bar stock may be required.

5.3.6.1 Material

The bars and picket panels used as part of AWS diffuser systems should be made of aluminum, stainless steel, or epoxy-coated carbon steel. The use of submerged galvanized steel should be minimized or eliminated, especially when used in close proximately to fish (i.e., fishways).

Galvanized steel is coated with zinc, a metal that can be toxic to fish.

5.3.6.2 Velocity and orientation

The maximum AWS diffuser velocity should be less than 1 ft/s for wall diffusers and 0.5 ft/s for floor diffusers based on the total submerged diffuser panel area (Bell 1991). Wall diffusers should only be used when the orientation can be designed to assist with guiding fish within the fishway. Diffuser velocities should be nearly uniform, which may require the use of porosity control panels (Section 5.3.6.3). The face of the diffuser panels (i.e., the surface exposed to the fish) should be flush with the wall or floor.

These criteria are based on *Design of Fishways and Other Fish Facilities* (Clay 1995), which states that 1 ft/s “has been adopted as the best compromise between practicality and efficiency,” These criteria are also based on the results of laboratory studies where spring- and fall-run Chinook salmon and steelhead passage times increased when diffuser flows were added and were progressively longer as floor diffuser velocity increased from 0.25 to 1.25 ft/s (Gauley et al. 1966).

An example of wall diffusers being used to assist in guiding fish is when the diffusers in the entrance pool of a fishway are situated such that fish are naturally lead upstream to the first ladder pool.

When wall diffusers are used in conjunction with a half Ice Harbor-style ladder, the diffuser should be located on the same side as the overflow weir, and the diffuser bars should be oriented horizontally.

5.3.6.3 Porosity control baffles

Similar to juvenile fish screens, diffusers should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure that average velocities at the face of the diffuser are uniform and can meet criteria (Section 5.3.6.2).

The purpose of the porosity control panels is to control the amount of flow through the diffuser pickets and create a uniform flow condition at the face of the pickets.

5.3.6.4 Debris removal

The AWS design should include access for personnel to remove debris from each diffuser unless the AWS intake is required per the criteria listed in Section 5.3.4 to be equipped with a juvenile fish screen (Chapter 8).

5.3.6.5 Edges

All flat bar diffuser edges and surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.

5.3.6.6 Lamprey passage

At sites where Pacific lamprey are present, horizontal diffusers should not extend the complete width of the floor of the fishway or entrance pool. A solid surface, approximately 1.5 feet wide, should be located along the floor between the lateral sides of the diffuser panels and the base of either wall.

5.3.6.7 Elevation

Wall AWS diffusers should be submerged throughout the range of operation (i.e., the top elevation of the wall diffuser should be below the lowest water surface elevation that will occur based on the fishway design).

This is to prevent water from cascading through the diffuser, which can induce fish to leap at the surface disturbance.

5.3.7 Specific Criteria and Guidelines – Bedload Removal Devices

At locations where bedload may cause accumulations at the AWS intake, sluice gates or other simple bedload removal devices should be included in the design.

5.4 Transport Channels

5.4.1 Description and Purpose

A transport channel conveys flows between different sectors of the upstream passage facility, providing a route for fish to pass.

5.4.2 Specific Criteria and Guidelines – Transport Channels

5.4.2.1 Velocity range

The transport channel velocities should be between 1.5 and 4 ft/s (Gauley et al. 1966; Bates 1992), including flow velocity over or between fishway weirs inundated by high tailwater (Bell 1991).

Gauley et al. (1966) reported that Chinook and sockeye salmon and steelhead passage times did not differ significantly between water velocities of 1 and 4 ft/s in an experimental 270-foot-long transportation channel. However, Weaver (1963) reported that Chinook salmon moved progressively slower in a test flume as velocities increased from 2 to 8 ft/s.

5.4.2.2 Dimensions

The transport channels should be a minimum of 5 feet deep and 4 feet wide.

This is based on providing the narrowest, shallowest flow path that adult fish are known to move through readily while also displaying the least amount of fallback behavior and delay. In addition, this size of channel relates to the goal of keeping water velocities in the transport channel low.

5.4.2.3 Lighting

Ambient natural lighting should be provided in all transport channels, if possible. If ambient (natural) lighting is not available, acceptable artificial lighting should be used.

In laboratory tests, fish were presented with the choice of a large entrance (3.9 feet by 3.9 feet) that was dark or a smaller entrance (1.5 feet by 2 feet) that was lighted. Study results corroborate the understanding that fish prefer lighted entrances and channels: 80% of Chinook salmon, 90% of coho salmon, 69% of steelhead, and 86% of sockeye salmon chose the lighted entrance (Bates 1992).

5.4.2.4 Design (general)

Based on the literature and experiences of fish biologists at many facilities located in the WCR, the following features should be included in the design of transport channels:

- *The transport channels should be of open channel design (Bell 1991).*
- *Designs should avoid hydraulic transitions or lighting transitions (USFWS 1960; Bell 1991).*
- *Transport channels should not expose fish to any moving parts.*
- *Transport channels should be designed so that there is no standing water in the channel when the system is dewatered.*
- *Transport channels should be free of exposed edges that protrude from channel walls.*

5.5 Fish Ladder Design

5.5.1 Description and Purpose

The purpose of a fish ladder is to convert total project head at the passage barrier into passable increments and provide suitable conditions for fish to hold, rest, and ultimately pass upstream. Nearly all of the energy from the upstream ladder pool is dissipated in the downstream ladder pool volume, resulting in a series of relatively calm pools that migrating fish may use to rest and stage before ascending upstream. The criteria provided in this section have been developed to provide conditions to pass all anadromous salmonid species upstream with minimal delay and injury.

5.5.2 Common Types of Fish Ladders

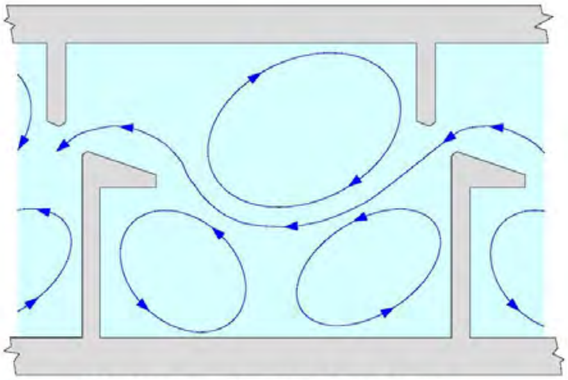
Fish ladders or fishways, in one form or another, have been around for more than 300 years (Clay 1995). Over time, ladder designs have developed and evolved and have been adapted to meet site-specific conditions. For the purpose of this document, fish ladders are divided into the following two categories:

- Pool-style ladders, including:
    - Vertical slot
    - Pool and weir
    - Weir and orifice
    - Pool and chute
- Roughened (Baffled) chute-style ladders, including:
    - Denil steeppass
    - Alaska steeppass (ASP)

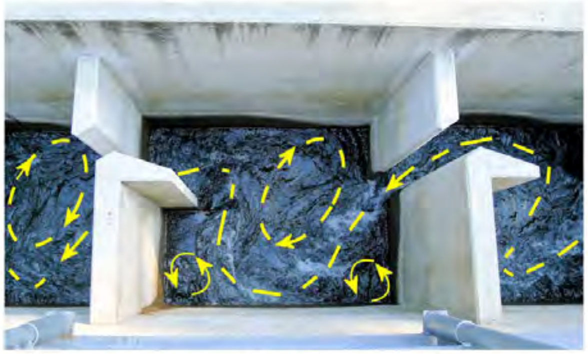
The following sections present brief discussions of criteria and guidelines for the more common styles of fish ladders.

5.5.2.1 Vertical slot ladder

The vertical slot configuration is a pool-style of fish ladder (Figures 5-3 through 5-5; Table 5-1). The vertical slot ladder is suitable for passage impediments that have tailrace and forebay water surface elevations that fluctuate within large ranges. The maximum head differential—typically associated with the lowest river flows—establishes the design water surface profile, which usually parallels the fishway floor gradient.



(a) Generalized Flow Path



(b) In actual fishway pools

Figure 5-3. Plan view of a vertical slot ladder showing generalized flow paths

Figure 5-4. Oblique view of a vertical slot ladder baffle when dewatered

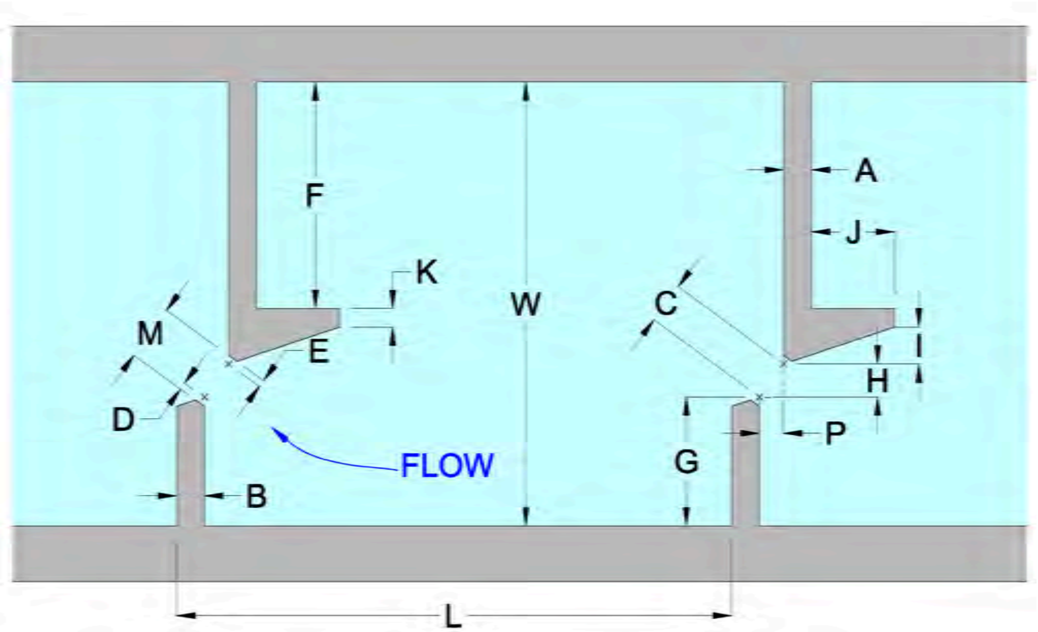


Figure 5-5. Dimensions of a typical vertical slot ladder pool

(Note that information for Figure 5-6 is provided in Table 5-1. “D” is the dimension of the layout points used during ladder design and construction (i.e., the framing and the form work for the concrete pours); it determines the chamfer for the slot and the width of the slot; and knowing “D” allows the designer to layout the complex angles used during construction.)

Table 5-1. Dimensions for vertical slot ladder components measured in feet.

Symbol		Dimension Nomenclature (Refer to Figure 5-6)			
L		Pool length	10’0”	10’0”	10’0”
W		Pool width	6’0”	8’0”	8’0”
A		Long baffle width[A]	0’6”	0’6”	0’6”
B		Short baffle width[A]	0’6”	0’6”	0’6”
M		Slot width	1’0”	1’0”	1’3”
C		Slot width layout points	0’9”	0’9”	0’9”
D, E		Dimension “C” layout points (separation from baffles)	0’1½”	0’1½”	0’3”
F		Long baffle wall length	3’1”	4’1”	4’1”
G		Short baffle wall length (wall to layout point)	1’3¾”	2’3¾”	2’3¾”
I		Flow deflector width change	0’7”	0’8”	0’7”
J		Flow deflector length	1’3”	1’6”	1’3”
K		Flow deflector upstream width	0’5”	0’4”	0’5”

Note:
A: Short baffle and long baffle widths may need to be increased in certain instances for structural integrity in large fishway installations.

The full-depth vertical slots allow fish passage at any depth (Clay 1995). Fish are assumed to be able to move directly from slot to slot in a straight path, although this has not been verified (Clay 1995). However, hydraulic studies have verified that velocity through the slot is constant throughout the vertical profile (Katopodis 1992). The vertical slot may not be well suited for species that require overflow weirs for passage or that tend to orient to walls such as American shad.

5.5.2.1.1 *Vertical slot width and depth*

For adult anadromous salmonids, slots should never be less than 1 foot in width. If larger Chinook salmon are expected to pass, the minimum slot width is 1.25 feet (Clay 1995). Bell (1991) recommends a minimum slot depth of 3 feet, although they are typically on the order of 5- to 6-feet deep to match the required pool depth.

The passage corridor typically consists of 1- to 1.25-foot-wide vertical slots between fishway pools. However, narrower slots have been recommended (Clay 1995) and used in applications for other fish species that are smaller than salmon or steelhead. In some situations, wider slots (or two slots per ladder weir) are used if AWS flow is not being added to the ladder.

Vertical slot ladders tend to require more water to operate properly compared with other styles of fishways because of the width and depth of the slot and the head differential between pools. Low sills can be added to the bottom of each slot to reduce the overall amount of flow in the ladder that is required. However, these sills may block the passage of species that prefer or need to travel along the floor of a ladder.

5.5.2.1.2 *Vertical slot geometry (pool size)*

Standard, proven design dimensions should be adhered to unless it can be proven through physical hydraulic modeling that changes do not affect the function of the ladder.

Vertical slot ladders are sensitive to changes in pool geometry (e.g., pool width, length, slope, and slot width; Clay 1995), and initial construction costs are higher than other types of ladders because of the more complex design and concrete placement.

5.5.2.2 Pool and weir ladder

The simplest style of fish ladder is the pool and weir ladder (Bell 1991); it is also one of the oldest styles of fish ladder. The pool and weir fish ladder passes the entire, almost constant, fishway flow through successive pools separated by overflow weirs that break the total project head into passable increments (Figure 5-6). This design allows fish to ascend to higher elevations by passing over weirs, and it provides resting zones within each pool. When passing this style of ladder, fish must leap or swim over the weir flow. Pools are sized to allow flow energy to be nearly fully dissipated through turbulence within each receiving pool (Clay 1995).

Figure 5-6. Examples of pool and weir ladders

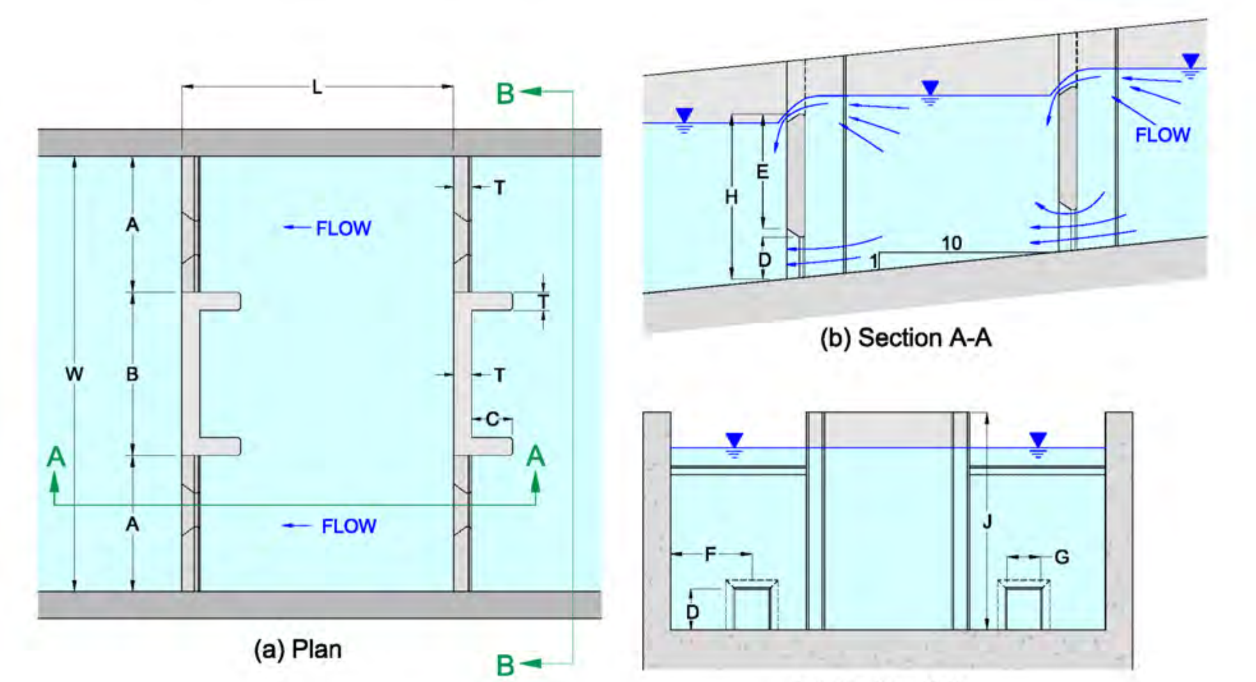
(Note that the orifices in the weir wall on the left-side photo are to drain each of the pools and are not meant for fish passage.)

In contrast to vertical slot ladders, pool and weir ladders require nearly constant water surface elevations in the forebay pool to function properly (Bell 1991; Clay 1995). When the water surface elevation fluctuates outside of the design elevation, too much or too little flow enters the fishway. This flow fluctuation may affect upstream passage by causing fishway pools to be excessively turbulent or providing insufficient flow. To accommodate forebay fluctuations and maintain a consistent flow in the ladder, pool and weir ladders are often designed with an AWS (Section 5.3) and fishway exit control section (Section 5.7; Bell 1991). To accommodate tailwater fluctuations, pool and weir ladder designs may include an adjustable fishway entrance (i.e., adjustable geometry and attraction flow) and an AWS to provide additional flow to meet the channel velocity criterion (Section 5.4.2.1; Bell 1991).

5.5.2.3 Weir and orifice ladder

The weir and orifice fish ladder passes flow from the forebay through successive fishway pools connected by overflow weirs and submerged orifices, which divide the total project head into passable increments (Figures 5-7 and 5-8, Table 5-2; Clay 1995). Weir and orifice ladders are similar to pool and weir ladders in the following ways:

- Weir and orifice ladders require nearly constant water surface elevations in the forebay pool (unless adjustable components are included to accommodate the varying forebay level); water surface elevations outside of the design elevation result in too much or too little flow entering the fishway, which may affect fish passage due to turbulence or insufficient flow.
- Weir and orifice ladders are often designed with an AWS and fishway exit control section (Section 5.7), an adjustable fishway entrance (i.e., adjustable geometry and attraction flow), and an AWS to provide additional low diffusers to meet the transport channel velocity criterion (Section 5.4.2.1).



(a) Plan

(b) Section A-A

(c) Section B-B

Figure 5-7. Ice Harbor-style weir and orifice ladder (adapted from Gauley et al. 1966

(Note that information for Figure 5-7 is provided in Table 5-2.)


(a) Looking downstream (b) Looking upstream

Figure 5-8. Overhead views of Ice Harbor-style weir and orifice fish ladders

Table 5-2. Dimensions for Ice Harbor fishways measured in feet

Symbol	Dimension Nomenclature (Refer to Figure 5-8)	Bell 1991	Gauley et al. 1966
L	Pool length	8–20	10
W	Pool width	6–20	16
A	Weir length	1.5–5	5
B	Center baffle width	W/2*	6
C	Flow stabilizer length	NA	1’6”
D	Orifice height	1’6”	1’6”
E	Baffle height above orifice	4’3”	4’6”
F	Wall to orifice center line	NA	3
G	Orifice width	1’3”	1’6”
H	Weir height	6	6
J	Wing baffle height	8	8
T	Weir and baffle thickness	NA	NA

Notes:
* See “W” in panel (a) of Figure 5-8.
Dimensions listed under Bell (1991) are taken from https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Bell_1991_Fisheries_handbook_of_engineering_requirements_and.pdf.
Dimensions listed under Gauley et al. 1966 are taken from the report located here: https://www.nwfsc.noaa.gov/assets/26/7778_08132014_135336_Gauley.et.al.1966.pdf.
NA: not available

When passing this style of ladder, fish have the choice of leaping or swimming over the weir or swimming through the orifice, and it is NMFS' experience that most salmonids prefer to swim through the orifice. The Ice Harbor ladder is an example of a weir and orifice fish ladder. This ladder design was developed in the 1960s for use at Ice Harbor Dam on the Snake River in Washington by the Bureau of Commercial Fisheries at USACE Fisheries-Engineering Research Laboratory (FERL), which was located at the Bonneville Dam on the Columbia River in Oregon (Figure G-1 in Appendix G). Fish passage research was conducted at FERL from 1955 until it was decommissioned in the 1980s (see Appendix I for a listing of reports of research conducted at the FERL). The research provided basic knowledge of the behavior, abilities, and requirements of fish in fish passage situations (Collins 1976).

Development and testing at FERL resulted in the design of the l-on-10 slope ladder for Ice Harbor Dam, which was studied in a full-scale section of the ladder consisting of six ladder pools. A prototype ladder was tested during its first year of operation at Ice Harbor Dam. The design is a pool and weir ladder with submerged orifices, flow stabilizers, and a non-overflow section in the middle of each weir (Figures 5-7 and 5-8). See Table 5-2 for typical dimension of this type of fishway. There is a 1-foot rise between pools, and the average water depth under normal operating conditions is 6.5 feet (Gauley et al. 1966). The Ice Harbor-style of ladder includes two rectangular orifices centered on and located directly below each overflow weir. The position and depth of the orifices were found to have a significant effect on the passage of fish through rectangular submerged orifices (Thompson et al. 1967). The orifice and weir combinations are located on each side of the longitudinal centerline of the ladder. Between the two weirs is a slightly higher non-overflow wall with an upstream-projecting flow baffle located at each end. An adaptation for lower flow designs is the half Ice Harbor ladder design, which consists of a weir, an orifice, and a non-overflow wall between fishway pools.

5.5.2.4 Pool and chute ladder

A pool and chute ladder is a hybrid that operates under varying river flow conditions. This ladder is designed to operate as a pool and weir ladder at low river flows and as a roughened chute-style fishway at higher river flows (Figure 5-9). This ladder is an alternative style of ladder for sites with a low hydraulic drop that must pass a wide range of streamflows with a minimum of flow control features. Placement of stoplogs—a cumbersome and potentially hazardous operation—is required to optimize operation of this ladder. However, once suitable flow regimes are established, the need for additional stoplog placement may not be required. Criteria for this type of ladder design are still evolving, and design proposals will be assessed by NMFS on a site-specific basis. Bates (1992) provides specific criteria and guidelines for this style of ladder where fish have the option of swimming over, or leaping the overflow weir, or swimming through the orifice. The lateral slope of the weirs presents fish with flow conditions that range from plunging flow near the edges to streaming flow towards the center of the ladder.

Figure 5-9. Pool and chute ladder dewatered (at left) and watered (at right)

5.5.2.5 Half Ice Harbor and half-pool and chute ladders

The flow rate available to pass through a fishway at small projects is often too low to take advantage of the benefits of the standard Ice Harbor or pool and chute ladder designs. In these situations, it is possible to design and construct weirs shaped as one-half of an Ice Harbor-style weir and orifice ladder or one-half of a pool and chute-style ladder (Figure 5-10). These designs share the same advantages and disadvantages as their full-sized counterparts and should meet all of the design criteria for each type of full-sized ladder. The hydraulic design process used for half-ladders is analogous to the design process used for full-sized ladders.

Figure 5-10. Half ladder designs for projects with reduced available fishway flows

(Note: panel on left is a half-Ice Harbor ladder weir and orifice design; panel on right is a half-pool and chute ladder with weir design.)

5.5.3 Specific Criteria and Guidelines – Fish Ladder Design

5.5.3.1 Hydraulic drop

The maximum hydraulic drop between fish ladder pools should be 1 foot or less (Bell 1991; Clay 1995). Where pink or chum salmon are present, the maximum hydraulic drop between pools should be 0.75 foot or less (Bates 1992; Clay 1995).

5.5.3.2 Flow depth

Fishway overflow weirs should be designed to provide at least 1 foot (± 0.1 foot) of flow depth over the weir crest (Clay 1995; WDFW 2000).

The depth should be indicated by locating a single staff gage in an observable, hydraulically stable location that is representative of flow depth throughout the fishway. The zero reading of the gage should be at the overflow weir crest elevation.

5.5.3.2.1 *Streaming flow*

Some fish species will not leap or are poor leapers and will refuse to pass or become delayed by plunging flow conditions in a ladder. They may also refuse to pass through the orifices in a ladder (e.g., all shad species). For those species, streaming flow should be created *between ladder pools to provide acceptable passage conditions. When pink or chum salmon are present, the upstream weir crest should be submerged by at least 0.5 foot by the downstream water surface level (Bates 1992). Where American shad are present, the upstream weir crest should be submerged by at least 0.3 foot by the downstream water surface level.*

Streaming flow occurs when the weir is backwatered by the downstream weir (Bates 1992; Katapodis 1992). The transition between plunging flow and streaming flow is hydraulically unstable and should be avoided according to Bell (1991) and Bates (1992) because passage can be delayed when flow is in this transition. Hydraulic instability occurs in the transition regime between the upper range of plunging flow and the lower range of streaming flow. The instability can also cause large oscillations that are transmitted throughout the fishway because energy is not dissipated in each pool of the fishway, which makes the streaming flow jet difficult to manage. For these reasons, streaming flow in a fishway should be used cautiously (Bates 1992).

Submerging the upstream weir crest by 0.3 foot is based on experience with adjusting ladder flows at Columbia River dams to pass American shad. In addition, Larinier and Travade (2002) state that a head of around 1.3 feet and streaming flow in an Ice Harbor-style ladder are needed for shad passage. Rideout et al. (1985) report substantial improvements in American shad passage at the Turners Falls dam fishway in Massachusetts when flow over weir crests was changed from plunging to streaming.

5.5.3.3 Pool dimensions

In general, pool dimensions should be a minimum of 8 feet long (upstream to downstream), 6 feet wide, and 5 feet deep. However, specific ladder designs may require pool dimensions that are different from the minimums specified in this criterion, depending on site conditions and ladder flows (see Clay 1995).

For small stream ladders, Bell (1991) provides minimum dimensions for some pool and weir fishway designs. The minimum pool should not be less than 6 feet long, 3 feet deep, and 4 feet wide. It is recommended that the fishway slope not exceed 1:8. For pools less than 8 feet in length, the drop between pools should be reduced proportionally. To allow for the proper dissipation of the orifice flow, the pool dimensions for a pool and orifice-style ladder should not be reduced (Clay 1995).

Ladder pools should be designed so that there is no standing water in the pools when the system is dewatered. The floors of the ladder should be sloped from the sides to the floor orifice to encourage fish to move downstream during salvage operations conducted when a ladder is dewatered for maintenance.

5.5.3.4 Turning pools

Turning pools (i.e., pools where the fishway direction changes more than 90 degrees) should be at least double the length of a standard fishway pool, as measured along the centerline of the fishway flow path. The orientation of the upstream weir to the downstream weir should be such that energy from flow over the upstream weir does not affect the hydraulic conditions at the downstream weir.

5.5.3.5 Pool volume

The pool volume within the fishway should provide sufficient volume (i.e., hydraulic capacity) to absorb and dissipate the pool-to-pool energy and accommodate the maximum daily run of fish (i.e., fish capacity; Appendix H).

Generally, the volume required to provide adequate hydraulic capacity governs pool sizing (Bell 1991; Bates 1992). To provide adequate hydraulic capacity, the fishway pools should be a minimum volume (of water) based on Equation 5-2.

$$V = \frac{(\gamma)(Q)(H)}{4\, ft{-}lb\ /ft^3/s} \tag{5-2}$$

where:

V = pool volume in ft^3
γ = specific weight of water, 64.2 lb per ft^3
Q = specific weight flow, in ft^3/s
H = energy head of pool-to-pool flow, in feet

This pool volume should be provided under every expected design flow condition, with the entire pool volume having active flow and contributing to energy dissipation.

If large numbers of fish are expected to pass the fish ladder in a relatively short amount of time, overcrowding can occur, leading to delay. Delay in passage is minimized by providing ample volume to accommodate the peak of the run without overcrowding (Clay 1995). Therefore, it may be necessary to increase the individual pool volume to accommodate the peak run of fish. See Appendix H for sizing a fish ladder based upon run size.

5.5.3.6 Freeboard

The freeboard of the ladder pools should be at least 3 feet at high design flow.

5.5.3.7 Orifice dimensions

At sites where large salmonids are expected, the minimum dimensions of the orifice should be 18 inches high by 15 inches wide (Bell 1991), based on the Ice Harbor ladder design dimensions (Section 5.5.3.3).

The minimum dimensions of orifices where large salmonids are not expected should be at least 15 inches high by 12 inches wide.

The top and sides of the orifice should be chamfered 0.75 inch on the upstream side and chamfered 1.5 inches on the downstream side of the orifice to provide the most stable flow (Bates 1992).

For sites where Pacific lamprey are present, the floor of the fishway should provide a continuous, uninterrupted surface through the orifice. USACE (Portland District) has developed and installed an orifice with rounded edges to facilitate Pacific lamprey passage.

The primary concern with smaller orifices is the increased risk of plugging by debris (WDFW 2000).

5.5.3.8 Lighting

Ambient lighting should be provided throughout the fishway, and abrupt lighting changes should be avoided (Bell 1991). In enclosed systems, such as transport tunnels, provisions for artificial lighting should be included. In cases where artificial lighting is required, lighting in the blue-green spectral range should be provided. Artificial lighting should be designed to operate under all environmental conditions at the installation.

These lighting criteria are based in part on laboratory studies where a majority of Chinook and sockeye salmon and steelhead entered the lighted orifice when given a choice between a dark experimental orifice and a lighted control orifice where head was equal between the two orifices (Weaver et al. 1976).

5.5.3.9 Change in flow direction

At locations where the flow changes direction more than 60 degrees, 45-degree vertical miters (minimum 20 inches wide) or a 2-foot minimum, vertical radius of curvature should be included in the design of the outside corners of fishway pools (Bell 1991).

Bell reports that “Fish accumulate when pool hydraulic patterns are altered. If the design includes turn pools, fish will accumulate at that point. Square corners, particularly in turn pools, should be avoided as fish jump at the upwelling so created” (1991). Depending upon the pool configuration, size of the turning pool, and amount and velocity of the flow in the ladder, larger radii of curvatures may be necessary.

5.6 Counting Stations and Windows

5.6.1 Description and Purpose

Counting stations provide a location and facility to observe and enumerate fish utilizing the fish passage facility. Although not always required, a typical counting station includes a video camera or fish counting technician, crowder, and counting window (Bell 1991). Counting stations are often included in a fish ladder design to allow fishery managers to assess fish population status, observe fish size and condition, and conduct scientific research.

5.6.1.1 Operation

Counting stations should not interfere with the normal operation of the ladder and should not create excessive fish passage delay.

A decision to include a counting station as part of the ladder design should be carefully considered. Regardless of how well the counting station is designed, oftentimes fish hold and delay at counting stations because of conditions that change the facility such as crowding, lighting, and hydraulics. Instead of a counting station, other means of enumeration may be acceptable, including the use of submerged cameras and their associated lighting, adult PIT-tag detectors, and orifice counting tubes.

5.6.2 Specific Criteria and Guidelines – Counting Stations

5.6.2.1 Location

Counting stations should be located in a hydraulically stable, low velocity (i.e., around 1.5 ft/s), and accessible area of the upstream passage facility.

5.6.2.2 Downstream and upstream pools

The pool downstream of the counting station should extend at least two standard fishway pool lengths from the downstream end of the picket leads. The pool upstream of the counting station should extend at least one standard fishway pool length from the upstream end of the picket leads. Both pools should be straight and in line with the counting station (Bell 1991).

5.6.3 Specific Criteria and Guidelines – Counting Windows

5.6.3.1 Design and material

The counting window should be designed such that cleaning of the window can be accomplished completely, conveniently, and at a frequency that ensures window visibility will be maintained and accurate counting can be accomplished. The counting window material should be abrasion-resistant to accommodate frequent cleaning.

5.6.3.2 Orientation

Counting windows should be vertically oriented.

5.6.3.3 Sill

The counting window sill should be positioned to allow full viewing of the fish passage slot (from floor to water surface).

5.6.3.4 Lighting

The counting window design should include sufficient indirect, artificial lighting to provide satisfactory fish identification at all hours of operation and without causing passage delay.

5.6.3.5 Dimensions

The minimum observable length of the counting window in the upstream-to-downstream flow direction should be 5 feet, and the minimum height (depth) should be full water depth.

5.6.3.6 Counting window slot width

The width of the counting station slot (the area between the counting window and the vertical surface at the back of the slot) should be at least 18 inches. The design should include an adjustable crowder to move fish closer to the counting window (but not closer than 18 inches) to allow fish counting under turbid water conditions. The counting window slot width should be maximized as water clarity allows and when not actively counting fish.

5.6.3.7 Picket lead

A downstream picket lead should be included in the design to guide fish into the counting window slot, and it should be oriented at a deflection angle of 45 degrees relative to the direction of fishway flow. An upstream picket lead oriented at a deflection angle of 45 degrees to the flow direction should also be provided. Picket orientation, picket clearance, and maximum allowable velocity should conform to specifications for diffusers (Section 5.3.7).

Combined maximum head differential through both sets of pickets should be less than 0.3 foot. Both upstream and downstream picket leads should be equipped with witness marks to verify correct position when picket leads are installed in the fishway. A 1-foot-square opening should be provided in the upstream picket lead to allow smaller fish that pass through the downstream picket lead to escape the area between the two picket leads.

Picket leads may comprise flat stock bars oriented parallel to flow or other cross-sectional shapes, if approved by NMFS.

5.6.3.8 Transition ramps

If the counting window requires a false floor to force fish to swim higher in the water column to be more easily identified, then transition ramps should be included in a counting station design. The ramps should smoothly transition from the floor of the counting station pool to the false floor at the counting window and then back to the counting station floor.

These ramps provide gradual transitions between walls, floors, and the false floor in the counting window slot. The purpose is to minimize flow separations created by head loss that may impede fish passage and induce fallback behavior at the counting window. In situations where space is available, the transitions should be more gradual than 1:8, and where space is confined, a 1:4 transition should be used.

5.6.3.9 Water surface through the counting slot

A free water surface should exist over the length of the counting window.

5.7 Fishway Exit Control

5.7.1 Description and Purpose

This section describes and provides criteria for a ladder exit control channel for fish to egress the fishway and enter the forebay of a dam to continue upstream migration. The exit control channel may include the following features: add-in auxiliary water valves and diffusers, exit pools with varied flow, exit channels, a coarse trash rack that keeps large debris out of the ladder but allows fish to pass through the trash rack and exit the ladder, and fine trash racks and control gates on AWS systems. The exit control section of the ladder also attenuates fluctuations in forebay water surface elevation, thus maintaining hydraulic conditions suitable for fish passage in the ladder pools. Other functions that should be incorporated into the design of the exit control section include minimizing the entrainment of debris and sediment into the fish ladder. Different types of ladder designs (Section 5.5) require specific fish ladder exit design details unique to each type of ladder.

5.7.2 Specific Criteria and Guidelines – Fishway Exit Control

5.7.2.1 Hydraulic drop

The exit control section hydraulic drop per pool should range from 0.25 to 1 foot.

5.7.2.2 Length

The length of the exit channel upstream of the exit control section should be a minimum of two standard ladder pools.

5.7.2.3 Design requirements

Exit section design should utilize the requirements for AWS diffusers, channel geometry, and energy dissipation as specified in Sections 5.3, 5.4, and 5.5.

5.7.2.4 Closure gates

Any closure gate that is incorporated into the exit control section should be operated either in the fully opened or closed position (i.e., the gates cannot be partially open to regulate flow).

5.7.2.5 Location

In most cases, the ladder exit should be located along a shoreline, in a velocity zone of less than 4 ft/s, and sufficiently far enough upstream of a spillway, sluiceway, or powerhouse to minimize the risk of fish non-volitionally falling back through these routes (Clay 1995).

The distance the exit needs to be upstream of these hazards depends on bathymetry near the dam spillway or crest and associated longitudinal river velocities (Bell 1991).

5.7.2.6 Public access

Public access near the ladder exit should be prohibited.

5.8 Fishway Exit Sediment and Debris Management

5.8.1 Description and Purpose

As stated in Section 5.7.1, the design of the ladder exit should strive to minimize the entrainment of debris and sediment into the fish ladder. Floating and submerged debris can become lodged in ladder orifices or on weir crests, alter hydraulic conditions in these fish passage routes, and impact fish behavior and passage rates. Similarly, sediment transported into the fishway can deposit in low-velocity areas, alter hydraulic conditions, and impact fish passage. Removing debris and sediment from ladders can be difficult and costly. Therefore, preventing debris and sediment from entering the ladder from the forebay should be a goal of the ladder exit design.

5.8.1.1 Coarse trash rack

For facilities where maintenance is frequently required and provided, coarse trash racks should be included at the fishway exit to minimize the entrainment of debris into the fishway (Figure 5-9; Bell 1991).

5.8.2 Specific Criteria and Guidelines – Coarse Trash Rack

5.8.2.1 Velocity

The velocity through the gross area of a clean coarse trash rack should be less than 1.5 ft/s to reduce debris accumulation and thus facilitate cleaning of the racks regularly (Bates 1992).

Bell (1991) indicated there is no evidence of fish refusing to pass through trash racks at velocities normal to the trash rack of 2 ft/s or less.

5.8.2.2 Depth

The depth of flow through a coarse trash rack should be equal to the pool depth in the ladder exit channel.

5.8.2.3 Maintenance

At locations where manual cleaning is anticipated, the coarse trash rack should be installed at 1:5 slope (or flatter) for ease of cleaning (Bates 1992). The coarse trash rack design should allow for easy maintenance and provide access for personnel, travel clearances for manual or automated trash raking, and the removal of debris.

5.8.2.4 Bar spacing

The coarse trash rack on the ladder exit should have a minimum clear space between vertical flat bars of 10 inches if Chinook salmon are present, and 8 inches for all other species and instances. Lateral support bar spacing should be a minimum of 24 inches and should be sufficiently set back from the face of the coarse trash rack to allow trash rake tines to fully *penetrate the rack for effective debris removal. Coarse trash racks should extend to the appropriate elevation above water to allow debris raked from the trash racks to be easily removed.*

Bell (1991) recommends that the clear openings of a trash rack be adapted to the width of the largest fish to be passed, which is usually 12 inches for large salmon. Figure 5-11 shows an example of a sloping coarse trash rack on the exit channel of a small fishway.

Figure 5-11.Sloping coarse trash rack on a fishway exit channel

5.8.2.5 Orientation

The fishway exit coarse trash rack should be oriented at a deflection angle greater than 45 degrees relative to the direction of river flow.

5.8.3 Specific Criteria and Guidelines – Debris and Sediment

5.8.3.1 Coarse floating debris

Debris booms, curtain walls, or other provisions should be included in the design of a fishway if coarse floating debris is expected.

5.8.3.2 Debris accumulation

If debris accumulation is expected to be high, the fishway design should include an automated mechanical debris removal system. If debris accumulation potential is unknown, the *design should anticipate the need for debris removal in the future and include features to allow an automated mechanical debris removal system to be retrofitted to the design.*

5.8.3.3 Sediment entrainment and accumulation

The fishway exit should be designed to minimize sediment entrainment into the fishway and sediment and debris accumulation at the exit under normal operations.

5.9 Roughened (Baffled) Chute Fishways

5.9.1 Description and Purpose

This section discusses the baffled chute, which is another general type of fish passage system. It consists of a hydraulically roughened flume that has nearly continuous energy dissipation throughout its length.

5.9.2 Specific Criteria and Guidelines – Baffled Chutes

The baffled chute fishway utilizes a relatively steep, narrow flume with internal roughness elements that generate lower water velocities that allow the fish to swim through the fishway. Denil and ASP fishways are examples of baffled chute fishways that share a similar design philosophy. Baffled chute fishways are designed to operate with less flow and at steeper slopes than traditional ladders.

5.9.2.1 Uses

Denil and ASP fishways should not be used as the primary route of passage at permanent fishway installations in the WCR.

Baffle chute fishways are not considered a substitute for a permanent style of ladder (e.g., a pool and weir ladder) because of their tendency to collect debris and their limited operating range. Denil and ASP fishways are primarily used at sites where the fishway can be closely monitored and inspected daily. This includes off-ladder fish traps, temporary fishways used during construction of permanent passage facilities, and fishways operated temporarily each year to collect hatchery broodstock. Baffle chute fishways should not be used at locations or in situations where the downstream passage of adults or juvenile salmonids occurs.

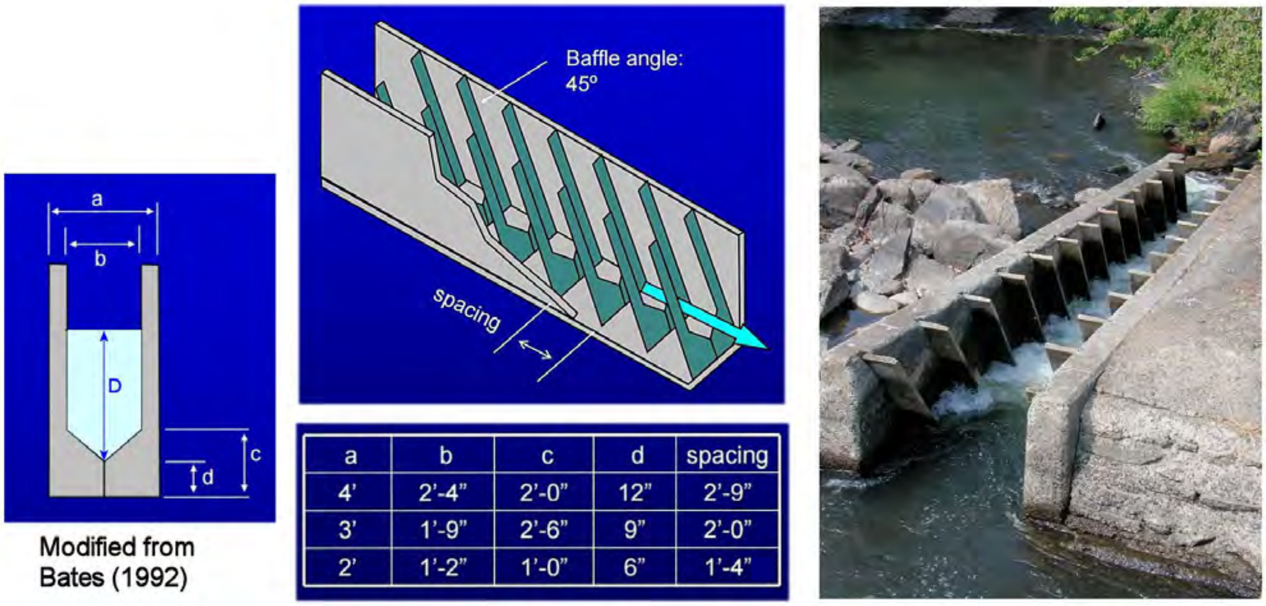
5.9.2.2 Debris

Denil and ASP fishways should not be used in areas where even minor amounts of debris are expected (Bell 1991).

Debris accumulation in any fishway, in combination with turbulent flow, may injure fish or render the fishway impassable. Because of their internal baffle geometry and narrow flow paths, baffle chute fishways are especially susceptible to debris accumulation, creating a blockage to passage.

5.9.2.3 Design

Denil and ASP fishways are designed with a sloped channel that has a constant discharge for a given normal depth, chute gradient, and baffle configuration (Figure 5-12). Energy is dissipated consistently throughout the length of the fishway via channel roughness and results in an average velocity compatible with the swimming ability of adult salmonids. The passage corridor consists of a chute flow between and through the baffles. A wide range of flows are possible for Denil fishways depending on fishway size, slope, and water depth (Bates 1992).



Modified from Bates (1992)

a	b	c	d	spacing
4’	2’-4”	2’-0”	12”	2’-9”
3’	1’-9”	2’-6”	9”	2’-0”
2’	1’-2”	1’-0”	6”	1’-4”

Figure 5-12. Drawings, dimensions, and a photo of a Denil fishway

5.9.2.3.1 *Specific design information – Denil fishways*

The standard dimensions shown in Figure 5-12 and the following design information for Denil fishways is taken from Bates (1992):

- *NMFS recommends a maximum slope of 20%.*
  - The normal slope for a Denil-style fishway is 17% (Bell 1991), though they have been used at slopes up to 25% (Bates 1992).
- *Discharge through Denil fishways can be calculated using Equation 5-3 (Bates 1992).*

$$Q = 5.73D^2\sqrt{bS} \tag{5-3}$$

where:

Q = ladder flow, in ft^3/s
D = depth (feet) of flow above the vee baffle
b = clear opening in the baffle (feet)
S = slope (feet/feet)

- *The average chute design velocity should be less than 5 ft/s (Bell 1991).*
    - The most common size of Denil fishway used is the 4-foot-wide flume (Bates 1992).
- *Flow control is important though not as critical for a Denil fishway as for a weir and pool ladder. The forebay should be maintained within several feet to maintain good passage conditions in a Denil fishway.*
    - According to the velocity profiles developed by Rajaratnam and Katopodis (1984), centerline velocities increase towards the water surface in Denil fishways where the ratio of flow depth to width (D/b in Figure 5-13) is more than 3. The height of the Denil fishway is not limited; additional height adds attraction flow and operating range without additional passage capacity because of the higher velocities in the upper part of the fishway (Bates 1992).
- *Minimum depth in a Denil fishway should be 2 feet, and depth should be consistent throughout the fishway for all flows.*
    - Bates (1992) reports that Denil fishways are typically constructed with depths from 4 to 8 feet.
- *The standard length is 30 feet (Bell 1991).*
- *Denil fishways can be constructed out of plywood, steel, or concrete with steel or plywood baffles.*

5.9.2.3.2 *Specific design information – Alaska steeppass fishways*

The ASP fishway is a specially designed baffle chute fishway developed for use in a variety of locations in Alaska (Figure 5-14; Ziemer 1962). It is typically constructed in sections that can be bolted together on site, making the system portable.

(a) Downstream end. (b) Upstream end. (c) In operation.

Figure 5-13. Examples of ASP fishways

The following design information for ASP fishways is taken from Rajaratnam and Katopodis (1984):

- *Discharge through the ASP fishway can be calculated as shown in Equation 5-4:*

$$Q = 1.12S^{0.5} D^{1.55} g^{0.5} \tag{5-4}$$

where:

Q = flow (ft^3/s)
S = slope (ft/ft)
D = depth (feet) of flow above the floor vane
g = gravitational acceleration (32.2 ft/s^2)

Most of the following design information on ASP fishways is taken from Bates (1992), and standard ASP fishway dimensions are shown in Figure 5-14.

- *NMFS recommends a maximum slope of 28%.*
  - The normal slope is about 25%, but ASP fishways have been tested and used up to a slope of 33% (Bates 1992).
- *The average chute design velocity should be less than 5 ft/s.*
- *Flow control is very important for properly functioning ASP fishways. The forebay water surface cannot vary more than 1 foot without creating passage difficulties, and the tailwater should be maintained within this same range to prevent a plunging flow or backwatered condition from forming. Backwatering the entrance results in reduced entrance velocity and fish attraction (Bates 1992).*
  - For example, Slatick (1975) found that the median passage time for salmon increased fourfold, and 25% fewer salmon entered the fishway when the downstream end was submerged by 2.5 feet.
- *Minimum depth in an ASP fishway is 1.2 feet.*
- *The standard length of each unit is 10 feet. Individual units can be bolted together to create lengths of 20 to 30 feet.*
- *ASP fishways are usually constructed of heavy gauge aluminum.*

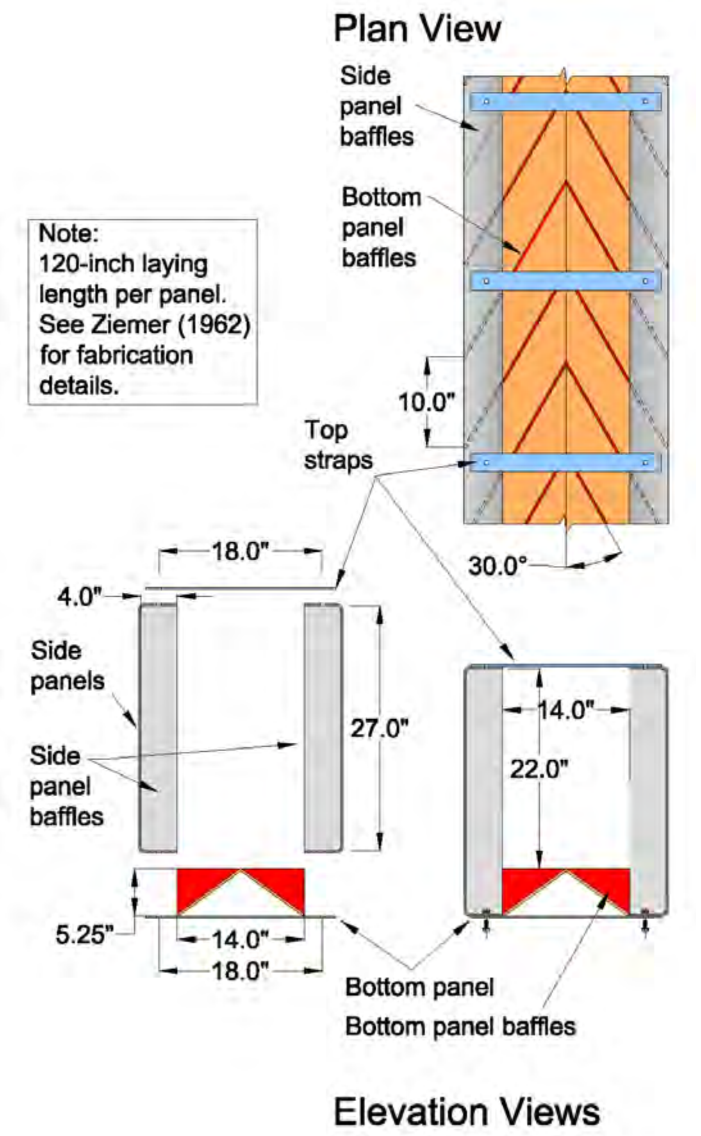


Figure 5-14. Plan and elevation views of a typical ASP fishway

5.9.2.3.3 *Special considerations for Denil and Alaska steeppass fishways*

The following unique aspects of Denil or ASP fishways must be carefully considered: intermediate resting pools, minimum resting pool volume, and exit locations.

- Intermediate resting pools:

If the Denil or ASP fishway is long, intermediate resting pools should be included in the design. Resting pools (where water velocities are less than 1 ft/s) should be provided for Denil fishways longer than 30 feet in length (Bell 1991); resting pool size should be based on minimum pool size or EDF (energy dissipation factor) calculations. These guidelines also apply to ASP fishways longer than 30 feet in length.

Typically, there are no resting locations within a given length of Denil or ASP fishway. Once a fish starts to ascend a length of an ASP or Denil fishway, it must pass all the way upstream and exit the fishway or risk injury when falling back downstream. Therefore, if the Denil or ASP fishway is long, intermediate resting pools should be included in the design. Clay (1995) recommends that resting pools be provided for every 12 feet of height ascended and that average velocity in the resting pool should not exceed 1 ft/s. NMFS recommends that the designer size the resting pool based on the minimum pool size necessary to achieve either an average velocity of 1 ft/s or an adequate pool size based on the expected run size, if known (Appendix H), or on the EDF formula for pool volume (Equation 5-5), whichever is larger.

- Minimum resting pool volume:

The minimum volume of the resting pool is calculated as shown in Equation 5-5, which is similar to Equation 5-2 in Section 5.5.3.5 except that the volume required is increased by a factor of 2 since this equation is for a resting pool.

$$V = (\gamma)(Q)\left(\frac{v^2}{2g}\right)\Big/\left\{\left(2ft\ \frac{lbs}{s}\right)\Big/ft^3\right\} \tag{5-5}$$

where:

V = *volume, in* ft^3
γ = *specific weight of water, 62.4 lb per* ft^3
Q = *Denil or ASP flow, in* ft^3/s
v = *velocity of pool-to-pool flow, in ft/s*
g = *gravitational acceleration (32.2* ft/s^2*)*

Blackett (1987) conducted experimental modifications to an ASP fishway at a 10-meter-high falls to improve sockeye salmon entry and passage. Sockeye salmon passage was equivalent between an ASP fishway of approximately 200 feet in length with no resting pools and an adjoining ASP fishway where three resting pools were incorporated into the design—although significant year-to-year differences in passage occurred amongst each ASP fishway. However, resting pools were beneficial for holding slower or descending salmon without blocking the passage of other salmon. Also, sockeye salmon passage was greater in the original ASP fishway with three resting pools than in another ASP fishway tested that contained a single resting pool.

- Exit locations:

Denil and ASP fishway exits should be located to minimize the potential for fish to fallback over the barrier.

5.10 Nature-Like Fishways

The nature-like fishway is a fishway type characterized by its use of natural materials (such as rocks and boulders) and incorporation of natural riverine characteristics in its construction and design (Katopodis et al. 2001; Wildman et al. 2003). Nature-like fishway design simulates the hydraulic conditions of natural channels, natural passage windows, and migration timing for target fish species. The resulting project should provide natural hydraulic conditions for target species (mimicking the geomorphic form and complexity found in natural channels the target species inhabit).

Nature-like fishways are thought to facilitate the passage of a wide assemblage of fish and aquatic species, sometimes purported to provide better passage than traditional methods (fish ladders). However, Castro-Santos (2011) concluded that nature-like fishway designs evaluated in his study were not superior to traditional fish ladders for the 23 fish species from the northeastern United States (of those that were evaluated). More recently, Landsman et al. (2018) compared the passage of salmonid and non-salmonid species at nature-like fishway and pool-and-weir fishways in eastern Canada and reported similar results. Nature-like fishways have been observed to pass anadromous and resident salmonids with varying degrees of success at projects of varying hydraulic complexity (Aarestrup et al. 2003; Calles and Greenberg 2005, 2009; Dodd et al. 2017).

At the project-scale, design variables related to nature-like fishways are nearly synonymous with more traditional fish ladder designs typically used at these same locations (such as a vertical slot or ice harbor). The main difference being that nature-like fishways are constructed using natural materials, not concrete. Like any other fishway, if the design variables between the tailrace and the forebay are improperly designed, the result may be adverse passage effects to the project. All project-scale passage variables should be properly analyzed, accounted for, and work together to provide safe, timely, and effective upstream passage for salmonids and other target species (the same expectation as had for any other style of fishway).

5.10.1 Experimental Applications

Nature-like concepts and methods are sometimes used in conjunction with more traditional fishway designs. When combining nature-like methods with traditional methods many of the passage assumptions and anticipated hydraulic conditions associated with traditional fishways do not hold, or are hard to predict. Combined designs are classified by NMFS as experimental. Experimental designs are addressed in Section 1.5 and should be vetted using the guidelines contained in Appendix C.

5.10.2 Design Methods

Nature-like fishways are intended to simulate passage conditions of a natural channel. Like natural channels, there is a high degree of hydraulic variability within the fishway. This high variability makes recommending a universal design approach challenging. The following guidelines will help designers better understand critical components of nature-like fishway design, regardless of the engineering methods and approaches implemented.

Nature-like fishway designs may simulate the form and roughness of a reference reach selected as a design template from a natural channel, or the design may rely on hydraulic analysis and physical modeling, or both. The following sources provide additional information on the hydraulic and geomorphic concepts and potential design methods used in nature-like fishway design: Acharya et al. 2000; Keils et al. 2000; Katopodis et al. 2001; Courtice et al. 2016.

5.10.3 Specific Criteria and Guidelines

The criteria contained in this section apply primarily to fish passage projects where the fishway is designed to provide passage around a dam or diversion.

5.10.3.1 Maximum average channel velocity

Maximum average channel velocity at the 5% exceedance flow should be no greater than 5 ft/s, regardless of channel slope. The relationship between channel roughness and channel slope should be carefully engineered to ensure this criterion is not exceeded.

Barnard (2013) indicates that at the 10% exceedance flow, high gradient streams in Washington State exhibit similar average channel velocities, regardless of channel slope, on the order of 4 ft/s. The velocity criterion in the section is presented to help designers express a more realistic relationship between channel slope and roughness in nature-like fishway designs. When channel slope and roughness have the proper relationship to maintain a 5 ft/s average channel velocity at the 5% exceedance flow, energy dissipation and turbulence are much more likely to be within the range observed in natural high gradient streams of similar slope and roughness. This criterion also simplifies and improves design and monitoring by providing a simple value to compare against hydraulic models and field measurements. An in-depth discussion on turbulence in higher gradient natural channels in contained in CH 6 of Barnard (2013).

The origin of the 4ft/s criterion used the 10% exceedance flow to back calculate EDF in high gradient natural channels. When using a 5% exceedance flow it seems reasonable to increase the maximum average channel velocity to 5 ft/s. When using a 1% exceedance flow, it seems reasonable to use a maximum average channel velocity of 6 ft/s. These assumptions are supported by data from Castro and Jackson (2001) which indicates the average bankfull channel velocity in the Pacific Northwest can be well represented as an average of 6 ft/s. Work by Love and Lang (2014) reported that annual exceedance values associated with a discharge equal to 50% of the 2-year return interval ranged between 0.2% and 1.8%. Annual exceedance flows between 10% and 1% exceedance are likely well represented by a range of average channel velocities between 4ft/s and 6ft/s.

5.10.3.2 Pool depth

If drop structures are used in the fishway, minimum pool depth should be 4 feet in the receiving pool of each drop structure.

5.10.3.3 Maximum hydraulic drop

Maximum hydraulic drop is 1 foot for adult salmonids and 0.5 foot for juvenile salmonids.

5.10.3.4 Maximum fishway slope

Maximum fishway slope is 5% for all salmonid species.

5.10.3.5 Channel stability

Beds and banks should be designed to be immobile at all anticipated fishway discharges.

5.10.3.6 Channel roughness

Simulated or modeled roughness values should be physically expressed in the post-construction roughness of the channel design. Actual fishway roughness should produce a maximum 5 ft/s average velocity at the high fish passage design flow. Designers should provide a summary discussion of how modeled roughness will be translated and transformed into actual project roughness.

Modeling requires the use of roughness values to estimate the effects of boundary roughness on water depth and velocity in channel design. NMFS has observed there can be large discrepancies between modeled roughness values and the actual roughness physical expressed in the design post-construction. These discrepancies are typical expressed as higher velocities, increased turbulence, unanticipated scour and erosion, and a fewer holding and resting areas than were expected. Individually and in aggregate these issues can adversely affect fish passage. It is expected that documentation of the methods, assumptions, and specifications used to detail and explain the roughness design process will result in fewer projects failing to meet passage requirements.

Channel roughness providing the bulk of fish passage benefits are best described and specified comparing the size of the elements to the depth of water at the high fish passage design flow. Large roughness elements will possess an exposed dimension above the thalwag that is analogous to the high fish passage design depth. Meaning once stable, the element should have a portion exposed to the air, or nearly exposed, at the high fish passage design flow. This relationship between water depth and roughness size is critical to providing the necessary energy dissipation and velocity reduction for fish to rest and move in higher gradient channels. Channels with low relative roughness (uniformly sized bed and bank material), are characterized as hydraulically smooth. Hydraulically smooth channels at high gradients provide little to no resting or holding areas for fish. Hydraulically smooth channels commonly fail to meet fish passage velocity criteria.

The above discussion was developed based on the relationship between natural D84 and D90 class material and bankfull depth for streams in Washington State with slopes greater than 2% (Barnard et al. 2013). Barnard et al. measured stream discharge and bed roughness, observing that the rock providing the bulk of velocity reduction and hydraulic diversity were those elements which had a dimension analogous to the bankfull depth of the channel. Over a diverse range of project sizes, NMFS has also observed that velocity conditions are most often passable when somewhere in the range of 20%-40% of the project surface area is occupied by roughness elements extending significantly into the water column at the bankfull discharge.

5.10.3.7 Technical components

The technical components, and their associated criteria, used in nature-like fishway project remain consistent with more traditional fish ladder designs and include the following:

Section 5.2, Fishway Entrance

Section 5.3, Auxiliary Water Systems

Section 5.6, Counting Stations

Section 5.7, Fishway Exit Control

Section 5.8, Fishway Exit Sediment and Debris Management

Section 5.11, Miscellaneous Considerations

Appendix H: Sizing Fish Ladder Pools Based on Energy Dissipation and Fish Run Size

5.10.4 Monitoring and Maintenance

A monitoring and maintenance plan for nature-like fishways is required. The frequency of monitoring and maintenance needed will be determined in consultation with NMFS. The plans should address how morphology and fish passage hydraulics will be monitored and modified, as needed, by developing an adaptive management approach that identifies triggers for when additional actions are to be implemented that address changes in nature-like fishway channel morphology and hydraulic conditions.

5.10.4.1 Passage assessment

Depending on project-specific considerations, monitoring may include an assessment of passage efficiency via fish tagging or fish counts. This monitoring criterion will be identified by NMFS on a project-by-project basis.

5.10.4.2 Channel stability

The loss or displacement of bed and bank material after a high-flow event does not necessarily equate with a failure of the nature-like fishway to maintain passage conditions. Any resulting loss or displacement of bed and bank material should be evaluated to determine the effects, if any, on passage criteria. Needed modification or repairs to bring the fishway into criteria should be discussed with NMFS and implemented by the facility owner. Proposed actions to bring the design into compliance with velocity criteria should be approved by NMFS.

5.10.4.3 Channel velocity

Channel velocity should be verified through post construction monitoring. When average channel velocity exceeds 5 ft/s at the high fish passage design flow needed modifications or repairs to bring the fishway into criteria should be identified be discussed with NMFS and *implemented by the facility owner. Proposed actions to bring the design into compliance with velocity criteria should be reviewed by NMFS.*

Two methods of measuring average velocity are used. First, longitudinal, or reach average velocity is measured. This is defined as the travel time of a particle beginning at the fishway exit and ending at the entrance, divided by the fishway length, and reported in ft/s. The velocity. Second, cross section average velocity is measured. Cross section velocity is measured at discrete sections of the fishway not associated with a hydraulic drop. Cross sections are measured every 40 feet of fishway beginning immediately upstream of the fishway entrance.

5.11 Miscellaneous Considerations

5.11.1 Security

Fishway facilities and areas should be secured to discourage vandalism, preclude poaching opportunity, and provide for public safety.

Security fencing around the facility and grating over the fishway may be required.

5.11.2 Access

Access for personnel to all areas of the fishway should be provided to facilitate operational and maintenance requirements. Walkway grating should allow as much ambient lighting into the fishway as possible. Consideration should be given to providing access for personnel to each pool of the ladder to support fish salvage operations.

5.11.3 Edge and Surface Finishes

All metal edges in the flow path used for fish migration should be ground smooth and rounded to minimize risk of lacerations. Concrete surfaces should be finished to ensure smooth surfaces, with 1-inch-wide, 45-degree corner chamfers.

5.11.4 Protrusions

Protrusions that fish could contact, such as valve stems, bolts, gate operators, pipe flanges, and permanent ladders rungs, should not extend into the flow path of the fishway.

5.11.5 Exposed Control Gates

All control gates exposed to fish (e.g., entrances in the fully open position) should have a shroud or be recessed to minimize or eliminate fish contact.

5.11.6 Maintenance Activities

To ensure fish safety during in-season fishway maintenance activities, all fish ladders should be designed to provide a safe egress route or safe holding areas for fish prior to any temporary (i.e., less than 24 hours) dewatering. Longer periods of fishway dewatering for *scheduled ladder maintenance should occur outside of the passage season and with procedures in place that allow fish to be evacuated in a safe manner.*

5.12 Operations and Maintenance Considerations

5.12.1 Activity Near the Ladder

There should be no construction or heavy activity within 100 feet of a ladder entrance or exit or within 50 feet of any other portion of the ladder, but this can be reviewed on a case by case basis.

5.12.2 Maximum Outage Period

A fishway should never be inoperable due to mechanical or operational issues for more than 48 hours during the fish passage season of any anadromous species.

6 Exclusion Barriers

6.1 Introduction

Upstream-migrating salmonids are often attracted to areas of a river where flow is concentrated or velocities are high such as the discharge from a hydroelectric powerhouse. This behavior may cause fish to attempt to ascend a barrier at locations where passage is poor or blocked, which could result in the following:

- Injuries (e.g., lacerations, abrasions) caused by
  - Brushing against rocks or structures while swimming in turbulent areas
  - Jumping and striking rocks or structural projections
- Direct or delayed mortality due to injuries
- Migration delays

Exclusion barriers are structures or devices that are designed and used to halt the upstream migration of fish (BOR 2006). These barriers can guide fish to an area where upstream migration is allowed or to holding, sorting, evaluation, and transportation facilities. They are also used to prevent fish from entering an area where no upstream egress or suitable spawning habitat exists. For example, exclusion barriers could be required to protect upstream-migrating salmon and steelhead from injuries or mortality caused by ascending powerhouse turbine draft tubes or tunnels. Exclusion barriers can also be used for the following:

- Preventing fish from entering return flow from an irrigation ditch; tailrace of a power plant; channels subject to sudden flow changes; and channels with poor spawning gravels, poor water quality, or insufficient water quantity
- Guiding fish to counting facilities as well as trap facilities for upstream transport, research, or broodstock collection

6.1.1 Fish Safety

Exclusion barriers should be designed to minimize both the potential for fish injury and mortality and migration delays.

Fish may be physically injured (e.g., lacerations, abrasions) when attempting to pass exclusion barriers in migration pathways (FERC 1995). Therefore, barrier design and operation should consider and eliminate sources of injury due to shallow depths, exposed components, and rough surfaces. Barriers that are poorly designed can cause fish to delay migration while undertaking multiple attempts to pass the barrier.

6.1.2 Barriers Used to Collect Information

Installing exclusion barriers solely for the purpose of collecting information needed for fisheries management will be discouraged, especially if ESA-listed fish are present in the watershed.

6.1.3 Other Species

Installing an exclusion barrier in river systems with multiple species of migratory fish should be carefully considered because some designs may inadvertently block the upstream and downstream movement of non-target species.

Conversely, exclusion barriers may also be used to restrict the movement of undesirable species into upstream habitat (Clay 1995) such as sea lamprey in the Great Lakes (McLaughlin et al. 2007).

6.1.4 Flow Range

All barriers should be designed to function safely over the expected design range of flow conditions for the site when target fish are present (BOR 2006).

6.2 Types of Exclusion Barriers

Barriers to upstream fish passage are either physical or behavioral (e.g., acoustic, chemical, thermal, or lighting). They can be natural or fabricated. Natural barriers consist mainly of waterfalls and debris jams, whereas fabricated barriers consist mainly of dams, culverts, and log jams (Powers and Orsborn 1985). This chapter focuses on fabricated physical barriers, which present fish with structures or conditions that block farther upstream migration.

Fabricated physical barriers are classified into three categories: diffusers, weirs, and drop structures (Figure 6-1). Picket and weir barriers rely on bars racks, pickets, porous rigid panels, screens, or fences to physically exclude fish from entering an area. Fixed bar racks and picket barriers have similar meanings and purposes, and fish passage designers often use these terms interchangeably. However, the term ‘picket barrier’ carries an added nuance—these barrier panels tend to guide fish in some preferred direction—in addition to blocking farther upstream passage. Figure 6-2 is a schematic illustration of a temporary fish weir that uses pickets to guide fish to a trap at the riverbank.

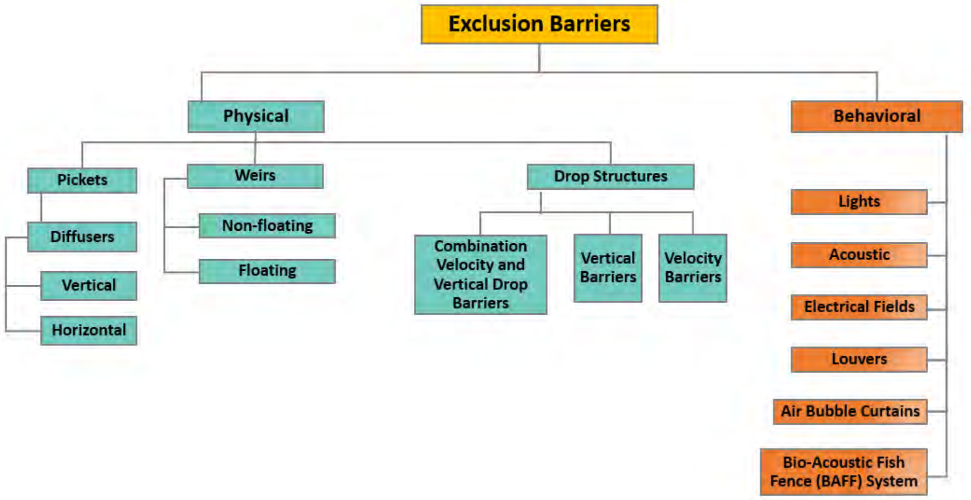
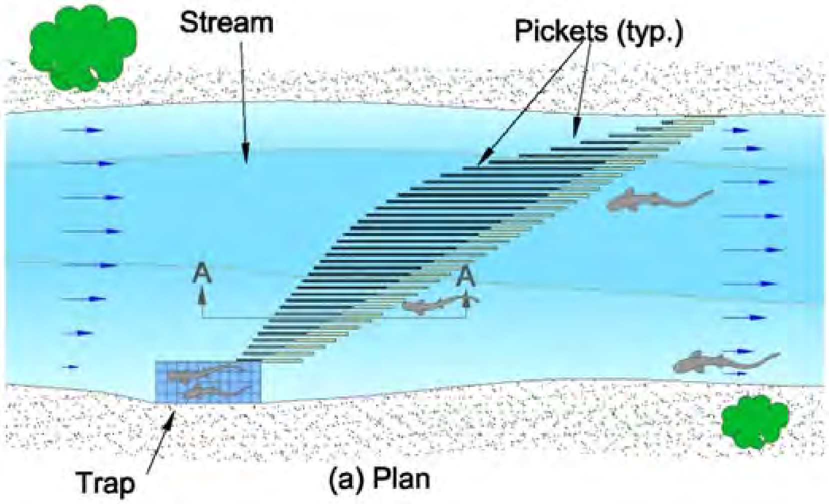
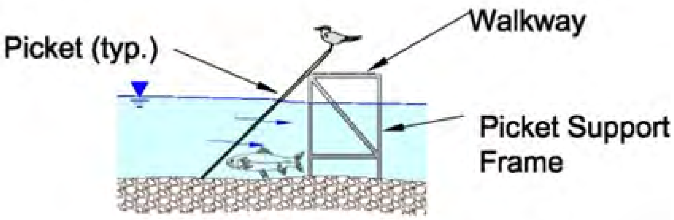


Figure 6-1. Classifications of exclusion barriers



(a) Plan



(b) Section A-A

Figure 6-2. Fish weir constructed with pickets in plan (a) and section (b) views

Advantages of pickets and weir barriers include the following:

- They induce a small loss of head under clean and partially plugged conditions.
- They can function over a wide range of river flow stages.
- They can be designed to be removable.

Disadvantages of pickets and weir barriers include the following:

- Bar spacing that is too wide will not function effectively as a barrier, and bar spacing that is too narrow can collect debris more quickly than it can be removed. Striking a balance between the competing design objectives of excluding fish while not collecting more debris than can be managed may be difficult or impossible, depending on the river system and target fish species being excluded.
- Downstream juvenile and adult fish that need to pass the barrier can be excessively delayed and, in some designs, injured or killed. It is important to recognize that this type of barrier can cause injury and mortality to downstream migrants.
- Barrier components require periodic cleaning and are subject to rapid plugging (BOR 2006).

Drop structure barriers involve a combination of local hydraulic conditions downstream of a barrier and the swimming capabilities of the species and life stage to block migration (Powers and Orsborn 1985). They create hydraulic conditions that exceed the swimming or leaping capabilities of the fish to overcome the hydraulic condition. Examples include velocity barriers, vertical drop barriers, and velocity drop barriers. Hydraulic conditions at a specific site function as a barrier when one or more of the following conditions are present:

- Water velocity downstream from a barrier exceeds the swimming speed of fish.
- A standing wave develops downstream of the barrier that fish cannot pass through, or it forms too far downstream to allow the fish to rest before bursting upstream.
- A downstream plunge pool is too shallow to allow fish to jump the barrier.
- Barrier height exceeds jumping ability of fish.

Advantages of drop structure barriers include the following:

- These have lower maintenance requirements compared to picket and weir barriers.
- Debris passes over the barrier with flow (instead of plugging the barrier, which can be the case with structural barriers).
- All species and life stages of fish whose swimming capabilities are weaker than the species the barrier was designed to address are excluded.
- The passage of downstream migrants over drop barriers is usually safer than through picket and weir barriers.

Disadvantages of drop structure barriers include the following:

- They require a significant head to function properly.
- Their performance depends on maintaining a minimum head differential across the barrier.
- The pool upstream of the barrier structure may increase sediment deposition, which reduces channel capacity (BOR 2006).
- Drop structures may create a serious hazard to boaters and swimmers and precautions to protect boaters and swimmers should be included in the design.

Several reports contain additional information on the topic of exclusion barriers and fish swimming performance. Bell (1991) provides information on the swimming and jumping capabilities of various salmonid species. Powers and Orsborn (1985) provide equations for calculating maximum swim distances and estimating leap height and distance. Katopodis (1992) provides endurance curves for fish of various lengths for the two main modes of fish locomotion and a formula for calculating swimming distance. The two main modes of locomotion are anguilliform body shapes (e.g., lamprey and Burbot) and subcarangiform body shapes (e.g., anadromous salmonids and various freshwater species such as bass, suckers, and chub).

6.3 Picket and Weir Barriers

Physical barriers typically rely on a combination of low-velocity flow discharged through bar racks, pickets, diffusers, screens, or fences to physically block fish from entering an area. Picket and weir barriers include fixed bar racks, picket panels (Figure 6-3), diffusers (a specialized form of picket barrier usually used in AWS in fishways), horizontal outlet diffusers, and a variety of hinged, floating weir designs and framework-supported (rigid) weir designs. The clear opening between bars in bar rack panels or pickets in picket panels should be sufficiently narrow to create a barrier to the smallest-sized migrant fish being excluded from farther passage upstream. Depending on the design and site conditions, weir barriers may need to be removed during high-flow events to prevent structural damage, which potentially reduces the barrier's ability to prevent target fish from passing into undesirable areas.

Figure 6-3. Picket barrier panels under construction at the Slide Creek tailrace barrier located on the North Umpqua River, Oregon

Because both debris and downstream-migrating fish must pass through physical barriers, sites should be selected based on the following design objectives:

- Minimizing the entrainment of debris
- Maximizing the ability to remove debris
- Preventing the entrainment and delay of downstream-migrating fish and adult fish that fall back across the barrier
- Maximizing the ability to rapidly remove and bypass any fish that are entrained on the barrier
- Allowing the most advantageous orientation of the barrier (typically angled to guide fish to a collection point)

6.3.1 Risk of Fish Impingement

If adult fish are exposed to the upstream side of physical barriers, they have a high likelihood of being impinged. Therefore, these types of barriers cannot be used in waters containing species listed under the ESA unless they are continually monitored by personnel on site and have an approved operational plan and a facility design that allows impinged or stranded fish to be removed in a timely manner and prior to becoming injured. Also, these types of barriers should not be used at sites where adult fish are actively migrating downstream or may inadvertently pass over a nearby dam or weir in a downstream direction prior to reorienting again to continue their upstream migration.

In addition to blocking the upstream passage of adult fish, physical barriers can effectively block or injure fish migrating downstream (e.g., steelhead kelts, adult salmon that passed a dam and subsequently migrated back downstream, juvenile salmonids, and resident fish). This can impact population productivity and should be fully considered during the planning process.

6.3.2 Debris

Physical barriers should be continually monitored for debris accumulations, and debris should be removed before it concentrates flow and results in the velocity and head differential criteria being exceeded (Sections 6.3.3.2 and 6.3.3.3). Additionally, excessive debris loading could cause permanent damage to weir structures.

Allowing debris to accumulate on components of physical barriers results in increased water velocity through the remaining open areas. As debris accumulates, the potential for impinging downstream migrants increases progressively and can reach unacceptable levels that result in mortality and injury. Concentrating flow through the remaining open areas of the barrier (e.g., the open picket area) will also attract upstream migrants to these areas. This can increase the potential for injury due to adult fish jumping into structural components and for fish accessing unwanted areas because they jumped and landed over the barrier.

6.3.3 Picket Barriers and Fixed Bar Racks

Picket barriers and fixed bar racks create a uniform, low-velocity flow that is discharged through a series of bars or screens that cover the entire exclusion area.

The following specific criteria or guidelines apply to picket barriers and fixed bar racks.

6.3.3.1 Openings

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bates 1992). The clear opening between bars in bar rack panels, between pickets in picket panels, and between panels and abutments should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Openings larger than 1 inch may allow the heads of small salmon and steelhead to pass through the picket opening. This can lead to salmonids and other species becoming caught on the picket by their operculum that covers and protects the gills. Fish caught in this manner—between bars or pickets and gaps between panels or panels and abutments—often die because they are unable to extricate themselves off the picket.

6.3.3.2 Design velocity

The average velocity through pickets should be less than 1 ft/s for all design flows (Clay 1995). The maximum velocity through the pickets should be less than 1.25 ft/s, or one-half the velocity of adjacent passage route flows, whichever is lower. When river velocities exceed these criteria, such as due to increasing flows or debris accumulations, the picket barrier should be removed.

The average design velocity is calculated by dividing streamflow by the total submerged picket area over the design range of streamflows (Gauley et al. 1966). As discussed in Section 6.3.2, non-uniform or excessive velocities through the structure can create false attraction conditions that delay fish and induce upstream migrants to attempt to jump over the barrier, potentially injuring the fish.

6.3.3.3 Head differential

The maximum head differential under fouled conditions should not exceed 0.3 foot above the normal head differential across the pickets that occurs under clean picket conditions. If this differential is exceeded, the pickets should be cleaned as soon as possible.

Excessive head differential (head loss) through the structure can cause a cascading effect of water through the pickets, which increases the likelihood of upstream migrating fish leaping at the structure. Clay (1995) and DOI (1987) provide formulas to calculate head loss through picket barriers and trash racks.

6.3.3.4 Debris and sediment

A debris and sediment removal plan should be considered in the design of the barrier that anticipates the entire range of conditions expected at the site. Debris should be removed before accumulations develop that violate the average design river velocity and head differential criteria (Sections 6.3.3.2 and 6.3.3.3, respectively).

6.3.3.5 Orientation of physical barrier

Physical barriers should be designed to lead fish to a safe passage route.

Leading fish to a safe passage route can be achieved by angling the structural barrier toward the route, providing nearly uniform velocities across the entire horizontal length of the structural barrier, and providing a sufficient level of attraction flow that leads fish to the route and minimizes the potential for fish being falsely attracted to flow coming through the picket barrier.

6.3.3.6 Picket freeboard

Depending on the angle of the pickets (from vertical), the pickets should be designed such that they extend out of the water and at least 2 vertical feet above the water surface at the upper design flow level.

The purpose of the picket freeboard is to prevent fish from leaping over the barrier. Note that if the angle of the pickets is relatively steep, a freeboard of 2 feet may be insufficient to block stronger fish from leaping over the pickets, depending on site-specific conditions.

6.3.3.7 Submerged depth

The minimum depth at the picket barrier at low design flow should be 2 feet for at least 10% of the river cross section at the barrier. Picket barriers should be sited where there is a relatively constant depth over the entire stream width.

6.3.3.8 Picket porosity

The picket array should have a minimum of 40% open area.

Picket barriers with insufficient porosity may generate excessive head loss for the given river velocity. This head loss is exhibited as a cascade of water as it passes through the pickets, which may induce fish to jump and increase the potential for injury at the barrier.

6.3.3.9 Picket construction and material

Pickets should comprise flat bars where the narrow edge of the bar is aligned with flow or round columns of steel, aluminum, or durable plastic. Other shapes may be approved by NMFS, but should not increase the risk of fish impingement.

Picket panels should be of sufficient structural integrity to withstand high streamflows and some debris loading without deforming (i.e., without exceeding the clear opening criteria cited in Section 6.3.3.1, compromising the cleaning system, or permanently changing the shape of the picket panel). Pickets that become permanently deformed should be repaired or replaced as soon as possible. Pickets that deform or bend to a point where the clear opening criteria cited in Section 6.3.3.1 is no longer met under the design flow and debris loading conditions incorporated into the design can create openings that allow fish to pass the barrier or become injured as they try to force their way through the pickets.

6.3.3.10 Sill

A uniform concrete sill, or an alternative approved by NMFS, should be provided to form a foundation for the pickets and ensure that fish cannot pass under the picket barrier.

6.3.4 Diffusers

Diffusers are a specialized type of picket barriers or fixed bar racks where a flow control or hydraulic baffling structure is incorporated into the design to regulate flow through the barrier or bar rack. Wall-oriented (i.e., vertical) and floor-oriented (i.e., horizontal) diffusers are most commonly used as part of the AWS in adult ladders to prevent adult fish from entering the AWS system or delaying their migration due to being attracted to AWS flow entering the ladder. Wall diffusers are also used as tailrace barriers to prevent fish from entering tailraces downstream of hydroelectric dams, while encouraging fish to continue to move upstream through another stream, river route, or channel.

The following specific criteria or guidelines apply to diffusers.

6.3.4.1 Openings

The spaces between bars of a diffuser should be sized to prevent fish from passing through the bars or becoming injured (Bates 1992). The clear opening between pickets and between pickets and abutments should be less than or equal to 1 inch to block anadromous salmonids. These clear openings should be less than or equal to 0.75 inch to block Pacific lamprey. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Wall diffusers consist of vertically oriented diffuser panels of flat bar stock using non-corrosive materials. The orientation of flat bar stock should be designed to maximize the open area of the diffuser panel. If smaller fish species or life stages are present, smaller clear openings between the bars may be required.

6.3.4.2 Design velocity and orientation

The average velocity through a wall diffuser should be less than 1 ft/s for all design flows based on total submerged diffuser area. The maximum velocity at any point on the diffuser should be less than 1.25 ft/s, or one-half the velocity of flow in an adjacent passage route, whichever is lower. Diffuser velocities should be nearly uniform. The orientation of the diffuser should be selected that assists in guiding fish towards the safe passage route. The face of the diffuser panels (the surface exposed to the fish) should be flush with the wall or floor.

These criteria are based on results of laboratory studies where passage times of spring- and fall-run Chinook salmon and steelhead increased progressively with increased diffuser flows and where diffuser velocities increased from 0.25 to 1.25 ft/s (Gauley et al. 1966).

6.3.4.3 Porosity control baffles

Similar to juvenile fish screens, a *diffuser should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure the average velocities at the face of the diffuser can meet criteria.*

Porosity control panels control the amount of flow and velocities through the diffuser pickets and create a uniform flow condition at the face of the pickets.

6.3.4.4 Debris removal

The diffuser design should include access for personnel to be able to remove debris from each diffuser. This criterion is not required when the intake to the diffuser water supply is equipped with a juvenile fish screen (Chapter 8).

The dewatering screen system also removes debris from water being supplied to the diffuser.

6.3.4.5 Edges

The edges of all diffuser surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane.

Rounding and grinding smooth surfaces that fish can contact and making all diffuser surfaces flush reduces the potential for fish injury.

6.3.4.6 Elevation

Wall-style diffusers should be submerged throughout the range of operation (i.e., the top elevation of the wall diffuser should be below the water surface elevation associated with the low flow selected for the design).

Maintaining a submerged wall-style diffuser prevents water from cascading through the diffuser, which can induce adult fish to leap at the surface disturbance and become injured when contacting the diffuser material and wall and delay their migration up the ladder.

6.3.5 Horizontal Outlet Diffusers

A horizontal outlet diffuser is a device that can be used to prevent fish from entering a drain or discharge pipe. They can also be used below a powerhouse at the turbine draft tube outlet to prevent adult fish from ascending up the draft tube discharge during unit start up or shut down or during normal operations if draft tube velocity is low (typically less than 16 ft/s; Figure 6-4). This type of diffuser also prevents fish from entering the draft tube and contacting the turbine runners, which may result in injury or mortality. If the turbine draft tubes are located in close proximity to the entrance of an upstream passage system (e.g., a fishway), a horizontal outlet diffuser system may be the appropriate choice for an exclusion system.

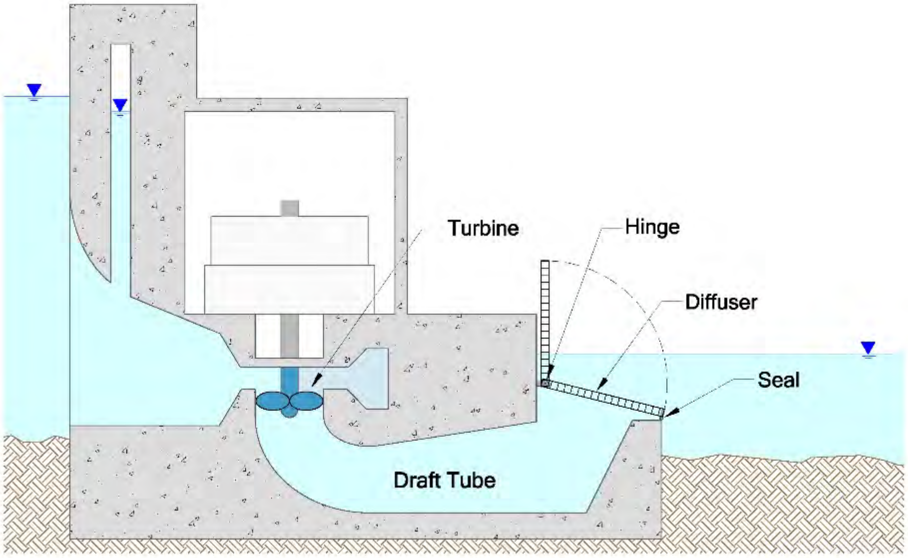


Figure 6-4. Layout of a horizontal outlet diffuser covering the entrance to a turbine draft tube

6.3.5.1 Design velocity

Average flow velocity exiting the horizontal outlet diffuser grating should be less than 1.25 ft/s and be distributed as uniformly as possible. The maximum point velocity should not exceed 2 ft/s.

6.3.5.2 Porosity control baffles

Similar to juvenile fish screens, diffusers should include a system of porosity control baffles located just upstream of the diffuser pickets to ensure the average velocities at the face of the diffusers can meet criteria.

Porosity control panels control the amount of flow and velocities through the diffuser pickets and create a uniform flow condition at the face of the pickets.

6.3.5.3 Openings

The spaces between bars of a diffuser should be sized to prevent fish passage and injury (Bates 1992). The clear opening between bars, and between bars and abutments, should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to prevent Pacific lamprey from entering the chamber behind the diffuser. Smaller openings may be required if resident species are also present that need to be excluded by the facility.

Horizontal outlet diffuser panels consist of non-corrosive, horizontally oriented flat bar stock. The orientation of flat bar stock should be designed to maximize the open area of the diffuser panel.

6.3.5.4 Edges

The edges of all diffuser surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane.

Rounding and grinding smooth surfaces that fish can contact and making all diffuser surfaces flush reduces the potential for fish injury.

6.3.5.5 Debris removal

The diffuser design should include access for personnel to be able to remove debris from each diffuser. This criterion is not required when the intake to the diffuser water supply is equipped with a juvenile fish screen (Chapter 8).

Trash (bar) racks installed at the intake to the diffuser system and a juvenile fish screen (if installed) remove debris from water being supplied to the diffuser.

6.3.5.6 Submergence

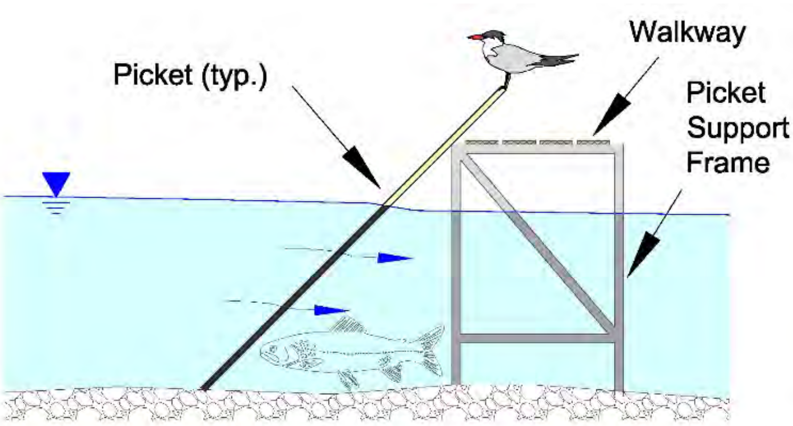
Horizontal outlet diffusers should be submerged a minimum of 2 feet for all tailwater elevations.

6.3.6 Fish Weirs

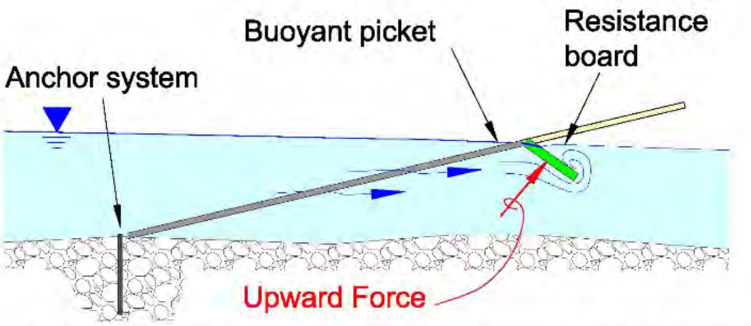
Fish weirs are physical barrier systems that are constructed across a stream (Figure 6-2). The purpose of fish weirs is to prevent fish from passing upstream of the weir and guide upstream-migrating fish to a trap. The weirs are constructed of panels of metal or plastic pickets that extend from the bottom of the stream to an elevation several feet above the water surface. The clear spacing between the pickets is selected based upon the size of the target species being trapped. When viewed from above, weirs are usually placed at angles greater than 90 degrees from the main thread of the current (Figure 6-2). The trap is placed at the most upstream area of the weir. The angle between the direction of stream or river flow and the weir results in the weir being longer than if it was positioned perpendicular to the bank and reduces water velocity through the pickets.

6.3.6.1 Types of fish weirs

The two most commonly used types of weirs in the WCR are rigid (frame-supported) weirs and floating resistance board picket weirs (Figure 6-5). Weirs can be temporary or permanent.



(a) Cross section through rigid (frame-supported) picket weir.



(b) Cross section through floating resistance board picket weir.

Figure 6-5. Cross sections of rigid and floating picket weirs

The pickets in rigid weirs are placed at an angle greater than 45 degrees above the water surface. Clean pickets in a floating weir have a very small angle above the water surface, and increased flow velocity and debris loading can further reduce the angle and can eventually submerge the floating weir panels.

Rigid weirs use panels of solid metal rods or hollow conduits that are supported by rigid frameworks (Figure 6-6). The supporting structures for temporary weirs can be light metal trusses or frames that are installed at the start of the fish passage season and are removed at the end of the trapping season. Permanent installations consist of foundations, frameworks, and abutments that stay in the river. However, the pickets at permanent installations are removed from the weir during periods when fish are not being trapped and during winter at locations that experience icing.

Figure 6-6. Elk Creek Dam picket weir (Elk Creek, Oregon)

The main advantage of rigid weirs is that the pickets are supported both along the river bottom and above the water surface, which may provide greater lateral stability and help to maintain constant spacing between the pickets. The main disadvantage of rigid weirs is that they are more susceptible to damage with increased debris loads experienced during high flows. High flows and debris can create sufficient force on the face of the panels such that the entire structure can be washed away. Some trap operators remove the pickets from the weir when they anticipate the occurrence of high flows.

Floating resistance board weirs are constructed using panels of hollow plastic piping or conduits that are capped at both ends to provide buoyancy. A resistance board at the downstream end of the pickets directs the local flow downwards, which creates an uplift force and a drag force on the pickets (Tobin 1994). In situations where the resistance board does not provide enough uplift (i.e., under conditions of low stream velocities), the board can be replaced with a long, linear float to support the picket panels. The pickets extend downstream and above the water surface to prevent fish from jumping over. The Alaska Department of Fish and Game has developed a user’s manual for installing, operating, removing, and storing resistance board weirs used to count adult salmon migrating upstream based on direct experience, providing considerable information on this type of picket barrier (Stewart 2003).

The advantage of floating weirs is that they are less prone to damage over a wider range of flows and debris loads. High flows can also submerge the panels, which also tends to move debris off the panels and reduce the downstream pressure on the panels. The main disadvantages of floating weirs include the following:

- Debris can easily be trapped on top of the pickets due to the low angle of the panels.
- Fish can pass over the pickets when the pickets are submerged during high flows.
- The pickets may be more susceptible to lateral current forces because the pickets are supported only by the bottom of the river.
- In situations where adult fish are upstream of the weir and they fall back downstream, or they are migrating downstream, the fish can easily become stranded on the pickets and die due to

the low approach angle and force of the flow that tends to push the fish up onto the dry part of the pickets.

6.3.6.2 Site selection

Weirs should be constructed at sites that have the following characteristics (Zimmerman and Zabkar 2007):

- *Construction, operation, and maintenance activities can be conducted safely.*
- *The river should be wide and shallow (about 3 feet maximum depth at normal flows) with uniform flow distribution.*
- *The substrate should consist of gravel and small cobbles and be without boulders in the weir alignment.*
- *Traps should have sufficient flow depth during minimum expected river flow stages and be accessible during flood flows. More than one trap location may be required.*

The site should be low gradient and straight, with uniform depth and width, and have areas of sufficient depth for adult holding pools upstream and downstream of the weir (Hevlin and Rainey 1993).

6.3.6.3 Velocity

Water velocity at the river channel cross section of the weir location should be a maximum of 2 ft/s at low flows if a concrete apron is used (Hevlin and Rainey 1993), and velocity and depth should allow for safe access to the weir under normal flows (Zimmerman and Zabkar 2007)

6.3.6.4 Picket spacing and freeboard

The clear spacing between the pickets and the freeboard has the same requirements as those for other structural barriers (Sections 6.3.3.1, 6.3.4.1, and 6.3.5.2). The clear opening between bars in bar rack panels, between pickets in picket panels, and between panels and abutments should be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey.

6.3.6.5 Suitability at sites with downstream migrants and monitoring

Fish weirs are not suitable for sites with downstream-migrating adult fish (e.g., steelhead kelts, salmon that pass the structure but migrate downstream [i.e., fallback], and resident fish). If deployed in these situations, weir operators should provide around-the-clock monitoring and fish salvage efforts for as long as these barriers are in place (Section 6.3.1).

While blocking the upstream passage of fish, fish weirs can also block the migration of, or injure, fish migrating downstream (e.g., steelhead kelts, adult salmon, juvenile life stages, and resident fish) and prevent them from completing their life cycle. When weir pickets are at a low angle with respect to the water surface (i.e., floating weirs), downstream-migrating adult fish can become stranded as they are pushed downstream along the pickets and the water becomes shallow. Juvenile passage openings or structures should be provided as part of the design, or these weirs should be removed during the juvenile salmonid outmigration season. When rigid weirs are properly designed and sited, adult and juvenile fish that are migrating downstream are guided along the face of the weirs to the downstream apex of the weir and the shoreline where they can be trapped or released downstream.

6.4 Drop Structure Barriers

Drop structure barriers create conditions that target species are incapable of overcoming based on their swimming abilities or behavioral traits. A condition affecting swimming ability is the creation of a shallow, high-velocity flow for a significant distance, which most salmonids cannot pass. Hydraulic conditions can also interact with fish behaviors, including the reluctance of American shad to pass through a submerged orifice in a ladder or leap a ladder weir under plunging flow conditions. Both are examples of incorporating knowledge about the swimming ability and behavior of target species into facility designs so that the facility becomes a migration barrier. Note: Drop structures may create a serious hazard to boaters and swimmers, and precautions to protect boaters and swimmers should be included in the design.

6.4.1 Orientation of Drop Structure Barriers

As with physical barriers, drop structure barriers should be designed to lead fish to a safe passage route.

This can be achieved by angling the barrier toward a safe passage route and by providing the following:

- Nearly uniform velocities across the entire horizontal length of the barrier
- Sufficient attraction flow that leads fish into the safe passage route and minimizes the potential for false attraction

6.4.2 Upstream Impacts

Since this type of barrier creates an upstream impoundment, the designer should consider backwater effects upstream of the barrier that may induce loss of power generation, inundation of property, and sediment deposition in the impoundment.

6.4.3 Combination Velocity and Vertical Drop Barriers

6.4.3.1 Description and purpose

A combination velocity and drop barrier consists of a weir and concrete apron (Figure 6-7). Upstream passage is prevented by a shallow, high-velocity flow on the apron with an impassable vertical jump over the weir upstream of the apron. A fish that negotiates the apron and reaches the base of the weir is unable to pass the weir due to insufficient water depth needed to reorient its position and the lack of a pool needed to accelerate to leap over the weir sill (Wagner 1967; Weaver et al. 1976).

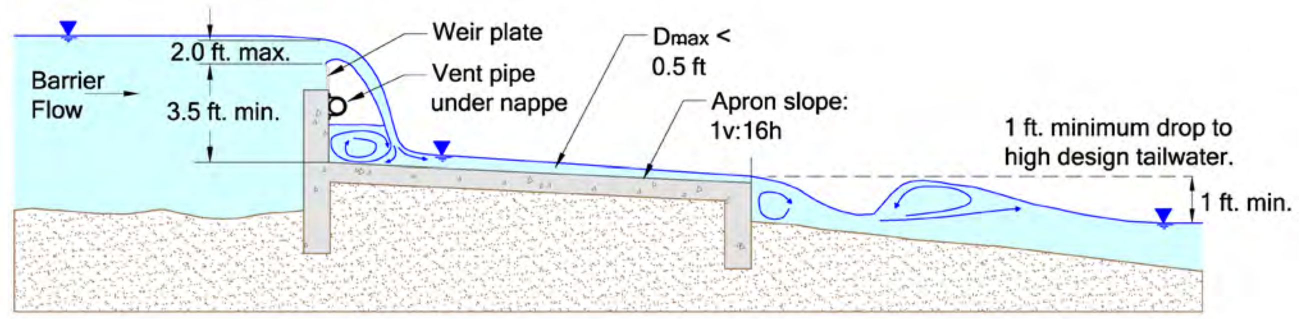


Figure 6-7. Cross section of a combination velocity and vertical drop barrier

6.4.3.2 Specific criteria and guidelines

6.4.3.2.1 *Weir height*

The minimum weir height relative to the maximum apron elevation is 3.5 feet (Wagner 1967).

This design assumes a straight, uniform, linear weir crest that will create uniform flow conditions on the apron. Labyrinth-style weirs are not allowed since they concentrate flow on the apron and create non-uniform flow conditions downstream.

6.4.3.2.2 *Apron length*

The minimum apron length (extending downstream from the base of a weir) is 16 feet.

This criterion is based, in part, on results of laboratory studies where adult Chinook salmon and steelhead were blocked by a velocity barrier dam with a 15-foot-long apron under two test conditions: 1) a vertical dam height of 3 feet with 1 foot of head; and 2) a vertical dam height of 4 feet with 2 feet of head (Slatick and Wagner 1989).

6.4.3.2.3 *Apron slope*

The minimum apron slope in a downstream direction is 1:16 (vertical:horizontal).

6.4.3.2.4 *Weir head*

The maximum head over the weir crest is 2 feet.

Other combinations of weir height and weir crest head may be approved by NMFS on a site-specific basis.

6.4.3.2.5 *Apron elevation*

The elevation of the downstream end of the apron should be greater than the tailrace water surface elevation corresponding to the high design flow (BOR 2006). There should be at *least 1 foot of elevation difference between the water surface elevation at the downstream end of the apron and the high design tailwater elevation.*

6.4.3.2.6 *Flow venting*

The flow over the weir should be fully and continuously vented along the entire weir length to allow a fully aerated flow nappe to develop between the weir crest and the apron (BOR 2006).

Full aeration of the flow nappe prevents an increase in water surface behind the nappe, reducing the opportunity for fish to stage and jump the weir.

6.4.3.2.7 *Flow depth on the apron*

Flow depth on the apron should not exceed 0.5 foot (Wagner 1967).

At sites where a maximum depth of 0.5 foot cannot be maintained, apron velocities of 20 ft/s in association with a sill height (i.e., minimum weir height relative to the maximum apron elevation) of 5.25 feet have been used successfully (Wagner 1967).[4]

6.4.3.2.8 *Minimum flow velocity over the apron*

A minimum velocity of 16 ft/s is recommended by Wagner (1967).

The recommendation by Wagner (1967) is based on Weaver (1963) who reported that Chinook salmon and steelhead could swim against a 16-ft/s velocity for a distance of at least 85 feet in a test flume.

6.4.4 Vertical Drop Barriers

6.4.4.1 Description and purpose

A vertical drop barrier functions as an exclusion barrier by providing head in excess of the leaping ability of the target fish species (Figure 6-8). Vertical drop barriers can be designed based on a concrete monolith, rubber dam, bottom-hinged leaf gate, or an alternative approved by NMFS.

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[4] Wagner (1967) does not provide any additional information on this particular barrier configuration. If it is assumed that flow on the apron is 8 inches deep at 20 ft/s, the discharge per linear foot is approximately 13.5 ft^3/s. This translates to a maximum of 2.5 feet of head over a sharp crested weir. This barrier configuration should be biologically tested before a prototype facility is constructed.

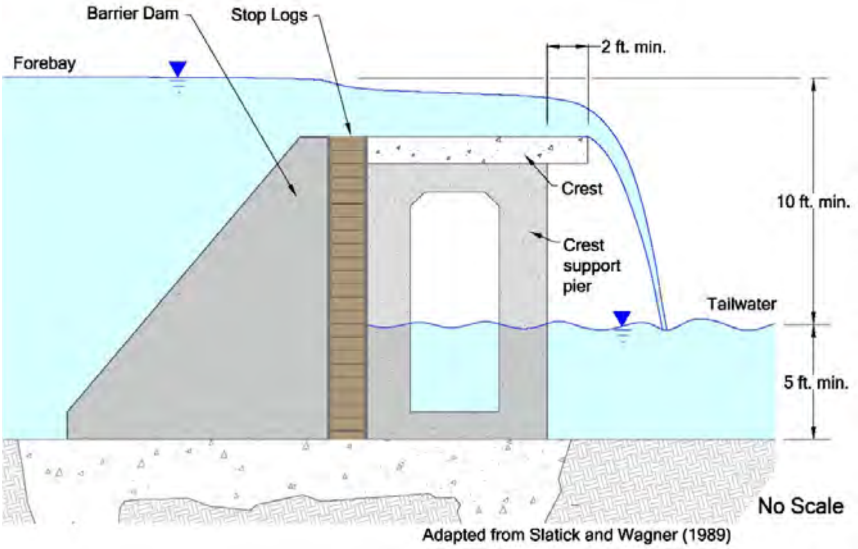

Figure 6-8. Cross section of a vertical drop barrier

6.4.4.2 Specific criteria and guidelines

6.4.4.2.1 *Minimum height*

The minimum height of a vertical drop structure should be 10 feet relative to the high design flow (Wagner 1967; Bell 1991; Clay 1995). This is measured as the water surface level of the forebay relative to the water surface level of the tailrace.

6.4.4.2.2 *Cantilever*

If the potential for injury to fish from leaping exists, the downstream crest of the barrier should extend over the tailwater at least 2 feet beyond any structural surfaces.

6.4.4.2.3 *Minimum flow depth*

Provisions should be made to ensure that fish jumping at flow over the vertical drop structure will land without contacting any solid surface and in a pool that is a minimum of 5 feet deep.

6.4.5 Velocity Barriers

Figure 6-9 shows a cross section of a velocity barrier and its main characteristics that include high water velocity and the long longitudinal length of the barrier over which the design velocity is maintained. The design approach is to provide a combination of water velocity, travel distance, and shallow depth that, taken together, exceed the swimming ability of the target fish.

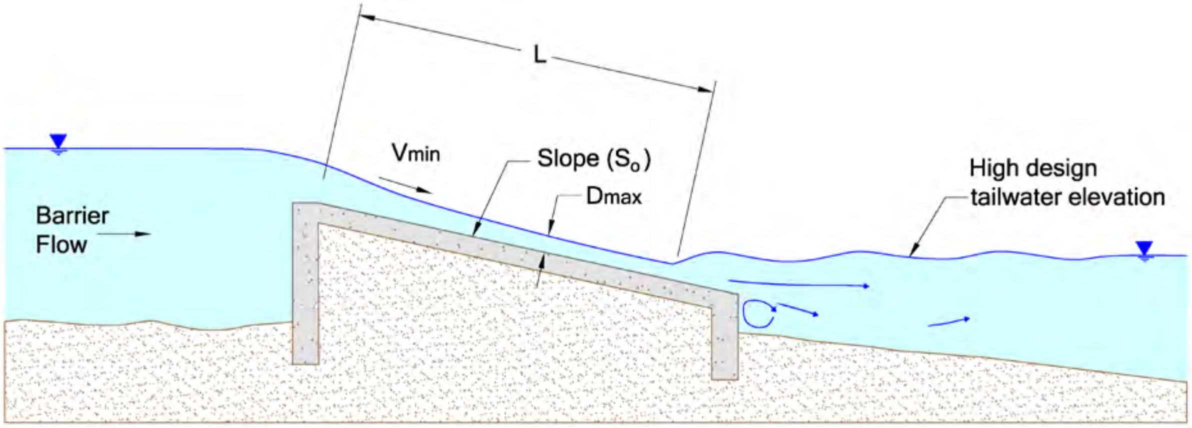

Figure 6-9. Cross section of a velocity barrier

Designing a velocity barrier to prevent the upstream migration of adult salmonids can be challenging due to their strong swimming capabilities. Experience has shown that salmonids will seek flow concentrations or discontinuities in flow (often near the edges of the flow) and use these features to find a route over this style of barrier. In addition to combining high velocity and shallow depth, the design should also create uniform flow conditions across the barrier, which can be difficult to achieve.

NMFS currently does not have criteria or guidelines for a velocity barrier.

NMFS will evaluate a proposed velocity barrier design based upon the hydraulic conditions created by the barrier and by comparing these conditions to the swimming capabilities of the target species. In general, velocity barriers are not recommended by NMFS because fish may spend a long time trying to negotiate the obstacle before seeking an alternate route, which delays the fish and may exhaust them in the process. As discussed in Section 6.3.3.5, barriers should also lead fish to a safe passage route, and NMFS will assess this when reviewing a proposed velocity barrier design.

6.5 Behavioral Barriers

Behavioral types of barriers, such as electric and acoustic fields, have had limited application and were ineffective in most cases (BOR 2006). While electric fields have been used as barriers for decades, persistent problems with early installations limited their widespread use (FERC 1995). These limitations included fish injury and mortality, safety, and effectiveness over a wide range of flow and environmental conditions (Clay 1961). Strobe lights and acoustical systems have been tested in various applications to block juvenile or adult fish from entering water intake systems. These systems were tested in the 1980s and 1990s and seemed promising at first (EPRI 1994) but were found to have limited effectiveness. Thus, electrical fields, strobe lights, acoustical systems, and other behavioral barriers are not widely used within the WCR and are considered experimental. Additional information regarding the various types of behavioral barriers and their performance and limitations may be found in Appendix C. Appendix C also provides information regarding the processes to be followed in order to use experimental devices such as behavioral barriers.

7 Adult Fish Trapping Systems

7.1 Introduction

Chapter 7 presents criteria and guidelines that address the design of new adult fish trapping systems. This chapter also includes criteria and guidelines that may apply to existing trapping programs that are being retrofitted. In both cases, traps should be designed to utilize known or observed fish behaviors to benignly route fish into a holding pool. The holding pool does not include a volitional exit, and once the fish are allowed or encouraged to exit the holding pool, they can be examined for research and management purposes and loaded into transportation tanks for transport to release locations or hatcheries.

NMFS typically prefers the use of volitional passage for upstream fish passage facilities, as opposed to non-volitional facilities and operations. Volitional passage is defined as the passage of fish under all naturally passable flows, whereby a fish can enter and exit any passage apparatus or structure under its own power, instinct, swimming ability, and migration timing. Non-volitional is defined as the collection, handling, transportation, and release of adult fish from a collection site at or below a barrier to a release point located upstream from the barrier or location.[5]

For some facilities, fish transportation is not a requirement and fish are trapped, monitored, sorted, and released from the trap to continue their upstream migration. For example, at some trapping facilities hatchery-origin fish are removed to protect wild-origin fish or collect hatchery broodstock. In the Pacific Northwest, certain areas within watersheds are designated as wild fish sanctuaries, and hatchery-origin fish should be collected and removed from traps located below these areas. Also, fish of a specific species or life stage or fish previously tagged for research purposes may also need to be collected and monitored at trap locations and then released.

The operational requirements for a trapping facility and its design are highly interdependent: management objectives for trap operation define the facility's functional design, and the objectives should be identified before trap design development can proceed. NMFS' primary objective is that a fish passage facility be designed and operated in a manner that the facility helps restore the viability of anadromous fish populations, which is why NMFS often prefers that volitional passage be used. Volitional passage facilities can operate 24 hours per day, 7 days per week, year-round.

However, there are instances where passing fish over a barrier using trap and haul techniques may be the only viable passage alternative. For example, thermal stratification can occur in

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[5] An illustration of a trap and haul operation is available at http://www.westcoast.fisheries.noaa.gov/fish_passage/about_dams_and_fish/trap_and_haul.html.

reservoirs at high head dams during summer, resulting in temperature differentials between the fishway entrance and water released below the dam. This can affect how fish utilize volitional passage facilities, and a trap and haul program would provide passage to areas above the thermally stratified reservoir.

The success of collection and transport operations relies on a high degree of engineering, technical, and operational competence. The process is generally composed of the following distinct phases: (1) Collection, (2) Handling, (3) Transportation, and (4) Release. This sequence is sometimes abbreviated by the acronym ‘CHTR’. The essential idea is to engineer effective system components for each phase, and to consistently execute operations to move fish in a safe and timely manner to designated release location(s). This section provides guidance on how to collect, handle and release fish from a collection facility. For all of these steps, careful attention must be given to maintenance of aquatic conditions and water quality to keep fish in good condition. It is very important to properly acclimate fish to any changing aquatic conditions or environmental transitions. Stressors associated with the aquatic environment (as experienced by the fish) must be minimized and carefully managed. All technical details for each phase of the overall process must be properly addressed.

7.2 Types of Traps

There are two types of traps. The first type is where a trap is an integral component of the primary route of fish passage above a barrier. Examples of these traps include the following:

- Traps located directly adjacent to a barrier
- Traps at the upstream end of a fish ladder
- Traps that serve as holding box associated with broodstock collection facilities in tributary streams in conjunction with intermittent barriers

A collection and transport facility located at the upstream end of a fish ladder is the most common application of this type of trap.

The second type of trap is an off-ladder design wherein the trap is situated adjacent to a ladder such that it is not the primary route of passage and does not interfere with the normal operation of the ladder. The ladder provides volitional passage from the tailrace to the forebay of the barrier under normal conditions, but when necessary or desired, all or some fish can be diverted into the trap.

For both types of traps, once fish are in a trap they can be accessed for a variety of purposes, including the following:

- Enumeration
- Evaluation for tags and injuries
- Sampling for genetic identification
- Sorting for various management purposes
- Transportation to various locations
- Tagging to support fisheries management or research

Fish that are enumerated or evaluated can be released back into the ladder or at another location.

7.2.1 General Criteria

Fish ladders should not be designed or retrofitted with in-ladder traps or fish loading facilities. Rather, fish holding and loading facilities should be placed in an adjacent, off-ladder location in order to route fish targeted for trapping purposes.

Fishway ladder pools typically do not meet the requirements of trap holding pools. Therefore, use of fishway ladder pools to site traps can create adverse impacts to the migrating fish. These impacts include elevated stress, delay, injury, or mortality caused by turbulence, jumping at water being supplied to the holding pool, and handling. Locating the trap off-ladder allows the facility to have the operational flexibility to readily switch between volitional ladder passage and trapping modes of operation.

7.3 Design Scoping

7.3.1 Purpose

Proposals to design new facilities or complete major upgrades to existing facilities should address the following issues, or at the very least show how the following issues were considered:

- *Describe the objective of the trapping operation and identify how the fish will be counted, collected (including the expected holding densities), handled, sampled for research or management purposes, transported (how and what frequency), and released.*
- *Identify the number of fish that will be targeted and the total number potentially present. This should include the expected peak number of fish per day, seasonal and daily fish returns, future fish return expectations, expected incidental catch, etc.*
- *Identify the target species, including ESA-listed species.*
- *Identify other species likely to be present at the trap, including ESA-listed species.*
- *Describe the environmental conditions expected to occur during trap operation such as water and air temperature, flow conditions (lows and peaks), and debris load.*
- *Describe the location, duration, frequency, predicted fish numbers, and scale of the trap and haul operations by developing an operations plan for the trap.*
- *Describe the facility's security mechanisms and procedures that will be in place in the operations plan.*
- *Identify when, what and how many fish will be taken to what location and for what purpose for the entire trapping season.* (Many times different species or origins have different destinations from the trapping facility. Understanding the fish disposition for each species, run type and origin plays a huge role in the facility design (e.g. number of holding tanks and raceways).)
- *Describe the maximum duration of delay or holding within the trapping system for target and non-target species and life stages.*
- *If a Hatchery and Genetic Management Plan, ESA Section 4(d) Limit 7 Scientific Research and Take Authorization application, ESA Section 7(a)(2), or ESA Section 10(a)(1)(A) permit application exists, show how one of these documents was used as the basis for design of a*

trapping facility. At least one of these types of documents will have to be developed for most trapping facilities and will be available for designing the facility.

7.4 Fish Handling Criteria

Section 7.4 provides criteria and guidelines that are applicable to handling fish in traps.

7.4.1 Nets

The use of nets to capture or move fish should be minimized or eliminated. If individual adult fish need to be moved, then they should be placed into rubber tubes with one end sealed. The tube should be partially filled with sufficient water to keep the head and gills of the fish submerged. Avoid handling the fish by hand, unless they have been adequately sedated. All fish should be handled with extreme care.

7.4.2 Anesthetization

Fish should be anesthetized before being handled.

The method of anesthetization for ESA-listed anadromous salmonids may be specified by the appropriate ESA permit, which should be in place prior to any directed take of listed species. The type of anesthetic to be used can be selected by agreement with NMFS during the design process and prior to submittal of an ESA permit request. Determination of the method and anesthetic used should be decided early in design, since each has different infrastructure requirements.

Once the anesthesia is selected protocols should be written to guide appropriate application of the chemical to allow for safe handling while minimizing the risk of over-exposure and mortality. The protocol should include details on water temperature and adjustment of dosage based on water temperature. Finally, a water temperature maximum should be set when fish handling will not be done.

7.4.2.1 Recovery

Fish that have undergone anesthetization should be allowed to recover from the effects of the anesthetic before being released (Section 7.5.10).

Fish require time to recover from the effects of anesthesia. The amount of recovery time needed will depend on several variables including the exposure time to the anesthesia, the water temperature (and general water quality conditions), and the individual sensitivity of the fish. Warm water temperatures and prolonged exposure to anesthetic will result in extended recovery times.

Fish should be monitored to ensure they are recovering. Signs of recovery include fish that are consistently upright and oriented, display normal gilling activity, and are responsive to stimuli.

During recovery fish should be protected from risk of impingement or accidental release back to the river (see specific guidance in Section 7.5.10).

7.4.3 Non-Target Fish

New or upgraded trapping facilities should be designed such that non-target fish can bypass the anesthetic tank.

7.4.4 Frequency

Unless otherwise agreed to by NMFS, all fish (i.e., adults and juveniles of all species and sizes) should be removed from the trap holding pool and raceways at least once every 24 hours whenever the trap is in operation. When either environmental (e.g., water temperature extremes, low dissolved oxygen, or high debris load) or biological conditions (e.g., migration peaks or delay) warrant, fish should be removed more frequently to preclude overcrowding or adverse water quality conditions from developing (Section 7.5.5.2).

7.4.5 Personnel

Trap personnel that handle fish should be experienced or trained to ensure that fish are handled safely.

7.5 Trap Design Criteria

Section 7.5 provides criteria and guidelines that apply to trap design.

7.5.1 Trap Components

Trap systems should include the following components:

- *Removable diffusers or gates located within the fish ladder to block passage and guide fish into the trap*
- *A holding pool; a transition channel or port that connects the fish ladder to the holding pool; and a trapping mechanism as described in Section 7.5.4 (attraction flow is discharged via devices described in Section 7.5.4)*
- *A gate to prevent fish from entering the trap area during crowding operations*
- *A fish crowder (and brail if needed) to encourage adult fish to exit the off-ladder holding pool and enter sorting and loading facilities*
- *Separate holding pool inflow supply and outflow facilities*
- *Distribution flume used in conjunction with false weir or steeppass systems to enable fish to exit the holding pool*
- *A lock or lift (or hopper) for loading fish onto the transportation truck*
- *A flume, pipe, or ladder to return fish either to the ladder or to the dam forebay where they can continue their upstream migration (when returning fish to the ladder, fish should be allowed to volitionally enter the ladder from a resting pool)*

7.5.2 General

7.5.2.1 Location

The entrance to trap facilities should be located in a hydraulically stable, low-velocity (i.e., approximately 1.5 ft/s), accessible area of the upstream passage facility, similar to the requirements for a counting station (Section 5.6).

This location allows fish to be more easily directed toward the trap entrance without excessive turbulence.

7.5.2.2 Flow

Fish ladders should not experience any significant change in fishway flow volume during trap operations.

Fish ladders are often designed to operate within a narrow range of flows; thus, changing the flow volume during trap operations can often compromise the function of the ladder. Depending on the design, it may be necessary to add or remove flow from the ladder in order to adjust for the operation of the trap.

7.5.2.3 Edges

All trapping components exposed to fish should have all welds and sharp edges ground smooth to the touch to minimize injuries. Additional features, such a neoprene padding covered by UV stabilized rubber, may also be required to minimize fish injuries.

7.5.2.4 Fish safety

Provisions should be included in the facility design to provide guaranteed safety to the fish or a method or manner to release fish back to the river in case of emergency (e.g., power outage or loss of water supply).

Fish safety provisions may include guaranteed water supply, water level and water supply alarms, aeration systems, and backup pumps and generators.

7.5.3 Pickets

Pickets are used to prevent fish from entering a specific area (e.g., AWS) or to guide fish to a particular area (e.g., toward a counting window for enumeration or a trap entrance).

7.5.3.1 Design velocity

The average velocity through pickets should be less than 1 ft/s for all flows (Clay 1995).

The average design velocity is calculated by dividing flow by the total submerged picket area. Non-uniform or excessive velocities through the structure can create false attraction conditions that delay fish and induce upstream migrants to attempt to jump over the pickets, potentially injuring the fish.

7.5.3.2 Material

Pickets should be constructed of non-corrosive materials. Panels may consist of flat bars (where the narrow edge of the bar is aligned with flow) or round columns of steel, aluminum, or durable plastic. All surfaces exposed to fish should be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.

7.5.3.3 Bar spacing

The maximum clear spacing between picket bars is 1 inch for adult trapping facilities. At sites where lamprey may be present, pickets should have a maximum 0.75-inch clear spacing between bars.

At sites where smaller fish are present, a smaller spacing between bars may be required.

7.5.3.4 Pickets in off-ladder holding pools

Off-ladder holding pools should include intake and exit pickets designed to prevent adult fish from exiting the holding pool. These should conform to the criteria identified in Section 6.3. The design of off-ladder holding pools should also include an adjustable overflow weir located downstream of, or in conjunction with, the entrance pickets to control the water surface elevation in the holding pool.

7.5.3.5 Blocking pickets

Removable pickets installed within the ladder to block fish from ascending further and route them into an off-ladder trapping pool should be angled toward the off-ladder trap entrance and comply with the criteria listed in Sections 5.3.7 and 5.6.3.7. Pickets installed within ladders should be completely removed from the ladder when trapping activities are not occurring.

7.5.4 Trapping Mechanisms

7.5.4.1 Description and purpose

There should be a mechanism that allows fish to enter, but not volitionally exit, a holding pool. The most commonly used mechanisms include finger weirs, Vee trap fykes, or false weirs (Section 7.5.8).

The maximum velocity over finger traps is 8 ft/s. The amount of flow over the top of a finger weir is usually 2 to 6 inches but varies based upon species. The height of a finger weir varies but is usually in range of 6 to 10 inches (Bell 1991). When using finger traps, an escape area should be provided at both ends to prevent fish from being held against the fingers and killed (Bell 1991).

For a Vee trap, Bell (1991) recommends a minimum velocity of 4 ft/s. The opening at the apex is usually around 8 inches but may need to be larger or smaller depending upon the species present. Being able to adjust this opening can be very beneficial.

Figure 7-1 shows a schematic of a finger weir. Figure 7-2 shows a cutaway of a Vee trap.

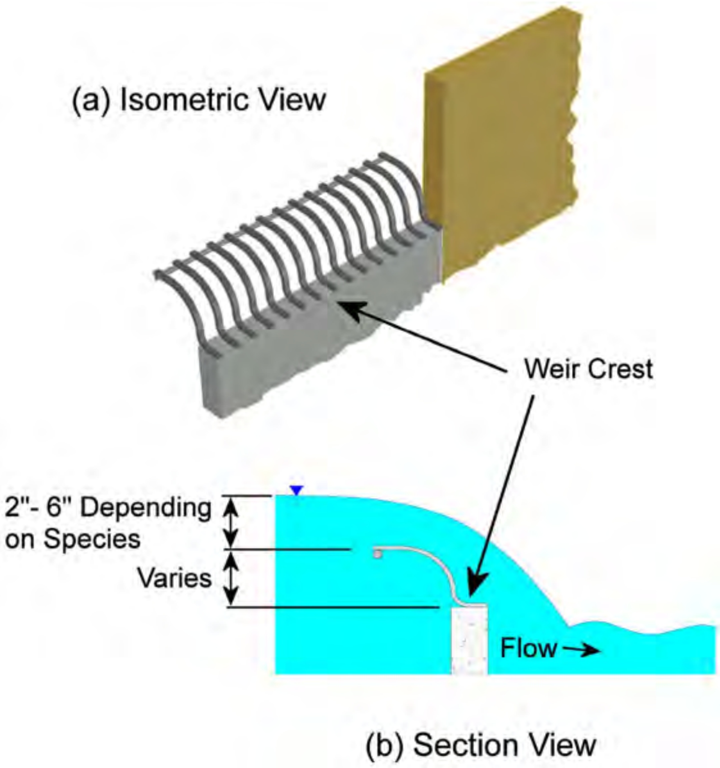

Figure 7-1. Finger weir schematic

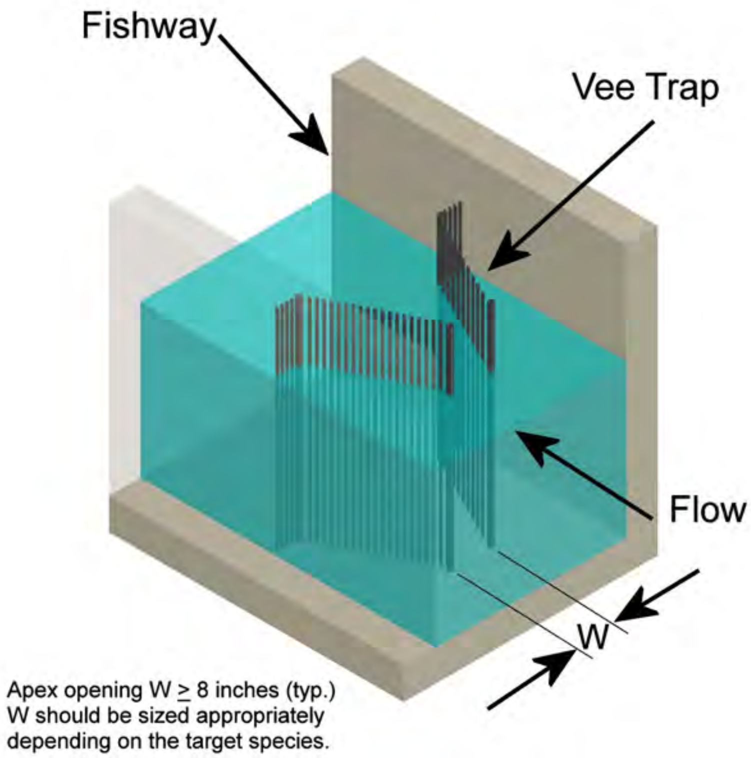

Figure 7-2. Cutaway of a Vee trap

7.5.4.2 Edges

All trapping components exposed to fish should have all welds and sharp edges ground smooth to the touch to minimize injuries. Additional features, such a neoprene padding (covered by UV stabilized rubber), may also be required to minimize fish injuries.

7.5.4.3 Materials and bar spacing

Materials and bar spacing should conform to Sections 7.5.3.2 and 7.5.3.3.

7.5.4.4 Closure

Trapping mechanisms should be able to be closed temporarily to avoid spatial conflict with brail crowding and loading operations. The trapping mechanisms should be designed to safeguard against fish gaining access to unsafe areas such as areas behind a crowder or under a floor brail.

7.5.5 Holding Pools

Holding pools and raceways are used to provide safe areas where fish can be held and accumulated until the facility operators are prepared to process them (for actions such as sorting, evaluation, or transportation).

7.5.5.1 Water quality

Holding pool water quality should be equal to or exceed that of the ambient waters from which fish are trapped.

Key water quality parameters include water temperature, oxygen content, and pH. The purpose of this criterion is to provide fish with a safe, healthy holding environment.

7.5.5.2 Trap holding pool capacity

The following criteria should be followed with regard to trap holding pool capacity:

- *Trap holding pool capacity is based on the number and poundage of fish that can be safely held in a given pool volume for a given time period as well as water quality and quantity.*
- *The number of fish is determined by the maximum daily number of fish passing through the ladder or facility, or by the number of fish expected to be trapped and held prior to being transported.*
- *Fish poundage is determined by multiplying the weight of the average fish targeted for trapping by the maximum number of fish expected to occupy the trap. Note that the poundage calculation may entail calculations for a number of different fish species.*

7.5.5.3 Short-term holding

Trap holding pools should be sized to provide a minimum volume of 0.25 ft^3*/lb of fish. Trap water supply flow rate should be at least 0.67 gallon per minute (gpm) per adult fish for the predetermined adult fish trap holding capacity.*

These criteria apply to conditions when water temperatures are less than 50 degrees Fahrenheit (°F), dissolved oxygen is between 6 and 7 parts per million, and fish are held less than 24 hours (Senn et al. 1984; Bell 1991; Bates 1992). For example, to hold 100 lb of fish for less than 24 hours, the holding pool would need to provide a volume of 25 ft^3 (100 lb × 0.25 ft^3/lb of fish) at 50°F. These criteria are based on the long-term holding requirements presented by Senn et al. (1984), which have been modified and adapted to short-term holding conditions. (See Section 7.5.5.5 for guidance on when water temperatures exceed 50°F.)

7.5.5.4 Long-term holding

Trap holding pool water volumes and water supply rates should be increased by a factor of 2 (0.5 ft^3*/lb of fish and at least 1.34 gpm per adult fish, respectively).*

For example, to hold 100 lb of fish for more than 24 hours (but less than 96 hours), the holding pool would need to provide a volume of 50 ft^3 (100 lb × 0.5 ft^3/lb of fish) at 50°F. Long-term holding should not exceed 96 hours. Trap and haul facilities are not intended for the long-term holding of adults (e.g., hatchery broodstock). However, NMFS will consider additional information or research regarding adult fish holding times and densities, if provided. (See Section 7.5.5.5 for guidance on when water temperatures exceed 50°F.)

7.5.5.5 Holding pool capacity when water temperatures are greater than 50°F

If water temperatures are greater than 50°F, the poundage of fish held should be reduced by 5% for each degree above 50°F (Senn et al. 1984). The trap capacity and average weight of targeted fish values to be used in a design are subject to approval by NMFS.

For short term holding (less than 24 hours) at 60°F, to hold 100 lb of fish, the holding pool would need to provide a volume of 50 ft^3*. For long term holding (greater than 24 hours but less than 96 hours) at 60°F, the holding pool would need to provide a volume of 100* ft^3*.*

Extreme care should be taken when water temperatures are above 68°F during trap operations.

Table 7-1 is provided for reference.

Table 7-1. Holding Pool capacity when water temperature exceeds 50°F

Temp (°F)	Short Term Holding (0.25 lb/$ft^{3)}$	Short Term Holding (0.25 ft^3/lb)	Long Term Holding (0.5 lb/$ft^{3)}$	Long Term Holding (0.5ft^3/lb_
50	4.00	0.25	2.00	0.50
51	3.80	0.26	1.90	0.53
52	3.60	0.28	1.80	0.56
53	3.40	0.29	1.70	0.59
54	3.20	0.31	1.60	0.63
55	3.00	0.33	1.50	0.67
56	2.80	0.36	1.40	0.71

57	2.60	0.38	1.30	0.77
58	2.40	0.42	1.20	0.83
59	2.20	0.45	1.10	0.91
60	2.00	0.50	1.00	1.00
61	1.80	0.56	0.90	1.11
62	1.60	0.63	0.80	1.25
63	1.40	0.71	0.70	1.43
64	1.20	0.83	0.60	1.67
65	1.00	1.00	0.50	2.00
66	0.80	1.25	0.40	2.50
67	0.60	1.67	0.30	3.33
68	0.40	2.50	0.20	5.00
69	0.20	5.00	0.10	10.00

7.5.5.6 Trap holding pool inflow

The following criteria should be followed with regard to trap holding pool inflow:

- *Inflow should be routed through an upstream diffuser designed in accordance with the criteria identified in Section 5.3.7.*
- *The maximum average velocity through the diffuser that is acceptable is 1 ft/s for vertical diffusers and 0.5 ft/s for horizontal diffusers.*
- *Horizontal diffusers should be used when supplying water directly to fish holding pools to reduce the potential for fish jumping at the diffuser flow (Bell 1991).*
- *For both vertical and horizontal diffusers, baffling and other methods of energy dissipation should be used to prevent excessive turbulence and surging, which may induce adult jumping within the trap.*
- *Flow distribution through the diffuser should not cause fish to crowd into a particular area of the holding pool. However, when fish are being crowded for handling or routing, it is best to take advantage of their natural behavior and concentrate the water supply near the end of the pool where fish are being encouraged to move to as part of the operation.*

7.5.5.7 Shading

Consideration should be given to providing shading for holding pools and raceways.

Shading can reduce stress and jumping in adult fish and can reduce the potential for sun burn (Bell 1991).

7.5.5.8 Holding pool water depth

The minimum depth of water in the holding pool is 5 feet.

This is the same minimum depth criterion as is specified for fish ladder pools.

7.5.5.9 Adult jumping

Trap holding pool designs should include provisions that minimize adult jumping, which may result in fish injury or mortality.

Examples of provisions that reduce jumping include the following (Bell 1991):

- Incorporating a high freeboard on holding pool walls of 5 feet or more (note that Bell [1991] recommends incorporating up to 6 feet of freeboard into the facility design)
- Covering or shading the holding pool to keep fish in a darkened environment
- Providing netting over the pool that is strong enough to prevent adults from breaking through the mesh fabric
- Providing sprinklers above the holding pool water surface to break up the water surface and reduce the ability of fish to detect movement above the trap pool
- Designing the corners of the holding pools to have a minimum radius of 18 inches
- Ensuring that water from distribution flumes and pipes does not drop directly into the holding pool
- Ensuring that there are no areas of strong horizontal light nor dark areas present on the surface of the holding pool

7.5.6 Crowders

Crowders are porous panels that can be deployed into a holding pool and used to move fish horizontally to the end of the pool for collection by a hopper or lift, or to encourage the fish to leave the holding pool. Crowders can be pushed by personnel or mechanically operated.

7.5.6.1 Bar spacing

Holding pool crowders should have a maximum clear opening between bars of 0.875 inch. Gaps around the sides of crowder panels should not exceed 1 inch. The side and bottom seals of the crowder panel should allow the crowder to move without binding and should prevent fish from entering the area behind the crowder panel.

If smolt-sized juvenile salmonids or other small fish are expected to be retained in the adult holding pool, the maximum clear bar spacing of the crowder panel (and brail if present) should be reduced to 0.25 inch, and any gaps around the sides the crowder panels should not exceed 0.375 inch.

Often, smaller-sized fish find their way into and become caught in the adult trap holding pool. Provisions should be incorporated into the trap design to safely remove smaller-sized fish from the holding pool and return them to the river.

7.5.6.2 Material

Crowder panels should be constructed of non-corrosive materials. The use of galvanized material should be avoided if possible, and otherwise minimized. Panels may consist of fish screen material such as profile bar or perforated plate material, flat bars where the narrow edge *of the bar is aligned with flow, or round columns of steel, aluminum, or durable plastic. All edges and surfaces exposed to fish should be rounded or ground smooth to the touch.*

The galvanization process uses zinc, which can be toxic to fish (this is why non-corrosive materials for crowder panels should be used). During the crowding process, fish are extremely likely to come into direct contact with the crowder panels. To reduce the potential for fish to be descaled or injured when being crowded, all surfaces and edges that fish can contact need to ground smooth or rounded.

7.5.6.3 Crowding process and crowding speeds

For mechanical crowders, the beginning of the crowding process can be automated, but at the end of the process when fish densities are high the crowder should be manually controlled.

Speeds for horizontally oriented crowders are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools. Maximum crowder speed should not exceed 2 ft/s and should be adjustable.

Crowders are often controlled by a variable frequency drive (VFD). VFDs allow for crowder travel speed to be slowly increased or decreased. This moves the equipment to crowd, but not stress, adult fish in the holding pool. Further, it eliminates erratic (jerking) crowder movement provided with a simple on-off switch. Crowder speeds are also sometimes controlled by a switch to toggle between fast and slow speeds. In all cases, the VFD should be programmed not to increase the crowder or brail speed beyond a maximum level.

7.5.6.4 Coverage

Crowders should be able to cover (crowd) the entire holding pool and should not leave any areas where fish may escape the crowding process.

Being able to crowd the entire holding pool ensures that all fish can be removed from the pool and that no fish spends more time than necessary in the holding pool.

7.5.6.5 Fish entering the holding pool while crowding

If the crowder cannot be removed from the holding pool, it is important that fish do not enter that portion of the holding pool located behind the crowder during crowding operations.

Fish should not be able to access the area behind the crowder where they could become trapped resulting in injury or death.

7.5.7 Brails

Brails are porous panels that can be used to move fish vertically in a holding pool or fish lock. For large holding pools, they are often used in conjunction with a crowder to encourage fish to exit the holding pool.

7.5.7.1 Floor brails

The following criteria should be followed with regard to floor brails:

- *Floor brails should be composed of screen material that is sized according to the life stage and species present to preclude injury or mortality from occurring to target and non-target fish species. Gap openings along the sides of the brail should not exceed 1 inch.*
- *For adult salmonids, brails should have a maximum clear spacing between bars of 0.875 inch. Gaps around the sides of crowder panels should not exceed 1 inch, and seals should be installed that cover all gaps. The side and bottom seals of the crowder panel should allow the crowder to move without binding and prevent fish from moving underneath the brail.*
- *If juvenile salmonids (i.e., smolt-sized fish) or other small fish are expected to be caught in the holding pool, consideration should be given to including a separator system and juvenile sanctuary area as part of the brail system. Also, the maximum clear spacing between bars of the brail should be reduced to 0.25 inch, with side tolerances of no more than 0.375-inch opening or the openings sealed with a brush material.*

7.5.7.2 Material

Brail panels should be constructed of non-corrosive material. The use of galvanized material should be avoided if possible, and otherwise be minimized. Panels may consist of fish screen material such as profile bar or perforated plate material; flat bars where the narrow edge of the bar is aligned with flow; or round columns of steel, aluminum, or durable plastic. All edges and surfaces exposed to fish should be rounded or ground smooth to the touch.

The galvanization process uses zinc, which can be toxic to fish (this is why non-corrosive materials for crowder panels should be used). During the crowding process, fish are extremely likely to come into direct contact with the crowder panels. To reduce the potential for fish to be descaled or injured when being crowded, all surfaces and edges that fish can contact need to ground smooth or rounded.

7.5.7.3 Slope

The sides and the floor of the brail should be sloped toward the holding pool egress point to encourage adult fish to move off the brail.

7.5.7.4 Lifting

The brail should not be used to lift fish out of the water.

7.5.7.5 Brail speed

Brail speeds are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools. Maximum brail speed should not exceed 2 ft/s and should be adjustable. The beginning of the brailing process can be automated, but at the end of the process when fish densities are high, the brail should be manually controlled.

7.5.7.6 Fish lock brails

When floor brails are used in association with fish locks (Section 7.6.2), the floor brail hoist should be designed for both manual and automatic operation and should allow the brail to move at a maximum rate of 2.3 ft/s (both upward and downward). Also, the brail should be able to be operated at speeds that match changes in water surface elevation. Automated operation is allowed only when the water depth above the brail is 4 feet or more. At water depths less than 4 feet, operation of the brail should be conducted manually.

These criteria are designed to minimize stressing fish during crowding between the floor brail and the point where water in the lock exits over an egress weir.

7.5.8 False Weirs

A false weir is a specialized floor diffuser used to introduce water at the top of a fishway or entrance to a distribution flume for the purpose of attracting and encouraging fish to volitionally move into a specific area (Figure 7-3). The device usually creates a strong upwelling flow that simulates flow cascading over a weir. Fish are attracted to the cascading flow and swim through the upwelling into the distribution flume. Care should be taken when locating a false weir to avoid light-to-dark transition at the location of the false weir (shadows) or movement by operator personnel around the false weir. These conditions could cause a fish to reject (not enter) the false weir.

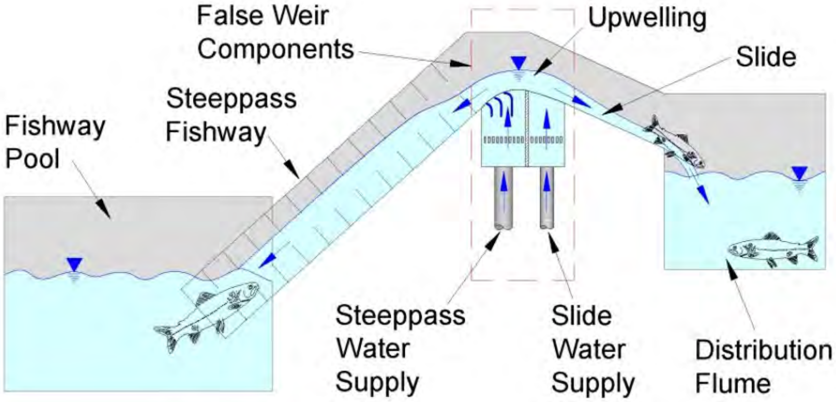

Figure 7-3. Cross section of a false weir

7.5.8.1 Depth

Water depth over the crest of the false weir should be at least 6 inches to facilitate fish egress from the holding pool.

7.5.8.2 Water Supply and Dewatering

The false weir design should include independent water control for both the weir side (steeppass water supply side in Figure 7-3) and flume side (slide water supply in Figure 7-3). Additionally, the slide side of the false weir should include a dewatering screen/system to allow the operator to trim the flow down the slide/flume.

Tuning the amount of flow over the false weir to encourage fish movement while having the ability to limit the amount of flow down the flume is very important. Too much flow down the flume, may allow the fish to try to swim against the flow until exhaustion (Section 7.5.9.3). Achieving the balance between sufficient weir flow and reduced flume flows can be impossible with a common water supply. The addition of a drain between the weir supply and the flume supply is very helpful and allows the operator to maximize attraction flow entering the holding pool. Finally, the independent water control and drain allows the operator to continue to supply the flume with flow both before and after the weir is turned on and off, respectively.

7.5.8.3 Adjustability

The false weir and the downstream water level should have enough adjustability to backwater the false weir and create a streaming flow condition, rather than a plunging flow condition over the weir.

Incorporating this adjustability in the design of the false weir allows the operator to adjust conditions at the false weir to allow adult fish to swim through the weir, rather than having to leap at it to pass the weir. Care should be taken when raising the downstream water surface elevation to ensure this does not adversely affect hydraulic conditions in the trap facility further downstream of the false weir.

7.5.8.4 Fish entering a distribution flume

In situations where fish are entering a distribution flume after passing over a false weir, the ability to change the amount of flow coming from the false weir should be rapid and easy to change in order to regulate the movement of fish over the weir.

Oftentimes it is necessary to control (i.e., meter) the number of fish passing through the false weir so operator personnel can identify and sort fish into various holding tanks. Having the ability to rapidly change the amount of flow coming from the false weir allows the operator some control over how many fish enter the false weir at time. Operator-controlled neoprene doors that open and close in front of, or vary the width of, the entrance to the false weir can be used to allow the operator to more efficiently meter fish through the false weir. Care should be taken in providing sufficient freeboard (around, above, through and downstream of the false weir), since very strong leapers (like steelhead) can jump much higher than the water level on the weir crest.

7.5.8.5 Edges

Provisions, such as neoprene padding (covered by UV stabilized rubber), should be installed around a false weir to protect fish that make an inaccurate leap at the weir from being injured.

7.5.8.6 Gravity flow

A gravity flow (i.e., not pumped) water supply should be used for false weirs and steeppass ladders to prevent fish from potentially rejecting the trap component due to the production of noise or vibration from a pump or motor. At sites where it is necessary or *desirable to use a pumped water supply, care should be taken to isolate the pump noise and vibration from affecting the fish.*

7.5.9 Distribution Flumes and Pipes

7.5.9.1 General

A distribution flume (or pipe) should be used whenever fish are routed from one area to another.

Distribution flumes are used to convey fish to anesthetic tanks, recovery tanks, pre-transport holding tanks, fish ladders, and project forebays. They are also used to convey fish to various locations after they pass through false weirs.

7.5.9.2 Smoothness

The flume should have smooth joints, sides, and bottom, with no sharp or abrupt edges and no abrupt vertical or horizontal bends.

7.5.9.3 Wetted surfaces, water depth, and velocity

The following criteria should be followed with regard to wetted surfaces, water depth, and velocity:

- *The flume should have continuously wetted surfaces.*
- *For flumes less than 50 feet in length, water depth in the flume should be between 1 and 3 inches, and water velocity should be between 6 and 8 ft/s.*
- *For flumes that are longer than 50 feet, a closed pipe with open channel flow should be used for the entire length of the flume. The water depth in the pipe should be between 2 and 4 inches (a depth of 4 inches is preferred), and water velocity should be greater than 8 ft/s, but less than 15 ft/s.*
- *Site-specific adjustments to these values may be required.*

The combination of low water depth and high velocity is intended to prevent adult fish from holding in the pipe or swimming upstream in the pipe. If the pipe is above ground, observation ports with removable covers should be provided so that conditions in the flume can be observed and the pipe can be accessed for maintenance and debris removal. If the pipe is located belowground, access ports should be provided for inspection and maintenance.

7.5.9.4 Outfalls

When distribution flumes lead to holding tanks or raceways, care should be taken so that adults entering the tank do not hit the walls, floor, or end of the tank or collide (land on top of) with other fish. A dewatering drain should be located immediately upstream of the outfall to eliminate flow from the outfall which can cause false attraction and jumping.

When a distribution flume is used to return adults to the river, the criteria for juvenile outfalls (Section 8.6.4) should be followed (i.e., the bypass flow should not impact the river *bottom or other physical features at any stage of river flow, and the maximum bypass outfall impact velocity should be less than 25 ft/s).*

7.5.9.5 Bends

Horizontal and vertical radii of curvature should be at least 5 times the width of the flume to minimize the risk of fish-strike injuries. A removable flume cover should be provided when flumes go through bends greater than 30 degrees in alignment.

Removable covers are necessary to prevent active fish from leaping out of the flume and allow personnel to inspect the flume for debris accumulation in the bend.

7.5.9.6 Size

The minimum inside diameter of the distribution flume should be 15 inches for fish weighing 20 lb or less and 18 inches for fish weighing 20 lb or more.

The minimum sidewall height of a distribution flume is 24 inches.

This height is in addition to the radius of the flume. For example, the minimum total height of a 15-inch diameter flume would be 31.5 inches (24 inches plus half of the diameter at 7.5 inches), as measured from the invert of the flume.

7.5.9.7 Length

Distribution flumes should be as short as possible.

7.5.9.8 Flume structure

Overhead structures that are part of the flume, such as overhead bracing to stiffen the walls of the flume or gate operation arms, should be eliminated if possible, or minimized. If overhead structures are necessary, they should be located above the top of the flume sidewalls or 30 inches above the invert of the flume, whichever is greater.

7.5.10 Anesthetic Recovery Pools

The following criteria should be followed with regard to anesthetic recovery pools:

- *Anesthetized fish should be routed to a recovery pool to allow the fish to be monitored prior to release to ensure they have fully recovered from the anesthesia.*
- *Fish that are recovering from anesthesia should not be routed directly back to the river where unobserved mortality may occur.*
- *Recovery pool inflow should satisfy the water quality guidelines specified in Section 7.5.5.*
- *Recovery pool hydraulic conditions should not result in partially or fully anesthetized fish being impinged on an outflow grating or any other hazardous area.*
- *A recovery pool should allow fully recovered fish to volitionally exit the pool.*
- *The recovery pool should have a brail or crowder system to force fish from the recovery pool if necessary.*

Often, fish require time to recover from effects of anesthetic. Anesthetized fish released directly to an uncontrolled environment (i.e., directly back to the river or into a ladder) often fail to orient themselves upright and sometimes sink to the bottom where they may suffocate or are swept downstream. It is important to provide fish recovering from anesthetic with a safe recovery area where they can be monitored by personnel. Some indications that fish are fully recovered include they are upright and oriented, display normal gilling activity, and are responsive to stimuli. If a fish appears to be struggling to recover or appears distressed, it may be necessary to retrieve the fish and revive it. Revival may involve manually ventilation of the gills by gently moving the fish forward and backward in the water. The ability of a fish to volitionally exit the recovery pool is an indication that the fish has recovered sufficiently from the anesthetic. Fish should not be forced out of the recovery pool for at least 30 minutes after exposure to anesthetic.

7.6 Lifting Devices

Section 7.6 provides criteria and guidelines that apply to fish lifting devices.

7.6.1 Fish Lifts and Hopper Passage Systems

A fish lift is a mechanical system that utilizes a hopper and hoist to allow fish to be trapped at one elevation and raised to a higher elevation. Once raised to the higher elevation, fish can be loaded into a transport tank or truck for release at a remote location, routed to a monitoring and sorting facility, or released above a dam directly into the forebay.

7.6.1.1 Maximum hopper loading densities

The hopper water volumes should be greater than or equal to 0.15 ft^3*/lb of fish estimated to occur at the maximum fish load. When large fish (fish ranging from 30 to 40 lb in weight) are being transported, the poundage being transported should be reduced by 50% (Bell 1991).*

Hopper loading densities are designed to ensure that a sufficient volume of water is available to fish to be raised safely. Normally, the size of the hopper and transport tank loading match, such that a full hopper volume equals a full transport tank volume. The density of fish being held when water temperatures become elevated is a concern that needs to be considered. Bell (1991) recommends that the poundage of fish being transported in tanks be reduced by 10% for each degree of water temperature above 60°F.

7.6.1.2 Hopper freeboard

The distance from the water surface in the hopper to the top of hopper bucket should be greater than the water depth within the hopper.

This is to reduce the risk of fish jumping out of the hopper during lifting operations.

7.6.1.3 Sump

When a trap design includes a hopper sump into which the hopper is lowered during trapping, side clearances between the hopper and sump sidewalls should not exceed 1 inch to *minimize access to the area below the hopper. Flexible side seals or brushes should be used to ensure that fish do not pass below the hopper.*

It is very important that the hopper and gates around the sump provide a positive seal and do not allow fish to get into the sump area. If fish do get into this area, they can be very difficult to remove due to the water depth and confined area.

7.6.1.4 Fish hopper egress opening

The fish egress opening from the hopper into the transport tank should have a minimum horizontal cross-sectional area of 3 square feet and a smooth transition to minimize the potential for fish injury.

7.6.1.5 Safeguarding fish

Fail-safe measures should be provided to prevent fish entering the holding pool area from accessing the area occupied by the hopper before the hopper is lowered into position. The interior surfaces of the hopper should be smooth to eliminate fish injuries.

7.6.2 Fish Lock

A fish lock is a mechanical-hydraulic system that utilizes a water chamber or tower to raise fish from one elevation to another. It allows fish that are collected (trapped) at a lower elevation to be raised to a higher elevation by increasing the water level in the chamber or tower until it reaches a predetermined elevation where fish can be released. The fish can be brailed (i.e., crowded) to the higher elevation and then loaded into a transport truck for release at a remote location, routed to a monitoring and sorting facility, or released directly above a dam into the forebay (Clay 1995).

Section 7.6.2.1 outlines the process for routing fish from a holding pool to the forebay or transport vehicle using a fish lock.

7.6.2.1 Holding pool crowding

The following criteria and guidelines should be followed with regard to holding pool crowding:

- *Fish are crowded into the lock; the crowder should meet up with the entrance to the lock so that no fish can become trapped or crushed between the crowder and the lift structure or closure gate.*
- *When the closure gate to the fish lock chamber is shut it should create a uniform surface with the interior of the lock so that the brail can pass the gate without creating excessive gaps that could allow fish to get past the brail.*
    - The closure gate is the gate that seals the lock chamber from the holding pool.
- *Once the closure gate is shut, the crowder should be backed up to reduce the stress on the fish.*

  - Crowding, especially the last part of the crowd when fish are forced from the holding pool, can be very stressful to the fish. If there is a break in the crowding operation for some reason (lifting and operating the hopper for example), the crowder should be backed off to reduce the stress on the fish.

- *Flow to fill the lock should be introduced into the lock through floor diffusers below the floor brail.*
  - As the water level rises within the lock, it will ultimately reach an equilibrium elevation with a control weir or false weir.
- *The floor brail should be raised only after the water surface elevation in the lock is at an equilibrium with the control weir or false weir. If the brail is being operated while the fish lock is being filled, the speed of the brail should not exceed the rate of change in water surface elevation. The brail should be greater than 4 feet from the water surface until the water level reaches equilibrium with the control or false weir. The brail should not be used to lift fish out of the water (Section 7.5.7.4).*
  - Speeds for brails (vertically oriented crowders) are typically in the 0.5- to 1-ft/s range for pre-anesthesia, sorting, and holding pools, but can range up to 2.3 ft/s for vertical fish locks.
- *Fish should exit the lock via a false weir or through the overflow water draining over the control weir.*
- *Fish and water that pass over the control weir or false weir can be routed using a distribution flume to other destinations, including an anesthetic tank, sorting or holding pools, or a transportation vehicle.*
  - Floor dewatering screens in the distribution flume can be used to drain off excess flow just before fish are delivered to anesthetic tanks, holding pools, or transportation vehicles.

7.6.2.2 Lock inflow chamber

The lock inflow chamber located below the lowest-floor brail level should be of sufficient depth and volume (Section 5.5.3.5) to limit turbulence into the fish holding zone when lock inflow is introduced. The inflow sump should be designed so that flow upwells uniformly through add-in floor diffusers (Section 5.3.7; Bell 1991).

Properly designed lock inflow chambers will limit turbulence and unstable hydraulic conditions within the lock that may agitate fish.

7.7 Single Holding Pool Traps

Single pool traps are often used in tandem with intermittent exclusion barriers (Figure 6-5) for broodstock collection from small streams. These trapping systems are used to collect, sort, and load adult fish. Key criteria for single holding pool traps are as follows:

- *The trap holding pool water volume should be designed according to Section 5.5.3.5 to achieve stable interior hydraulic conditions and minimize jumping of trapped fish.*
- *Intakes should conform to Section 5.3.2.*

- *Sidewall freeboard should be a minimum of 4 feet above the trap pool water surface at high design streamflow.*
- *The trap holding pool interior surfaces should be smooth to reduce the potential for fish injury.*
- *A description of the proposed means of removing fish from the trapping pool and loading them onto a transport truck should be submitted to NMFS for approval as part of the ESA incidental take permit application.*

7.8 Upstream Transportation Criteria

Section 7.8 provides criteria and guidelines that are applicable to truck transportation equipment and facilities.

7.8.1 Maximum Transport Tank Loading Densities and Time

Transport tank loading water volumes should be greater than or equal to 0.15 ft^3*/lb of fish at the maximum fish loading density to provide a sufficient volume of water for fish safety. When large fish (fish ranging from 30 to 40 lb in weight) are being transported, the poundage being transported should be reduced by 50% (Bell 1991). Every effort should be made to reduce the amount of time fish spend in a transport tank.*

These loading densities are to ensure that a sufficient volume of water is available in the tank for fish to be transported safely. Normally, the size of the hopper and transport tank loading match, such that a full hopper volume equals a full transport tank volume. The density of fish being held when water temperatures become elevated is a concern that needs to be considered. Bell (1991) recommends that the poundage of fish being transported in tanks be reduced by 10% for each degree of water temperature above 60°F.

Due to the high loading densities in transport tanks and the stress it may create, every effort should be made to minimize the amount of time the fish spend in these tanks. Fish should not be held for long in a transport tank while waiting for other fish to be processed or while waiting for other fish to fill the tank.

7.8.2 Transport Tanks

To minimize handling stress, truck transport tanks should be compatible with the hopper design. If an existing vehicle will be used, the hopper should be designed to be compatible with existing equipment. If the transport tank opening is larger than the tube or hopper opening, a cap or other device should be designed to prevent fish from jumping at the opening. Truck tanks for hauling adults should be closed systems, and the tanks should be kept full to prevent sloshing (Bell 1991).

7.8.2.1 Fish transfer from hopper to tank

The transfer of fish should be made water-to-water. The design of the hopper and transport tanks should allow for hopper water surface control to be transferred to the truck *transport tank during loading so that water and fish do not plunge abruptly from the hopper into the fish transport tank.*

7.8.2.2 Transport tank egress

The fish egress opening from the transport tank should have a minimum cross-sectional area of 2 square feet (Clay 1995). The bottom of the transport tank should be sloped (front to back and side to side) toward the release opening and have a smooth transition that minimizes the potential for fish injury.

7.8.2.3 Oxygen and temperature requirements

Depending upon site-specific conditions, the transportation tank should have the capability to maintain dissolved oxygen levels between 6 and 7 parts per million. The transportation tank should also contain water chillers to maintain ambient water temperature if the transport cycle time could result in unhealthy increases in the water temperature in the tank or temperature differential between the tank water temperature and the ambient water temperature where the fish are released exceed the water tempering described in Section 7.8.3.5.

Many existing fish transport trucks do not include water chillers because they are designed for short transport trips during which the water temperature conditions in the tank do not result in temperature changes that exceed the water tempering requirements when the fish are released. Water tempering can be performed using chillers or mixing with cooler or warmer water at loading or release sites.

7.8.3 Release Location

After being transported, fish should be released in a safe location with sufficient depth and good water quality.

The criteria and guidelines in Sections 7.8.3.1 through 7.8.3.6 apply to release locations.

7.8.3.1 Direct release from a transport tank

Fish should not be dropped more than 6 vertical feet during release. The receiving water should be at least 3 feet deep, and fish should not contact the bottom. The impact velocity of fish entering the receiving water should be less than 25 ft/s.

7.8.3.2 Release pipe from a transport tank

For locations where release pipes are required, the minimum diameter for a release pipe is 24 inches (30 inches is preferred). The end of the release pipe should not be submerged. The internal surface of the pipe joints should be smooth to the touch to prevent descaling and injury to fish. The release pipe elevation criteria, receiving water depth, and impact velocity are the same as for fish being released directly from a transport tank (Section 7.8.3.1).

Depending on how fish are released from the transport tank, the entrance to the release pipe may have to be larger (e.g., 36 inches), or a funnel or flume should be created that smoothly transitions from the release tank outlet to the release pipe. Care should be taken to minimize the possibility of a fish leaping out of the system during transfer from the tank to release pipe.

7.8.3.3 Release water

Water should be supplied to the release pipe prior to fish being released and also used to flush the last fish out of the pipe.

7.8.3.4 Water quality

Water quality (i.e., water temperature and dissolved oxygen) at the release site should be representative of the general water conditions in the river in the vicinity of the release site.

7.8.3.5 Water tempering

Fish should not be subjected to rapid temperature changes. Temperature differentials between the transport tank and release location should be no more than 2 degrees Celsius (°C). If tempering is required to meet this criterion, changes in temperature should not exceed 1°C every 2 minutes or 5°C per hour. Tempering may take longer when temperatures are further away from the optimal temperature for the target species and life stage.

Changes in water temperature that occur too rapidly or are beyond the normal survival range of fish may cause thermal trauma (Post 1987). Mortality associated with rapid temperature changes may occur in the short term from loss of equilibrium (Bell 1991) and increased predation (Groot et al. 1995). Over longer time periods, thermal stress can act as an additive stressor and increase susceptibility to disease (Piper et al. 1982). Fish adapt more rapidly when the temperature change is nearer their thermal optimum than when the change is further away from that temperature (Schreck and Moyle 1990). Rapid changes in temperature have more significant negative effects at the upper end of a fish’s temperature tolerance. As temperatures increase, fish are more active and have greater potential for self-inflicted injury, oxygen consumption is higher, and the saturation level of oxygen is lower, which increases the possibility of hypoxia (Murphy and Willis 1996).

7.8.3.6 Release site egress

The release site should provide direct and simple egress for fish into the river for continued migration upstream.

8 Fish Screen and Bypass Facilities

8.1 Introduction

Chapter 8 provides criteria for designing fish screen facilities for hydroelectric, municipal, irrigation, and other water-withdrawal projects that prevent fish (primarily young fish, fish with poor swimming capabilities, and larvae) from being entrained into water diversions. The objectives of these criteria are to develop fish screen facility designs that prevent fish impingement on the outward face of all fish screen material, do not increase predation above background levels, and ensure the structural integrity and longevity of all facility components is maintained. This allows the facility to be operated within its design criteria and protects fisheries resources over the design life of the project.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other that salmonids, NOAA will consider deferring to the more conservative criteria on a case by case basis.

The criteria are to be used when designing new facilities or performing major retrofits to existing facilities. The criteria are also to be used for temporary diversions such as water drafting operations (Section 8.7) and when stream flow is to be routed around a construction site. In addition, information presented in Chapter 1, Introduction; Chapter 3, Design Development; and Chapter 4, Design Flow Range, of this document apply to the design of fish screen and bypass facilities.

8.1.1 100% Flow Screening

All facilities that divert or use water from a body of water should convey 100% of the diverted flow through a fish screen or bypass that is designed, constructed, tested, and operated using the criteria contained herein.

The application of these criteria to existing fish screen facilities is addressed in Section 8.2.

8.1.2 Deviation from These Criteria

The criteria can be adjusted by NMFS as needed to meet the specific requirements of a project. It is the responsibility of the applicant to provide compelling evidence in support of any proposed waiver (Section 1.6) or modification of a criterion to NMFS early in the design process and well in advance of a proposed federal action. Appendix C (Experimental Technologies) *provides additional information on the NMFS approval process for unproven fish passage technologies.*

There may be cases where site constraints or extenuating circumstances weigh in favor of a deviation or waiver of these criteria. Extenuating circumstances may include environmental factors that affect a fish's swimming ability or condition such as abnormally warm or cold waters or waters low in dissolved oxygen.

The swimming ability of target fish species and their life stages are primary considerations in designing effective fish screen facilities. The swimming abilities of fish vary with species, age-class, size, and duration (i.e., endurance) and type of swimming activity required (e.g., sustained versus burst swim speed). Bell (1991) provides information on swimming speeds for multiple fish species and age-classes and for different functional speeds (cruising, sustained, and darting). Swimming ability also depends upon a number of biological and physical factors, including the physical condition of individual fish; water quality parameters, such as dissolved oxygen concentration and water temperature; and ambient lighting conditions. For example, swimming effort may be reduced by 60% at oxygen levels that are one-third of saturation, and temperatures above and below the optimum range for any species affect swimming effort (Bell 1991). Adverse temperatures may reduce swimming effort by 50% (Brett et al. 1958).

8.1.3 Experimental Technology

The process to evaluate experimental screening technology is described in Appendix C. Proponents of new, unproven fish passage designs (i.e., designs not meeting the criteria and guidelines contained in this chapter) should provide NMFS with the types of information identified in Section 1.5.

NMFS considers several categories of screen designs that are currently in use to be experimental technologies. These include Eicher screens, modular inclined screens, and Coanda intake screens. Infiltration galleries may be considered an acceptable alternative for excluding fish at water diversions, but these are not considered positive exclusion barriers. Therefore, they are not addressed in this chapter. Information on the design and use of infiltration galleries is presented in Appendix B. The design and use of experimental technologies may be considered on a case-by-case basis through discussions with NMFS and in accordance with the procedures outlined in Appendix C.

8.2 Existing Fish Screens

8.2.1 General

If a fish screen was constructed prior to the date of this document, but in accordance with the NMFS criteria that were established on August 21, 1989, or later, NMFS considers these screens to be compliant provided that all of the following conditions have been met:

- *The entire screen facility functions and is operated as designed.*
- *The entire screen facility has been maintained and is in good working condition.*

- *When screen material wears out, it is replaced with screen material meeting the current criteria stated in this chapter (Section 8.5.8). To comply with this condition, structural modifications may be required to retrofit an existing facility with new screen material.*
- *Mortality, injury, entrainment, impingement, migration delay, or other harm to anadromous fish caused by the facility has not been observed.*
- *Emergent fry are unlikely to be located in the vicinity of the screen, as agreed to by NMFS biologists familiar with the site.*
- *When biological uncertainty exists, access to the diversion site by NMFS is permitted by the owner or operator of the facility for verification that the criteria in this chapter are being met.*

8.3 Project Design Review

The most effective approach to designing fish screening and bypass projects is to have NMFS included in all phases of the design. This can occur by having NMFS participate in a technical advisory team convened for the project or having NMFS review and comment on project designs, or both. While both the preliminary and final designs should be developed in cooperation and interaction with engineering staff from NMFS WCR Environmental Services Branch (Section 3.2), it is especially important that NMFS be involved in the preliminary design phase of a project. This is to ensure that the design parameters needed to produce a functional fish passage project are established early in the design process.

The project design process is most efficient when design criteria are identified and accepted by NMFS while a project is in its infancy. The entire project design development process and information typically required for a preliminary design are discussed in Chapter 3.

8.4 Structure Placement

All screen facilities should be designed to function properly and protect fish from being entrained into the water diversion throughout the full range of hydrologic conditions expected to occur at the location.

For in-stream facilities, the full range of conditions is normally from the minimum stream flow during which water diversions may take place, up to a 100-year flood event. In situations where streambanks will overtop allowing flow into the canal outside of the screen area at flows lower than the 100-year flood event, the screen may be designed to resist overtopping up to the lower flows. NMFS may require the facility operator to capture and relocate fish that become stranded behind a fish screen.

8.4.1 In-Stream Installations

Where it is physically practical and biologically desirable to do so, the fish screen should be constructed at the point of water diversion, and the screen face should be oriented parallel to the streamflow.

Several physical factors may preclude a fish screen from being located and constructed at the water diversion. These include excess channel gradient; the potential for large debris to damage the screen facility; access for personnel and equipment to conduct facility maintenance, operations, and repair; unsuitable soils for constructing a fish screen facility at the point of diversion; and the potential for heavy sediment accumulations.

Depending on site-specific conditions, in-stream screens may be subject to increased damage by debris. However, they typically offer the following advantages:

- They do not require a formal bypass system.
- They keep migrating fish in the streamflow.
- They may reduce fish proximity to the screen face.

8.4.1.1 Bankline screens

For screens constructed at the edge of a stream (Figures 8-1 through 8-3), the screen face should be aligned with the adjacent bankline, and the transition between the native streambank and the fish screen face should be shaped to minimize turbulence and eddying in front, upstream, and downstream of the screen. For inclined, flat plate screen designs, the screen angle should not be greater than 45 degrees from vertical, and the top of the screen should be submerged a minimum of 1 foot at low stream design flow. The design should also minimize any adverse alteration of riverine and riparian habitat.

Figure 8-1. Aerial view of the Garden City-Lowden 2 water diversion on Walla Walla River near Touchet, Washington (Notes: River flow is from left to right. The bankline screen is located at the head end of the canal, just upstream of the spillway and adult ladder exit.)

Figure 8-2 Bankline screens at the Garden City-Lowden 2 diversion on the Walla Walla River near Touchet, Washington, under construction

Figure 8-3 Bankline vertical flat plate fish screen sized for 3,000 ft3/s (Glenn-Colusa Irrigation District) along the Sacramento River in California (Note: the screen is shown in operation (left) and during construction (right).)

8.4.2 In-Canal Installations

All screen facilities installed within canals should include an effective fish bypass system (Section 8.6) to collect and transport screened fish safely back to the river with minimum delay (Figure 8-4). In instances where the returned bypass flow represents a substantial proportion of the remaining instream flow downstream from the water diversion, the bypass outfall should be placed as close to the point of diversion as practicable to minimize the length of the dewatered stream channel.

Where installation of fish screens at a diversion entrance is not desirable or is deemed impractical, the screens may be installed at a suitable location in the canal downstream of the water diversion. Locating the bypass outfall as close to the point of diversion as possible reduces the length of dewatered stream channel.

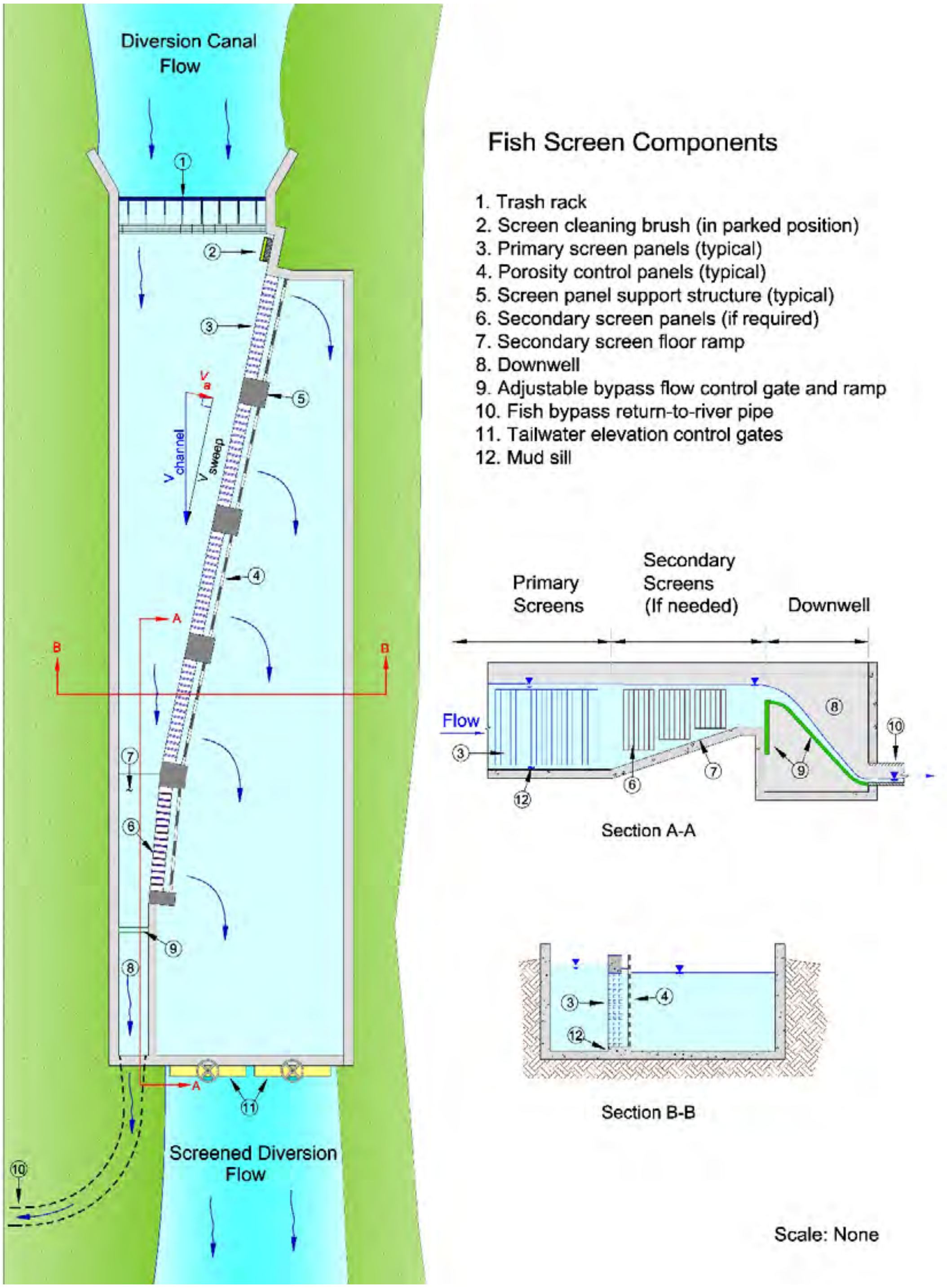

Figure 8-4 Schematic of a typical in-canal fish screen system layout and components at water diversions

Figure 8-5 Vertical plate screen facility under construction in a diversion canal located on the Santiam River near Stayton, Oregon

8.4.2.1 Headworks Control Gates

Canal flow should be controlled with gates located downstream from the screen (Figure 8-4, tailwater control gates). If headworks gates must be used to throttle flow, they should not create a head differential greater than 12 inches. Submerged headworks control gates should be operated fully closed or open at least 12 vertical inches.

Fish can be injured if forced to pass through a small opening created by a partially open headgate. Head drops greater than one foot through gates can prevent bidirectional movement of fish. Higher heads can create high water velocities and pressure differentials that may injure fish from shear stresses or impacts with hard surfaces.

8.4.2.2 Headworks trash rack

All in-canal screens should have a trash rack at the canal headworks to minimize the amount of debris that will reach the fish screen structure (Bell 1991). Trash racks should have openings that are at least 10 inches wide for Chinook salmon passage and 8 inches wide for all other salmonid species.

Additional trash rack design criteria are provided in Section 5.8 of this document. Bell (1991) recommends that openings be 12 inches wide for large salmon.

8.4.3 Lakes, Reservoirs, and Tidal Areas

Intakes in lakes, reservoirs, and tidal areas should be located offshore where feasible to minimize shoreline-oriented fish from coming into contact with the facility. When possible, intakes should be located in areas with sufficient ambient velocity to minimize sediment *accumulation in or around the screen. Intakes in reservoirs should be at an appropriate depth to reduce the number of juvenile salmonids that encounter the intake.*

The appropriate depth for intakes in lakes, reservoirs, and tidal areas will be determined on a case-by-case basis. One factor that will be considered when locating these intakes is that although juvenile salmonids are surface oriented, they may congregate in colder water located at depth if surface waters are too warm.

8.4.3.1 Required submergence

For facilities in lakes, reservoirs, and tidal areas, the facility should be placed such that the screen area is adequately submerged to meet the design approach velocity criterion at the historical low water conditions (Section 8.5.7).

8.5 Screen Design Specifications

8.5.1 Approach Velocity

The design approach velocity for active screens should not exceed 0.4 ft/s for fish screens where exposure time is limited to less than 60 seconds, or 0.33 ft/s where exposure time is greater than 60 seconds (Smith and Carpenter 1987; Clay 1995). The design approach velocity for passive screens, as described in Section 8.5.6, should not exceed 0.2 ft/s (Cech et al. 2001).

For the purposes of this document, approach velocity, “V_a” in Figure 8-4, is defined as the water velocity component normal (perpendicular) to the screen surface. The minimum amount of screen area required is calculated by dividing the maximum diversion rate (in ft^3/s) by the design approach velocity (in ft/s). The porosity of the screen is not considered in the calculation of approach velocity. The operating approach velocity for any fish screen at any diversion rate may be calculated by dividing the current diversion flow rate by the effective screen area (Section 8.5.2).

Exposure time is defined as the time it takes a particle to traverse the length of the fish screen when moving at the speed of the sweeping velocity (Section 8.5.3). The design approach velocity criteria have been shown to minimize juvenile fish contact with, and impingement on, screen materials. This includes the impingement of emergent fry under cold water temperature conditions. (Appendix E provides a discussion of how to measure approach velocity.)

Note that these criteria apply to salmonids. Other species may require different approach velocity standards. For example, in California, the U.S. Fish and Wildlife Service requires that a design approach velocity of 0.2 ft/s be used at locations where Delta smelt (*Hypomesus transpacificus*) are present.

8.5.2 Effective Screen Area

The effective screen area is defined as the total wetted screen area minus the area occluded by major structural elements. The minimum effective screen area required is defined as the maximum screen flow divided by the allowable approach velocity. For rotary drum screens, *the effective screen area is defined as the vertical projection of the wetted screen area minus the vertical projections of the area occluded by major structural elements.*

When calculating effective screen area, components (bars and rods) that make up the screen material are not considered to be "major structural elements" as long as the screen porosity remains greater than 27% when considering those structural elements. Major structural elements are elements of the facility that support the screen panels or cylinders.

8.5.3 Sweeping Velocity

The design sweeping velocities should never be less than the design approach velocity and should not decrease along the length of the screen.

Sweeping velocity is defined as the water velocity component parallel to the face of a fish screen (Figure 8-4). A swift sweeping velocity may help move fish and debris past the fish screen and reduce the chance of impingement of juvenile salmonids on the screen material (Cech et al. 2001). Based on laboratory studies, (Cech et al. 2001) a high sweeping velocity (2 ft/s) minimized juvenile Chinook salmon contacts with screens during daylight conditions and maximized downstream passage during day and night conditions. Sweeping velocities between 0.8 and 3 ft/s are generally considered to be optimal. Higher sweeping velocities may be desired to prevent fish from swimming upstream out of the fish screen forebay.

8.5.3.1 In-canal screens

In-canal screens should be angled across the canal to provide a sweeping velocity within the optimal range for the entire range of design conditions (Clay 1995). For screens shorter than 6 feet in length, the screen may be arranged perpendicular to canal flow. The sweeping velocity should remain constant or increase, but may not accelerate faster than 0.2 feet per second per foot (ft/s/ft) toward the bypass entrance.

Studies show juvenile salmonids may resist entering a bypass system when encountering a sudden acceleration in water velocity (Haro et al. 1998). The acceleration criterion is designed to gradually guide fish toward and into the bypass entrance.

In some situations, angling of the screen for sweeping velocity optimization may best be accomplished using a vee-shaped arrangement, as shown in figure 8-5.

Brett and Alderdice (1953), as referenced in Clay (1995), recommend a uniform acceleration rate of no more than 0.1 ft/s/ft of length.

8.5.3.2 On-river screens

Designers have less control over sweeping flow for screens built in a river or on the bank of a river; however, designers should make every attempt to ensure that sweeping velocity does not decrease along the length of the screen. This is to encourage fish to move past the facility and reduce the chance that sediment will deposit along the length of the screen.

8.5.3.3 Quiescent and tidal areas

To mitigate for a lack of sweeping velocity in quiescent and tidal areas, designers should use a design approach velocity not greater than 0.33 ft/s when calculating the effective screen area.

Fish screens in lakes and tidal areas usually cannot meet the sweeping velocity criteria for in-canal or on-river screens. A lower approach velocity is required for these types of screens to allow fish to volitionally swim away from the screen face.

8.5.4 Flow Distribution

The screen design should provide for nearly uniform flow distribution over the screen surface, thereby minimizing approach velocity over the entire screen face. The designer should demonstrate how a uniform flow distribution will be achieved. The maximum deviation from the target design approach velocity is 10%.

Achieving a uniform flow distribution eliminates localized areas of high velocity that have the potential to impinge fish and debris. Methods that could be used to achieve uniform flow distribution include incorporating porosity control features on the downstream side of screens that can be adjusted and training walls to direct flow into the design. Large facilities may require hydraulic modeling to identify areas of flow distribution that are of concern to NMFS.

8.5.4.1 Porosity controls

To ensure uniform flow distribution, most screens should be equipped with some form of tunable porosity controls (i.e. baffles) placed immediately behind the screen. Screen porosity controls should be tuned to achieve approach velocity criteria at the earliest opportunity available. For screens greater than 10 feet tall, NMFS may require that the baffles be capable of controlling flow through the lower parts of screen panels independently of the upper parts. The use of louver-style porosity control baffles should be limited to flat plate screens 6 feet in height or shorter.

A fish screen facility equipped with adjustable baffles to distribute flow uniformly over all wetted screen area is not considered complete until it undergoes a hydraulic evaluation to adjust the baffles. NMFS will determine one or more operating scenarios under which the hydraulic evaluation should take place. For most facilities, hydraulic evaluations should take place at or near the maximum diversion rate but there are cases where a lower diversion rate may be justified. In rare cases, a hydraulic evaluation may be required at two or more operating scenarios to account for various operating conditions such as, but not limited to, the following examples:

- A possible worst-case scenario for a fish screen may be when head waters are too low to submerge all screen area. In such cases, the fish screen hydraulics may need to be studied at a low water condition under a reduced diversion rate.
- At a high-water condition under the full diversion rate.
- At a low water condition under the full diversion rate.

The most common porosity control devices used to date have been louvers, where the angle of the louver can be varied to control the quantity of water flowing through the screen in front of the louver. However, it has been shown that it can be difficult to achieve uniform flow when using louver baffles (e.g., AECOM 2009). A newer method provides a more effective means of tuning screen velocity and flow distribution. It consists of sliding, overlapping porosity plates that are in contact with each other (Figure 8-6). As the moveable plate (vertically adjustable slotted plate; Figure 8-6) is adjusted, it obscures a progressively larger percentage of the perforations of the fixed plate (the stationary slotted plate; Figure 8-6). These panels (baffles) are typically installed in sections no greater than 2 feet wide, which provides fine-scale porosity adjustments for the screen as a whole. Porosity plates with square or slotted openings provide linear adjustability unlike porosity plates with circular openings (i.e., the change in porosity is linearly proportional to the distance the adjustable plate is moved). The adjustable and stationary slotted plates (parts 2 and 3, respectively, in Figure 8-6) should be of the same material or of different materials with similar coefficients of thermal expansion to maintain relative positioning over a range of temperatures. Ultra-high-molecular-weight (UHMW) polyethylene has a high coefficient of thermal expansion and should not be paired with aluminum or steel for this purpose. Using UHMW for both panels works well as the two sheets will slide easily and prevent leakage between sheets, but both panels should be manufactured under identical conditions to ensure holes align well. Metal panels may warp during fabrication which may prevent the panels from mating well.

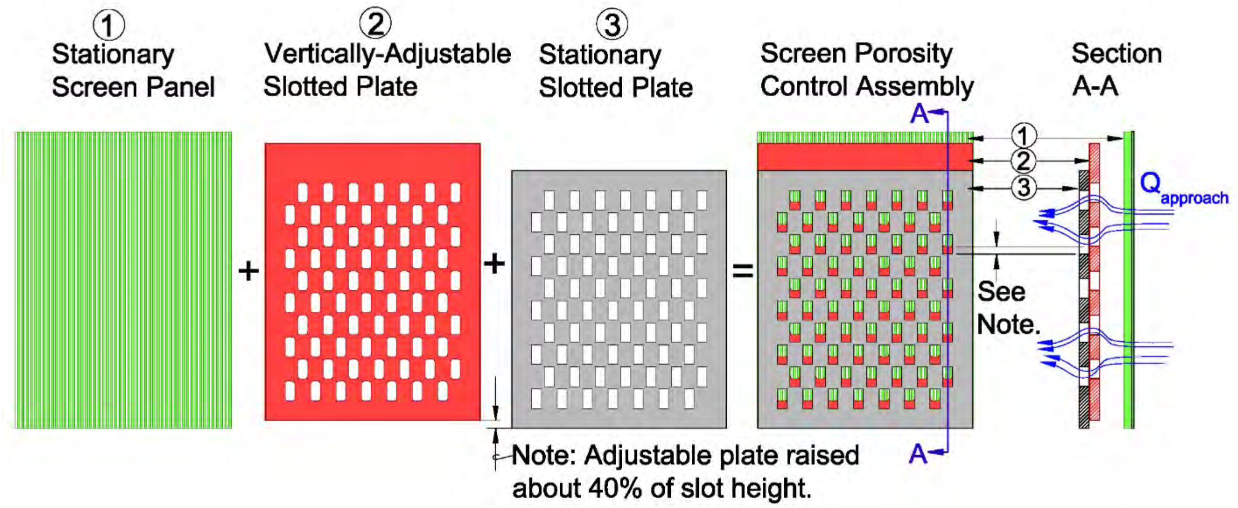

Figure 8-6 Schematic diagram of sliding, overlapping porosity plates used to control porosity and achieve uniform flow conditions through fish screens

8.5.5 Active Screen Cleaning Systems (Active Screens)

All new fish screens should incorporate an automated cleaning system unless the project meets the requirements for passive screens listed in Section 8.5.6.

8.5.5.1 Screen cleaning systems (in-canal or on-river screens)

Screen cleaners should be capable of removing debris from the entire screen surface at least once every 5 minutes and should be operated as required to prevent debris accumulation. Cleaning systems should be designed to operate continuously or on an adjustable timer. On larger screens, the cleaning system should also be triggered whenever the head differential across the screen exceeds 0.3 foot over the clean screen condition. The cleaning system and operations protocol should be effective, reliable, and satisfactory to NMFS. Physical cleaning systems that use a travelling brush or wiper should provide a means for the brush to move away from the screen face at the downstream end of brush travel to allow for the release of accumulated debris.

Fish screens operate most efficiently when they are clean and free of impinged material and attached growth such as algae or sponges (Bell 1991). Fish screen material with a porosity of about 50% will result in negligible head loss at the design approach velocity values identified in Section 8.5.1. Head loss across a screen due to impinged debris increases with the loss of screen open area at a geometric rate (BOR 2006). With increasing head loss, the force impinging debris (or fish) on the screen material also increases, making cleaning the screen more difficult. A screen experiencing 0.3 foot of head loss under an operating approach velocity of 0.4 ft/s may have less than 10% open area due to debris impingement. Under this condition, any weak-swimming fish coming in contact with the screen would experience injury or death due to the excessive forces acting on its body. Additionally, the water diversion would begin to experience significant reduction in diversion rate, and the facility could experience structural damage. Systems to monitor head differential across a screen should be designed to distinguish head loss due to debris impingement from loss caused by wave action or other transient disturbances.

Automated screen cleaning systems are generally categorized as physical, hydraulic, or pneumatic. Physical cleaning systems use a brush or other wiper device to physically remove impinged debris and attached growth and have a long history of successful deployments. NMFS recommends the use of a physical cleaning system for most screen applications; however, there are instances when a hydraulic or pneumatic cleaning system may be more practical.

Hydraulic cleaning systems use high-pressure water jets to remove debris from the screen face and rely on a current (or trash removal systems in the case of traveling belt screens) to remove debris from the vicinity of the screen facility. However, hydraulic cleaning systems do not remove attached growth as effectively as physical cleaning systems and may stimulate the growth of some types of algae.

Pneumatic cleaning systems use compressed air to lift debris from the screen face and rely on a current to remove debris from the vicinity of the screen facility. Pneumatic cleaning systems provide a cleaning force by displacing water primarily in the upwards direction; therefore, air burst cleaning systems in horizontal cylindrical screens may not remove debris impinged on the bottom of those screens. Pneumatic cleaning systems cannot completely remove attached growth and may stimulate the growth of some types of algae. If a screen material were to become occluded with attached growth, the compressed air can impart tremendous buoyant forces on the screen material and the facility overall. Screens employing a pneumatic cleaning system should consider the buoyancy force of trapped air when designing facility foundation and structural components. An additional problem faced by pneumatic cleaning systems is that they are frequently undersized and cannot provide the required volume of air to clean the entire screen face. This is exacerbated by the tendency for the air bubbles to take the path of least resistance, which can often be the clean portions of the screen. Because pneumatic cleaning systems only lift debris from a screen, adequate sweeping flow should be present to move debris downstream away from the water intake.

8.5.5.2 Screen cleaning systems for screens in quiescent and tidal areas

At locations that do not have sufficient sweeping velocity, fish screens should be equipped with an automated cleaning system that is capable of removing debris from the body of water, rather than one that may merely push debris to one side or the other.

Effective cleaning systems rely on the sweeping flow, sometimes combined with the mechanical action of the cleaner, to carry the debris downstream and away from the screen face. Cleaning systems that merely push debris to the side of the screen face are inappropriate for low-velocity locations. This is because without a means to collect and remove debris, the debris lifted from the screen face is likely to become impinged again on the screen face. Additional measures are recommended in these situations to keep floating debris away from the face of a fish screen. Cleaning systems that push debris to the side of a screen are best suited for situations where sweeping flow is present that will carry any debris away from the screen.

8.5.6 Passive Screens

A passive screen, meaning a screen without an automated cleaning system, may only be used when all of the following criteria are met:

- *The combined rate of flow at the diversion site is less than 3* ft^3/s.
- *Sufficient ambient river velocity exists to carry debris away from the screen face.*
- *The site is not suitable for an active screen.*
- *Uniform approach velocity conditions exist at the screen face, as demonstrated by laboratory analysis or field verification.*
- *The debris load is low.*
- *A maintenance program exists that is approved by NMFS and implemented by the water user.*
- *The screen is frequently inspected, and debris accumulations are removed as site conditions dictate.*
- *For cylindrical screens, sufficient stream depth exists at the site to provide a water column of at least 1 screen radius around the screen surface.*
- *The screen is designed to be easily removed for maintenance and to protect it from flood events.*

8.5.7 Screen Submergence and Clearance

Fish screens should be submerged sufficiently to maintain adequate wetted screen area to meet the approach velocity design criterion whenever the diversion is in operation; additional submergence is required in some circumstances.

Effective screen area will be reduced if screen area becomes exposed due to a drop in the water surface. (Section 8.5.2) Under this condition the diversion rate should be adjusted and maintained such that the operating approach velocity does not exceed the design approach velocity criteria at any given time.

8.5.7.1 Vertical flat plate screens

Fish screen facilities with flat, vertical screen panels, or panels inclined less than 20 degrees from vertical, should be designed to remain fully submerged over the entire range of expected water surface elevations. Facility designs may allow for vertical screen panels, or panels inclined less than 20 degrees from vertical, to become partially exposed when water surface elevation is lowered so long as the operating approach velocity does not exceed the design approach velocity.

8.5.7.2 Inclined flat plate screens

Fish screen facilities with flat plate screens installed at an incline of more than 20 degrees but less than 45 degrees from vertical should be designed to remain fully submerged over the entire range of expected water surface elevations. The top of the screen should be submerged a minimum of 1 foot at low stream design flow.

The tops of inclined flat plate screens need to be sufficiently submerged at low stream design flow to prevent hydraulic conditions from forming at the interface between the screen and the water surface that could trap and impinge debris and fish.

8.5.7.3 Rotary drum screens

For rotary drum screens, the design submergence should be between 65% and 85% of the drum diameter. In many cases, stop logs may need to be installed downstream of the drum screens to achieve the design submergence criteria. The stop logs should be located at least two drum diameters downstream from the back of the drum.

Submergence levels greater than 85% of the drum diameter increase the possibility of entrainment over the top of the screen, fish impingement on the screen, and the subsequent entrainment of any fish impinged on the narrow screen area above the 85% submergence level due to the almost horizontal angle of impact of surface-oriented fish. Submergence levels that are less than 65% may reduce the self-cleaning capability of the screen due to the inability of material to temporarily adhere to the screen face and be carried over the top of the screen. Clay (1995) recommends that submergence be between 66% and 75% of the screen diameter. Examples of rotary drum screens are shown in Figures 8-7, 8-8, and 8-9.

Figure 8-7 Large-sized rotary drum screen at the Sunnyside Canal located on the Yakima River near Yakima, Washington

(Note: The person standing upstream of a drum and an intermediate bypass entrance. Water flow direction is from the foreground to the background of the photograph.)

Figure 8-8 Medium-sized rotary drum screen at the Burlingame Diversion located on the Walla Walla River near Walla Walla, Washington

Figure 8-9 Rotary drum screens installed in a water diversion canal and operated (i.e., powered) by paddle wheels

8.5.7.4 Cylindrical screens

Cylindrical screens (other than rotary drum screens) should be submerged to a depth of at least 1 screen radius below the minimum water surface and have a minimum of 1 screen radius clearance between the screen surfaces and natural or constructed features.

These clearances provide escape routes for fish to avoid the draw of water passing through the screen material.

8.5.7.5 End-of-pipe screen submergence and clearance

All end-of-pipe screens should have adequate submergence below the water surface and adequate clearance from the streambed and any structure to provide an escape route for fish approaching the screen. For cylindrical-shaped screens, 1 screen radius or 6 inches, whichever is greater, is normally adequate submergence and clearance.

Submergence and clearance requirements for screens with other shapes will be determined by NMFS on a case-by-case basis. An example of an end-of-pipe screen is shown in Figure 8-10.

Figure 8-10 Typical end-of-pipe screen equipped with "wagon wheels" to elevate the screen off the stream bottom

8.5.7.6 End-of-pipe screen design

All end-of-pipe screens should meet the approach velocity criteria described in Section 8.5.1 and should be located in areas with sweeping velocities great enough to aid in moving fish and debris away from the intake. All end-of-pipe screens should be oriented to take maximum advantage of sweeping velocity in moving fish and debris away from the screen face.

For the purposes of this document, an end-of-pipe screen is defined as a fish screen of any shape that may be attached to the end of a pipe or hose.

8.5.7.7 Horizontal flat plate screens

Design criteria specific to horizontal screens are provided in Section 8.8.

8.5.7.8 Conical screens

Design criteria specific to cone screens are provided in Section 8.9.

8.5.8 Screen Material

Screen materials should be corrosion-resistant and sufficiently durable so as to maintain a smooth, uniform surface over the course of long-term use. Perforated plate surfaces should be smooth to the touch, with the openings punched through in the same direction as the water flow.

Screen materials commonly used include stainless steel, aluminum, plastic, and antifouling alloys containing copper and other metals.

8.5.8.1 Opening size

The maximum screen opening allowed is based on the shape of the opening:

- *Circular screen face openings should not exceed 3/32 inch in diameter (Neitzel et al. 1990a).*
- *Slotted screen face openings should not exceed 0.069 inch (1.75 millimeters [mm]) in the narrow direction (Mueller et al. 1995).*
- *Square screen face openings should not exceed 3/32 inch as measured on a diagonal (Neitzel et al. 1990b).*

8.5.8.2 Open area

The percent open area (porosity) for any screen material should be at least 27%.

8.5.8.3 Gaps

Screens and associated civil works that are exposed to fish should be constructed such that there are no gaps greater than 0.069 inch (1.75 mm). For traveling belt screens or other screens with moving screen material, screen seals should be sufficient to prevent gaps larger than 0.069 inch (1.75 mm) from opening during screen operations.

Clay (1995) notes that care is required in the construction, adjustment, and operation of rotary drum screens. The drum should be fitted carefully in the box to eliminate spaces around the edges that are larger than the openings in the screen mesh.

8.5.9 Civil Works and Structural Features

8.5.9.1 Smoothness

All concrete and steel surfaces, including edges and corners, in areas fish have access to should be smooth to the touch and free from burrs and sharp edges. These can injure fish or people that come in contact with the structure.

8.5.9.2 Pressure differential protection

Larger fish screen structures should be equipped with fail-safe systems that protect the structure from large pressure differentials across the screen face, should the screen become plugged. If a fail-safe system is tripped, the diversion operation should cease until the system can be reset and protection from entrainment into the diversion is restored.

The fail-safe systems installed so that the structural integrity of the facility is never compromised may include governors that reduce the water diversion rate when the pressure differential exceeds a given value. Fused blow-out panels, slide gates, and pressure relief valves may also be acceptable solutions for preventing excessive pressure differentials that can result in screen facility failure.

8.5.9.3 Placement of screen surfaces

The face of all screen surfaces should be placed flush with any adjacent screen bay, pier noses, and walls to the greatest extent possible.

This is needed to allow fish to have unimpeded movement parallel to the screen face and unobstructed access to bypass entrances and routes.

8.5.9.4 Structural features

Structural features should be provided to protect the integrity of fish screens from large debris and to protect the facility (Bell 1991).

A trash rack, log boom, sediment sluice, and other measures may be required to protect the structural integrity of a fish screen, especially for on-river screens.

8.5.9.5 Civil works

The civil works should be designed in a manner that prevents undesirable hydraulic effects, such as eddies and stagnant flow zones, that may delay or injure fish or provide predator habitat or openings that allow predators to access the facility.

8.5.9.6 Canal dewatering and fish salvage

For in-canal screens, the floor of the screen civil works should be designed to allow fish to be routed back to the river safely when the canal is dewatered. An acceptable fish salvage plan should be developed in consultation with NMFS and included in the O&M plan.

Canal dewatering and fish salvage may be accomplished via the bypass system or by using a small gate and drain pipe, or similar provisions, to drain all flow and fish back to the river. The operations and maintenance plan should address the rate at which water can be drained back to the river to allow fish to move volitionally to the river to minimize stress. Trained personnel should be on site to rescue stranded fish. A rescue plan may need to consider collect lamprey larvae (ammocoetes) that may be living in sediments deposited in a diversion canal, and possibly even in sediments behind a fish screen.

8.6 Bypass Systems

Bypass systems are required for in-canal screens to provide a safe and efficient means of routing fish from the area in front of in-canal screens to the stream from which they were diverted.

8.6.1 Bypass Design

Bypass systems should work in tandem with the fish screens to move all fish present (target and non-target species and all life stages) from the area in front of the screens and return them back to the stream or river (or to a holding pool, in the case of collection and transport facilities) with a minimum of injury and delay (Clay 1995).

8.6.2 Bypass Entrance

The bypass entrance should be located at the downstream terminus of the fish screens and should be designed to allow downstream migrants to easily locate and enter the bypass (Clay 1995). The screen and any guidewalls should naturally funnel downstream migrants and flow to the bypass entrance. For screens that are less than 6 feet in length and are constructed perpendicular to canal flow, the bypass entrance(s) may be located at either end (or both ends) of the screen.

8.6.2.1 Flow control

Each bypass entrance should be capable of controlling the flow rate through that entrance. If an orifice plate is used, the opening should have smooth, rounded-over edges and the opening should be large enough to safely pass the largest fish that may be entrained into the diversion canal. For steelhead kelts, the opening should be at least 8 inches in the smallest dimension.

Typically, an overflow weir is used to regulate flow through the entrance. Orifice plates are discouraged from being used because they may hinder fish from moving into the bypass and they are more likely to clog with debris.

8.6.2.2 Minimum velocity

The minimum bypass entrance flow velocity should be greater than 110% of the maximum canal velocity upstream from the bypass entrance. At no point may flow decelerate along the screen face or in the bypass channel. Bypass flow amounts should be of sufficient quantity to ensure these hydraulic conditions are achieved whenever downstream passage is required.

8.6.2.3 Lighting

Lighting conditions upstream of a bypass entrance should be ambient and extend downstream to the structure or device controlling bypass flow. In situations where transitions from light to dark conditions or vice versa cannot be avoided, they should be gradual or occur at a point in the bypass system where fish cannot escape the bypass and return to the canal (i.e., at a location where bypass flow velocity exceeds fish swimming ability).

8.6.2.4 Dimensions

For diversions greater than 3 ft^3/s*, the bypass entrance should extend from the floor of the canal to the water surface and be at least 18 inches wide (Ruggles and Ryan [1964] as cited in Clay [1995]). For diversions of 3* ft^3/s *or less, the bypass entrance should be a minimum of 12 inches wide. The bypass entrance should be sized to accommodate the entire range of bypass flow, utilizing the criteria listed in Section 8.6.*

8.6.2.5 Weirs

For diversions greater than 25 ft^3/s and where weirs are incorporated into the bypass entrance, the minimum water depth over the weir is 1 foot; however, a depth of 1.5 feet over a weir is preferred. Similarly, weir width should be a minimum of 1.5 feet; greater widths are preferred.

Juvenile outmigrating salmonids appear to be less reluctant to go over a weir when water depth over the weir is greater than 1 foot (Manning et al. 2005). As a general rule and based on field observations, NMFS believes that water depth over a weir should be at least 1 foot, but if additional flow is available, a depth of 1.5 feet or even 2 feet is preferred. Manning et al. (2005) reported significantly faster travel times for steelhead moving through a dam forebay when the crest of an inflatable spillway was deformed and water depth and velocity over the spillway were increased. Water depth increased from 0.13 foot to 2.4 or 3 feet, and water velocity increased from 0.2 ft/s to 3.9 or 4.6 ft/s during test replicates. Also, wider passageways are preferred; the recommended minimum width is 1.5 feet.

8.6.2.6 Intermediate bypass entrances

The fish screen design should include intermediate bypass entrances if the design approach velocity is greater than 0.33 ft/s and the sweeping velocity may not convey fish to a terminal bypass entrance within 60 seconds, assuming that fish are transported along the length of the screen face at a rate equal to the sweeping velocity.

Clay (1995) notes that if the screen is extremely long, it may be advisable to place bypass entrances at intervals across the face.

8.6.2.7 Training walls

All intermediate bypass entrances should have a training wall to guide fish into the bypass system.

8.6.2.8 Flow acceleration

All bypass entrances should be designed to gradually accelerate flow into the bypass entrance and between the entrance and the flow control device at a rate not to exceed 0.2 ft/s per linear foot.

Juvenile salmonids have been observed to resist moving with water flow that accelerates too quickly (Haro et al. 1998). Brett and Alderdice (1953), as referenced in Clay (1995), recommend a uniform acceleration rate of no more than 0.1 ft/s per linear foot.

8.6.2.9 Secondary dewatering screens

Secondary dewatering screens should meet all design criteria (e.g., approach velocity, sweeping velocity, cleaning, and screening material) of the primary screens.

Secondary dewatering screens may be used within the bypass system to reduce bypass flow.

8.6.3 Bypass Conduit and System Design

8.6.3.1 Bypass conduit

Depending on the site-specific conditions, the bypass conduit can be either U-shaped flume or round pipe.

8.6.3.2 Surface smoothness

The interior surfaces and joints of bypass flumes or pipes should be smooth to the touch to provide conditions that minimize turbulence, the risk of catching debris, and the potential for fish injury.

Pipe joints may be subject to inspection and approval by NMFS prior to completion of the bypass. Every effort should be made to minimize the length of the bypass pipe while meeting the hydraulic criteria listed in Sections 8.6.3.4 through 8.6.3.6.

8.6.3.3 Bypass pipe diameter

The minimum bypass pipe diameter is 10 inches.

The bypass flume or pipe diameter is a function of the bypass flow and slope, and the diameter incorporated into the bypass pipe design should achieve the velocity and depth criteria identified in Sections 8.6.3.5 and 8.6.3.6. Bypass flume or pipe hydraulic characteristics should be calculated to determine a suitable pipe diameter.

8.6.3.4 Bypass flow rate

The minimum design bypass flow is 5% of the total diverted flow rate unless otherwise approved by NMFS.

While the minimum bypass flow is 5% of the total diverted, larger bypass flow proportions will aid in cleaning the fish screen and will guide fish toward the bypass system more quickly.

8.6.3.5 Bypass velocity

Water velocity in the bypass conduit should be between 6 and 12 ft/s for the entire operational range of bypass flow, and should always be greater than 2 ft/s. If higher velocities are approved by NMFS, special attention to pipe and joint smoothness should be demonstrated by the design.

Bypass systems with velocities that are less than 2 ft/s can accumulate sediment deposits within the bypass system.

8.6.3.6 Water depth

The design minimum depth of free surface flow in a bypass pipe should be at least 40% of the bypass pipe diameter unless otherwise approved by NMFS.

8.6.3.7 Closure valves

Closure valves cannot be used within the bypass system unless specifically accepted by NMFS.

8.6.3.8 Pumps

Fish should transition through bypass system components via gravity flow and never be pumped. Use of a pump would only be acceptable if NMFS required the installation of a bypass where insufficient head was available to support gravity flow.

8.6.3.9 Downwells and flow transitions

Downwells should be sized based on an EDF between 8 to 10 ft-lb/ft^3*/s. Fish should never free-fall within a bypass system pipe or enclosed conduit. Downwells should be designed to produce a free water surface when turbulence, geometry, and alignment aspects of the design are considered.*

Equation 8-1 should be used to calculate downwell volume.

$$\mathrm{V} = \frac{(\gamma)(Q_{bypass})(H)}{EDF} \tag{8-1}$$

where:

V = pool volume (ft^3)
γ = unit weight of water (62.4 lb/ft^3)
Q_{bypass} = bypass flow, in ft^3/s
H = height of drop between water surfaces, in feet
EDF = energy dissipation factor, from 8 to 10 ft-lb/ft^3/s

8.6.3.10 Pressurized flow

Flow in all types of fish conveyance structures should be open channel (i.e., not pressurized). Bypass systems should be vented or open to the atmosphere. If a pressurized bypass conveyance is required by site constraints, pressures in the bypass pipe should remain equal to or above atmospheric pressures. Transitions from pressurized to non-pressurized conditions within a bypass pipe, and vice versa, should be avoided.

8.6.3.11 Bends

The ratio of bypass pipe center-line radius of curvature (R) to pipe diameter (D), or R/D, should be greater than or equal to 5. If mitered pipe fittings are used to change conveyance direction, the maximum miter angle allowed is 15 degrees (11.25 degrees is preferred). If multiple miter joints are used to change the direction of the conveyance more than 15 degrees, *each miter joint should be separated by length(s) of pipe that are sufficiently long to achieve the required ratio of R/D for the bend assembly as a whole.*

In situations that involve super-critical flow velocities, R/D ratios greater than 5 may be required. Bends should be minimized in the layout of bypass systems due to their potential to facilitate debris clogging and produce turbulence.

8.6.3.12 Debris management

Bypass pipes or open channels should be designed to minimize debris clogging, sediment deposition, and facilitate their inspection and cleaning as necessary.

8.6.3.13 Access for maintenance

Access for maintenance inspections and debris removal should be provided at locations in the bypass system where debris accumulations may occur. Bypass systems greater than 150 feet in length should include access ports at appropriate spacing to allow for the detection and removal of debris.

Alternate means of providing for bypass pipe inspection and debris removal may be considered by NMFS.

8.6.3.14 Natural channels and fishways

Natural channels and fishways may be used as a bypass transit channel under limited circumstances and only upon approval by NMFS.

Use of natural channels and fishways as juvenile fish bypasses expose fish to increased delay and predation (compared to a typical bypass system). Use of a natural channel will require that adequate water depth and velocity, flow volume, protection from predation, and good water quality conditions can be provided. The potential for increased predation is typically extremely high for natural channels due to the high concentration of fish in a small amount of flow in the bypass system and area. Additionally, sufficient flow would be required to mitigate for any seepage occurring within the bypass system while maintaining adequate water depth and velocity. If a natural channel is to be used, special consideration needs to be given to where the bypass channel connects to the river.

8.6.3.15 Sampling facilities

Sampling facilities installed in the bypass conduit should not impair the operation of the facility during non-sampling periods in any manner.

Refer to Appendix F for additional information on the design of juvenile fish sampling facilities.

8.6.3.16 Hydraulic jumps

There should be no hydraulic jump(s) within a bypass system.

8.6.4 Bypass Outfalls

8.6.4.1 Location

Bypass outfall locations should meet the following conditions:

- *Bypass outfalls should be located to minimize predation by selecting an outfall location that is free of eddies and reverse flow and does not place bypassed fish into an area of known predator habitat (Bell 1991).*
- *The point of impact for bypass outfalls should be located where ambient river velocities are greater than 4 ft/s when in operation (Shively et al. 1996).*
- *Bypass outfall locations should provide good egress conditions for juvenile fish exiting the bypass and re-entering the stream channel (Bell 1991).*
- *The bypass flow should not impact the river bottom or other physical features at any stage of river flow. Bypass outfalls should be located where the receiving water is of sufficient depth to ensure that fish injuries are avoided at all river and bypass flows.*
- *The bypass outfall should not release fish into areas where conditions downstream from the bypass discharge point will pose a risk of injury, predation, or stranding (Bell 1991). For example, bypass outfalls should avoid discharging fish into areas from which they can enter reaches where flows run subsurface. Also, bypass outfalls should not discharge in the vicinity of any unscreened water diversion or near eddies that may be habitat for predator fish.*

8.6.4.2 Impact velocity

Maximum bypass outfall impact velocity (i.e., the velocity of the bypass flow as it enters the receiving water) should be less than 25 ft/s, including both the vertical and horizontal velocity components (Bell 1991).

Impact velocity may be greater for very large bypass flows that discharge a confined jet that plunges deep into the receiving waters and results in fish deceleration occurring over a longer distance compared to a broader jet not plunging far into the receiving water. For example, Johnson et al. (2003) reported no injuries to juvenile Chinook salmon that were returned to the Columbia River in bypass flow greater than 1,000 ft^3/s and when impact velocities ranged up to 50 ft/s.

8.6.4.3 Predation prevention

Predator control systems may be required in areas with a high potential for avian predation.

Predation suppression systems include bird wires (thin wires) strung over the bypass outfall area to prevent predatory birds from flying near the outfall or diving at fish exiting the outfall and high-pressure water spray nozzles over the outfall area to deter birds.

8.6.4.4 Adult fish attraction to bypass discharge

Bypass outfall discharge into the receiving water should be designed to avoid attracting adult fish to the discharge. If the potential exists that adult salmonids may be attracted to and *jump at the bypass outfall discharge, the design of the bypass outfall should include a provision for adult fish to land safely in a zone or location after jumping.*

8.7 Water Drafting

Water drafting is the practice of pumping water for short durations from streams or impoundments at low pumping rates to fill water trucks or tanks, often for dust suppression or wildfire management. Water drafting may also be used to dewater a construction site or temporarily divert water around a construction site. When dewatering a construction site an approved dewatering plan should be followed to rescue and relocate stranded fish.

The specifications below are primarily for the protection of juvenile anadromous salmonids in waters where they are known to exist. However, they may also be applied to protect a host of other aquatic organisms.

8.7.1 Water Drafting Operating Guidelines

When engaged in water drafting operations, the following restrictions apply:

- *Operations are restricted to 1 hour after sunrise to 1 hour before sunset.*
- *The pumping rate should not exceed the lesser of 350 gpm or 10% of the streamflow.* The operator should measure streamflow prior to initiating pumping to ensure the pumping rate will not exceed 10% of streamflow.
- *Pumping should be restricted to locations where the water is deep and flowing; pumping from isolated pools should be avoided.*
- *Pumping should not result in a drawdown of the water surface elevation by more than 10% in the area where pumping is taking place nor in any riffles downstream.*
- *Pumping should be terminated when the water truck or tank is full.*
- *An operator should be present during pumping operations and observe stream conditions during pumping to ensure the above restrictions are being met.*
- *A fish screen should be used when pumping. Fish screens should meet guidelines for end-of-pipe screens of this document (Section 8.5.7.5). The operator should be capable of cleaning debris from the fish screen when needed and possess the equipment necessary to do so.*
- *Water drafting truck parked on streambeds, floodplains, or within a riparian corridor should use drip pans or other devices such as absorbent blankets, sheet barriers or other materials as needed to prevent soil and water contamination from motor oil or hydraulic fluid leaks*

8.7.2 Fish Screens for Water Drafting

Design and operation criteria and guidelines for use of fish screens required during pumping operations for water drafting are described in Section 8.7.2.1 through 8.7.2.6.

8.7.2.1 Design

Fish screens for water drafting may be off-the-shelf designs or custom fabricated. The fish screen should be sturdy enough to not compromise the integrity of the screen during pumping when the screen becomes clogged with debris.

The screens may be cylindrical or rectangular in shape as long as the other screen criteria are met.

8.7.2.2 Cleaning

Fish screens for water drafting do not need to have an automated cleaning system; however, an operator should regularly clean the screen during the pumping operation to maintain the minimum amount of screen area that is required to not be occluded with debris.

8.7.2.3 Approach velocity

The design approach velocity should not exceed 0.33 ft/s.

Based on a pumping rate of 350 gpm, the screen for this flow rate should have at least 2.4 ft^2 of surface area.

8.7.2.4 Uniform flow

Screens should be designed to draw water relatively uniformly over the entire screen area.

Screens may require internal baffles to achieve this criterion.

8.7.2.5 Screen porosity and openings

The screen material should have a porosity of at least 27% and have openings consistent with criteria provided in Section 8.5.8.1. The screen surface should be smooth to the touch.

The size of screen openings depends on the shape of the openings.

8.7.2.6 Screen support and submergence

Fish screens should be supported off the stream bottom by at least 6 inches and be submerged by at least 6 inches (Figure 8-10).

8.8 Special Case: Horizontal Screens

Horizontal flat plate screens operate fundamentally differently than conventional cylindrical and vertically oriented screens. This fundamental difference relates directly to fish safety. When inadequate flow depth exists with vertically oriented screens, the bypass will usually remain operational, and there is only a slight increase in the potential for fish to become impinged on the surface of the screen. In contrast, when the water level on horizontal screens drops and most or all diverted flow goes through the screens, the bypass flow is greatly reduced or ceases completely and there is a high likelihood that fish will become impinged and expire on the screen surface.

8.8.1 NMFS Engineer Involvement

Since site-specific design considerations are required, NMFS should be consulted throughout the development of a horizontal screen design.

NMFS considers horizontal screens to be biologically equivalent to conventional screens if the design and operation of a horizontal screen meets the criteria and conditions listed in Section 8.8.

8.8.2 Design Process

The horizontal screen design process should include an analysis to verify that sufficient hydrologic and hydraulic conditions exist within the stream so as not to exacerbate a passage impediment in the stream channel or in the off-stream conveyance (including the screen facility and bypass system). This analysis should conclude that all of the following criteria can be achieved for the entire fish passage season, as defined in Chapter 2. If the criteria listed here in Section 8.8 cannot be maintained per this design analysis, a horizontal screen design should not be used at the site. If this analysis concludes that the removal of the bypass flow required for a horizontal screen from the stream channel results in inadequate passage conditions or unacceptable loss of riparian habitat, other screen design styles should be considered for the site and installed at the site if the other screen styles will reduce the adverse effects to passage or riparian habitat.

8.8.3 General Criteria

The screen and bypass criteria specified in Chapter 8 apply to horizontal screens. The exceptions to these general criteria are noted in Section 8.8.4.

8.8.4 Specific Criteria

As described in Section 8.8, horizontal flat plate screens are fundamentally different than conventional cylindrical and vertically oriented screens. Specific criteria and guidelines that apply only to horizontal screens are described in Sections 8.8.4.1 through 8.8.4.13.

8.8.4.1 Site limitation

Horizontal screens should be installed in an off-river canal.

Due to the need for very precise hydraulic controls, horizontal screens are not suitable for in-river or in-stream installations.

8.8.4.2 Flow regulation

For a horizontal screen facility to function properly, the site should provide a headgate facility that maintains a water diversion rate that is sufficient and consistent enough to allow the fish screen and bypass system to meet the criteria listed in this section (Section 8.8.4).

8.8.4.3 Channel alignment

Horizontal screens should be installed such that the approaching conveyance channel is parallel to, and in line with, the screen channel (i.e., there is no skew), and uniform flow conditions exist across the upstream edge of the screen. A straight channel should exist for at least 20 feet upstream of the leading edge of the screen, or for a distance of up to two screen channel lengths if warranted by approach flow conditions in the conveyance channel. Horizontal screens should be installed such that a smooth hydraulic transition occurs from the approach channel to the screen channel and there are no areas of abrupt flow expansion, contraction, or separation.

Flow conditions that require a longer approach channel include turbulent flow, supercritical hydraulic conditions, or uneven hydraulic conditions in a channel cross section.

8.8.4.4 Bypass flow depth

The bypass flow should pass over the downstream end of the screen at a depth of at least 1 foot.

8.8.4.5 Bypass flow amount

Bypass flow amounts should be sufficient to continuously provide the hydraulic conditions specified in this section and those specified in Section 8.6. In general, for diversion rates of less than 100 ft^3*/s, approximately 15% of the total diverted flow should be used as bypass flow. For diversion rates greater than 100 ft*^{3}*/s, approximately 10% of the total diverted flow should be used for bypass flow. Small horizontal screens may require up to 50% of the total diverted flow be dedicated for bypass flow. The amount of bypass flow should be approved by NMFS.*

Bypass flow is used for transporting fish and debris across the plane of the screen and through the bypass conveyance back to the stream.

8.8.4.6 Diversion shut-off

If hydrologic analysis demonstrates that the diverted flow rate could drop below the flow rate required to satisfy the diversion and supply the bypass with its full design flow rate, the horizontal screen design should include a means to automatically shut off the diversion flow or a means to route all diverted flow back to the originating stream.

8.8.4.7 Sediment removal

The horizontal screen design should include a means to simply and directly remove sediment that accumulates under the screen without compromising the integrity of the screen while water is being diverted.

8.8.4.8 Screen approach velocity

Screen approach velocity should be less than 0.25 ft/s and uniform over the entire screen surface area. If the horizontal screen is equipped with an automated mechanical screen cleaning system, screen approach velocity should be less than 0.4 ft/s and uniform over the entire screen surface area.

The best available science regarding horizontal screens is evolving. Therefore, NMFS may require a lower approach velocity or may specify a minimum ratio of sweeping velocity to approach velocity. Recent prototype development has demonstrated that better self-cleaning of a horizontal screen is achieved when the ratio of sweeping velocity and approach velocity exceeds 20:1, and approach velocities are less than 0.1 ft/s.

8.8.4.9 Screen sweeping velocity

Sweeping velocity should be maintained or gradually increase for the entire length of screen. Sweeping velocity should never be less than 2.5 ft/s or an alternate minimum velocity approved by NMFS that is based on an assessment of sediment load in the water diversion system.

Higher sweeping velocities may be required to achieve reliable debris removal and to keep sediment mobilized.

8.8.4.10 Post-construction inspection and testing

Upon completion of screen construction and watering up of the system, velocity testing should be performed to ensure that approach velocity is uniform over the entire screen area. For the purpose of this test, uniform is defined as all test velocities falling between 90% and 110% of the nominal screen approach velocity. Sweeping velocity should also be verified to be in a uniformly downstream direction to ensure that fish and debris are bypassed rapidly.

8.8.4.11 Monitoring and maintenance

Daily inspection and maintenance (if required) should occur on the screen and bypass system to maintain operations consistent with these criteria.

8.8.4.12 Post-construction monitoring

Post-construction physical and operational monitoring of all components of new horizontal screen facilities should occur for at least the first year of operation and cover all periods of operation.

8.8.4.13 Inspection log

An inspection log should be kept for each horizontal screen. A copy of the inspection log should be provided annually to the NMFS design reviewer upon request, who will review the inspection log and may make recommendations for the next year of operation. The inspection log should include:

- *Inspection dates, times, and the observer's name*
- *Water depth at downstream end of the screen (i.e., the entrance to the bypass)*
- *Debris present on the screen, including any sediment retained in the screen openings*
- *Fish observed on or passing over the screen surface*
- *Operational adjustments and maintenance performed on the facility*

8.9 Special Case: Conical Screens

Conical (or cone) screens were developed for small water diversions in shallow tidal areas. They have been installed on pumped and gravity diversions since 1996. The conical shape provides a large amount of screen area in a small footprint (Figure 8-11). The screen units sit on a constructed steel or concrete platform connected to a diversion pipe. They have rotating brush cleaning systems that are driven by hydraulic or electric motors, some of which run off batteries charged by solar panels. Turbine-driven units, where the cleaning system is driven by a propeller installed in the conveyance pipe and mechanically connected to the cleaning system through a large gear reducer, have been used successfully in a few cases. For turbine-driven units, screen cleaning does not occur unless water is being diverted. A turbine-driven cleaning system may not be appropriate for seasonal use unless the units are removed seasonally.

Figure 8-11 Conical screen

Conical screens were designed for use on inverted siphons in tidal areas where the screen units would be partially exposed at lower tides. Because they were used only on siphons, as the source water stage decreased on an ebb tide and screen area became exposed, the rate of diversion decreased proportionally so the operational approach velocity never exceeded the design approach velocity. As a side benefit, the daily exposure to air and sunlight helped keep the screen surface free of algal growth.

8.9.1 Locations

Conical screens should be sited in locations where fish have a clear escape route past a screen. They should not be installed in enclosed vaults or in close proximity to a structure that prevents fish from freely moving away from the screen.

8.9.1.1 Maximum ambient velocity

Conical screens are acceptable for use in lakes, reservoirs, backwater channels, and tidal areas where the ambient velocity does not exceed 1 ft/s. They may be used where the current is greater than 1 ft/s if other (i.e., superior) screening alternatives are not available, an appropriate flow distribution baffle system is used, and the design is acceptable to NMFS.

8.9.2 Approach Velocity

The maximum design approach velocity for conical screens is 0.33 ft/s.

The minimum effective screen area required for an installation may be determined by dividing the maximum diversion rate in ft^3/s by 0.33 ft/s.

8.9.3 Flow Uniformity

Conical screens have been equipped with two types of baffle systems to distribute flow over all screen area. Early screens used an inverted cone design that divided the interior space into upper and lower areas. That design performed well in quiescent water with a narrow plenum, but field testing in a live stream showed that the inverted cone baffle did not balance flows well when flow was moving past the screen. In fact, the approach velocity on the leading edge of the screen unit could exceed the design value even when not diverting water because stream flow could enter the upstream side and exit the downstream side. To solve this problem, a new baffle design was developed.

The BOR’s Technical Service Center near Denver, Colorado, developed a relatively complex baffle system with vertical dividers and a central flow balancing cylinder to distribute intake flow more evenly into four hydraulically-isolated quadrants (Hanna 2011). The vertical dividers prevented stream flow from passing completely through the screen unit. The manufacturer routinely includes a simplified internal baffle based on the USBR design in all of their conical screens.

BOR also tested an external baffle system to control how water approaches and passes into a conical screen (Hanna 2013). The external baffle concept created more uniform flow into the screen but debris could accumulate on the baffles in a riverine setting; therefore, NMFS recommends the use of an internal baffle system to allow stream flow to move debris and fish away from the diversion intake.

8.9.4 Effective Screen Area

All screen area submerged greater than 6 inches may be considered as effective screen area (Figure 8-12). If conical screens become exposed to air, the rate of diversion should be reduced to meet the design approach velocity criterion (Section 8.9.2) due to the reduced effective screen area.

When conical screens become exposed to air in tidal or backwater environments, the top 6 inches of screen material below the water surface may become occluded by debris.

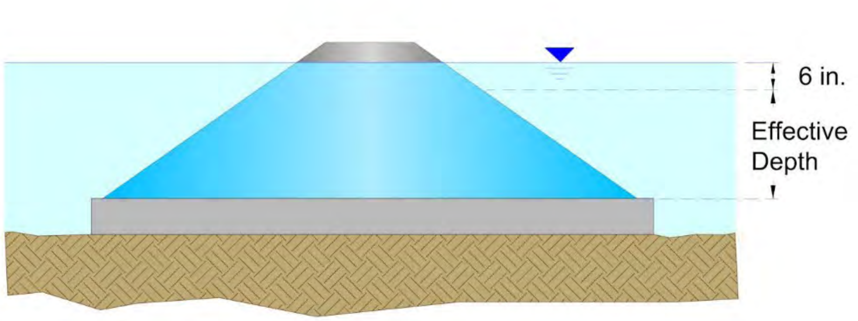

Figure 8-12 Elevation view of a conical fish screen showing the effective depth

8.9.5 Submergence

Conical screens may be operated while partially exposed above water but should be designed such that the screen is sufficiently submerged to maintain adequate effective screen area for the rate of diversion at any given moment.

The definition of effective screen area is provided in Section 8.5.2.

8.10Project Inspections and Evaluations

8.10.1 General

Inspections and evaluations should be performed at each appropriate phase of a project. This includes during construction, when the project is substantially complete but not yet operating, and after construction.

Inspections of project details and evaluations of project systems are necessary to ensure that a fish screen project functions as intended.

8.10.2 Quality Assurance and Quality Control

An on-site project engineer or inspector should be assigned to every project. The inspector should provide notice to NMFS of key milestones in the construction process and access to the site for inspections.

The inspector is responsible for ensuring construction specifications and tolerances are met and for testing all project systems. NMFS should be allowed to witness testing of project systems.

8.10.3 Inspection

8.10.3.1 During construction

During the course of construction, activities may preclude various facets of screen and bypass construction from being inspected. In instances where these facets of construction may pose a risk of injury or mortality to fish later on during normal operations, the on-site engineer or inspector should inspect these items prior to construction continuing. In some instances, NMFS may require that a NMFS inspector be given the opportunity to inspect these items prior to construction continuing. If this is the case, NMFS will provide the project proponent with a list of screen and bypass elements that will require NMFS inspection during the course of construction. These may include (but are not limited to) the following:

- *Bypass pipe joints, either welded or mechanical*
- *Bypass downwells*
- *Bypass outfalls, if protected during construction by a cofferdam*
- *Any components that convey water that may contain fish*

8.10.3.2 Facilities near completion

Nearly completed fish screen and bypass facilities should be made available to NMFS staff for inspection prior to watering up to verify that the screen is operable in a manner consistent with the design criteria. NMFS staff may inspect construction quality, pipe joints, fit, and finish of components exposed to fish.

8.10.3.3 Evaluations

At some sites, screen and bypass facilities may need to be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved and debris removal systems are effective. At the discretion of NMFS, this may entail a complete biological evaluation, especially if waivers to screen and bypass criteria are granted, or merely a visual inspection of the screen in operation if the screen is relatively simple and designed and constructed to the standard criteria listed throughout the chapters of this document.

8.10.3.4 Mechanical and electrical systems evaluations

Testing of mechanical and electrical systems should be performed before initiating operations.

This should include testing of any alarm systems, including audible alarms, pagers, and other warning systems; data recording equipment, emergency shut-off systems, cleaning systems, actuators, and solenoids; backup systems; and other mechanical and electrical systems. These evaluations should be included in a list of final items to be completed by the contractor and carried out prior to contractor demobilization and should be written into the construction contract.

8.10.3.5 Automatic cleaning systems evaluations

Cleaning systems and their components should be tested in the dry, when possible, and again when screen facilities are operable, but prior to initiating normal operations.

Using O&M documentation of the cleaning systems provided by the designer or fabricator, all cleaning systems should be tested in automatic and manual operating modes. These evaluations should be included in a list of final items to be completed by the contractor and carried out prior to contractor demobilization and should be written into the construction contract.

8.10.3.6 Biological evaluations

Depending on the size of a project, any variances from established criteria, and the complexity and uniqueness of the project design, NMFS may require that biological evaluations be conducted on a fish screen facility. The biological evaluations may involve monitoring fish that naturally inhabit the site or releasing test fish obtained from another source such as a hatchery. If biological evaluations are required, the applicant must submit a biological evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. Biological evaluations must be performed by qualified personnel using established methods.

The biological evaluations could include monitoring to assess the number of fish being injured or delayed, entrained behind the fish screen, impinged on the fish screen and evidence of fish predation associated with the water intake structure. The biological evaluation study plans should describe the source of fish, test equipment, and methods that will be used; the statistical analysis that will be conducted and associated precision of any tests; and the proposed frequency, timing, and duration of any monitoring and testing.

8.10.3.7 Juvenile fish bypass systems

Hydraulic testing of juvenile fish bypass systems is required to create rating curves for gate openings needed to achieve prescribed flow rates, and to ensure that the bypass system hydraulics conform to hydraulic design criteria.

Biological testing of juvenile bypass systems may be required to ensure that juvenile fish are being returned safely to the main river channel. If biological evaluations are required, the applicant must submit a biological evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. Biological evaluations should be performed by qualified personnel using established methods.

The study plan should consider the complexity of the bypass system and the size and number of juvenile fish likely to be present during water diversion operations.

8.10.3.8 Fish screen hydraulic evaluations

The hydraulic evaluations described in this section are required for fish screen facilities. Appendix E (Performing Hydraulic Evaluations) provides information on how to conduct hydraulic evaluations.

Hydraulic evaluations are required on all screens equipped with adjustable flow tuning baffles designed to distribute flow evenly over all wetted screen areas, and where confirmation of hydraulic conditions at a fish screen is necessary. The applicant should submit a hydraulic evaluation study plan to NMFS for review and approval prior to completing a substantial portion of the project. The final hydraulic evaluation should be conducted under the high design (diversion) flow unless otherwise agreed to by NMFS.

Hydraulic evaluations involve taking water velocity measurements at locations that are oriented both perpendicular (i.e., the approach velocity) and parallel (i.e., the sweeping velocity) to the screen face. Hydraulic evaluations are used on screen facilities with flow-balancing baffles to adjust the baffles to achieve uniform approach velocities across all wetted screen surfaces. Baffle systems should be adjusted in this manner prior to initiating normal water diversion operations. The hydraulic evaluation plan should include the proposed equipment, methods, and time schedule that will be used when conducting the hydraulic evaluations.

In the event that hydraulic conditions are found by NMFS to be unacceptable and the existing baffle system is incapable of adjusting flows to meet the hydraulic criteria, physical modifications to the facility may be required along with follow-up hydraulic evaluations of the modified hydraulic conditions.

Hydraulic evaluations should be carried out as soon as practical to ensure the facility is operating as near to design criteria as practical using the guidelines described in Appendix E. If the facility cannot be operated at an optimal diversion rate for the hydraulic evaluation within the first year of operation, the facility owner should seek to extend the deadline for carrying out the hydraulic evaluation from NMFS.

Hydraulic evaluations should be performed by qualified personnel using established methods.

A final hydraulic evaluation report should be provided to NMFS that includes the following:

- *A description of site and environmental conditions at the time of testing*
- *A list of technicians performing tests*
- *The materials and methods employed in the test, including locations of all velocity measurements in the final iteration of baffle adjustments, including justification of the number of points at which velocity measurements were taken*
- *A description of the final baffle settings*
- *The approach and sweep velocity data for all measured points in the final iteration of baffle adjustments presented in a table format*
- *The approach and sweeping velocity values for all measured points in the final iteration of baffle adjustments presented in a graphical format*

- *An objective evaluation of hydraulics at the site and anticipated screen performance*

8.11 Operations and Maintenance Plans

8.11.1 General

All fish screen projects should have an approved O&M plan. The plan should include procedures deemed acceptable by NMFS for operating the screen facility under a variety of environmental conditions, the full range of water diversion operations, and the procedures for periodic inspections and maintenance required to achieve fish screening effectiveness over the design life of the facility.

The purpose of an O&M plan is to ensure that the facility performs as designed and is providing effective fish screening over the life of the project. The O&M plan is the manual that describes exactly how the fish screen facility will be operated and maintained as well as procedures and personnel to contact in the event of emergencies. The following guidelines provide a template that can be used to prepare an O&M plan.

8.11.2 Operations

The O&M plan should include procedures that will ensure the fish screen meets all previously agreed to criteria. In addition to normal operation conditions, the plan should include information, procedures (including fish salvage plans), and personnel contact information in case of emergencies.

The O&M plan should include the seasonal maximum diversion rates agreed to in the design process, other criteria identified in the project description, project mitigation measures, and any applicable permit conditions or ESA Biological Opinion requirements. Additionally, the plan should address specific criteria on pump use at pumped diversions and gate use at gravity diversions that are required to achieve uniform approach velocities across screen surfaces.

8.11.2.1 Posting

A list of operating procedures that is easy to follow should be posted in a highly visible location at the water diversion site.

The list should include specific operating procedures needed to achieve uniform approach velocities across the screen face at various diversion rates. Emergency power cut-off switches, pressure relief valves, instructions for operating any auxiliary equipment, and emergency shutdown procedures should also be placed in locations that are easily found.

8.11.3 Maintenance

The diversion owner should incorporate maintenance procedures recommended by the designers, contractors, and suppliers into the O&M plan.

The maintenance section of the O&M plan should specify the frequency and interval for performing each maintenance procedure. The project owner is responsible for obtaining documentation (including specifications and maintenance requirements) from suppliers of off-the-shelf and custom systems and equipment and ensuring that all necessary maintenance equipment, tools, and component parts are readily available and on-hand for the maintenance. The O&M manual should identify activities that need to be carried out on a periodic basis (e.g., daily, weekly, monthly, quarterly, annually, or another periodic schedule).

8.11.4 Maintenance Records

The facility owner should maintain a log of O&M activities, which should be made available upon request of appropriate federal and state agencies. The logbook should include the following:

- *One copy of the operating procedures list discussed above (Section 8.11.2)*
- *One copy of the periodic maintenance schedule discussed above (Section 8.11.3)*
- *Records of regularly scheduled and unscheduled maintenance procedures performed*

8.11.5 Periodic Visual Inspections

The project owner, or their agent, should perform visual inspections of the screens on an annual basis or more frequently if required to ensure design criteria are being met. Inspectors should examine cleaning system performance, structural integrity of the screen area, fish-exclusion integrity of seals and transition areas, and other factors affecting screen facility performance. Inspectors should determine if the current maintenance procedures are sufficient to ensure that screen performance will continue to meet the facility’s design criteria into the future.

Guidelines for conducting periodic inspections are as follows:

- Auditing maintenance records:
    - Review the O&M logbook to identify any recurring problems.
    - Compare logged records with the O&M plan to ensure the plan is under compliance and note any areas that need troubleshooting.
- Inspecting underwater components:
    - Check for gaps at joints and seams that could compromise screen efficiency.
    - Note any accumulation of debris.
    - Inspect screen material for damage and material integrity.
    - Check screens and structural members for corrosion, wear, or other deterioration.
    - Check sacrificial anodes and replace if necessary.
    - Check screen hold-down plates and other protrusions from the screen face for damage and debris accumulation.

- Witness cleaning system operations:
    - Intentionally foul the fish screen with locally available materials if possible and view the efficiency of the screen cleaning system.
    - Inspect spray orifices for fouling and erosion and whether the water or air spray systems need to be enlarged.

  - Inspect screen faces for undulations in the screen material that may reduce cleaning efficiency (i.e., for traveling brush systems).
  - Inspect screen cleaning brushes for wear and deterioration (e.g., for traveling brush systems).
  - Inspect seals for wear and deterioration.
  - Assess the overall efficiency of the cleaning system and identify any recommended solutions in the inspection report.
  - Inspect underwater moving parts for corrosion and damage.
- Inspect the morphology of the stream channel in the immediate vicinity of the project for debris, erosion, and sedimentation that may potentially damage screens and their supporting structures or adversely affect screen operation and effectiveness.
- If warranted, measure water velocities perpendicular to the screen face to determine flow uniformity over all screen surfaces. Above normal debris accumulation in small areas may indicate approach velocities exceed the design criteria in those locations. Excessively high approach velocities can result in debris accumulation. If the accumulation is not addressed in a timely manner it may result in less efficient water withdrawal and eventual damage to the screen material or its structure.
- Test backup systems and alarms that could include the following:
  - Pump shut-off controls
  - Blow out panels
  - Mechanical brush shut-off system controls
  - Screen cleaning system failure alarms

9 Operations and Maintenance

9.1 Introduction

The design criteria and guidance provided in this document were developed to produce a high level of effectiveness and reliability at installed fish passage and protection facilities. Achieving this requires that these facilities be operated and maintained properly to optimize their performance in accordance with the design objectives of the facility. Failure to do so is a key concern of NMFS. This is because insufficient attention to the operational and maintenance aspects of a facility can compromise its fish passage effectiveness and result in fish injury and mortality.

This chapter addresses O&M issues in general and describes the components needed in a facility O&M plan. Where necessary, other chapters of this document will also address O&M issues that apply specifically to the topics covered in those chapters (e.g., Chapters 5 and 8).

9.2 General Criteria

Passage and screening facilities at barriers, diversions, water intakes, traps, and collection facilities should be operated and maintained in accordance with the O&M plan over the entire life of the project. This is needed to meet the mechanical design and biological objectives of the facility and the goal of providing optimal conditions for fish that result in successful passage (i.e., no mortality and minimal injury and delay).

NMFS requires that facility owners and operators commit to accepting responsibility for installing and properly operating, maintaining, and repairing the fish passage facilities described in the Guidelines. This is to ensure that: 1) fish affected by the facility are protected in a manner that is consistent with the intended performance of the facility based on its design; and 2) fish protection is provided on a sustained basis. For example, the proper function and operation of a fish passage facility would need to be restored immediately after damage from flooding and prior to the arrival of migratory fish, including repairing damaged structures and removing accumulated gravel and sediment.

Where facilities are inadequately operated or maintained, and the injury or mortality of listed fish can be documented, the responsible party is liable to enforcement measures as described in Section 9 of the ESA.

9.3 Specific Criteria – Staff Gages

Staff gages should be installed and maintained at critical locations throughout the facility.

Staff gages allow personnel to quickly determine if the facility is being operated within the established design criteria. Staff gage locations will be identified in the O&M plan.

9.4 The Operations and Maintenance Plan

This section describes how O&M plans are developed and approved and their contents.

9.4.1 O&M Plan Development and Approval

The O&M plan for a facility should be submitted to and accepted by NMFS prior to initiating project construction. The design of facilities should be made in consideration of O&M requirements and vice versa. Therefore, O&M plans need to be developed during the planning and design processes and must be reviewed and approved by NMFS at this time, along with project design documents.

For new facilities, it is recommended that a description of intended operations be obtained from the designer and then incorporated into the O&M plan. Such a description is often referred to as the "designer's intent."

The complexity of the O&M plan should reflect the complexity of the facility it addresses. For example, a facility with complex components, narrow operating requirements, and sophisticated water control systems will require a detailed plan that addresses all of the components, systems, and operational scenarios. This should include potential emergency scenarios, including the identification of spare parts for essential components that need to be on hand in case of failure.

9.4.2 Group O&M Plans

Comprehensive O&M plans for a group of projects will satisfy the requirement for an O&M plan for each project in the group as long as NMFS is in agreement with the O&M of the passage facilities.

Examples of group projects include road maintenance plans for culverts and small screen facilities within a network of water diversions.

9.4.3 General

The O&M plan should include the following criteria, procedures, and staffing requirements.

9.4.3.1 Facility operating criteria

The O&M plan should list the facility operating criteria. This includes (but is not limited to) criteria for water levels at critical locations, gate operations, gate settings, how the system is adjusted to accommodate changes in forebay and tailwater levels, and inspection procedures and frequency (e.g., daily, monthly, and annually).

9.4.3.2 Procedures

The O&M plan should include a description of routine O&M procedures. In addition, the O&M plan should include procedures for dewatering the facility, salvaging fish during a dewatering event, sediment and debris removal, and emergency operations.

Procedures, such as dewatering plans, fish salvage plans, and emergency operations, can have a direct impact on the survival of fish in the facility. It is important that these procedures be incorporated into O&M plans and operators are familiar with them in order to minimize any adverse impacts.

9.4.3.3 Staffing requirements

The O&M plan should discuss the staffing requirements needed to support the O&M plan, including the hours staff are required to be on site to monitor and operate the facility. The staffing requirement component of the plan should incorporate automatic controls and telemetry into the O&M plan and facility that notify operators of problems to increase overall reliability of the facility.

9.4.4 Posting the O&M Plan

The O&M plan should be posted at the facility or otherwise made available to the facility operator. Operators should be familiar with and understand the O&M plan and operate the facility accordingly.

It is important that the O&M plan be available and easily accessed by the facility operator should questions or emergency situations arise.

9.4.5 Periodic Review of O&M Plans by NMFS

Operations and maintenance documents should be reviewed and revised (with NMFS involvement) annually for the first 3 years of operation and then periodically after that as conditions and operations dictate.

NMFS intends that O&M plans be “living” documents. O&M documents should be revised periodically as the owner and operator develop more experience with a new facility. This is important because over time, experience will be gained as to how the facility performs under various hydrologic and environmental conditions, and ideas on how to improve the O&M of the facility will develop. For example, it is important that facility owners and operators note areas in the O&M plan that are deficient or need revision.

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Science, Service, Stewardship

2022 5-Year Review:
Summary & Evaluation of
Snake River Basin Steelhead

National Marine Fisheries Service
West Coast Region

U.S. Department of Commerce I National Oceanic and Atmospheric Administration I National Marine Fisheries Service

5-Year Review: Snake River Basin Steelhead

Species Reviewed	Evolutionarily Significant Unit or Distinct Population Segment
Steelhead (*Oncorhynchus mykiss*)	*Snake River Basin Steelhead*

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1. General Information

1.1 Introduction

Many West Coast salmon and steelhead (*Oncorhynchus sp.*) stocks have declined substantially from their historical numbers and now are at a fraction of their historical abundance. There are several factors that contribute to these declines, including overfishing, loss of freshwater and estuarine habitat, hydropower development, poor ocean conditions, and hatchery practices. These factors collectively led to the National Marine Fisheries Service's (NMFS) listing of 28 salmon and steelhead stocks in California, Idaho, Oregon, and Washington under the Federal Endangered Species Act (ESA).

The ESA, under section 4(c)(2), directs the Secretary of Commerce to review the listing classification of threatened and endangered species at least once every 5 years. A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12; 50 CFR 223.102, 224.101) is accurate (USFWS and NMFS 2006; NMFS 2020c). After completing this review, the Secretary must determine if any species should be: (1) removed from the list; (2) have its status changed from endangered to threatened to endangered; or (3) have its status changed from threatened to endangered to threatened. If, in the 5-year review, a change in classification is recommended, the recommended change will be further considered in a separate rule-making process. The most recent listing reviews for salmon and steelhead occurred in 2016. This document describes the results of the 2022 5-year review for ESA-listed Snake River Basin (SRB) steelhead.

A 5-year review is:

- A summary and analysis of available information on a given species;
- The tracking of a species' progress toward recovery;
- The recording of the deliberative process used to make a recommendation on whether or not to reclassify a species; and
- A recommendation on whether reclassification of the species is indicated.

A 5-year review is not:

- A re-listing or justification of the original (or any subsequent) listing action;
- A process that requires acceleration of ongoing or planned surveys, research, or modeling;
- A petition process; and
- A rulemaking.

1.1.1 Background on salmonid listing determinations

The ESA defines species to include subspecies and distinct population segments (DPS) of vertebrate species. A species may be listed as threatened or endangered. To identify taxonomically recognized species of Pacific salmon, we apply the "Policy on Applying the Definition of Species under the ESA to Pacific Salmon" (56 FR 58612). Under this policy, we identify population groups that are "evolutionarily significant units" (ESUs) within taxonomically recognized species. We consider a group of populations to be an ESU if it is substantially reproductively isolated from other populations within the taxonomically recognized species and represents an important component in the evolutionary legacy of the species. We consider an ESU as constituting a DPS and therefore a "species" under the ESA.

Under this policy, a DPS of steelhead must be discrete from other populations, and it must be significant to its taxon.

Artificial propagation programs (hatcheries) are common throughout the range of ESA-listed West Coast salmon and steelhead. Prior to 2005, our policy was to include in the listed ESU or DPS only those hatchery fish deemed "essential for conservation" of a species. We revised that approach in response to a court decision and on June 28, 2005, announced a final policy addressing the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204) (Hatchery Listing Policy). This policy establishes criteria for including hatchery stocks in ESUs and DPSs. In addition, it: (1) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (2) requires that hatchery fish determined to be part of an ESU or DPS be included in any listing of the ESU or DPS; (3) affirms our commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (4) affirms our commitment to fulfilling trust and treaty obligations with regard to the harvest of some Pacific salmon and steelhead populations, consistent with the conservation and recovery of listed salmon ESUs and steelhead DPSs.

To determine whether a hatchery program is part of an ESU or DPS and therefore must be included in the listing, we consider the origins of the hatchery stock, where the hatchery fish are released, and the extent to which the hatchery stock has diverged genetically from the donor stock. We include within the ESU or DPS (and therefore within the listing) hatchery fish that are derived from the population in the area where they are released and that are no more than moderately diverged from the local population.

Because the new Hatchery Listing Policy changed the way we considered hatchery fish in ESA listing determinations, we completed new status reviews and ESA listing determinations for West Coast salmon ESUs on June 28, 2005 (70 FR 37159), and for steelhead DPSs on January 5, 2006 (71 FR 834). On August 15, 2011, we published our 5-year reviews and listing determinations for 11 ESUs of Pacific salmon and 6 DPSs of steelhead from the Pacific Northwest (76 FR 50448). On May 26, 2016, we published our 5-year reviews and listing determinations for 17 ESUs of Pacific salmon, 10 DPSs of steelhead, and the southern DPS of eulachon (*Thaleichthys pacificus)* (81 FR 33468), including reaffirming threatened status for SRB steelhead.

1.2 Methodology Used to Complete the Review

On October 4, 2019, we announced the initiation of 5-year reviews for 17 ESUs of salmon and 11 DPSs of steelhead in Oregon, California, Idaho, and Washington (84 FR 53117). We requested that the public submit new information on these species that has become available since our 2015-2016 5-year reviews. In response to our request, we received information from federal and state agencies, Native American tribes, conservation groups, fishing groups, and individuals. We considered this information, as well as information routinely collected by our agency, to complete these 5-year reviews.

To complete the reviews, we first asked scientists from our Northwest and Southwest Fisheries Science Centers to collect and analyze new information about ESU and DPS viability. To evaluate viability, our scientists used the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000). The VSP concept evaluates four criteria – abundance, productivity, spatial structure, and diversity – to assess species viability. Through the application of this concept, the Science Centers considered new information on the four salmon and steelhead population viability criteria. They also considered new information on ESU and DPS composition. At the end of this process, the Science Centers prepared reports detailing the results of their analyses.

To further inform the reviews, we asked salmon management biologists from our West Coast Region familiar with hatchery programs to consider new information available since the previous listing determinations. Among other things, they considered hatchery programs that have ended, new hatchery programs that have started, changes in the operation of existing programs, and scientific data relevant to the degree of divergence of hatchery fish from naturally spawning fish in the same area. We also consulted salmon management biologists from the West Coast Region familiar with habitat conditions, hydropower operations, and harvest management. These biologists identified relevant information and provided their insights on the degree to which circumstances have changed for each listed entity. Finally, we solicited information on tributary habitat conditions and limiting factors from geographically based salmon conservation partners from federal agencies, state agencies, Tribes, and non-governmental organizations.

In preparing this report, we considered all relevant information, including the work of the Northwest Fisheries Science Center (Ford 2022); the report of the regional biologists regarding hatchery programs; recovery plans for the species in question; technical reports prepared in support of recovery plans for the species in question; the listing record (including the designation of critical habitat and adoption of protective regulations); recent biological opinions issued for SRB steelhead; information submitted by the public and other government agencies; and the information and views provided by geographically based salmon conservation partners. The present report describes the agency's findings based on all of the information considered.

1.3 Background – Summary of Previous Reviews, Statutory and Regulatory Actions, and Recovery Planning

1.3.1 Federal register notice announcing Initiation of this review

84 FR 53117; October 4, 2019.

1.3.2 Listing history

In 1997, NMFS listed SRB steelhead as threatened (Table 1).

Table 1. Summary of the listing history under the Endangered Species Act for the SRB steelhead DPS.

Salmonid Species	ESU/DPS Name	Original Listing	Revised Listing(s)
Steelhead (*O. mykiss*)	Snake River Basin Steelhead	**FR Notice:** 62 FR 43937 **Date:** 8/18/1997 **Classification:** Threatened	**FR Notice:** 71 FR 834 **Date:** 1/5/2006 **Classification:** Threatened

1.3.3 Associated rulemakings

The ESA requires NMFS to designate critical habitat, to the maximum extent prudent and determinable, for species it lists under the ESA. Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical or biological features essential to the conservation of the species, and which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination by the Secretary that such areas are essential for the conservation of the species. We designated critical habitat for SRB steelhead in 2005.

Section 9 of the ESA prohibits the take of species listed as endangered. The ESA defines take to mean harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. For threatened species, the ESA does not automatically prohibit take, but instead authorizes the agency to adopt regulations it deems necessary and advisable for species conservation and to apply the take prohibitions of Section 9(a)(1) through (ESA section 4(d)). In 2000, NMFS adopted 4(d) regulations for threatened salmonids that prohibit take except in specific circumstances. On July 10, 2000, we applied these 4(d) regulations to SRB steelhead (65 FR 42422).

Table 2. Summary of rulemaking for 4(d) protective regulations and critical habitat for SRB steelhead.

Salmonid Species	ESU/DPS Name	4(d) Protective Regulations	Critical Habitat Designations
Steelhead (*O. mykiss*)	Snake River Basin Steelhead	**FR Notice:** 65 FR 42422 **Date:** 7/10/2000 **Revised**: 6/28/2005 (70 FR 37159)	**FR notice:** 70 FR 52630 **Date:** 9/2/2005

1.3.4 Review history

Table 3 lists the numerous scientific assessments of the status of the SRB steelhead DPS. These assessments include reviews conducted by our Northwest Fisheries Science Center and technical reports prepared to support recovery planning for these species.

Table 3. Summary of previous scientific assessments for SRB steelhead.

Salmonid Species	ESU/DPS Name	Document Citation
Steelhead (*O. mykiss*)	Snake River Basin Steelhead	Ford 2022 NMFS 2016a NWFSC 2015 Ford et al. 2011 ICTRT 2007a ICTRT and Zabel 2007 Good et al. 2005 McClure et al. 2003 ICTRT 2003 NMFS 1997 Busby et al. 1996

1.3.5 Species’ recovery priority number at start of 5-year review process

On April 30, 2019, NMFS issued new guidelines (84 FR 18243) for assigning listing and recovery priorities. Under these guidelines, we assign each species a recovery priority number ranging from 1 (high) to 11 (low). This priority number reflects the species demographic risk (based on the listing status and species’ condition in terms of its productivity, spatial distribution, diversity, abundance, and trends) and recovery potential (major threats understood, management actions exist under U.S. authority or influence to abate major threats, and certainty that actions will be effective). Additionally, if the listed species is in conflict with construction or other development projects or other forms of economic activity, then they are assigned a ‘C’ and are given a higher priority over those species that are not in conflict. Table 4 lists the recovery priority number for the SRB steelhead DPS that was in effect at the time this 5-year review began (NMFS 2019a). In January 2022, NMFS issued a new report with updated recovery priority numbers. The number remained unchanged for SRB steelhead DPS (NMFS 2022).

1.3.6 Recovery plan or outline

Table 4. Recovery Priority Number (2019a) and Endangered Species Act Recovery Plan for SRB steelhead DPS.

Salmonid Species	ESU/DPS Name	Recovery Priority Number	Recovery Plan/Outline
Steelhead (*O. mykiss*)	Snake River Basin Steelhead	**3C**	Title: Recovery Plan for Snake River Spring/Summer Chinook Salmon and Snake River Basin Steelhead https://www.fisheries.noaa.gov/resource/document/recovery-plan-snake-river-spring-summer-chinook-salmon-and-snake-river-basin **Date:** 11/30/2017 **Type:** Final

2. Review Analysis

In this section, we review new information to determine whether the SRB steelhead delineation remains appropriate.

2.1 Delineation of Species under the Endangered Species Act

Is the species under review a vertebrate?

ESU/DPS Name	YES	NO
Snake River Basin Steelhead	X	

Is the species under review listed as an ESU/DPS?

ESU/DPS Name	YES	NO
Snake River Basin Steelhead	X	

Was the ESU/DPS listed prior to 1996?

ESU/DPS Name	YES	NO	Date Listed if Prior to 1996
Snake River Basin Steelhead		X	n/a

Prior to this 5-year review, was the ESU/DPS classification reviewed to ensure it meets the 1996 ESU/DPS policy standards?

In 1991, NMFS issued a policy explaining how the agency would apply the definition of “species” in evaluating Pacific salmon stocks for listing consideration under the Endangered Species Act (ESA) (56 FR 58612). Under this policy a group of Pacific salmon populations is considered a “species” under the ESA if it represents an “evolutionarily significant unit” (ESU) which meets the two criteria of: (1) being substantially reproductively isolated from other con-specific populations; and (2) representing an important component in the evolutionary legacy of the biological species. The 1996 joint NMFS-Fish and Wildlife Service (FWS) “distinct population segment” (DPS) policy (61 FR 4722) affirmed that a stock (or stocks) of Pacific salmon is considered a DPS if it represents an ESU of a biological species. Accordingly, in listing the SRB steelhead DPS under the DPS policy in 1997, we used the joint DPS policy to delineate the DPS under the ESA.

2.1.1 Summary of relevant new information regarding the delineation of the SRB steelhead DPS

DPS Delineation

This section provides a summary of information presented in the Northwest Fisheries Science Center's *Biological viability assessment update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest* (Ford 2022).

We found no new information that would justify a change in the delineation of the SRB steelhead DPS (Ford 2022).

Membership of Hatchery Programs

For West Coast salmon and steelhead, many of the ESU and DPS descriptions include fish originating from specific artificial propagation programs (e.g., hatcheries) that, along with their naturally produced counterparts, are included as part of the listed species. NMFS' Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead (70 FR 37204) guides our analysis of whether individual hatchery programs should be included as part of the listed species. The Hatchery Listing Policy states that hatchery programs will be considered part of an ESU/DPS if they exhibit a level of genetic divergence relative to the local natural population(s) that is not more than what occurs within the ESU/DPS.

In preparing this report, our hatchery management biologists reviewed the best available information regarding the hatchery membership of this DPS. They considered changes in hatchery programs that occurred since the last 5-year review (e.g., some have been terminated while others are new) and made recommendations about the inclusion or exclusion of specific programs. They also noted any errors and omissions in the existing descriptions of hatchery program membership. NMFS intends to address any needed changes and corrections via separate rulemaking subsequent to the completion of the 5-year review process prior to any official change in hatchery membership.

In the 2016 5-year review, the SRB steelhead DPS was defined as including all naturally spawned anadromous *O. mykiss* (steelhead) populations below natural and manmade impassable barriers in streams in the Snake River basin of southeast Washington, northeast Oregon, and Idaho, as well as six artificial production programs: the Tucannon River, Dworshak National Fish Hatchery, Lolo Creek, North Fork Clearwater River, East Fork Salmon River, and the Little Sheep Creek/Imnaha River Hatchery steelhead hatchery programs (71 FR 834).

Since 2016, we updated the SRB DPS listing to reflect the following six changes to hatchery programs (85 FR 81822). We: (1) added the Salmon River B-run Program because the existing release is now classified as a separate and distinct program; (2) added the South Fork Clearwater (Clearwater Hatchery) B-run program because the existing release is now classified as a separate and distinct program; (3) changed the name of the East Fork Salmon River Program to the East Fork Salmon River Natural Program; (4) removed the Lolo Creek Program because it is now considered part of the listed Dworshak National Fish Hatchery Program; (5) removed the North Fork Clearwater Program because it is now considered part of the listed Dworshak National Fish Hatchery Program, and; (6) changed the name of the Little Sheep Creek/Imnaha River Hatchery Program to the Little Sheep Creek/Imnaha Program.

The addition or removal of an artificial propagation program from a DPS does not necessarily affect the listing status of the DPS; however, it revises the DPS's composition to reflect the best available scientific information as considered under our Hatchery Listing Policy. The addition of an artificial propagation program to a DPS represents our determination that the artificially propagated stock is no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the ESU (70 FR 37204). We relied on the Hatchery Listing Policy in our 2020 Final Rule on Revisions to Hatchery Programs as Part of Pacific Salmon and Steelhead Species Listed under the Endangered Species Act (85 FR 81822).

2.2 Recovery Criteria

The ESA requires that NMFS develop recovery plans for each listed species, unless the Secretary finds a recovery plan would not promote the conservation of the species. Recovery plans must contain, to the maximum extent practicable, objective measurable criteria for delisting the species, site-specific management actions necessary to recover the species, and time and cost estimates for implementing the recovery plans.

Evaluating a species for potential changes in ESA listing requires an explicit analysis of population or demographic parameters (the biological criteria) and also of threats under the five ESA listing factors in ESA section 4(a)(1) (listing factor [threats] criteria). Together these make up the objective, measurable criteria‖ required under section 4(f)(1)(B).

For Pacific salmon, NMFS appointed Technical Recovery Teams (TRTs) to define criteria to assess each listed Pacific salmonid species' biological viability. NMFS adopted the TRT's viability criteria as the biological criteria for Pacific salmonid recovery plans, based on the best available scientific information and other considerations as appropriate. NMFS also developed criteria to assess progress toward alleviating the relevant threats to Pacific salmonid species (listing factor [threats] criteria). For the Recovery Plan for Snake River Spring/Summer Chinook Salmon and Snake River Basin Steelhead (recovery plan), NMFS adopted the viability criteria metrics defined by the Interior Columbia Technical Recovery Team (ICTRT) (ICTRT 2007) as the biological recovery criteria for the ESA-listed SRB steelhead.

Biological review of the species continues as the recovery plan is implemented and additional information becomes available. This information, along with new scientific analyses, can increase certainty about whether the threats have been abated, whether improvements in population biological viability have occurred for the salmon and steelhead, and whether linkages between threats and changes in biological viability are understood. NMFS assesses these biological recovery criteria and the delisting criteria through the adaptive management program for the plan during the ESA 5-year review (USFWS and NMFS 2006; NMFS 2020a).

2.2.1 Approved recovery plan with objective, measurable criteria

Does the species have final, approved recovery plans containing objective, measurable criteria?

ESU/DPS Name	YES	NO
Snake River Basin Steelhead	X	

2.2.2 Adequacy of recovery criteria

Based on new information considered during this review, are the recovery criteria still appropriate?

ESU/DPS Name	YES	NO
Snake River Basin Steelhead	X	

Are all of the listing factors that are relevant to the species addressed in the recovery criteria?

ESU/DPS Name	YES	NO
Snake River Basin Steelhead	X	

2.2.3 The biological recovery criteria as they appear in the recovery plan

For the purposes of reproduction, salmon and steelhead typically exhibit a metapopulation structure (McElhany et al. 2000; Schtickzelle and Quinn 2007). Rather than interbreeding as one large aggregation, ESUs and DPSs function as a group of demographically independent populations separated by areas of unsuitable spawning habitat. For conservation and management purposes, it is important to identify the independent populations that make up an ESU or DPS.

McElhany et al. (2000) defined an independent population as: "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season.” For our purposes, not interbreeding to a “substantial degree” means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame. Independent populations exhibit different population attributes that influence their abundance, productivity, spatial structure, and diversity. Independent populations are the units that are combined to form alternative recovery scenarios for multiple similar population groupings and ESU viability.

NMFS used the viable salmonid population (VSP) concept (McElhany et al. 2000) to define the independent populations in an ESU or DPS. The VSP concept is based on the biological parameters of abundance, productivity, spatial structure, and diversity for an independent salmonid population to have a negligible risk of extinction over a 100-year time frame. The VSP concept identifies the attributes, provides guidance for determining the conservation status of populations and larger-scale groupings of Pacific salmonids, and describes a general framework for how many and which populations within an ESU/DPS should be at a particular status for the ESU/DPS to have an acceptably low risk of extinction. McElhany et al. (2007) developed combined VSP criteria metrics that describe the probability of population extinction risk in 100 years (Figure 1). NMFS color-coded the risk assessment to assist the readers to more easily distinguish the various risk categories.

VSP Criteria Metrics		**Spatial Structure/Diversity Risk**			
	Risk	Very Low	Low	Moderate	High
Abundance/Productivity Risk	Very Low (<1%)	Very Low Risk (Highly Viable)	Very Low Risk (Highly Viable)	Low Risk (Viable)	Moderate Risk
	Low (<5%)	Low Risk (Viable)	Low Risk (Viable)	Low Risk (Viable)	Moderate Risk
	Moderate (<25%)	Moderate Risk	Moderate Risk	Moderate Risk	High Risk
	High (>25%)	High Risk	High Risk	High Risk	High Risk

Figure 1. VSP Criteria Metrics.

For the purposes of recovery planning and the development of recovery criteria, the NMFS-appointed ICTRT identified independent populations for SRB steelhead, and then grouped them together into genetically similar major population groups (MPGs) (ICTRT 2003).

The ICTRT also developed species biological viability criteria for applications at the ESU/DPS, MPG, and independent population scales (ICTRT 2007). The viability criteria are based on the VSP concept described above. Recovery scenarios outlined in the ICTRT viability criteria report (ICTRT 2007) are targeted to achieve, at a minimum, the ICTRT's biological viability criteria for each major population grouping. Accordingly, the criteria are designed "[t]o have all major population groups at viable (low risk) status with representation of all the major life history strategies present historically, and with the abundance, productivity, spatial structure, and diversity attributes required for long-term persistence." Recovery criteria and strategies outlined in the Recovery Plan for Snake River Spring/Summer Chinook Salmon and Snake River Basin Steelhead are targeted on achieving, at a minimum, the ICTRT biological viability criteria for each major population grouping in the ESU/DPS (NMFS 2017a).

Recovery scenarios outlined in the ICTRT viability criteria report (ICTRT 2007b) are targeted to achieve, at a minimum, the ICTRT's biological viability criteria for each major population grouping. Accordingly, the criteria are designed "[t]o have all major population groups at viable (low risk) status with representation of all the major life history strategies present historically, and with the abundance, productivity, spatial structure, and diversity attributes required for long-term persistence." The Snake River management unit recovery plans (SRSRB 2011; NMFS 2017b, 2017c, 2017d) identify a set of most likely scenarios to meet the ICTRT recommendations for low-risk populations at the MPG level. In addition, the management unit plans generally call for achieving moderate risk ratings (maintained status) across the remaining extant populations in each MPG. The following describes the combination of population status most likely to achieve viability for each MPG.

The SRB steelhead DPS has six MPGs (five extant and one – Hells Canyon – with no associated independent populations) with 24 extant populations (Figure 2). The SRB steelhead DPS includes all naturally spawned anadromous *O. mykiss* (steelhead) originating below natural and manmade impassable barriers from the Snake River basin. Also, steelhead from six artificial production programs: Tucannon River, Salmon River B-run, South Fork Clearwater (Clearwater Hatchery) B-run, Dworshak National Fish Hatchery, East Fork Salmon River, and Little Sheep Creek/Imnaha River Hatchery (71 FR 834; 85 FR 81822).

The five extant SRB steelhead MPGs are described in the recovery plan (NMFS 2017b), with recovery scenarios identified for each MPG. The recovery plan recognizes that, at the MPG level, there may be several alternative combinations of populations and statuses and risk ratings that could satisfy the ICTRT viability criteria.

Lower Snake River MPG (two populations)

- The Tucannon River and Asotin Creek populations must achieve at least *Viable* status (low risk), with one of the populations at *Highly Viable* (very low risk) status.

Grande Ronde River MPG (four populations)

- At least two steelhead populations in the MPG must achieve at least *Viable* status (low risk), with at least one population at *Highly Viable* status (very low risk) status. The Upper Grande Ronde is the only large population in the MPG and must attain *Viable* status.
- All remaining populations should at least achieve *Maintained* status (moderate risk).

Imnaha River MPG (one population)

- The Imnaha River population must attain *Highly Viable* status (very low risk) for the MPG to achieve viable status and support delisting of the SRB steelhead DPS.

Clearwater River MPG (five extant and one extirpated population)

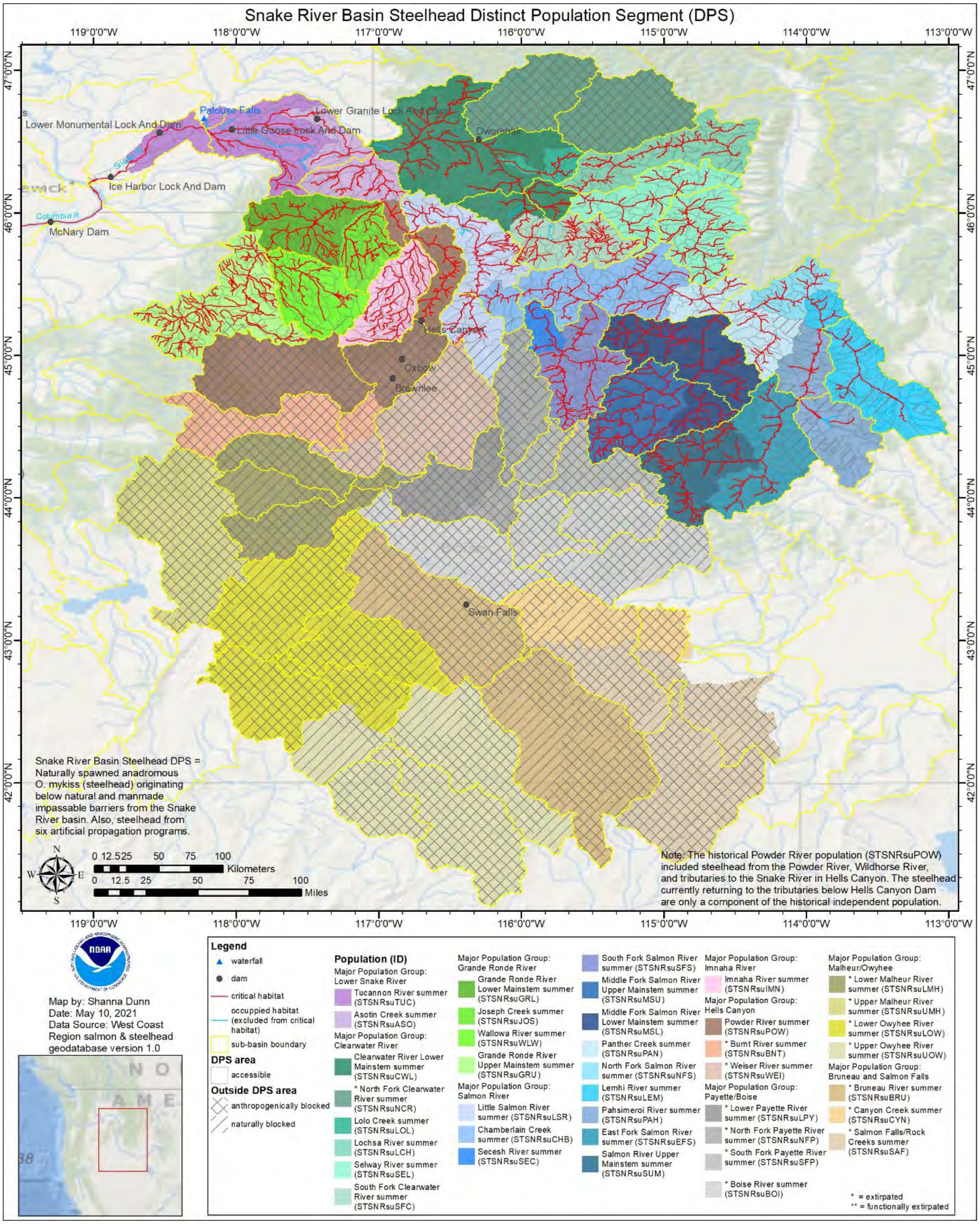
- At least three of the MPG's six populations must be *Viable*, and one of these populations must be *Highly Viable* for the MPG to meet the criteria.
- Because the North Fork Clearwater population is extirpated, the only Large-size population left is the Lower Mainstem Clearwater River, and it must achieve viability to meet this criterion. At least two of the three Intermediate-size populations must also attain V*iable* status (Selway, Lochsa [targeted for *Highly Viable*] SF Clearwater).
- All remaining populations should at least achieve *Maintained* status.

Salmon River MPG: (12 extant populations)

- Since there are 12 steelhead populations in the Salmon River MPG, at least six must be *Viable* (low risk) for the MPG to be viable. One of these populations must achieve *Highly Viable* (very low risk) status.
- At least four of the six viable populations must be Intermediate size.
- At least two of the six viable populations need to be populations with predominantly B-run fish so that all major life histories are represented. Also, because the geographic area of this MPG is so large, it is important that spatial distribution of the viable populations be considered.
- All remaining populations should at least achieve *Maintained* status.

Hells Canyon Tributaries MPG

This MPG historically contained three independent populations. However, all three populations were above Hells Canyon Dam (Powder River, Burnt River, and Weiser River) and are now extirpated. A small number of steelhead occupy some tributaries below Hells Canyon Dam; however, none of these tributaries (nor all combined) appear to be large enough to support an independent population. Based on the extirpated status of these populations, the MPG is not expected to contribute to the recovery of the DPS (NMFS 2017c).



Snake River Basin Steelhead DPS = Naturally spawned anadromous O. mykiss (steelhead) originating below natural and manmade impassable barriers from the Snake River basin. Also, steelhead from six artificial propagation programs.

Note: The historical Powder River population (STSNRsuPOW) included steelhead from the Powder River, Wildhorse River, and tributaries to the Snake River in Hells Canyon. The steelhead currently returning to the tributaries below Hells Canyon Dam are only a component of the historical independent population.

Map by: Shanna Dunn
Date: May 10, 2021
Data Source: West Coast Region salmon & steelhead geodatabase version 1.0

Figure 2. SRB steelhead DPS populations and major population groups.

2.3 Updated Information and Current Species' Status

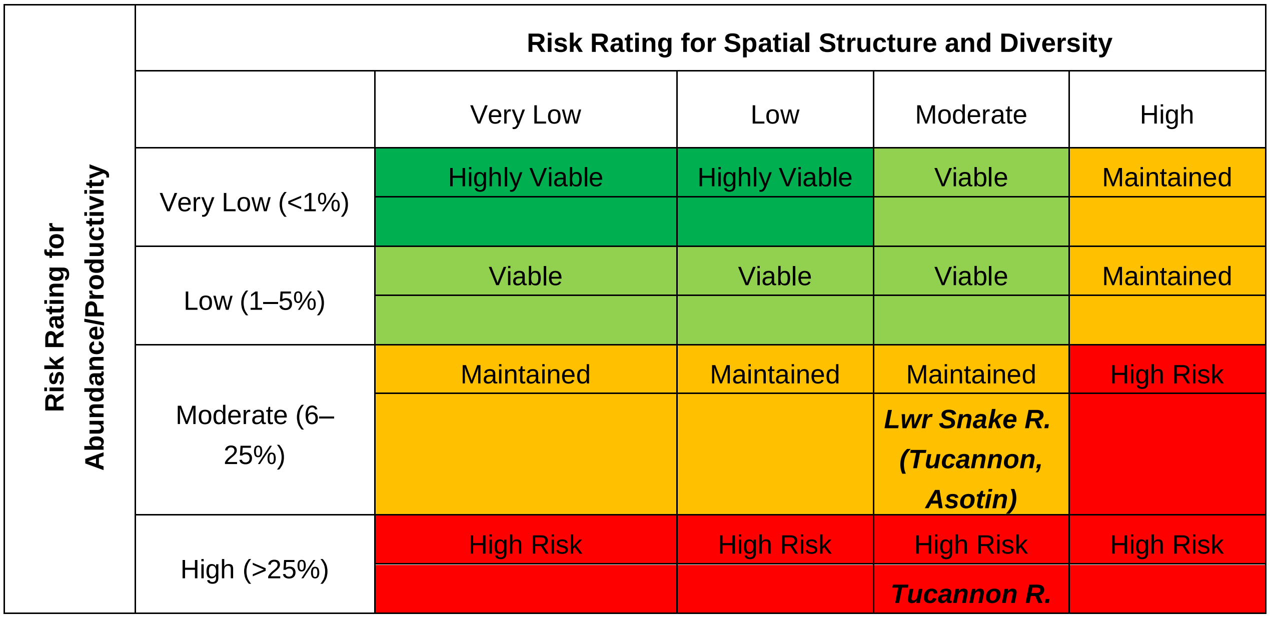
Information provided in this section includes a summary from the *Biological viability assessment update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest* (Ford 2022) (Subsection 2.3.1) and our current listing factors analysis (Subsection 2.3.2).

2.3.1 Analysis of VSP criteria (including discussion of whether the VSP criteria have been met)

Updated Biological Risk Summary

Below are the Ford (2022) updated viability status summaries integrated across the four VSP parameters for the SRB steelhead populations and grouped by MPG.

The Lower Snake River MPG is not viable. It does not meet the recovery viability criteria of both populations meeting viable status, with one being highly viable (Figure 3). The Tucannon River population must achieve viable status, and either the Asotin population or Tucannon population must reach Highly Viable, for MPG viability.



Risk Rating for Abundance/Productivity	Risk Rating for Spatial Structure and Diversity				
		Very Low	Low	Moderate	High
	Very Low (<1%)	Highly Viable	Highly Viable	Viable	Maintained
	Low (1–5%)	Viable	Viable	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained	Maintained ***Lwr Snake R. (Tucannon, Asotin)***	High Risk
	High (>25%)	High Risk	High Risk	High Risk ***Tucannon R.***	High Risk

Figure 3. Lower Snake River MPG population risk ratings **integrated** across the four VSP parameters. Viability key: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (Ford 2022, Table 23, p. 104).

The Grande Ronde MPG is not viable. To meet viability criteria, this MPG must bring the high-risk populations to at least maintained status (Figure 4). Further, the upper Grande Ronde population must remain at least viable, and one of the populations must improve to highly viable. The Grande Ronde MPG is rated as maintained (not viable), but more specific data on spawning abundance and the relative contribution of hatchery spawners for the Lower Grande Ronde and Wallowa populations would improve future assessments.

Risk Rating for Abundance/Productivity		**Risk Rating for Spatial Structure and Diversity**			
		Very Low	Low	Moderate	High
	Very Low (<1%)	Highly Viable	Highly Viable	Viable ***Upper Gr Ronde***	Maintained
	Low (1–5%)	Viable	Viable ***Joseph Creek***	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained	Maintained	High Risk
	High (>25%)	High Risk	High Risk **Wallowa**	High Risk ***Lower Gr Ronde.***	High Risk

Figure 4. Grand Ronde River MPG population risk ratings **integrated** across the four VSP parameters. Viability key: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (Ford 2022, Table 23, p. 104).

The Imnaha MPG is not viable; however, the Imnaha MPG’s single population moved from maintained to viable status in this review period (Figure 5). Still, the single population and MPG must achieve Highly Viable status to reach MPG viability.

Risk Rating for Abundance/Productivity		**Risk Rating for Spatial Structure and Diversity**			
		Very Low	Low	Moderate	High
	Very Low (<1%)	Highly Viable	Highly Viable	Viable ***Imnaha***	Maintained
	Low (1–5%)	Viable	Viable	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained	Maintained	High Risk
	High (>25%)	High Risk	High Risk	High Risk	High Risk

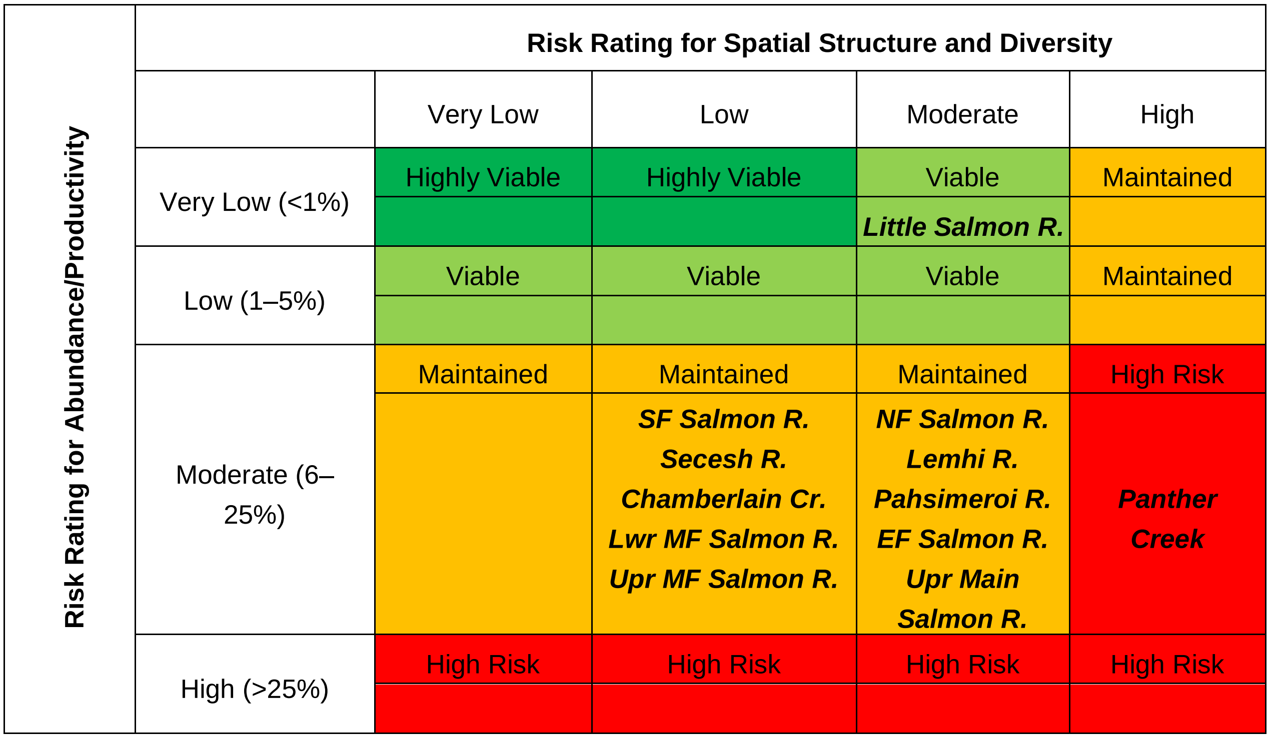
Figure 5. Imnaha River MPG population risk ratings integrated across the four VSP parameters. Viability key: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (Ford 2022, Table 23, p. 104).

The Clearwater River MPG is not viable. The only large population (Lower Mainstem) is rated at highly viable. For the MPG to be viable, two additional populations must be viable and the remaining populations must be rated as at least maintained (Figure 6). The SF Clearwater population is rated as viable; however, the Lolo population is rated high risk, and the Lochsa and Selway populations are rated as maintained. The viability assessment (Ford 2022) reported Lolo, Lochsa, and Selway as a three-population aggregate, which was rated as maintained. We reviewed the data underlying that analysis and determined that the Lolo population, when treated individually, rates as high risk. The Lolo population is a small size ("basic") population expected to maintain a mean abundance of at least 500 adults for viability; however, this population apparently has had less than 200 adults in each of the last 5 years, through the 2020/21 return. For the individual Lolo population, recent abundance and productivity tend not to support a rating of maintained but instead indicate high risk. Future ratings of populations in the MPG would benefit from more specific data on spawning abundance and the relative contribution of hatchery spawners.

		Risk Rating for Spatial Structure and Diversity			
		Very Low	Low	Moderate	High
Risk Rating for Abundance/Productivity	Very Low (<1%)	Highly Viable	Highly Viable ***Lower Main Clearwater R.***	Viable ***SF Clearwater R.***	Maintained
	Low (1–5%)	Viable	Viable	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained ***Selway R.*** ***Lochsa R.***	Maintained	High Risk
	High (>25%)	High Risk	High Risk	High Risk ***LoLo Creek***	High Risk

Figure 6. Clearwater River MPG population risk ratings integrated across the four VSP parameters. The Lolo Creek population was disaggregated from the Selway and Lochsa populations (see explanation in the MPG discussion). Viabilitykey: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (Ford 2022, Table 23, p. 104) .

The Salmon River MPG is not viable. The MPG has several criteria for MPG viability but fails on the first criteria, which calls for half, or six out of 12, populations to be viable and one to be highly viable (Figure 7). The Little Salmon River population is the only population in the MPG with a viable rating.



Risk Rating for Abundance/Productivity	Risk Rating for Spatial Structure and Diversity			
	Very Low	Low	Moderate	High
Very Low (<1%)	Highly Viable	Highly Viable	Viable ***Little Salmon R.***	Maintained
Low (1–5%)	Viable	Viable	Viable	Maintained
Moderate (6–25%)	Maintained	Maintained ***SF Salmon R.*** ***Secesh R.*** ***Chamberlain Cr.*** ***Lwr MF Salmon R.*** ***Upr MF Salmon R.***	Maintained ***NF Salmon R.*** ***Lemhi R.*** ***Pahsimeroi R.*** ***EF Salmon R.*** ***Upr Main Salmon R.***	High Risk ***Panther Creek***
High (>25%)	High Risk	High Risk	High Risk	High Risk

Figure 7. Salmon River MPG population risk ratings integrated across the four VSP parameters. Viability key: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (Ford 2022, Table 23, p. 104).

Based on the updated viability information available for this review, none of the five MPGs meet the viability criteria set forth in the 2017 recovery plan, and the viability of many individual populations remains uncertain. Of particular note, the updated, population-level abundance estimates have made very clear the recent (last 5 years) sharp declines that are extremely worrisome, were they to continue. The most recent 5-year metric indicates that each population has decreased by about 50 percent. The viability metrics used in these analyses (standardized PNW-wide and ICTRT) are intentionally based on long-time periods (10-20 year geometric means) to buffer against the rapid swings in abundance that salmon and steelhead populations are known to exhibit. While these filtering approaches intentionally result in muted responses to rapid abundance change, they also can lag in raising concerns about a dramatic change in population status. Rapid response metrics, or metrics that are more keyed to system-wide synchronous behavior of population productivity, may be appropriate for raising concern for the status in these situations.

Based on 20-year geometric means, productivity for all populations remains above replacement. Cyclical spawner-to-spawner ratios, which reflect combined impacts of habitat, climate, and density dependence, have been strongly below replacement since 2010. Productivity is also expected to decline in the coming years due to recent declines in abundance.

Spatial structure risk ratings for all of the SRB steelhead populations were low or very low risk given the evidence of broad distribution of natural production within populations. The exception was Panther Creek, which was given a high-risk rating for spatial structure based on the lack of spawning in the upper sections. Based on extensive survey information from the Salmon River and Clearwater River MPGs, the spatial structure ratings for SRB steelhead populations were maintained at the levels assigned in the original ICTRT assessment. Diversity risk ratings were low to moderate and nearly unchanged from the previous 5-year review period.

DPS Summary

Population abundance declines since the 2016 5-year review are sharp and are expected to negatively affect productivity in the coming years corresponding with these declines. These declines in abundance, according to short-term metrics, are of greater concern if they continue through the next 5-year review period. However, spatial structure risk is very low as SRB steelhead are widely distributed throughout their accessible range, and the species exhibits resilience to rapid changes in abundance. Overall, the information analyzed for the 2022 viability assessment does not indicate a change in the biological risk status of the DPS, which remains in the moderate extinction risk category, as supported by the population risk ratings summarized by MPG in section 2.3.1 above.

2.3.2 ESA listing factor analysis

Section 4(a)(1) of the ESA directs us to determine whether any species is threatened or endangered because of any of the following factors: (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or man-made factors affecting its continued existence. Section 4(b)(1)(A) requires us to make listing determinations after conducting a review of the status of the species and taking into account efforts to protect such species. Below we discuss new information relating to each of the five factors as well as efforts being made to protect the species.

Listing Factor A: Present or threatened destruction, modification or curtailment of its habitat or range

Significant habitat restoration and protection actions at the federal, state, tribal, and local levels have been implemented to improve the degraded habitat conditions and fish passage issues described in the Snake River recovery plans. While these efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations, we do not yet have evidence demonstrating that improvements in habitat conditions have led to improvements in population viability. The effectiveness of habitat restoration actions and progress toward meeting the viability criteria should continue to be monitored and evaluated with the aid of newly implemented monitoring and evaluation programs. Generally, it takes one to five decades to demonstrate increases in viability.

In the 2020 Columbia River System biological opinion (NMFS 2020a), NMFS concluded that tributary habitat conditions are likely improving in some areas as a result of habitat improvement actions. In addition, results from PACFISH/INFISH Biological Opinion (PIBO) monitoring have shown that mid-1990s changes in guidance for land management plans and actions on Pacific Northwest National Forest and Bureau of Land Management lands have led to measurable improvements in salmonid habitat over the past 20 years (Roper et al. 2019). These gains in habitat quality are likely from more conservative management standards in riparian areas and the implementation of best management practices to reduce sediment delivery to streams from roads. However, tributary habitat conditions are generally still degraded from ongoing development and land-use activities, which continue to negatively affect SRB steelhead abundance, productivity, spatial structure, and diversity. The potential exists to improve tributary habitat capacity and productivity in this DPS, although the potential is limited or uncertain in some areas (NMFS 2016a, 2017b). Strong density dependence in SRB steelhead populations (ISAB 2015) indicates that population abundance improvements through habitat restoration would best be achieved by targeting limiting life stages or habitat limiting factors. Additional improvements are needed in almost all populations to achieve recovery goals.

Current Status and Trends in Habitat

Below, we summarize information on the **current status and trends in tributary habitat** conditions by MPG since our last 2016 5-year review. We specifically address:

> **(1) population-specific key emergent or ongoing habitat concerns** (threats or limiting factors) focusing on the top concerns that potentially have the biggest impact on independent population viability;
>
> **(2) population-specific geographic areas of habitat concern** (e.g., independent population major/minor spawning areas) where key emergent or ongoing concerns about this habitat condition remain;
>
> **(3) population-specific key protective measures and major restoration actions taken since the 2016 5-year review** toward achieving the recovery plan viability criteria established by the recovery plan (NMFS 2017a) as efforts that substantially address a key concern noted in **above #1 and # 2**, or that represent a noteworthy conservation strategy;
>
> **(4) key regulatory measures that are either adequate, or, inadequate** and contributing substantially to the key tributary habitat concerns summarized above; and
>
> **(5) recommended future recovery actions over the next 5 years toward achieving population viability**, including: key near-term restoration actions that would address the key concerns summarized above; projects to address monitoring and research gaps; fixes or initiatives to address inadequate regulatory mechanisms, and addressing priority habitat areas when sequencing priority habitat restoration actions.

The following section describes the tributary habitat for each MPG. Migration corridor habitat in the Salmon River, Snake River, and Columbia River is vitally important to this DPS. This migratory habitat is addressed under *Listing Factor C (Disease and Predation) and Listing*

Factor D (Inadequacy of Regulatory Mechanisms), and Listing Factor E (Other Natural or Manmade Factors).

Lower Snake River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-year review

For the two independent SRB steelhead populations (Tucannon River and Asotin Creek) in the Lower Snake River MPG, the primary tributary habitat concerns since the 2016 5-year review continue. These concerns were identified in the 2011 South East Washington Snake River Recovery Plan (SRSRB 2011) and were reiterated by the SRSRB in 2020 (SRSRB 2020):

- lack of stream complexity;
- excess sediment;
- low stream flows;
- high stream temperatures;
- degraded riparian conditions;
- reduced floodplain connectivity; and
- passage barriers (Tucannon River population only).

2) Population-Specific Geographic Areas of Habitat Concern Since the 2016 5-year review

Both populations in the MPG are located in the geographic areas of tributary habitat concern (SRSRB 2011, 2020; NMFS 2017a).

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-year review

Population-specific key protective measures and major restoration actions taken since the 2016 5-year review and adoption of the 2017 Recovery Plan for Snake River Spring/summer Chinook Salmon and Snake River Basin Steelhead include:

- Tucannon River population. Addition of whole trees over 10 miles of Tucannon River habitat to reengage the river with its floodplain, increase side channels, lower summer water temperatures, and create more juvenile summer and winter rearing habitat (SRSRB 2020).
- Asotin Creek population. Installation of hundreds of low-cost post-assisted log structures in the headwaters of the Asotin Creek watershed to re-meander streams and reduce stream energy and hydrographic flashiness (SRSRB 2020).

- Asotin Creek population. Provision of natural fish passage to an additional 51 and 15 stream miles for Asotin Creek and Alpowa Creek fish passage barriers (Asotin Creek Headgate, Alpowa Creek County Culvert, Buford Creek Culvert), respectively (SRSRB 2020).

4) Key Regulatory Measures Since the 2016 5-year review

The recovery plan (NMFS 2017a) and previous 5-year review (NMFS 2016a) identified inadequate regulatory mechanisms as a priority issue affecting SRB steelhead recovery in all Snake River basin geographic areas with extant SRB steelhead populations and MPGs. Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last 5-year review indicates that the adequacy of several regulatory mechanisms has stayed the same on average, with some mechanisms showing the potential for some improvement, whereas others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions Over the Next 5 years Toward Achieving Population Viability

The greatest opportunities toward achieving population viability and advancing recovery of SRB steelhead in the Lower Snake River MPG include:

- Tucannon River population. Improve and increase summer and winter juvenile rearing habitat, especially in high potential reaches of the Tucannon River and Pataha Creek, by restoring riparian areas, reducing temperatures and substrate embeddedness, and increasing recruitment of large wood (SRSRB 2011).
- Tucannon River population. Enhance overwinter rearing habitat for Tucannon River juvenile steelhead, increase rearing habitat complexity, and reconnect the river to its floodplain (SRSRB 2011; CCD 2021).
- Tucannon River population. Address the Tucannon Tumalum and Hixon culverts and Cottonwood Creek culvert passage barriers in the next 5 years (SRSRB 2020).

Grande Ronde River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-year review

For the four independent SRB steelhead populations (Joseph Creek, Lower Grande Ronde River, Wallowa River, and the Upper Grande Ronde River) in the Grande Ronde River MPG, the primary tributary habitat concerns since the 2016 5-year review and identified in the 2017 recovery plan (NMFS 2017c) continue to be:

- Lack of large wood and large wood recruitment (all populations).

- Impaired riparian conditions, channelization, and loss of off-channel habitat and floodplain connectivity (all populations).
- High summer water temperatures (Upper Grande Ronde population).
- Ice flows increased by poor riparian conditions and altered floodplain/channel function (Upper Grande Ronde population).
- Low stream flows due to irrigation withdrawals (Upper Grande Ronde and Wallowa River populations).
- Loss of habitat complexity and connectivity sufficient to support summer and winter juvenile rearing steelhead (Upper Grande Ronde population) (USBR 2011).
- Timber management and grazing (Joseph Creek population).

2) Population-Specific Geographic Areas of Habitat Concern Since the 2016 5-year review

Population-specific geographic areas of habitat concern in the Grande Ronde River MPG are:

- Upper Grande Ronde River and Catherine Creek (Upper Grande Ronde population).
- Upper Grande Ronde and Joseph Creek (These two population areas host the majority of spawners for the MPG).
- Lostine and Wallowa River drainages (Wallowa River population).

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-year review

Partners have completed habitat restoration projects since 2016 through the Atlas Process for watershed planning (GRMW 2020), including:

- Wallowa River population. Four projects in the Lostine River increased instream flow through 12.5 miles of habitat.
- Upper Grande Ronde population. Nine projects increased summer stream flow to 10 miles of habitat in Catherine Creek.
- Upper Grande Ronde population. Conservation partners and the Wallowa-Whitman National Forest completed seven projects that added large wood to tributaries to the upper Grande Ronde River.
- Upper Grande Ronde population. Conservation partners completed a large-scale floodplain restoration project at Birdtrack Springs on the Grande Ronde River.

4) Key Regulatory Measures Since the 2016 5-year review

The recovery plan (NMFS 2017a) and previous 5-year review (NMFS 2016a) identified inadequate regulatory mechanisms as a priority issue affecting SRB steelhead recovery in all

Snake River basin geographic areas with extant SRB steelhead populations and MPGs. Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last 5-year review indicates that the adequacy of several regulatory mechanisms has stayed the same on average, with some mechanisms showing the potential for some improvement, whereas others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions Over the Next 5 years Toward Achieving Population Viability

The greatest opportunities toward achieving population viability and advancing recovery of SRB steelhead in the Grand Ronde MPG are to:

- Upper Grande Ronde and Wallowa River populations. Continue support and development of the Atlas planning framework for the Upper Grande Ronde and the Wallowa basin to guide and prioritize habitat restoration actions (Tetra Tech, Inc. 2017).
- All non-wilderness populations. Complete restoration actions that reduce summer stream temperatures and mitigate for climate change. These projects include: protecting in-stream flows through lease and acquisition, increasing hyporheic exchange and floodplain storage, reestablishing robust native riparian vegetation, and implementing Stage 0 floodplain restoration techniques where appropriate (Justice et al. 2017; Powers, Helstab and Niezgoda 2018; Wondzell, Diabat and Haggerty 2019). Continue funding projects through the Columbia Basin Watershed Transactions Program.
- All non-wilderness populations. Reconnect streams to their floodplains and increase habitat complexity by creating sustainable beaver habitat that supports beaver populations (e.g., beaver dam analogs, ponds, riparian vegetation), enhances fish habitat, and mitigates climate change (Pollock et al. 2017; Dwire, Mellmann-Brown and Gurrieri 2018). Continue to increase habitat complexity, reconnect floodplains, and improve riparian conditions, particularly in the Upper Grande Ronde River and Wallowa River population areas.

Imnaha River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-year review

The Imnaha MPG includes one population, the Imnaha population. NMFS’ recovery plan (NMFS 2017c) identifies the following ongoing habitat concerns for the Imnaha MPG:

- High stream temperatures and low summer stream flows due to water withdrawals.
- Impaired riparian and channel conditions resulting from past livestock grazing, timber harvest, and road construction.

- Excessive fine sediment.
- Reduced large wood, low pool frequency and quality, water quality, and flow conditions.

2) Population-Specific Geographic Areas of Habitat Concern Since the 2016 5-year review

Geographic areas of habitat concern within the Imnaha River MPG include Big Sheep Creek, Little Sheep Creek, and the Imnaha River below Freezeout Creek (NMFS 2017c).

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-year review

- Lick Creek culvert replacement project was completed in 2017. Actions included adding boulder, large wood, and spawning gravel; replacing culverts, structures, and fords with bridges; and adding culverts at locations other than above stream crossings (OWRI 2020).
- Imnaha upland weed control project was completed in 2018 (OWRI 2020).

4) Key Regulatory Measures Since the 2016 5-year review

The NMFS recovery plan (NMFS 2017a) and previous 5-year review (NMFS 2016a) identified inadequate regulatory mechanisms as a priority issue affecting SRB steelhead recovery in all Snake River basin geographic areas with extant SRB steelhead populations and MPGs. Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last 5-year review indicates that the adequacy of several regulatory mechanisms has stayed the same on average, with some mechanisms showing the potential for some improvement, whereas others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions Over the Next 5 years Toward Achieving Population Viability

NMFS’ recovery plan (NMFS 2017c) recommends the following habitat actions for the Imnaha MPG:

- Continue to support and develop the Atlas planning framework for the Imnaha population to guide and prioritize habitat restoration actions (Tetra Tech, Inc. 2017).
- Focus restoration actions in Big Sheep Creek, Little Sheep Creek, and the Imnaha River below Freezeout Creek to improve riparian conditions, help moderate summer temperatures, and reduce fine sediment.
- Restore tributary habitat conditions, especially for steelhead spawners and juvenile rearing.

- Maintain current wilderness protection to protect and conserve pristine tributary habitat.

Clearwater River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-year review

Six populations are included in the Clearwater River MPG. The five extant populations include the Lower Mainstem Clearwater River, Selway River, Lochsa River, Lolo Creek, and SF Clearwater River. The North Fork Clearwater River population is extirpated. NMFS' recovery plan (NMFS 2017a) identifies the following ongoing habitat concerns for all populations in the Clearwater MPG:

- Migration barriers.
- Sediment.
- Riparian condition, shade, large wood recruitment.
- Habitat complexity.
- Stream temperature.
- Altered stream hydrology and channels from land management and levees (Lower Mainstem Clearwater River population).

2) Population-Specific Geographic Areas of Habitat Concern Since the 2016 5-year review

NMFS' recovery plan (NMFS 2017a) identifies the following geographic areas of habitat concern for each population in the Clearwater MPG:

- Lower Mainstem Clearwater River population. Watersheds with the highest priority for protection and restoration are streams with relatively high natural base flows and current high steelhead densities or high intrinsic potential for production.
- Selway River population. Tributaries to the lower Selway River.
- Lochsa River population. Stream reaches with high intrinsic potential steelhead habitat in the major spawning areas of Crooked Fork, Fish, Lake, and White Sands creeks.
- Lolo Creek population. Lolo Creek mainstem, Yoosa Creek, Musselshell Creek, and Yakus Creek.
- South Fork Clearwater River population. Major spawning areas include the Crooked River, Newsome Creek, Red River, American River, and Elk Creek watersheds.
- South Fork Salmon River Population. Several federal grazing allotments were permanently closed, reducing potential impacts to spawning and rearing habitat.

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-year review

- Lower Mainstem Clearwater River population. Various project proponents have completed more than two dozen habitat restoration projects reconnecting floodplains and meadows, installing LWD, and removing passage barriers. Since the last 5-year review, these actions have improved more than 20 miles of steelhead habitat in the Lapwai Creek and Potlatch River drainages. The Lewiston Orchards Irrigation District (LOID) wells project was completed in 2016, adding additional flow to Sweetwater and Lapwai creeks (PCSRF 2021).
- Selway River population. Six tributary culverts on the O'Hara Creek Road were replaced in 2016, eliminating chronic sediment delivery to steelhead spawning and rearing habitat in O'Hara Creek (NMFS 2015).
- Lochsa River population. The Waw'aalamnima Creek LWD placement project was completed in 2016 (PCSRF 2021).
- Lolo Creek population. Nez Perce Tribe Collette mine channel and floodplain restoration improved 0.6 miles, 15 acres of habitat (NPCNF 2016). The Nevada Creek culvert replacement opened passage to 4.7 miles of cold-water habitat (PCSRF 2021).
- South Fork Clearwater River population. Crooked River mine tailings habitat restoration is ongoing, restoring floodplain processes to a 2-mile legacy dredge mining site (USDA 2015). Leggett Creek culvert replacement provided steelhead passage to Leggett Creek (PCSRF 2021).

4) Key Regulatory Measures Since the 2016 5-year review

The NMFS' recovery plan (NMFS 2017a) and previous 5-year review (NMFS 2016a) identified inadequate regulatory mechanisms as a priority issue affecting SRB steelhead recovery in all Snake River basin geographic areas with extant SRB steelhead populations and MPGs. Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last 5-year review indicates that the adequacy of several regulatory mechanisms has stayed the same on average, with some mechanisms showing the potential for some improvement, whereas others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions Over the Next 5 years Toward Achieving Population Viability

NMFS' recovery plan (NMFS 2017a) recommends the following habitat actions, for each population, over the next 5 years to achieve Clearwater MPG viability:

- Lower Mainstem Clearwater River population. Establish site-specific habitat restoration priorities using information the watershed plans developed from geomorphic stream assessments (also throughout the Clearwater basin) and updated information from fish population inventories in high priority watersheds. Habitat activities should be designed to preserve, restore, or rehabilitate natural habitat-forming processes (i.e., flood frequency and magnitude, sediment supply, and LWD recruitment).
- Selway River and Lochsa River populations. Prioritize habitat restoration projects to reduce road sediment and passage barriers in tributaries to the lower Selway River.
- Lolo Creek population. Eliminate migration barriers and chronic sediment sources from roads, and restore riparian conditions, large wood, and floodplain connectivity in the geographic areas of concern listed above to increase productivity and smolt production in the Lolo Creek population. Continue to support and develop the Atlas planning frameworks for the Lolo Creek and South Fork Clearwater River populations.
- South Fork Clearwater River population. Protect existing high-quality habitats, improve riparian conditions, eliminate chronic sediment and restore channel and floodplain function in historic mining sites by removing unnecessary bank stabilization structures. Support studies of juvenile rearing and migration to inform restoration of rearing habitat.

Salmon River MPG

1) Population-Specific Key Emergent or Ongoing Habitat Concerns Since the 2016 5-year review

The Salmon River MPG includes the following 12 populations: Little Salmon River, South Fork Salmon River, Secesh River, Chamberlin Creek, Lower Middle Fork Salmon River, Upper Middle Fork Salmon River, Panther Creek, North Fork Salmon River, Lemhi River, Pahsimeroi River, East Fork Salmon River, and the Upper Mainstem Salmon River. Habitat concerns reported in the 2016 5-year review (NMFS 2016a) and the ESA Recovery Plan for Idaho Snake River Spring/Summer Chinook Salmon and SRB Steelhead (NMFS 2017a) and reaffirmed in this review period (Biomark ABS et al. 2019; NPT 2020a) continue to exist:

- Low flows. The Lemhi River and Pahsimeroi River populations are particularly impacted by low flows caused by irrigation diversion.
- Degraded riparian conditions. The conditions affect the Lemhi River, Pahsimeroi River, East Fork Salmon River, and Upper Salmon Mainstem populations.
- Sediment. High sediment levels affect the Lemhi River, Pahsimeroi River, Upper Salmon Mainstem, and South Fork Salmon River populations.
- High summer water temperature. Temperatures affect rearing juveniles from all populations in the MPG, except in the Panther Creek and North Fork Salmon River populations.

- Passage barriers. Barriers restrict passage for the Secesh and South Fork Salmon River populations.
- Insufficient overwintering habitat. Insufficient overwintering habitat is limiting juvenile growth in the Lemhi River, Pahsimeroi River, and Upper Salmon Mainstem populations. A habitat concern identified since the 2016 5-year review, insufficient overwintering habitat is due in part to simplified stream channels and lack of floodplain complexity.
- Migration Corridor. Degraded habitat conditions in the Salmon River, Snake River, Columbia River, and Columbia River estuary continue to adversely affect juveniles and adults from all populations in this MPG.

2) Population-Specific Geographic Areas of Habitat Concern Since the 2016 5-year review

There are no additional population-specific geographic areas of habitat concern identified beyond the emergent and ongoing habitat concerns listed (all populations in the MPG) in the 2017 recovery plan (NMFS 2017a).

3) Population-Specific Key Protective Measures and Major Restoration Actions Taken Since the 2016 5-year review

The Tribes, U.S. Forest Service (USFS), and other partners have completed many habitat restoration projects in the Salmon River MPG since the 2016 5-year review:

- South Fork Salmon River population. The Nez Perce Tribe and the Payette National Forest decommissioned 42 miles of upland and 14 miles of riparian roads; improved 14 miles of road; and replanted several degraded riparian areas (NPT 2020a).
- Little Salmon River population. The Payette National Forest replaced six passage barrier culverts in the Boulder Creek subwatershed, reconnecting 6 miles of stream habitat (Payette National Forest 2020).
- Lower Middle Fork Salmon River population. The Nez Perce Tribe and the Payette National Forest decommissioned 3 miles of upland, and 3 miles of riparian roads eliminated 12 stream crossings; installed two bridges and improved 14 miles of road; and screened two water diversions (NPT 2020b).
- Lemhi River population. Conservation partners have improved summer instream flow, reconnected tributaries to the mainstem river, increased floodplain and habitat complexity, and altered grazing management to improve riparian habitat (Biomark ABS et al. 2019). The Hawley Creek project reconnected an important tributary to the Lemhi River after 100 years of agriculture-related disconnection. The Eagle Valley Ranch project, a large-scale floodplain restoration project, was implemented in an area critical to late summer/winter rearing juveniles. The Henry Project and the Lemhi Fayle Project also restored floodplain habitat, and the Big Timber 2 diversion created access to 8 miles

of tributary habitat. Overall, work in the Lemhi River basin between 2007 and 2019 has increased the summer rearing capacity for parr (Uthe et al. 2017; Haskell et al. 2019).

- Pahsimeroi River population. Since 2016, conservation partners have improved instream flow during the irrigation season, altered grazing management to improve riparian habitat, reconnected tributary flow to the mainstem river, and increased floodplain and habitat complexity (Biomark ABS et al. 2019). Installation of head gates, piping irrigation water, and closing ditches, coupled with the Idaho Department of Water Resources formally requiring compliance with existing water rights conditions (i.e., quantity diverted, timing of diversion, and usage of a measuring device), has resulted in the presence of perennial water in the Upper Pahsimeroi. Four additional restoration projects improved fish passage, habitat complexity, sediment transport, floodplain connectivity, and riparian health on three miles of habitat. Habitat restoration actions since 2008 effectively doubled the amount of spawning and rearing habitat available to salmon and steelhead (NMFS 2020b).
- Panther Creek population. Since 2016, the USFS and the Shoshone-Bannock Tribes have focused new efforts on stream habitat improvement in Panther Creek. The Panther Creek Riverscapes Conceptual Restoration Plan identifies mileages, reaches, and targeted restoration actions within the watershed (Hill et al. 2019). A 110-acre parcel adjacent to historically high-quality spawning habitat on Panther Creek was protected through the Land and Water Conservation Fund. Installation of a bridge on Musgrove Creek reconnected fish access to 7 miles of habitat.
- Multiple Populations – Instream Flow. Since 2016, the Idaho Water Transactions Program has remained an important means of ongoing habitat restoration and protection across the MPG. Mechanisms to improve instream flow during the irrigation season included minimum flow agreements, short-term or permanent water leases, and moving points of diversion from a flow-limited reach to a reach with adequate water for fish. From 2016 to 2019, the Idaho Water Transactions Program protected between 29 and 41 CFS per year (2,025 to 3,906 acre-feet per year) (IDWR 2020). These projects improved habitat for the Lemhi River, Pahsimeroi River, and Upper Mainstem Salmon River populations.
- Multiple Populations – Fish Screens. The Idaho Department of Fish and Game maintains fish screens on at least 264 water diversions across the MPG, including 124 in the Lemhi, 19 in the Pahsimeroi, and 23 in the Upper Salmon Mainstem rivers, preventing entrainment of the Lemhi, Pahsimeroi, and Upper Salmon Mainstem populations in irrigation diversions (NMFS 2020b). Additional screens exist in the East Fork Salmon River, North Fork, and Upper and Lower Mainstem Salmon River populations. Screens reduce diversion-related mortality for fish from every population in the MPG.
- Upper Mainstem Salmon River Population. Several miles of mainstem habitat historically degraded by dredge mining have been restored in the Yankee Fork since 2015.

Restoration improved floodplain connectivity, habitat complexity, increased quantity of habitat, and improved spawning substrate in key locations.

4) Key Regulatory Measures Since the 2016 5-year review

The NMFS' recovery plan (NMFS 2017a) and previous 5-year review (NMFS 2016a) identified inadequate regulatory mechanisms as a priority issue affecting SRB steelhead recovery in all Snake River basin geographic areas with extant SRB steelhead populations and MPGs. Various federal, state, and county regulatory mechanisms are in place to minimize or avoid habitat degradation caused by human use and development. New information available since the last 5-year review, including mainstem information, indicates that the adequacy of several regulatory mechanisms has stayed the same on average, with some mechanisms showing the potential for some improvement, whereas others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Regulatory Mechanisms* in this document for details.

5) Recommended Future Actions Over the Next 5 years Toward Achieving Population Viability

- All populations. Continue to conduct appropriate road maintenance, road obliteration, road relocation, and road resurfacing; improve riparian conditions in disturbed areas; eliminate passage barriers; and restore floodplains.
- South Fork Salmon and Secesh populations. Improve water quality by reclaiming abandoned mine sites, such as the Cinnabar mine (NPT 2020a). Improve planning for potential climate change effects by continuing to monitor stream temperature and validate fish distribution in modeled cold water refugia (Payette National Forest 2020).
- Lower Middle Fork Salmon River population. In Big Creek, reduce and prevent sediment delivery to streams by rehabilitating abandoned mine sites and roads, such as the Dewey Mine and associated roads in the Thunder Mountain Mining District. Reduce impacts of water diversions for domestic, irrigation, stockwater, and hydropower purposes on instream flows in upper Big Creek by administering special use permits for water diversions on National Forest lands (Payette National Forest 2020) (Big Creek).
- Lemhi River, Pahsimeroi River, and Salmon River Upper Mainstem populations. Increase winter juvenile rearing habitat by increasing floodplain connectivity and complex habitat structure, reducing width-to-depth ratios, increasing low- to zero-velocity pool habitat with cover, providing side channel habitat, and reducing fine sediment delivery to streams (Biomark ABS et al. 2019). As appropriate, replicate similar actions in other populations as new information identifies similar problems or is based on inference from data-rich populations. Complete Multiple Reach Assessment reports for the Upper Lemhi River basin, Lower Lemhi River basin, Lower Pahsimeroi River basin, and Upper Salmon River basin above Redfish Lake Creek to determine where habitat

restoration would be most effective at increasing population viability (Biomark ABS et al. 2019).

- East Fork Salmon, Lemhi, Pahsimeroi, and Upper Mainstem Salmon River populations. Reconnect tributaries to the mainstem Salmon River from the North Fork Salmon River to Valley Creek. This action will increase available spawning and rearing habitat in tributaries, provide temperature refugia for juveniles, and lower summer water temperatures for juvenile rearing in the mainstem Salmon River (NMFS 2017a; IDFG 2021).
- Increase instream flow through: (1) expanding and continuing the Idaho Water Transactions Program; (2) securing permanent water transactions for the lower Lemhi minimum flow needs, and continuing filling needs with shorter-term agreements until permanent agreements can be established; (3) seeking additional water transaction agreements throughout the MPG; and (4) limiting new water rights in the MPG. For aging fish screen infrastructure at water diversions, ensure ongoing funding sources to complete routine maintenance and necessary upgrades. Fund new fish screens when new habitat is opened up through tributary reconnection projects.
- Lemhi River population. In the lower mainstem Lemhi River (downstream of Hayden Creek), increase habitat complexity by increasing the sinuosity of the single-thread main channel while creating areas of island braiding with complex instream structure, hydraulic variability, and low-velocity areas with cover.
- Lemhi River population. In the upper mainstem Lemhi River, increase habitat complexity by creating multi-threaded channels, narrow width-to-depth ratios, stable banks, and willow-dominated riparian areas. Maintain and improve instream flow and tributary stream connections to the mainstem Lemhi River (Biomark ABS et al. 2019).
- For the Pahsimeroi River population. Maintain and improve instream flow. Increase habitat quantity by adding more channels within groundwater-influenced reaches that provide high-quality, complex habitat, including split flows, side channels, spring channels, and alcoves. Increase stream length by increasing sinuosity, which also increases hyporheic flow. Establish a robust, riparian community along the banks and floodplain, increasing shade, improving bank structure and habitat, and providing a buffer from upland and floodplain sediment sources (Biomark ABS et el. 2019).
- Upper Mainstem Salmon River population. Increase habitat complexity by creating or enhancing multi-threaded channels and increasing floodplain connection (Biomark ABS et al. 2019). Maintain and improve instream flow and tributary stream connections to the mainstem Upper Salmon River, particularly upstream of the Alturas Lake Creek confluence (Biomark ABS et al. 2019).
- Panther Creek population. Remove fish passage barriers at road-stream crossings, add large wood to streams, encourage beaver recolonization to restore floodplain connectivity, screen water diversions, and continue low-tech process-based stream habitat restoration efforts. Re-evaluate the role of the Panther Creek population in the MPG

recovery scenario in the recovery plan, considering the natural spawning that has occurred in this population since 2005 (Conley and Denny 2019).

Listing Factor A Conclusion

Conservation partners have implemented many tributary habitat restoration projects across the DPS since the last 5-year review. These projects have improved habitat conditions for SRB steelhead spawning, rearing, and migration in many reaches. In addition, PIBO landscape-scale monitoring has shown that habitat is improving on Pacific Northwest National Forests and Bureau of Land Management (BLM) lands. Still, habitat limiting factors remain the same since the last 5-year review. Widespread areas of degraded habitat persist, and further habitat degradation continues, across the basin, with a lack of habitat complexity, simplified stream channels, disconnected floodplains, impaired instream flow, loss of cold water refugia, and other limiting factors. We conclude that given the restoration, further degradation, and continuance of tributary habitat limiting factors, the overall habitat risks to the persistence of the SRB Steelhead DPS is moderate, remaining the same since the last 5-year review.

Recommended future actions

Future recommended habitat restoration actions will target habitat limiting factors found in the DPS recovery plan (NMFS 2017b), and limiting factors identified in large-scale restoration plans from watershed councils, Tribes, and state and federal agencies. Continued large-scale watershed and stream habitat restoration remains a key component of recovering this DPS, as described in the 2017 recovery plan (NMFS 2017a). Important considerations for tributary habitat restoration over the next 5 years include:

- Prioritize projects that improve habitat complexity and resiliency to climate change. Actions to restore channel complexity, passage, riparian vegetation, streamflow, and floodplain connectivity and re-aggrade incised stream channels can ameliorate temperature increases, base flow decreases, and peak flow increases, thereby improving population resilience to certain effects of climate change (Beechie et al. 2013).
- Prioritize projects that restore habitat where age classes of rearing juveniles are missing. Support geomorphic assessments and juvenile steelhead studies in the Clearwater basin to inform restoration plans that address missing age classes of rearing juveniles.
- Connect tributaries to mainstem migration corridors. Temperature refugia from tributaries is vital to successful migration and survival (Keefer et al. 2018; EPA 2021).
- Support and enhance local- to basin-scale frameworks to guide and prioritize habitat restoration actions and integrate a landscape perspective into decision making. Successful examples in the DPS include the Grande Ronde, Lolo Creek, and South Fork Clearwater Atlas process and the Integrated Rehabilitation Assessment in the Upper Salmon River (Tetra Tech Inc. 2017; Biomark ABS et al. 2019; White et al. 2021). White et al. (2021) suggest that these efforts would benefit from gaining broader public support and formalizing an adaptive management strategy.

- Implement habitat restoration at a watershed scale. Roni et al. (2010) found that, for a watershed, at least 20 percent of floodplain and in-channel habitat need to be restored to gain a 25 percent increase in salmon smolt production. Most watersheds occupied by this species have not yet reached that level of floodplain and habitat restoration.
- Reconnect stream channels with their floodplains. The reintroduction of beaver (Pollock et al. 2017) and use of low-tech process-based methods (Wheaton et al., eds. 2019) will facilitate widespread, low-cost floodplain restoration across the DPS, including in higher elevation spawning and rearing areas, to increase the productivity of freshwater habitat for steelhead.
- Ensure that habitat improvement actions are implemented consistent with best practices for watershed restoration (see, e.g., Beechie et al. 2010; Hillman et al. 2016; and Appendix A of NMFS 2020a).

Listing Factor B: Overutilization for commercial, recreational, scientific, or educational purposes

Harvest

Systematic improvements in fisheries management since the 2016 5-year review include implementation of a new *U.S. v. Oregon* Management Agreement for the years 2018-2027, which replaces the previous 10-year agreement. This new agreement maintains the limits and reductions in harvest impacts for the listed ESUs/DPSs that were secured in previous agreements (NMFS 2018a).

Steelhead encounters in the ocean are rare and incidental impacts to steelhead in ocean fisheries targeting other species are inconsequential (low hundreds of fish each year) to very rare (PFMC 2020). The majority of harvest-related impacts on SRB steelhead occurs in the mainstem Columbia River. Recreational fisheries targeting hatchery-run steelhead with incidental impacts on natural returns also occur in the mainstem Columbia River and sections of the Snake, Clearwater, and Salmon rivers (NWFSC 2015). Limits on harvest rates for SRB steelhead are established for treaty and non-treaty fisheries in the Columbia River. Treaty fisheries in the Columbia River are limited to an incidental take of 13 to 20 percent (depending on run size) of SRB steelhead returning to the Columbia River mouth (NMFS 2018a). For non-treaty fisheries, there are separate limits for A-Run and B-Run components during each of the management periods (management periods are: (1) winter, spring, and summer combined, and; (2) fall. The limit for non-treaty fisheries is two percent each for A and B-run steelhead during each management period (NMFS 2018a). Overall, impacts on SRB steelhead have declined since the last 5-year review. Impacts in treaty fisheries have declined from 13.8 percent in the last 5-year review period (NMFS 2016a) to an average of 8.7 percent during years 2014-2019 (TAC 2015, 2016, 2017, 2018, 2019, 2020). Impacts in non-treaty fisheries have averaged 0.58, 1.28, 0.08, and 1.52 percent for A-Run winter/spring/summer, A-Run fall, B-Run winter/spring/summer, and B-run fall, respectively during the years 2014-2019 (TAC 2015, 2016, 2017, 2018, 2019, 2020). Harvest rates have decreased since the 2016 5-year review. Impacts in treaty and non-treaty fisheries are limited by the 2018-2027 *U.S. v. Oregon* Management Agreement (NMFS 2018a). Therefore, harvest continues to pose a moderate risk to SRB steelhead.

Research and Monitoring

The quantity of take authorized under ESA sections 10(a)(1)(A) and 4(d) for scientific research and monitoring for these species remains low in comparison to their abundance. Much of the work is being conducted for the purpose of fulfilling state and federal agency obligations under the ESA to ascertain the species' status. Authorized mortality rates associated with scientific research and monitoring are generally capped at 0.5 percent across the West Coast Region for all listed salmonid ESUs and DPSs. As a result, the mortality levels that research causes are very low throughout the region. In addition, and as with all other listed salmonids, the effects research has on the Snake River salmonids are spread over various reaches, tributaries, and areas across all of their ranges. Thus no area or population is likely to experience a disproportionate amount of loss. Therefore, the research program, as a whole, has only a very small impact on overall population abundance, a similarly small impact on productivity, and no measurable effect on spatial structure or diversity for SRB steelhead.

Any time we seek to issue a permit for scientific research, we consult on the effects that the proposed work would have on each listed species' natural- and hatchery-origin components. However, because research has never been identified as a threat or a limiting factor for any listed species, and because most hatchery fish are considered excess to their species' recovery needs, examining the quantity of hatchery fish taken for scientific research would not inform our analysis of the threats to a species' recovery. Therefore, we only discuss the research-associated take of naturally-produced fish in these sections.

From 2015 through 2019, researchers were approved to take a yearly average of fewer than 683,200 SRB steelhead juveniles (<7,700 lethally). For adult salmonids during this same period, researchers were approved to take a yearly average of fewer than approximately 21,000 SRB steelhead (<260 lethally) per year (NMFS APPS database; https://apps.nmfs.noaa.gov/).

For the vast majority of scientific research actions, history has shown that researchers generally take far fewer salmonids than are authorized every year. Reporting from 2015 through 2019 indicates that over those 5 years, the average actual yearly total take for naturally-produced juveniles or adults was 12 percent of the amount authorized for SRB steelhead. The actual lethal take was also low over the same 5-year period: the average yearly lethal take of juveniles was only 7 percent of the average amount authorized per year, and the average yearly lethal take of adults was only 0.5 percent of the average amount authorized per year for SRB steelhead.

The majority of the requested take for naturally produced SRB steelhead juveniles has primarily been (and is expected to continue to be) capture via screw traps, electrofishing units, and beach seines. Smaller numbers are collected as a result of hand or dip netting, minnow traps, weirs, other seines, trawling, hook and line sampling, and those intentionally sacrificed. Adult take for the species has primarily been (and is expected to continue to be) capture via weirs or fish ladders, with smaller numbers getting unintentionally captured by, hook and line angling, and hand or dip nets screw traps, seining, and other methods that target juveniles (NMFS APPS database; https://apps.nmfs.noaa.gov/). Our records indicate that mortality rates for screw traps are typically less than one percent and backpack electrofishing are typically less than three percent. Unintentional mortality rates from seining, dip netting, minnow traps, weirs, and hook and line methods are also limited to no more than three percent.

The quantity of take authorized over the past 5 years has remained relatively stable for SRB steelhead compared to the prior 5 years. The total amount of take authorized for naturally-produced fish increased by 27 percent, and the amount of authorized lethal take increased by 32 percent from 2015 through 2019 when compared to 2010 through 2014. However, increases in take requested and authorized have not resulted in similar increases in the take actually occurring. From 2015 through 2019, the total take reported decreased by almost six percent compared to 2010 through 2014, and the lethal take that actually occurred increased by 25 percent when comparing the same two time periods.

Overall, research impacts remain minimal due to the low mortality rates authorized under research permits and that research is spread out geographically throughout the Snake River basin. Therefore, the overall effect on listed populations has not changed substantially since the last 5-year review (NMFS 2016a). We conclude that the risk to the species' persistence because of utilization related to scientific studies remains low.

Listing Factor B Conclusion

The majority of harvest-related impacts on SRB steelhead occurs in the mainstem Columbia River. New information available since the last ESA 5-year review indicates harvest impacts have declined (TAC 2015-2020). The overall risk to the species' persistence because of harvest since the 2016 5-year review continues to pose a moderate risk.

Since the last 5-year review, scientific research impacts on listed SRB steelhead have remained relatively stable compared to the past 5 years (NMFS APPS database; https://apps.nmfs.noaa.gov/). The risk to SRB steelhead persistence from overutilization emanating from scientific research since the previous 2016 5-year review remains low. Accounting for harvest and research impacts, the overall risk from overutilization is remains at moderate.

Recommended future actions

- Continue all research, monitoring, and evaluation activities.

Listing Factor C: Disease and Predation

Disease

Disease rates over the past 5 years are believed to be consistent with the previous review period. Climate change impacts, such as increasing temperature, likely increase susceptibility to diseases. For the 2016 5-year review (NMFS 2016a), we reported that the spread of a new strain (i.e., M clade) of infectious hematopoietic necrosis virus (IHNV) along the Pacific coast may increase disease-related concerns for Snake River salmon and steelhead in the future. Since then, the M clade of IHNV has not appeared in SRB steelhead and does not appear to pose an additional risk to the DPS (Linda Rhodes, NWFSC, email sent to C. Fealko, NMFS, April 5, 2021, regarding IHNV status). SRB steelhead continue to be affected by the U clade of IHNV, but this risk has not changed since the prior 5-year review.

The handling and transport of juveniles result in them being held at much higher densities than are observed in the wild, increasing the risk of disease transmission. Juvenile transport continues through the Columbia River, and the lower smolt to adult returns (SARs) produced by transported fish may be due, in part, to increased disease. Transport rates or methods have not materially changed since the prior 5-year review, so this risk appears relatively static across the period evaluated for this current review.

Overall, projections for increasing water temperatures across the species range, increased disease prevalence, and associated salmonid susceptibility to disease in warmer water present a substantial and increasing risk to the species since the prior review period.

Avian Predation

Avian predation in the lower Columbia River estuary

Piscivorous colonial water birds, especially terns, cormorants, and gulls, have significantly impacted the survival of juvenile salmonids in the Columbia River. Caspian terns on Rice Island, an artificial dredged-material disposal island in the estuary, consumed about 5.4 to 14.2 million juveniles per year in 1997 and 1998 (up to 15 percent of all the smolts reaching the estuary; Roby et al. 2017). Efforts to move the tern colony closer to the ocean at East Sand Island, where they would diversify their diet to include marine forage fish, began in 1999. During the next 15 years, smolt consumption was about 59 percent less than when the colony was on Rice Island. The U.S. Army Corps of Engineers (Corps) has further reduced smolt consumption by reducing the bare sand available on East Sand Island for nesting from 6 acres to 1 acre. Combined with harassment (kleptoparasitism) by bald eagles, and egg and chick predation by gulls, the number of nesting pairs has dropped from more than 10,000 in 2008 to fewer than 5,000 in 2018 and 2019 (Roby et al. 2021).

Hostetter et al. (2012) found that body size and behavior affect susceptibility to tern predation. Steelhead smolts are more susceptible to predation than other out-migrating salmonids due to their larger body size. Hatchery steelhead are also more susceptible to tern predation (surface predation) because hatchery steelhead swim closer to the surface of the water than wild steelhead smolts. Hostetter et al. (2012) reiterates that avian predation is a limiting factor to species survival and recovery.

The Corps has also reduced the size of the double-crested cormorant colony on East Sand Island, although efforts to reduce predation rates have not been successful. The pressures of lethal take and non-lethal hazing under the Corps' management plan (USACE 2015), combined with harassment by bald eagles, moved thousands of nesting pairs from the island to the Astoria-Megler Bridge. Because the colony on the bridge is 9 miles further up-river than East Sand Island, these birds are likely to be consuming more juvenile salmonids per capita than when they were foraging further downstream with access to plentiful marine forage fish (Evans et al. 2020; Lawes et al. 2021). Researchers cannot estimate predation rates for birds nesting on the bridge because PIT tags cannot be detected or recovered if they fall into the water. Although predation rates for East Sand Island cormorants on SRB steelhead decreased from 6.3 percent to 0.5 percent when birds moved to the bridge, cormorant predation may have increased in the estuary as a whole.

Avian predation in the mainstem Columbia and Snake rivers

Juvenile SRB steelhead also have been vulnerable to predation by terns nesting in the interior Columbia plateau, including islands in McNary Reservoir and in the Hanford Reach. The Corps has successfully prevented terns from nesting on Crescent Island since 2015. To improve survival for this and other salmonids, the Corps raised the elevation of John Day Reservoir during the spring smolt migration in 2020, inundating the Blalock Islands to prevent its use by terns. This operation will continue under the proposed action identified in the 2020 biological opinion for the Columbia River System (CRS) (BPA et al. 2020).

The 2008 FCRPS biological opinion first required that the CRS Action Agencies (Corps, U.S. Bureau of Reclamation, and Bonneville Power Administration) implement avian predation control measures at mainstem dams in the lower Snake and Columbia rivers. Since then, each of the CRS projects has used hazing and passive deterrence, including wire arrays across tailrace areas, spike strips along the edge of the concrete, water sprinklers at juvenile bypass outfalls, pyrotechnics, propane cannons, and limited amounts of lethal take. These measures have reduced the number of smolts consumed by birds at the dams and will continue to be implemented, with improvements as new techniques become available.

Avian predation on SRB steelhead is substantial. Evans et al. (2021) evaluated 11 years (2008-2018) of data on cumulative avian predation on SRB steelhead by all birds from major nesting locations from Lower Granite Dam to the Pacific Ocean. Cumulative predation probability is the percent of available out-migrating smolts consumed by birds and ranges from 18 to 46 percent annually (Evans et al. 2021). Data (Evans et al. 2021) averaged from 2016-2018 (2020 review period) show a 27 percent decline in avian predation mortality compared to the 5-year average for the 2015 review period. Evans et al. (2021) also demonstrated that avian predation for SRB steelhead is slightly lower above Bonneville Dam than below.

Overall, during this 5-year review period, avian predation rates on SRB steelhead in the Columbia and Snake River migration corridors and estuary are lower than the predation rates reported in our previous 2016 5-year review. Ongoing management practices, such as water elevation adjustments and avian predation control/hazing measures, have helped drive this change. However, for SRB steelhead, avian predation is the leading cause of smolt mortality in the Snake and Columbia River migration corridors and estuary, and is a limiting factor for SRB steelhead survival and recovery.

Marine Mammal Predation

Recent research over the past 5 years suggests that predation pressure on ESA-listed salmon and steelhead from seals, sea lions, and killer whales has been increasing in the northeastern Pacific over the past few decades (Chasco et al. 2017a, 2017b). Models developed by Chasco et al. (2017a) estimate that consumption of Chinook salmon in the eastern Pacific Ocean by three species of seals and sea lions and fish-eating (Resident) killer whales may have increased from 5 to 31.5 million individual salmon of varying ages since the 1970s, even as fishery harvest of Chinook salmon has declined during the same time period (Marshal et al. 2016; Chasco et al. 2017a; Ohlberger 2019). This same modeling suggests these increasing trends have continued across all regions of the northeastern Pacific over the past 5 years. The potential predation impacts of specific marine mammal predators of ESA-listed salmonids on the West Coast are discussed individually below.

Pinniped Predation (Seals and Sea Lions)

Numbers of pinnipeds that are predators of adult salmonids have increased considerably in the Pacific Northwest since the Marine Mammal Protection Act (MMPA) was enacted in 1972 (Carretta et al. 2013). California sea lions *(Zalophus californianus)*, Steller sea lions *(Eumetopias jubatus)*, and harbor seals *(Phoca vitulina)* all consume salmonids from the mouth of the Columbia River and its tributaries up to the tailrace of Bonneville Dam.

The current population size of California sea lions (CSL) is 257,606 (Carretta et al. 2019). The stock is estimated to be approximately 40 percent above its maximum net productivity level (183,481 animals), and it is therefore considered within the range of its optimum sustainable population (OSP) size (Carretta et al. 2019). The Oregon Department of Fish and Wildlife counted the number of individual California sea lions hauling out in the Columbia River mouth at the East Mooring Basin in Astoria, Oregon, from 1997 through 2017. Pinniped counts at the East Mooring Basin during September and October, when SRB steelhead are migrating, have generally increased and doubled from 2014 to 2016 (Wright 2018). Numbers at East Moring Bay peaked in 2016 and declined from 2017-2020, approaching 2014 numbers[1]. California sea lion predation as a percentage of the run averaged 1.0 percent from 2017-2019 (Tidwell and van der Leeuw 2020).

The current population size of Steller sea lions (SSL) is 71,562 (52,139 non-pups and 19,423 pups) (Muto et al. 2019). Muto et al. (2017) concluded that the eastern stock of SSL is likely within its OSP range; however, NMFS has not determined its status relative to OSP.

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[1] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, November 17, 2020.

Excluder gates and FOGs along the face of Powerhouse 2 at Bonneville Dam successfully prevent pinnipeds from entering the adult fish ladders, and thus minimize opportunities to prey on SRB steelhead. The number of Steller sea lions at Bonneville Dam over the past 5 years has been less on average than the previous 5-years, with a high of 66 animals in 2018 and a low of 50 animals in 2019, compared to a high of 89 animals in 2011 and a low 65 animals in 2014. In addition, peak numbers of Steller sea lions occur in the spring at Bonneville Dam, therefore not overlapping SRB steelhead peak migration in the fall. However, predation as a percentage of the run on Pacific salmon and steelhead stocks by Steller sea lions has been steadily increasing and was higher than that by California sea lions. Steller sea lion predation as a percentage of the run averaged 2.7 percent from 2017-2019.

The current population size of the Oregon and Washington Coast stock of harbor seals[2] is 15,533 (Pearson and Jeffries 2018). This stock's status relative to OSP is unknown. Harbor seals are seen only occasionally at Bonneville Dam, with 0-3 individuals sited annually from 2002-2020, or 0.5 percent of annual pinnipeds counted (Tidwell and van der Leeuw 2021). When compared to sea lion numbers and predation percents, harbor seals at Bonneville Dam are an insignificant source of pinniped predation.

New information since the last 5-year review suggests that the risk to the DPS from pinniped predation is significant and increasing, particularly from Steller Sea lions feeding immediately below Bonneville Dam, although predation in the lower Columbia River may be higher than previously understood. Pinniped counts at the East Mooring Basin during September and October, when SRB steelhead are migrating, have generally increased from 2014. Numbers at East Moring Bay peaked in 2016 and declined from 2017-2020, approaching 2014 numbers[3]. California sea lion predation as a percentage of the run averaged 1.0 percent from 2017-2019. For Steller sea lions, despite declines in numbers at Bonneville Dam due to exclusion measures, predation as a percentage of the run on Pacific salmon and steelhead stocks by Steller sea lions has been steadily increasing and was higher than that by California sea lions. Steller sea lion predation as a percentage of the run averaged 2.7 percent from 2017-2019. New management actions authorized under the Endangered Salmon Predation Prevention Act to lethally remove sea lions (see Listing Factor D for details) are expected to reduce pinniped predation on adult SRB steelhead in the lower Columbia River. However, given the logistical challenges of removing sea lions and other uncertainties, the magnitude of this expected reduction in pinniped predation is uncertain.

Although exclusion efforts have reduced the numbers of sea lions at East Mooring Basin and Bonneville Dam, with their increasing population numbers and expanded geographical range, marine mammals are consuming more Pacific salmon and steelhead since the 2016 5-year review. Because of the fall timing, SRB steelhead have less overlap with peak spring and summer pinniped presence and thus are less affected than other Pacific salmon. However, sea

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[2] For a complete stock status, definition and geographic range see Carretta et al. 2019.

[3] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, November 17, 2020.

lion predation currently accounts for 3.7 percent of the annual SRB adult steelhead run. This consumption of Pacific salmon is having an adverse impact on some ESA-listed species (Marshall et al. 2016; Thomas et al. 2016; Chasco et al. 2017a).

Northern Pikeminnow Predation

A sport fishing reward program was implemented in 1990 to reduce the numbers of Northern pikeminnow in the Columbia River basin (NMFS 2010). The program continues to meet expected targets, which may reduce predation on smolts of all salmon and steelhead species in the mainstem Columbia River. The sport reward fishery removed an average of 188,708 piscivorous pikeminnow per year during 2015 to 2019 in the Columbia and Snake rivers (Williams et al. 2015, 2016, 2017, 2018; Winter et al. 2019). Northern pikeminnow predation can increase when avian predation (for all fish species) is reduced (ISAB 2019). Northern pike minnow predation on juvenile ESA-listed salmonids in the Columbia River was estimated to be 8 percent in 1996 and reduced to an estimated 5 percent due to the ongoing sport fishing removal program for northern pikeminnow (ISAB 2019).

Aquatic Invasive Species

Non-indigenous fishes affect salmon and their ecosystems through many mechanisms.

The Independent Scientific Review Board (ISAB 2019) reported on non-indigenous fish predators. Of all the non-indigenous fish predators in the Columbia River system (rivers not lakes), the two major threats to native listed salmonids are smallmouth bass and walleye. When compared to northern pikeminnow predation in the John Day reservoir, the proportion of predation was northern pikeminnow (78 percent), walleye (13 percent), and smallmouth bass (9 percent). However, smallmouth bass are far more widespread than walleye in the Columbia River, are considered a larger and increasing threat, and increase predation when pikeminnow numbers are reduced. Threats are not restricted to direct predation; non-indigenous species compete directly and indirectly for resources, significantly altering food webs and trophic structure, and potentially altering evolutionary trajectories (Sanderson et al. 2009; NMFS 2010). ISAB (2019) reports that the range of warm-water non-indigenous species is expanding and may include the headwater tributaries of the Columbia River basin by 2080.

Listing Factor C Conclusion

Disease rates over the past 5 years are believed to pose a low risk to the persistence of SRB steelhead and are consistent with the previous review period.

The extinction risk posed to the DPS by predation from avian, pinniped, and other fish species has remained largely the same, at moderate levels, since the last 5-year review. Avian predation rates are much higher than predation rates from predatory fish or marine mammals. In the mainstem Snake and Columbia rivers, and Columbia River estuary, efforts by the Corps to reduce or relocate predatory birds has reduced or increased avian predation depending on location resulting in no overall change in avian predation impacts since the last 5-year review.

Pinniped predation during this review period averaged 3.7 percent of adult return to East Mooring Bay and Bonneville Dam. Moderate predation from all sources is similar to the last 5-year review, and poses a moderate risk to the persistence of SRB steelhead.

Recommended future actions

- Pacific salmon and steelhead recovery partners[4] are encouraged to develop and implement a long-term management strategy to reduce pinniped predation on Pacific salmon and steelhead in the Columbia River basin and Puget Sound by removing, reducing, and-or minimizing the use of manmade haul outs used by pinnipeds in select areas (e.g., river mouths/migratory pinch points).
- Pacific salmon and steelhead recovery partners[5] are encouraged to expand, develop, and implement monitoring efforts in the Columbia River basin, Puget Sound, and California to identify pinniped predation interactions in select areas (e.g., river mouths/migratory pinch points), and quantitatively assess predation impacts by pinnipeds on Pacific salmon and steelhead stocks.
- Continue current avian and predatory fish predation reduction programs.

Listing Factor D: Inadequacy of Regulatory Mechanisms

Various federal, state, county and tribal regulatory mechanisms are in place to reduce habitat loss and degradation caused by human use and development, such as the hydrosystem and harvest. For this review, we focus our analysis on regulatory mechanisms for habitat and harvest that have either improved for SRB steelhead, or are still causing the most concern in terms of providing adequate protection for SRB steelhead.

Habitat

Habitat concerns are described throughout Listing Factor A as having either a system-wide influence, or more localized influence, on the populations and MPGs that comprise the species. The habitat conditions across all habitat components (tributaries, mainstems, estuary, and marine) necessary to recover listed SRB steelhead are influenced by a wide array of federal, state, and local regulatory mechanisms. The influence of regulatory mechanisms on listed salmonids and their habitat resources is based in large degree by the underlying ownership of the land and water resources as Federal, state, or private holdings. Most of the land in the Snake River basin is managed by the Federal government (about 64 percent), including the U.S. Forest Service, U.S. Bureau of Land Management, and the U.S. Department of Energy. The U.S. Bureau of Reclamation works with other state and federal agencies and private groups to manage the basin’s water resources for the many, and sometimes competing, uses.

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[4] Federal and state agencies, tribes, landowners, watershed councils, private organizations, etc.
[5] Federal and state agencies, tribes, landowners, watershed councils, private organizations, etc.

One factor affecting habitat conditions across all land or water ownerships is climate change, the effects of which are discussed under Section 2.3.2 (*Listing Factor E: Other natural or manmade factors affecting its continued existence).* We reviewed summaries of national and international regulations and agreements governing greenhouse gas emissions. These documents indicate that, while the number and efficacy of such mechanisms have increased in recent years, there has not yet been a substantial deviation in global emissions from the past trend, and upscaling and acceleration of far-reaching, multilevel, and cross-sectoral climate mitigation will be needed to reduce future climate-related risks (IPCC 2014, 2018). These findings suggest that current regulatory mechanisms, both in the U.S. and internationally, are not adequate to address the rate at which climate change negatively impacts habitat conditions for many ESA-listed salmon and steelhead.

Regulatory Mechanisms Resulting in Adequate or Improved Protection

New information available since the last 5-year review indicates that the adequacy of some regulatory mechanisms has improved (or has the potential to improve) and has increased the protection of SRB steelhead. These include:

1. The Endangered Species Act Section 7 Biological Opinions

- Mainstem hydrosystem improvements. NMFS completed two biological opinions, one in 2019 (NMFS 2019b) and the second in 2020 (a), for the Columbia River System (CRS). The 2020 opinion increased the amount of spring spill to improve passage conditions for juvenile salmon. The Action Agencies hypothesize that spring spill improvements may increase downstream migration survival, which is expected to increase population productivity by delivering more smolts to the ocean, resulting in more adults returning. Additional improvements in survival are possible from a revised juvenile transport program and more estuary restoration. Since the last 5-year review, increased spring spill rates have and will continue to decrease the proportion of juveniles from the Snake River that are transported. This is anticipated to improve adult SRB steelhead survival through the CRS since fish transported as juveniles survive at roughly half the rate of non-transported fish (Crozier et al. 2020) during their upstream migrations.
- Estuary Habitat Improvements. The CRS Action Agencies are implementing an estuary habitat improvement program (the Columbia Estuary Ecosystem Restoration Program, CEERP), reconnecting the historical floodplain below Bonneville to the mainstem Columbia River. From 2007 through 2019, the Action Agencies implemented 64 projects, including dike and levee breaching or lowering, tide-gate removal, and tide-gate upgrades that reconnected over 6,100 acres of historical tidal floodplain habitat to the mainstem and another 2,000 acres of floodplain lakes (Karnezis 2019; BPA et al. 2020). This represents more than a 2.5 percent net increase in the connectivity of habitats that produce prey used by juvenile Snake River salmon and steelhead (Johnson et al. 2018). In addition to this extensive reconnection effort, about 2,500 acres of currently functioning floodplain habitat have been acquired for conservation.

Floodplain habitat restoration can affect the performance of juvenile salmonids whether they move onto the floodplain or stay in the mainstem. Wetland food production supports foraging and growth within the wetland (Johnson et al. 2018), but these prey items (primarily chironomid insects) (PNNL and NMFS 2018, 2020) are also exported to the mainstem and off-channel habitats behind islands and other landforms, where they become available to salmon and steelhead migrating in these locations. Thus, for any smolts that do not enter a tidal wetland channel, they still derive benefits from wetland habitats. Continuing to grow during estuary transit may be part of a strategy to escape predation during the ocean life stage through larger body size. The CEERP strategy includes a robust monitoring program that provides the basis for adaptive management. This includes action effectiveness monitoring at each restoration site. Monitoring will continue at completed sites and will be initiated for sites constructed during the period of the proposed action. Johnson et al. (2018) found that the action effectiveness monitoring data collected since 2012 generally indicated that the restoration of physical and biological processes was underway at these sites. Continued evaluation of these monitoring data will confirm that these floodplain reconnections are enhancing conditions for juvenile salmonids as they migrate through the mainstem or provide sufficient information to better inform site selection or project design.

As part of the adaptive management framework, the Action Agencies will continue to discuss relevant climate change science with their independent science panel, the Expert Regional Technical Group, and regional partners in an effort to understand how their planned estuary projects can be more resilient to sea-level rise, increasing temperatures, and changes in seasonal mainstem flows. The Action Agencies' annual update of their CEERP restoration and monitoring plans will document any adjustments in design, location, or other project elements to address climate change impacts, both during the implementation of the proposed actions and beyond.

- <u>Tributary Habitat Improvements</u>. Since 2008, under the biological opinions for the CRS (NMFS 2008a, 2014a, 2019, 2020), the Action Agencies have implemented a tributary habitat program as mitigation for the effects of the CRS. Implementation of the program has focused primarily on Upper Columbia spring Chinook salmon and steelhead and SR spring/summer Chinook salmon and SRB steelhead. Some actions have also been targeted to address Mid-Columbia steelhead. The level of investment in the program has remained relatively constant since the last 5-year review, as have the specific populations on which the Action Agencies have focused their efforts.

  The main changes in the program since the last 5-year review include a shift from having local expert panels evaluate benefits of actions using a method developed as part of the 2008 biological opinion to the use of life-cycle models, where available, to evaluate benefits of tributary habitat improvement actions (along with other considerations described in Appendix A of NMFS 2020a). In addition, a Tributary Habitat Steering Committee was formally convened under the 2019 biological opinion, and under the

2020 biological opinion, a Tributary Technical Team will be formed to provide scientific input on the implementation of the program to help ensure that program goals and objectives are achieved. The Action Agencies have remained committed to ensuring that the program is informed by recovery plans and other best available information and science, builds adaptively on science-based strategies and research and monitoring information, and maintains the extensive network of collaboration with local experts and implementing partners that was developed under previous CRS biological opinions. NMFS views these changes and commitments as positive and appropriate adaptations of the program to evolving science on both the prioritization and implementation of tributary habitat improvement actions and the evaluation of action and program benefits. Still, degraded habitat conditions continue to negatively affect abundance, productivity, spatial structure, and diversity. Additional improvement is needed to restore habitat to levels consistent with achieving the ESA recovery goals.

- <u>Fish Population and Habitat Research, Monitoring and Evaluation</u>. The CRS Action Agencies are implementing a comprehensive fish population and habitat research, monitoring, and evaluation (RME) program that began under the 2008 FCRPS biological opinion and its 2010 Supplement (NMFS 2008a, 2010) and continues under the 2020 CRS biological opinion. The habitat RME program is structured to include compliance, implementation, effectiveness, and status and trends monitoring and research. The Action Agencies' RME efforts are intended to work in concert with similar efforts funded by other federal, state, tribal, utility, and private parties that, when combined, will contribute to basinwide RME data and analyses. Under the 2020 CRS biological opinion, the Action Agencies will continue to implement a tributary habitat RME program to assist in regional efforts to assess tributary habitat conditions, limiting factors, and habitat-improvement effectiveness and to address critical uncertainties associated with offsite habitat mitigation actions.
- <u>Federally Authorized Water Diversions</u>. Examples of Federal authorities include The Federal Land Policy and Management Act of 1976, as amended (USDI 1976), the 1986 Ditch Bill Act (PL 99-545, HR 2921), and special-use authorizations. In Idaho, the USFS has recently completed jeopardy (NMFS 2012a, 2016b, 2016c, 2020b) or initiated (i.e., Sawtooth National Forest) ESA section 7 consultations on the use of Federal land to convey water to private irrigation water users. Future implementation of these consultations, including the associated voluntary conservation measures, is likely to provide minor improvements, relative to baseline conditions, to water quantity and water temperature within the migratory corridor for SRB steelhead.

2. Federal Land Policy and Management Act of 1976, as amended. Vital regional Federal land management strategies should continue, including PACFISH (USDA/USDI 1995), to maintain or improve the quality of aquatic systems for salmonids, and the Interior Columbia Basin Strategy (ICBEMP 2014), a science and ecosystem-based strategy for land management and actions. Equally important is continuance of the PACFISH/INFISH Biological Opinion Monitoring

Program (PIBO; Roper et al. 2019) which provides unique long-term regional-scale monitoring of the effects of federal land management on riparian and stream habitat in the Pacific Northwest. Current PIBO monitoring shows a measurable improvement in Columbia River basin anadromous fish habitat on National Forest and BLM lands since the last 5-year review.

3. Federal Energy Regulatory Commission. As part of the re-authorization process for the Hells Canyon Complex (HCC) of dams (i.e., Brownlee, Oxbow, and Hells Canyon dams), the Federal Energy Regulatory Commission (FERC) has issued annual operation licenses for each project since the original 50-year licenses expired in 2005. In 2019, Oregon DEQ and Idaho DEQ issued 401 certifications for the project, an important component of a complete license application. Most notably, the 401 certifications require a substantial commitment to reduce the temperature of water exiting Hells Canyon Dam in the late summer and fall and to improve water quality in the Snake River. If and when implemented, this is expected to be accomplished primarily through habitat restoration activities upstream of the Hells Canyon Complex (both in the mainstem Snake River and in several tributaries) which will address return flows from irrigation projects, narrow the channel width, and restore more normative river processes between Swan Falls Dam and the upper end of Brownlee reservoir. The Idaho Power Company amended their license application and provided FERC with a biological evaluation, assessing the impacts of the project, in 2020. As of March 2021, FERC has not indicated how they intend to proceed with the relicensing of the Hells Canyon project.

4. Marine Mammal Protection Act.

The United States Congress (Congress) amended the MMPA in 1994 to include a new section, section 120 – Pinniped Removal Authority. This section provides an exception to the MMPA “take” moratorium and authorizes the Secretary of Commerce to authorize the intentional lethal taking of individually identifiable pinnipeds that are having a significant negative impact on the decline or recovery of salmonid fishery stocks. In 2018, Congress amended section 120(f) of the MMPA, which expanded the removal authority for removing predatory sea lions in the Columbia River and tributaries.

To address the severity of pinniped predation in the Columbia River Basin, NMFS has issued six MMPA section 120 authorizations (2008, 2011, 2012, 2016, 2018, and 2019) and one section 120(f) permit (2020). Under these authorizations, as of May 13, 2022, the states have removed (transferred and killed) 278 California sea lions and 52 Steller sea lions. Removal of sea lions in the Columbia River has protected (fish escaping sea lion predation) an estimated 62,284 to 83,414 adult salmon and steelhead in the Columbia River Basin.

Continued management action under the MMPA is expected to reduce sea lion predation on adult salmon and steelhead in the Columbia River. Given the logistical challenges of removing sea lions and other uncertainties, the magnitude of this expected reduction in sea lion predation is uncertain.

Consistent with the Congressional intent of the Endangered Salmon Predation Prevention Act, under the MMPA section 120(f) permit, we encourage Eligible Entities to develop and implement a long-term management strategy to deter the future recruitment of sea lions into the MMPA 120(f) geographic area.

5. Clean Water Act. The Federal Clean Water Act (CWA) addresses the development and implementation of water quality standards, the development of Total Maximum Daily Loads (TMDLs), filling of wetlands, point source permitting, the regulation of stormwater, the discharge of dredge and fill material, and other provisions related to the protection of U.S. waters. The CWA has retained authorities, and delegated authorities administered by the states of Idaho, Oregon, and Washington with oversight by the U.S. Environmental Protection Agency (EPA). State water quality standards are set to protect beneficial uses, which include several categories of salmonid use. Together the state and federal clean water acts regulate the level of pollution within streams and rivers in Idaho, Oregon, and Washington.

- In December 2016, Congress amended the CWA by adding Section 123, which requires EPA and Office and Management and Budget to take actions related to restoration efforts in the basin. The U.S. Government Accountability Office (GAO) was asked to review restoration efforts in the Columbia River basin, and in 2018 the GAO presented its report to the Committee on Transportation and Infrastructure, House of Representatives: Columbia River basin, Additional Federal Actions Would Benefit Restoration Efforts. The report reveals that while multiple agencies had a variety of programs by which they engaged in restoration activities between 2010 and 2016, since 2016, the EPA had not yet taken steps to establish the Columbia River Basin Restoration Program, as required by the Clean Water Act Section 123. EPA stated it had not received dedicated funding appropriated for this purpose; however, EPA actually has not yet requested funding to implement the program or identified needed resources. Also, the GAO reports that an interagency crosscut budget has not been submitted. According to OMB officials, they have had internal conversations on the approach to develop the budget but have not requested information from agencies. EPA did develop a grants program in 2019, and in September of 2020 announced the award of $2 million in 14 grants to tribal, state and local governments, non-profits, and community groups throughout the Columbia River basin.
- In December 2019, the Ninth Circuit Court of Appeals issued an opinion that the EPA must identify a temperature TMDL for the Columbia River as neither the State of Washington nor Oregon has provided a temperature TMDL. On May 18, 2020, EPA issued for public review and comment the TMDL for temperature on the Columbia and Lower Snake rivers. The TMDL addresses portions of the Columbia and lower Snake rivers that have been identified by the states of Washington and Oregon as impaired due to temperatures that exceed those states' water quality standards. After considering comments, EPA may make modifications, as appropriate, and then transmit the TMDL to Oregon and Washington for incorporation into their current water quality management plans. Implementation of the TMDL will likely benefit SRB steelhead through improved thermal conditions in the migratory corridor.

- EPA released its final Columbia River Cold Water Refuges Plan on January 7, 2021. The plan focuses on the lower 325 miles of the Columbia River from the Snake River to the ocean. Cold water refuges serve an increasingly important role to some salmon and steelhead species as the lower Columbia River has warmed over the past 50 years and will likely continue to warm in the future due to climate change. The Columbia River Cold Water Refuges Plan is a scientific document with recommendations to protect and restore cold water refuges. EPA issued this plan in response to consultation under section 7 of the ESA associated with its approval of Oregon's temperature standards for the Columbia River. This plan also serves as a reference for EPA's Columbia and Snake Rivers Temperature TMDL.

6. CWA Delegated Authority:

- In 2015, jeopardy biological opinions were issued for Idaho and Oregon for water quality standards for toxic substances (NMFS 2012b, 2014b). These consultations called for the adoption of new water quality criteria for a number of toxic substances. Since the issuance of the biological opinions, Idaho has adopted new criteria for copper and selenium. Oregon has adopted new criteria for ammonia, copper, and cadmium, and EPA has promulgated new criteria for aluminum. Implementation of the RPA for the jeopardy consultations will result in greater protections for our listed salmonid and their habitats.
- In December 2016, EPA approved IDEQ's *Upper Salmon River Subbasin Assessment and TMDL: 2016 Addendum and 5-year Review* (IDEQ 2016). The TMDL addendum identified shade targets needed for the impaired streams to achieve compliance with temperature criteria. This document establishes the shade levels that land managers (i.e., private, state, and federal) should strive for through future implementation plans and actions.
- The Oregon Department of Environmental Quality submitted its 2018/2020 Integrated Report in April 2020 to the EPA. The current EPA assessment characterizes assessed rivers and streams in Oregon that support fish and aquatic life. In Oregon, there are roughly 19,000 miles of good habitat and roughly 113,000 miles of impaired habitat. Impaired waters have increased 33 percent since the 2012 integrated report, generally from non-attainment of water temperature criteria. These reports indicate that in general, water quality is declining: https://mywaterway.epa.gov/state/OR/water-quality-overview; https://www.oregon.gov/deq/wq/Documents/irFS1820.pdf ; https://www.oregon.gov/deq/wq/pages/2018-integrated-report.aspx
- Washington State relies on use-based (e.g., aquatic life use) Surface Water Quality Standards, found in Washington Administrative Code (WAC) 173-201A. The EPA approved the Washington State's updated Water Quality Assessment 305(b) report and 303(d) list in 2012. It has not been updated since that date. (http://www.ecy.wa.gov/programs/Wq/303d/index.html).

7. 90.94 RCW Streamflow Restoration.

In January 2018, the Washington State legislature passed the Streamflow Restoration law that helps restore streamflows to levels necessary to support robust, healthy, and sustainable salmon populations while providing water for homes in rural Washington. The State law requires that enough water is kept in streams and rivers to protect and preserve instream resources and values such as fish, wildlife, recreation, aesthetics, water quality, and navigation. One of the most effective tools for protecting streamflows is to set instream flows, which are flow levels adopted into rule. Instream flows cover nearly half of the state's watersheds and the Columbia River. In Washington, and especially on the east side of the state, out-of-stream uses, especially irrigation, exacerbate seasonally low flows, leading to passage and temperature problems, and the loss of instream habitat. Other water uses also play a contributing role, as well as land use (lack of recharge arising from impervious surfaces). The Washington State Department of Ecology has a list of 16 critical watersheds where instream flows are thought to be a contributing factor to "critical" or "depressed" fish status, as identified by the Washington Department of Fish and Wildlife. Some of these protected critical watersheds can be found in the following five counties which intersect the Snake River basin: Asotin, Garfield, Whitman, Columbia, and Walla Walla.

8. Idaho Forest Practices Act.

The Idaho Department of Lands administers the Idaho Forest Practices Act, a law created in 1974. The agency is currently considering revisions of the Idaho Forest Practices Act to improve shade and large woody debris delivery on private forest lands. The proposed revision to the 2014 Shade Rule provides a methodology crafted to provide the maximum amount of flexibility to landowners while ensuring protective levels of shade remain. The proposed revisions to the tree retention rule would simplify the methodology to calculate retention. Under the Idaho Forest Practices Act, stream protection zones generally have a width of 75 feet and, therefore, may not protect all riparian functions at some sites (Sweeney and Newbold 2014; Reeves et al. 2016).

- In 2015, the Washington legislature created the Fish Passage Barrier Removal Board to establish a new statewide strategy for fish barrier removal and administering grant funding available for that purpose.
- In 2018, the Oregon legislation placed restrictions on motorized in-stream placer mining. In order to protect indigenous anadromous salmonids and habitat essential to the recovery and conservation of Pacific lamprey, motorized in-stream placer mining is not permitted to occur below the ordinary high-water line in any river in Oregon containing essential indigenous anadromous salmonid habitat. Oregon DEQ has an online interactive map that shows areas where motorized in-stream placer mining is prohibited.[6] This restriction reduces potential sedimentation of instream anadromous habitat from placer mining.

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[6] http://geo.maps.arcgis.com/apps/webappviewer/index.html?id=1fedde6ecbff46feb7c41524f21d42d7

Harvest

1. Columbia River Harvest Management: U.S. v. Oregon.

Pursuant to a September 1, 1983, Order of the U.S. District Court, the allocation of harvest in the Columbia River was established under the "Columbia River Fish Management Plan" and implemented in 1988 by the parties of *U.S. v. Oregon*. Since 2008, 10-year management agreements have been negotiated through *U.S. v. Oregon* (NMFS 2008c and 2018a). Harvest impacts on ESA–listed species in Columbia River commercial, recreational, and treaty fisheries continue to be managed under the 2018-2027 *U.S. v. Oregon* Management Agreement (NMFS 2018a). The parties to the agreement are the United States, the states of Oregon, Washington, and Idaho, and the Columbia River Treaty Tribes: Warm Springs, Yakama, Nez Perce, Umatilla, and Shoshone-Bannock. The agreement sets harvest rate limits on fisheries impacting ESA-listed species, and these harvest limits continue to be annually managed by the fisheries co-managers (TAC 2015, 2016, 2017, 2018, 2019, 2020). The current *U.S. v. Oregon* Management Agreement (2018-2027) has, on average, maintained reduced impacts of fisheries on the Snake River species (TAC 2015, 2016, 2017, 2018, 2019, 2020), and we expect that to continue with the abundance-based framework incorporated into the current regulatory regime.

Regulatory Mechanisms Resulting in Inadequate or Decreased Protection

We remain concerned about the adequacy of existing habitat regulatory mechanisms with regard to water rights allocation, instream flow rules, and residential wells – each of which reduces available stream volume, flows, limits habitat connectivity, and increases the temperature regime; floodplain management and levees – which constrain floodplain connectivity, riparian conditions, and habitat complexity and habitat-forming processes; and the extensive federal land forest road networks, grazing, and recreation – which erode river banks, introduce sediment load, and impair riparian vegetation and large wood contribution. These concerns, which are key threats for SRB steelhead, fall within the control of federal and state land and water mechanisms, described below.

1. Clean Water Act. The current Clean Water Act (CWA) Navigable Waters Protection Rule: Definition of Waters of the United States, which went into effect on June 22, 2020, will have deleterious effects on SRB steelhead salmon as the regulatory nexus to consult on potentially harmful actions has been reduced and redefined. Redefined language and increased exemptions reduce the ability to utilize ESA and EFH to avoid, minimize and mitigate effects that impact listed species and their designated critical habitats. However, on December 7, 2021, the EPA and U.S. Army Corps of Engineers published a proposed rule to revise the definition of “Waters of the United States” (86 FR 69372). The agencies propose to put back into place the pre-2015 definition of “Waters of the United States,” updated to reflect consideration of Supreme Court decisions. This familiar approach would support a stable implementation of “Water of the United States” while the agencies continue to consult with states, tribes, local governments, and a broad array of stakeholders in implementing the Waters of the United States rule and future regulatory actions.

Additionally, in 2021, the U.S. Army Corps of Engineers finalized the re-issuance of existing Nation Wide Permits with modifications (86 FR 2744; 86 FR 73522). The modifications will allow an increase in the amount of fill and destruction of habitat for frequently used nationwide permits throughout the range of SRB steelhead. Although regional conditions may address some of these issues, there has not been any indication that regional conditions will be developed to address the impacts to listed species and their designated critical habitat.

2. CWA Delegated Authority. Implementation of the 2016 addendum to the Upper Salmon River subbasin assessment and TMDL (IDEQ 2016) rests with the land managers and is voluntary. As such, there is uncertainty relative to the extent to which land management changes and restoration activities will occur along the corridors of impaired streams.

3. 1872 Mining Law. Increased mining and mineral extraction activities. In Idaho, mining still takes place under the 1872 Mining Law, giving agencies limited discretion in how they regulate it. In addition, out-of-state miners are attracted to Idaho as Idaho is the only state in the west that allows suction dredging in streams with anadromous fish. Issues related to mining threats in the Snake River basin have expanded since the last 5-year review.

- Salmon River Basin. A key mining threat is present in the Upper Salmon and East Fork South Fork Salmon rivers where proposals exist for large-scale open pit mine expansion and mineral lease applications for suction dredge mining in the Salmon River. This includes proposing diversion of flows in areas with salmon and steelhead spawning habitats important for recovery. In addition, there is potential for other large-scale gold mining in the headwaters of the Middle Fork Salmon River based on the results of current exploration in the Big Creek drainage. The Thompson Creek Mine in the Upper Salmon River is approved for expansion and ten more years of operation, but is currently in a storage phase until molybdenum prices improve. For some populations, mining remains a threat because of past contamination issues, such as in Panther Creek, and there remains the potential to degrade water quality in large reaches of a stream, decreasing population viability.
- Clearwater River Basin. After completing consultations with NMFS, the USFS/BLM began permitting small suction dredge mining programs in 2013 for Lolo Creek and in 2016 for the South Fork Clearwater River (SFCR). Both programs are limited to mainstem reaches during summer and by the amount of disturbance or number of dredges allowed. The EPA also consulted on and established a general permit program (NPDES) for small suction dredging in 2014 and renewed it in 2019 (EPA 2018). The programs align with EPA's 2003 TMDL for sediment in the SFCR, which included load/activity limits for 15 suction dredges. Idaho Department of Water Resources (IDWR) also permits the SFCR recreational dredging program; and beginning in 2020 Idaho Department of Environmental Quality (IDEQ) assumed EPA's suction dredge permitting, as part of the NPDES program transfer from EPA to Idaho. Efforts to coordinate the Federal and State permitting have had mixed results but have improved. For instance, in 2018, IDWR issued substantially more permits for the SFCR than the Federal program

> allows, which led to levels of the activity and its effects beyond what NMFS and USFWS had authorized. However, by 2021 the State re-aligned the number of permitted dredges with the Federal SFCR program. Nevertheless, some unpermitted dredging continues to occur. Also, with this activity closed in several other states, requests of Federal and State agencies for dredging and placer mining in the SFCR, its tributaries, and nearby drainages continue to increase.

4. National Environmental Policy Act. The National Environmental Policy Act (NEPA) ensures that agencies consider the significant environmental consequences of their proposed actions and inform the public about their decision making. The NEPA final rule, November 19, 2020, includes new and revised categorical exclusions and a Determination of NEPA Adequacy provision that has the potential to accelerate timber management and road construction projects with reduced public input and effects analyses (85 FR 73620). However, ESA section 7 consultation requirements will still apply. In addition, beaver restoration and management is recommended as a recovery action for this species (see Listing Factor A). There is a corresponding need to evaluate management authorities within this DPS to determine whether changes could be made to support recolonization and/or reintroduction of beaver.

5. Federal Emergency Management Agency. National Flood Insurance Program (NFIP). The NFIP is a Federal benefit program that extends access to Federal monies or other benefits, such as flood disaster funds and subsidized flood insurance, in exchange for communities adopting local land use and development criteria consistent with federally established minimum standards. Under this program, development within floodplains continues to be a concern because it facilitates development in floodplains without mitigation for impacts on natural habitat values.

All West Coast salmon species, including 27 of the 28 species listed under the ESA, are negatively affected by an overall loss of floodplain habitat connectivity and complex channel habitat. Over decades, the reduction and degradation of habitat have progressed as flood control and wetland filling occurred to support agriculture, silviculture, or conversion of natural floodplains to urbanizing uses (e.g., residential and commercial development). Loss of habitat through conversion was identified among the factors for decline for most ESA-listed salmonids. NMFS has found that altering and hardening stream banks, removing riparian vegetation, constricting channels and floodplains, and regulating flows are primary causes of anadromous fish declines (65 FR 42450). Activities affecting this habitat include wetland and floodplain alteration (64 FR 50414).

Development proceeding in compliance with NFIP minimum standards ultimately results in impacts to floodplain connectivity, flood storage/inundation, hydrology, and to habitat-forming processes. Development consequences of levees, stream bank armoring, stream channel alteration projects, and floodplain fill, combine to prevent streams from functioning properly and result in degraded habitat. Most communities (counties, towns, cities) in Washington, Idaho, and Oregon, are NFIP participating communities, applying the NFIP minimum standards. For this reason, it is important to note that, where it has been analyzed for effects on salmonids, floodplain development that occurs consistent with the NFIP's minimum criteria has been found to jeopardize 18 listed species of salmon and steelhead (Chinook salmon, steelhead, chum salmon, coho salmon, sockeye salmon) (NMFS 2008b, 2016d). The Reasonable and Prudent Alternative provided in NMFS 2016d (Columbia River basin species, Oregon Coast coho salmon, Southern Oregon/Northern California Coast coho salmon) has not yet been implemented.

<u>FEMA No-Rise Analysis</u>. Region X previously adopted a limited exception to the hydraulic and hydrologic (H&H, also known as "no rise") analysis, for habitat restoration actions within floodways - the Policy on Fish Enhancement Structures in the Floodway (1999). The original intent of Region X's policy was to assist NFIP participating communities in their support of habitat restoration projects that benefit salmon species listed under the ESA. However, Region X found that the policy was being applied incorrectly both in terms of the projects to which it should apply and the consequences of the exception.

- Upon further consideration, in August 2020, FEMA Region X rescinded the policy because it was inconsistent with the requirements at 44 CFR 60.3(d)(3) and (4). The regulation requires communities that participate in the NFIP to review all "development" in mapped special flood hazard areas and issue permits as appropriate. Development is broadly defined to include any man-made alteration, and so would also cover in-stream habitat restoration projects. Essential to this permitting responsibility is the requirement that any proposal for development in the regulatory floodway be accompanied by an H&H analysis.
- The consequence of this policy rescission is that habitat restoration projects in the floodway must now include in their budgets the time and resources required for the H&H analysis needed by the local community, and if necessary, the additional time and resources needed to obtain a Letter of Map Revision (LOMR) if floodway and flood elevations are altered by the habitat structures. Such costs and permitting timeframes can make it more difficult to complete vital restoration projects.

Listing Factor D Conclusion

There have been improvements in the adequacy of some regulatory mechanisms affecting the SRB steelhead DPS since the 2016 5-year review (see above list of Regulatory Mechanisms Resulting in Adequate or Improved Protection). In addition, there have also been regulatory changes resulting in inadequate or decreased protection of ESA-listed SRB steelhead, some at the DPS and national scales (e.g., CWA, FEMA NFIP and H&H analysis, NEPA). Based on the information noted above for regulations in the Snake River basin and the Columbia River migratory corridor, we conclude that the overall risk to the species' persistence because of the adequacy of some existing regulatory mechanisms has improved slightly since our prior review. However, some landscape-scale regulations affecting floodplain connectivity continue to increase the risk to the persistence of SRB steelhead.

Recommended Future Actions

- Restrict development of floodplains to reduce impacts to floodplain connectivity and habitat-forming processes.
- Allow funding for levee setbacks when rebuilding levees.

Listing Factor E: Other natural or manmade factors affecting its continued existence

Climate Change

One factor affecting the rangewide status of SRB steelhead and aquatic habitat is climate change. Major ecological realignments are already occurring in response to climate change (Crozier et al. 2019). As observed by Siegel and Crozier in 2019, long-term trends in warming have continued at global, national, and regional scales. The five warmest years in the 1880 to 2019 record have all occurred since 2015, while 9 of the 10 warmest years have occurred since 2005 (Lindsey and Dahlman 2020). The year 2020 was another hot year in national and global temperatures; it was the second hottest year in the 141-year record of global land and sea measurements and capped off the warmest decade on record (http://www.ncdc.noaa.gov/sotc/global202013). Events such as the 2013-2016 marine heatwave (Jacox et al. 2018) have been attributed directly to anthropogenic warming in the annual special issue of Bulletin of the American Meteorological Society on extreme events (Herring et al. 2018). Global warming and anthropogenic loss of biodiversity represent profound threats to ecosystem functionality. These two factors are often examined in isolation, but likely have interacting effects on ecosystem function (Siegel and Crozier 2019). Conservation strategies now need to account for geographical patterns in traits sensitive to climate change, as well as climate threats to species-level diversity.

Climate change has negative implications for SRB steelhead survival and recovery, and for their designated critical habitat (Climate Impacts Group 2004; Zabel et al. 2006; ISAB 2007), characterized by the ISAB as follows:

- Warmer air temperatures will result in diminished snowpack and a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.
- With a smaller snowpack, watersheds will see their runoff diminished earlier in the season, resulting in lower stream flows in June through September. Peak river flows, and river flows in general, are likely to increase during the winter due to more precipitation falling as rain rather than snow.
- Water temperatures are expected to rise, especially during the summer months when lower stream flows co-occur with warmer air temperatures. Islam et al. (2019) found that air temperature accounted for about 80 percent of the variation in stream temperatures in the Fraser River, thus tightening the link between increased air and water temperatures.

These changes will not be spatially homogenous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of important cold-water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, earlier emergence of fry, and increased competition among species.

Impacts on Salmon and Steelhead

Range of effects caused by a changing climate

Climate change is predicted to cause a variety of impacts to Pacific salmon and their ecosystems (Mote et al. 2003; Crozier et al. 2008a; Martins et al. 2012; Wainwright and Weitkamp 2013). The complex life cycles of anadromous fishes, including salmon, rely on productive freshwater, estuarine, and marine habitats for growth and survival, making them particularly vulnerable to environmental variation. Ultimately, the effects of climate change on salmon and steelhead across the Columbia River basin will be determined by the specific nature, level, and rate of change and the synergy among interconnected terrestrial/freshwater, estuarine, nearshore, and ocean environments.

Synchrony between terrestrial and marine environmental conditions (e.g., coastal upwelling, precipitation and river discharge) has increased in spatial scale causing the highest levels of synchrony in the last 250 years (Black et al. 2018). A more synchronized climate combined with simplified habitats and reduced genetic diversity may be leading to more synchrony in the productivity of populations across the range of salmon (Braun et al. 2016). Climate change and anthropogenic factors continue to reduce the adaptive capacity in Pacific salmon. They also alter life history characteristics and simplify population structure.

The primary effects of climate change on Pacific Northwest salmon and steelhead are (Crozier 2016):

- Direct effects of increased water temperatures alter fish physiology and increase susceptibility to disease.
- Temperature-induced changes to stream flow patterns can block fish migration, trap fish in dewatered sections, dewater redds, introduce non-native fish, and degrade water quality.
- Alterations to freshwater, estuarine, and marine food webs alter the availability and timing of food resources.
- Changes in estuarine and ocean productivity change the abundance and productivity of fish resources.

The 2017 recovery plan (NMFS 2017a) identified the following potential effects of climate change on SR spring/summer Chinook salmon and SRB steelhead in freshwater areas:

- Winter flooding in transient and rainfall-dominated watersheds may scour redds, reducing egg survival.

- Water temperatures during incubation may accelerate the rate of egg development and result in earlier fry emergence and dispersal, which could be either beneficial or detrimental, depending on location and prey availability.
- Reduced summer and fall flows may reduce the quality and quantity of juvenile rearing habitat, strand fish, or make fish more susceptible to predation and disease.
- Reduced flows and higher temperatures in late summer and fall may decrease parr-to-smolt survival.
- Warmer temperatures will increase metabolism, which may increase or decrease juvenile growth rates and survival, depending on the availability of food.
- Overwintering survival may be reduced if increased flooding reduces suitable habitat.
- Timing of smolt migration may be altered due to a modified timing of the spring freshet, such that there is a mismatch with ocean conditions and predators.
- Higher temperatures while adults are holding in tributaries and migrating to spawning grounds may lead to increased prespawning mortality or reduced spawning success as a result of delay or increased susceptibility to disease and pathogens.
- Increases in water temperatures in Snake and Columbia River reservoirs could increase consumption rates and growth rates of predators and, hence, predation-related mortality on juvenile spring/summer Chinook salmon and steelhead.
- Lethal water temperatures (temperatures that kill fish) may occur in the mainstem migration corridor or in holding tributaries, resulting in higher mortality rates.
- If water temperatures in the lower Snake River (especially Lower Granite Dam and reservoir) warm during late summer and fall sufficiently that they cannot be maintained at a suitable level by cold-water releases from Dworshak Reservoir, then migrating adult Snake River summer Chinook salmon and steelhead could have higher rates of mortality and disease.

Effects caused by changing flows and temperatures

While all habitats used by Pacific salmon and steelhead will be affected, the impacts and certainty of the change vary by habitat type. Some effects (e.g., increasing temperature) affect all life stages in all habitats. In contrast, others are habitat-specific, such as stream-flow variation in freshwater, sea-level rise in estuaries, and upwelling in the ocean. How climate change will affect each stock or population of salmon and steelhead also varies widely depending on the level or extent of change, the rate of change, and the unique life history characteristics of different natural populations (Crozier et al. 2008b). For example, a few weeks difference in migration timing can have large differences in the thermal regime experienced by migrating fish (Martins et al. 2011). This difference between run times and survival is illustrated by comparing runs of SR sockeye and SRB steelhead. During 2015, the Columbia River experienced a combination of continued high summer temperatures and lower than average flows (due to the lower snowpack from the previous winter and drought conditions exacerbated due to increased occurrences of warm weather patterns) In 2015, about 475,000 adult sockeye salmon (all ESUs) passed Bonneville Dam in the Columbia River, but only 2 to 15 percent of these adult sockeye salmon, depending upon the population, survived to their spawning grounds. (NMFS 2016a). In contrast, the survival of SRB steelhead in 2015 exceeded that of SR sockeye salmon. SRB steelhead are a summer-run steelhead with a late summer and early fall mainstem migration time, and also express several behaviors for avoiding high water temperatures during adult migration.

Siegel et al. (2021) found different population groups of summer-run steelhead have variable temperature thresholds for delaying migration and variable delay times. SRB steelhead arrive in the Columbia River from August through September, with A-run steelhead arriving early and encountering higher water temperatures and B-run steelhead arriving about a month later (Siegel et al. 2021). Some steelhead go directly to spawning areas while others delay migration in the cooler refugia in the mainstem or tributaries, or overwinter in the mainstem rivers. This behavioral flexibility – which is not exhibited by other Columbia River salmon species to the same extent – may help steelhead respond to anticipated increases in river temperatures with climate change, assuming that temperature refuge habitats continue to be accessible (Siegel et al. 2021).

Like most fishes, salmon and steelhead are poikilotherms (cold-blooded animals); therefore, increasing temperatures in all habitats can have pronounced effects on their physiology, growth, and development rates (see review by Whitney et al. 2016). Increases in water temperatures beyond their thermal optima will likely be detrimental through a variety of processes, including increased metabolic rates (and therefore food demand), decreased disease resistance, increased physiological stress, and reduced reproductive success. All of these processes are likely to reduce the fitness of salmonids, including SRB steelhead (Beechie et al. 2013; Wainwright and Weitkamp 2013; Whitney et al. 2016).

By contrast, temperatures at ranges in thermal optima (i.e., when the water is cold) can increase growth and development rates. Examples of this include accelerated emergence timing during egg incubation stages, or increased growth rates during fry stages (Crozier et al. 2008a; Martins et al. 2011). Temperature is also an important behavioral cue for migration (Sykes et al. 2009), and elevated temperatures may result in earlier-than-normal migration timing. While there are situations or stocks where this acceleration in processes or behaviors is beneficial, there are others where it is detrimental (Sykes et al. 2009; Whitney et al. 2016).

Climate change is predicted to increase the intensity of storms, reduce winter snowpack at low and middle elevations, and increase snowpack at high elevations in northern areas. Middle and lower-elevation streams will have larger fall/winter flood events and lower late-summer flows, while higher elevations may have higher minimum flows. How these changes will affect freshwater ecosystems largely depends on their specific characteristics and location (Crozier et al. 2008b; Martins et al. 2012). For example, within a relatively small geographic area (the Salmon River basin in Idaho), survival of some Chinook salmon populations was shown to be determined largely by temperature, while for others, it was determined by flow (Crozier and Zabel 2006). Certain salmon populations inhabiting regions that are already near or exceeding thermal maxima will be most affected by further increases in temperature and, perhaps, the rate of the increases, while the effects of altered flow are less clear and likely to be basin-specific (Crozier et al. 2008b; Beechie et al. 2013). However, river flow is likely to become more variable in many rivers and is believed to negatively affect anadromous fish survival more than other environmental parameters (Ward et al. 2015). This increasingly variable flow will likely be detrimental to salmon and steelhead populations in the Columbia River basin.

Changes in stream temperature and flow regimes are likely to lead to shifts in the distributions of native species and facilitate the establishment of exotic species. This will result in novel species interactions, including predator-prey dynamics, where juvenile native species may be either predators or prey (Lynch et al. 2016; Rehage and Blanchard 2016). How juvenile native species will fare as part of “hybrid food webs,” which are constructed from native, native invaders, and exotic species, is difficult to predict (Naiman et al. 2012).

New Climate Change Information

The last 5-year review (NMFS 2016a) summarized the best available science on how climate change is predicted to impact freshwater environments, estuarine and plume environments, marine conditions and marine survival, the consequences of marine conditions, and drought management. The current best available science supports that previous analysis. The discussion below updates new information as it relates to how climate change is currently impacting and predicted to impact SRB steelhead in the future.

Marine Effects and Survival

Siegel and Crozier (2020) summarized new science published in 2019, with a number of publications describing the anomalous conditions of the marine heatwave that led to an onshore and northward movement of warm stratified waters into the California Current ecosystem off of the west coast of the U.S. Brodeur et al. (2019) described the community response of the plankton community composition and structure, suggesting that forage fish diets had to shift in response to food resources that are considerably less nutritionally dense. This was supported by the work of Morgan et al. (2019), who stated that it was unclear whether these observations represented an anomaly or were a permanent change in the Northern California Current.

Crozier et al. (2019) asserted in their vulnerability analysis (see below) that sea surface temperature and ocean acidification (as well as freshwater stream temperatures) were the most broadly identified climate-related stressors likely to impact populations.

Variation in marine productivity and prey quality can greatly impact the marine survival of salmon and steelhead populations. The specific ocean habitat use of different salmon populations is poorly defined. Recent work by Espinasse et al. (2019) used carbon and nitrogen stable isotopes derived from an extensive time-series of salmon scales to examine aspects of the marine environment used by Rivers Inlet (British Columbia) sockeye salmon. The authors were able to identify likely rearing areas before sampling. This work and other research cited in Siegel and Crozier (2020) are improving our understanding of how marine productivity impacts salmon and steelhead growth and survival, particularly during the early marine period.

While we understand that sea surface temperature is tightly linked to marine survival, we do not yet understand the mechanism involved. The work described above are important steps in our understanding.

Siegel and Crozier (2019) observe that changes in marine temperature are likely to have a number of physiological consequences on fishes themselves. For example, in a study of small planktivorous fish, Gliwicz et al. (2018) found that higher ambient temperatures increased the distance at which fish reacted to prey. Numerous fish species (including many tuna and sharks) demonstrate regional endothermy, which in many cases augments eyesight by warming the retinas. However, Gliwicz et al. 2018 suggest that ambient temperatures can have a similar effect on fish that do not demonstrate this trait. Climate change is likely to reduce the availability of biologically essential omega-3 fatty acids produced by phytoplankton in marine ecosystems. Loss of these lipids may induce cascading trophic effects, with distinct impacts on different species depending on compensatory mechanisms (Gourtay et al. 2018). Reproduction rates of many marine fish species are also likely to be altered with temperature (Veilleux et al. 2018). The ecological consequences of these effects and their interactions add complexity to predictions of climate change impacts in marine ecosystems.

Migration and Rearing Corridor Habitat

The lower Columbia River estuary provides important migratory habitat for juvenile SRB steelhead. Since the late 1800s, about 70 percent of the vegetated tidal wetlands of the Columbia River estuary have been lost to diking, filling, and bank hardening, combined with flow regulation and other modifications (Kukulka and Jay 2003; Bottom et al. 2005; Marcoe and Pilson 2017; Brophy et al. 2019). This disconnection of tidal wetlands and floodplains has reduced the production of wetland macrodetritus supporting the food web (Simenstad et al. 1990; Maier and Simenstad 2009), both for small Chinook and chum salmon that rear in shallow water and for larger juveniles, such as yearling SRB steelhead, which migrate in the mainstem (PNNL and NMFS 2020).

Restoration actions in the estuary have improved habitat quality and fish access to floodplain forests and wetlands. From 2007 through 2019, the Bonneville Power Administration the Corps implemented 64 projects that included dike and levee breaching or lowering, tide-gate removal, and tide-gate upgrades. These projects have reconnected over 6,100 acres of the historical floodplain to the mainstem Columbia River and another 2,000 acres of floodplain lakes (Karnezis 2019; BPA et al. 2020). This represents more than a 2.5 percent net increase in the connectivity of habitats that produce prey used by yearling steelhead (Johnson et al. 2018). In addition to this extensive reconnection effort, the Bonneville Power Administration and Corps have acquired conservation easements to protect about 2,500 acres of currently functioning floodplain habitat from development. Numerous other project sponsors have completed floodplain protection and restoration projects in the lower Columbia River.

Forests

Climate change will impact forests of the western U.S., which dominate the landscape of many watersheds in the region. Forests are already showing evidence of increased drought severity, forest fire, and insect outbreak. Forest fires affect salmon streams by altering sediment load, channel structure, and stream temperature through the removal of canopy. Holden et al. (2018) found strong correlations between the number of dry-season rainy days and the annual extent of forest fires, as well as a significant decline in the number of dry-season rainy days over the study period (1984-2015). Consequently, predicted decreases in dry-season precipitation, combined with increases in air temperature, will likely contribute to the existing trend of more extensive and severe forest fires.

Beyond environmental factors, many decades of fire suppression management practices have left forests more dense and less diverse, which increases vulnerability to greater fire damage. Attempts to restore forest composition to a state more similar to historical conditions will likely increase fire resiliency, although some restoration methods, including timber harvest and prescribed fire, are often contentious (Johnston et al. 2018).

Groundwater Effects

The effect of climate change on groundwater availability is likely to be uneven. Sridhar et al. (2018) coupled a surface-flow model with a ground-flow model to improve predictions of surface water availability with climate change in the Snake River basin. Combining the VIC and MODFLOW models (VIC-MF), they predicted flow for 1986-2042. Comparisons with historical data show improved performance of the combined model over the VIC model alone. Projections using RCP 4.5 and 8.5 emission scenarios suggested an increase in water table heights in downstream areas of the basin and a decrease in upstream areas. Such assessments will help stakeholders manage water supplies more sustainably, but ultimately will likely make it more challenging for adult salmon returning to spawn in late summer and early fall. In support of that idea, Leach and Moore (2019) found that groundwater may only make streams resistant to change in the short term since groundwater sources will be impacted on longer time scales.

Freshwater Effects

As cited in Siegel and Crozier (2019), Isaak et al. (2018) examined recent trends in stream temperature across the western United States using a large regional dataset. Stream warming trends paralleled changes in air temperature and were pervasive during the low-water warm seasons of 1996-2015 (0.18-0.35°C/decade) and 1976-2015 (0.14-0.27°C/decade). Isaak et al. (2018) concluded that most stream habitats will likely remain suitable for salmonids in the near future, with some becoming too warm.

The following is excerpted from Siegel and Crozier (2019), who present a review of recent scientific literature evaluating effects of climate change, describing the projected impacts of climate change on instream flows:

- Cooper et al. (2018) examined whether the magnitude of low river flows in the western U.S., which generally occur in September or October, are driven more by summer conditions or the prior winter's precipitation. They found that while low flows were more sensitive to summer evaporative demand than to winter precipitation, interannual variability in winter precipitation was greater. Sridhar et al. (2018), predicted that summer evapotranspiration is likely to increase in conjunction with declines in snowpack and increased variability in winter precipitation. Their results suggest that low summer flows are likely to become lower, more variable, and less predictable.

Streams with intact riparian corridors that lie in mountainous terrain are likely to be more resilient to changes in air temperature. These areas may provide refuge from climate change for a number of species, including Pacific salmon. Krosby et al. (2018) identified potential stream refugia throughout the Pacific Northwest based on a suite of features thought to reflect the ability of streams to serve as such refuges. Analyzed features include large temperature gradients, high canopy cover, large relative stream width, low exposure to solar radiation, and low levels of human modification. They created an index of refuge potential for all streams in the region, with mountain area streams scoring the highest. Flat lowland areas, which commonly contain migration corridors, were generally scored with the lowest refuge potential, and thus were prioritized for conservation and restoration. However, forest fires can increase stream temperatures dramatically in short time-spans by removing riparian cover (Koontz et al. 2018), and streams that lose their snowpack with climate change may see the largest increases in stream temperature due to the removal of temperature buffering (Yan et al. 2021). These processes may threaten some habitats that are currently considered refugia.

Siegel and Crozier (2019) point out concern that, for some salmon populations, climate change may drive mismatches between juvenile arrival timing and prey availability in the marine environment. However, phenological diversity can contribute to metapopulation-level resilience by reducing the risk of a complete mismatch. Carr-Harris et al. (2018) explored phenological diversity of marine migration timing in relation to zooplankton prey for sockeye salmon from the Skeena River of Canada. They found that sockeye salmon migrated over a period of more than 50 days. Populations from higher elevations and further inland streams arrived in the estuary later, and different populations encountered distinct prey fields. They recommended that managers maintain and augment such life-history diversity.

Climate Vulnerability Assessment

Crozier et al. (2019) recently completed a climate vulnerability assessment for Pacific salmon and steelhead, including SRB steelhead. The assessment was based on three components of vulnerability: (1) biological sensitivity, which is a function of individual species characteristics; (2) climate exposure, which is a function of geographical location and projected future climate conditions; and (3) adaptive capacity, which describes the ability of a DPS to adapt to rapidly changing environmental conditions. Objectives were to characterize the relative degree of threat posed by each component of vulnerability across DPSs and to describe landscape-level patterns in specific threats and cumulative vulnerability at the DPS level. Crozier et al. (2019) provides more information on the methodology they used to calculate climate vulnerability for each DPS.

Crozier et al. (2019) concluded that SRB steelhead has a high risk of overall climate vulnerability based on its high biological sensitivity, high risk for climate exposure, and moderate capacity to adapt. Increases in synchrony between climate and steelhead response to climate change across the DPS populations indicates that the DPS is losing its adaptability to climate change (Crozier et al. 2019). Ocean survival is well predicted by environmental climate indices, particularly upwelling and the Pacific Northwest Index (Williams et al. 2014). However, the impact of climate change specifically on marine survival is uncertain, leading to a high cumulative climate vulnerability score for the marine stage (Crozier et al. 2019).

Crozier et al. (2019) describes high vulnerability to climate change as a combination of high sensitivity to climate change and high exposure to changing environmental conditions at a given life stage. Crozier et al. (2019) assigns a moderate rating in adaptive capacity for SRB steelhead. This moderate rating reflects vulnerabilities in access to historic habitat both through blockage by dams and reduced access to floodplains. Reductions in vulnerability to climate change can be gained quickly by restoring access to historical and floodplain habitats, which in turn restores more natural ecological and physical processes. Juveniles are especially vulnerable to reduced summer flow and high stream water temperatures. However, their adaptive capacity is bolstered by heat tolerance and behavioral flexibility in the juvenile life stage. In addition, SRB steelhead are spring spawners with greater mobility and are able to use smaller higher elevation steams, making them less vulnerable to variations in fall and winter precipitation. This mobility during migration and staging also affords them greater access to temperature refugia in smaller cooler tributary streams.

Hatchery Effects

The effects of hatchery fish on the status of a DPS depends upon which of the four key attributes – abundance, productivity, spatial structure, and diversity – are currently limiting the DPS, and how the hatchery fish within the DPS affect each of the attributes (70 FR 37204). Hatchery programs can provide short-term demographic benefits, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of the risk depends on the status of affected populations and on specific practices in the hatchery program.

Currently, there are 13 steelhead hatchery programs in the Snake River basin (6 of which are included in the SRB DPS), plus one kelt reconditioning program. The hatchery programs that are considered to be part of the DPS are: Tucannon River, Salmon River B-run, South Fork

Clearwater (Clearwater Hatchery) B-run, Dworshak National Fish Hatchery, East Fork Salmon River, and Little Sheep Creek/Imnaha River Hatchery.

The kelt reconditioning program consists of the collection of post-spawned steelhead more than 60 centimeters in length and the administration of disease-preventative medications and feed to improve survival over what would be expected without intervention. (Typically kelts are in fairly poor condition after spawning and may have low chances of surviving downstream migration.) Upon release, these fish are intended to return to natal populations, thereby increasing spawner escapement and productivity if reconditioned individuals successfully spawn (NMFS 2016b, 2017d, 2017e, 2017f, 2019b).

Evidence indicates that several B-Index steelhead populations targeted by the kelt reconditioning program have likely benefited from this program. Since 2008, the Snake River kelt reconditioning program has been operating at a research scale. While the facility has been reported to be too small to reach the program's goal of increasing the Lower Granite Reservoir ladder count of B-Index steelhead by 6 percent (Hatch et al. 2018), the program has demonstrated the feasibility of reaching the goal. In 2013, 69 reconditioned B-Index steelhead were released (approximately 40 percent of the program's goal). In 2015, 24 reconditioned B-Index steelhead were released below Lower Granite Dam, and an additional 21 fish were determined to be skip spawners and retained for release in 2016. In 2016, 22 fish were released, and 98 fish were released in 2017. The 2017 release of 98 premature fish was composed of 77 skip spawners, with fecundities approximately 1.51 times those of maiden fish, and 21 consecutive spawners, with fecundities about 1.27 times those of maiden fish (Hatch et al. 2018). BPA funds the Snake River Kelt Reconditioning Program as mitigation for the CRS, but it is not a steelhead production program.

Hatchery programs for some SRB steelhead populations serve the dual purpose of providing fish for fisheries and providing supplemental spawners to help rebuild depressed natural populations.

Most hatchery production for SRB steelhead was initiated under the Lower Snake River Compensation Plan (LSRCP) as part of the Water Resources Development Act of 1976 (90 Stat. 2917). The LSRCP included a program to design and construct fish hatcheries to compensate for some of the losses of salmon and steelhead adult returns incurred as a result of the construction and operation of the four lower Snake River hydroelectric dams. Mitigation goals for the LSRCP program include 55,100 adult steelhead. The program is administered by the USFWS. Production under the LSRCP began in the mid-1980s.

The Dworshak Dam mitigation program provides hatchery production of steelhead as compensation for the loss of access to the North Fork Clearwater River (NMFS 2017b). Dworshak National Fish Hatchery, completed in 1969, is the focus for that production. Hatchery fish are also produced as mitigation for fish losses caused by construction of the Hells Canyon Complex in the Snake River Hells Canyon area. None of the Hells Canyon Complex dams, which are owned and operated by the Idaho Power Company, have fish passage facilities. The Idaho Power Company built four hatcheries to mitigate the Hells Canyon Complex's effects on native fish populations: Oxbow, Rapid River, Niagara Springs, and Pahsimeroi Hatcheries. The four hatchery facilities are managed by the Idaho Department of Fish and Game.

Several uncertainties exist regarding the effects of hatchery programs on natural-origin SRB steelhead populations. One of the main areas of uncertainty is the relative proportion and distribution of hatchery-origin spawners in natural spawning areas at the population level, particularly for SRB steelhead (Ford 2022). Because of this lack of information, the diversity status of most of the populations in the DPS remains uncertain (Table 5). Information is needed to determine where and to what extent unaccounted for hatchery steelhead are interacting with ESA-listed populations, particularly in Idaho (Ford 2022). Co-managers have continued to install PIT tag arrays throughout the Snake River basin that are likely to provide new information on population abundance and productivity, and hatchery fish proportions and distribution throughout the Snake River basin. In addition, NMFS, hatchery-funding agencies, and the state and tribal co-managers participate in a Snake River Steelhead Workgroup to continue to collaborate on addressing these uncertainties.

Table 5. ESA Status of hatchery programs within the SRB Steelhead DPS; NFH = National Fish Hatchery; HGMP = Hatchery and Genetic Management Plan; C = Review under the ESA is complete; U = undergoing ESA review; M = HGMP has not been submitted or is being modified by the applicant.

Program Stock Origin	Program	Run	Watershed Location of Release (State)	Currently Listed?	HGMP Status
Tucannon	Tucannon River	Summer	Tucannon River (WA)	Yes	C
Imnaha	Little Sheep Creek/Imnaha River Hatchery	Summer	Imnaha River (OR)	Yes	C
EF Salmon	EF Salmon River	A	EF Salmon River (ID)	Yes	C
NF Clearwater/ Dworshak stock	Dworshak NFH	B	Clearwater River (ID)	Yes	C
	Salmon River B-run	B	Pahsimeroi River, Yankee Fork, Little Salmon River (ID)	Yes	C
SF Clearwater	SF Clearwater (Clearwater Hatchery) B-run	B	SF Clearwater River (ID)	Yes	C
Wallowa stock	Lyons Ferry NFH	Summer	Tucannon River (WA), Cottonwood Creek (OR)	No	C
	Wallowa Hatchery	Summer	Wallowa River (OR)	No	C

Program Stock Origin	Program	Run	Watershed Location of Release (State)	Currently Listed?	HGMP Status
Hells Canyon/Oxbow	Hells Canyon Snake River	A	Snake River (ID)	No	C
Sawtooth/ Pahsimeroi	Pahsimeroi Hatchery	A	Pahsimeroi River (ID)	No	C
	Upper Salmon River	A	Upper Salmon River (ID)	No	C
	Streamside Incubator Project	A	Upper Salmon River (ID)	No	C
	Little Salmon River	A	Little Salmon River (ID)	No	C

Listing Factor E Conclusion

Climate Change

Climate change affects the rangewide status of SRB steelhead and aquatic habitat. Crozier et al. (2019) published a climate vulnerability analysis for Pacific salmon and steelhead based on species sensitivity, exposure, and adaptive capability. For SRB steelhead, the life stage that appears to be the most vulnerable to climate change is juvenile rearing. Summer habitats may have reduced flow, or restricted tributary access, particularly in areas impacted by irrigation withdrawals. High summer water temperatures are also prevalent. Climate change has and will cause earlier snow melt timing, reduced summer flows, and higher air temperatures; all of which will exacerbate the low flows and high water temperatures for juvenile SRB steelhead. This DPS is also considered to have only moderate capacity to adapt to climate change impacts. Given the extrinsic factors currently increasing the vulnerability of many populations to climate change impacts, it is unclear whether their adaptability would be sufficient to mitigate the risk climate change poses to the persistence of this DPS. The risk to SRB steelhead persistence from climate change has increased since the previous 2016 5-year review.

Terrestrial and Ocean Conditions, and Marine Survival

An anomalous marine heatwave led to an onshore and northward movement of warm stratified waters into the California Current ecosystem off of the west coast of the U.S. It is unknown at this time whether this warming is an anomaly or permanent. The coastal ocean warming caused changes in the plankton community composition and structure, suggesting that forage fish diets are considerably less nutritional. In addition, Crozier et al. (2019) asserted in their vulnerability analysis that sea surface temperature and ocean acidification (as well as freshwater stream temperatures) were the most broadly identified climate-related stressors likely to impact populations. The risk to SRB steelhead persistence from the climate change effects of sea surface temperature, ocean acidification, and freshwater stream temperatures has increased since the previous 2016 5-year review.

Hatchery Effects

In general, hatchery programs can provide short-term demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of risk depend on the affected populations' status and on specific practices in the hatchery program. Hatchery programs can affect naturally produced populations of salmon and steelhead in a variety of ways, including competition (for spawning sites and food) and predation effects, disease effects, genetic effects (e.g., outbreeding depression, hatchery-influenced selection), broodstock collection effects (e.g., to population diversity), and facility effects (e.g., water withdrawals, effluent discharge) (NMFS 2018b).

Hatchery practices for SRB steelhead have evolved as the status of natural populations has changed, and new plans are being implemented and evaluated as a result of recent ESA consultations on Hatchery and Genetic Management Plans for every steelhead hatchery program in the Snake River basin. These consultations concluded that hatchery programs in the Snake River basin are not likely to appreciably reduce the likelihood of survival and recovery of the Snake River Steelhead DPS (NMFS 2017b). The consultations also included terms and conditions for continued monitoring of the hatchery programs and their effects on listed species.

Several uncertainties exist regarding the effects of hatchery programs on natural-origin SRB steelhead populations. One of the main areas of uncertainty is the relative proportion and distribution of hatchery-origin spawners in natural spawning areas at the population level, particularly for SRB steelhead (Ford 2022). Because of this lack of information, the diversity status of most of the populations in the DPS remains uncertain. Information is needed to determine where, and to what extent, unaccounted for hatchery steelhead are interacting with ESA-listed populations, particularly in Idaho (Ford 2022). Co-managers have continued to install PIT tag arrays throughout the Snake River basin that are likely to provide new information on population abundance and productivity and hatchery fish proportions and distribution throughout the Snake River basin. In addition, NMFS, hatchery funding agencies, and the state and tribal co-managers participate in a Snake River Steelhead Workgroup to continue to collaborate on addressing these uncertainties. Information about the proportion and distribution of hatchery-origin spawners in natural spawning areas remains uncertain and similar to the previous 5-year review period. The risk to SRB steelhead persistence from hatcheries remains uncertain and at moderate to high risk, and has not changed since the last review period.

Recommended Future Actions

At this time, we are unable to mitigate for the effects of reduced ocean survival within the marine environment. Efforts to mitigate carryover effects from freshwater could affect marine survival in these populations and increase the resilience of populations during all life stages. These include:

- Improve and expand access to historical rearing habitats.This should increase smolt abundance and body condition, resulting in improved population viability. Intrinsic habitat potential is negatively correlated with present levels of disturbance, so restoring all critical habitat could yield substantial benefits. Specifically, efforts should aim to restore the lower elevation historically highly productive habitat that has been lost and higher elevation rearing habitats that are prone low flow and high water temperatures.
- Improve individual fish growth by reducing contaminant loads, increasing floodplain habitat, and increasing habitat complexity. These actions, in general, could boost population productivity.

2.4 Synthesis

The ESA defines an endangered species as one that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as one that is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. Under ESA section 4(c)(2), we must review the listing classification of all listed species at least once every 5 years. While conducting these reviews, we apply the provisions of ESA section 4(a)(1) and NMFS' implementing regulations at 50 CFR part 424.

To determine if a reclassification is warranted, we review the status of the species and evaluate the five risk factors, as identified in ESA section 4(a)(1): (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or man-made factors affecting a species' continued existence. We then make a determination based solely on the best available scientific and commercial information, taking into account efforts by states and foreign governments to protect the species.

We conclude:

Updated Biological Risk Summary: Our Northwest Fisheries Science Center completed an updated viability assessment for the DPS (Ford 2022). They concluded that population abundance declines in this review period warrant close monitoring of population abundance over the next 5-year review period to determine the need for an elevated biological risk status for this DPS at the conclusion of the next 5-year assessment period.

- Listing Factor A (Habitat): Conservation partners have implemented many tributary habitat restoration projects across the DPS since the last 5-year review, improving habitat conditions for SRB steelhead spawning, rearing, and migration in many reaches. In addition, PIBO landscape-scale monitoring has shown that habitat is improving on Pacific Northwest National Forests and BLM lands. However, habitat limiting factors remain the same since the last 5-year review. Widespread areas of degraded habitat persist, and further habitat degradation continues across the basin, with a lack of habitat complexity, simplified stream channels, disconnected floodplains, impaired instream flow, loss of cold water refugia, and other limiting factors. We conclude that given the restoration, further degradation, and continuance of tributary habitat limiting factors, the overall habitat risk to the persistence of SRB Steelhead DPS is moderate, remaining the same since the last 5-year review.

- Listing Factor B (Overutilization): The risk to the species' persistence because of overutilization remains essentially unchanged since the 2016 5-year review and remains at a moderate level. Although total exploitation rates on the species have declined since the last 5-year review, harvest continues to pose a moderate risk to the persistence of SRB steelhead. Since the last 5-year review, scientific research impacts on listed SRB steelhead have remained low and relatively stable The overall risk to SRB steelhead persistence from overutilization since the previous 5-year review remains moderate.
- Listing Factor C (Disease and Predation): Disease rates over the past 5 years are believed to pose a low risk to the persistence of SRB steelhead and are consistent with the previous review period. The extinction risk posed to the DPS by predation from avian, pinniped, and other fish species has remained largely the same, at a moderate level, since the last 5-year review. Avian predation rates are much higher than predation rates from predatory fish or marine mammals. In the mainstem Snake and Columbia rivers, and Columbia River estuary, efforts by the Corps to reduce or relocate predatory birds have reduced or increased avian predation, depending on location, resulting in no overall change in avian predation impacts since the last 5-year review. Pinniped predation during this review period averaged 3.7 percent of adult return to East Mooring Bay and Bonneville Dam. Moderate predation from all sources is similar to the last 5-year review and poses a moderate risk to the persistence of SRB steelhead.
- Listing Factor D (Inadequacy of Regulatory Mechanisms): There have been improvements in the adequacy of some regulatory mechanisms within the Snake River Basin Steelhead DPS since the 2016 5-year review (see above list of Regulatory Mechanisms Resulting in Adequate or Improved Protection). There have also been regulatory changes resulting in inadequate or decreased protection of SRB steelhead, some at the DPS and national scales (e.g., CWA, FEMA NFIP and H&H analysis, NEPA). Based on the information noted above for regulations in the Snake River basin and the Columbia River migratory corridor, we conclude that the overall risk to the species' persistence because of the adequacy of some existing regulatory mechanisms has improved slightly since our prior review. However, some landscape-scale regulations affecting floodplain connectivity continue to increase the risk to the persistence of SRB steelhead.
- Listing Factor E (Other Natural and Manmade Factors):
    - Climate change affects the rangewide status of SRB steelhead and aquatic habitat. Crozier et al. (2019) published a climate vulnerability analysis for Pacific salmon and steelhead based on species sensitivity, exposure, and adaptive capability. For

SRB steelhead, the life stage that appears to be the most vulnerable to climate change is juvenile rearing. Summer habitats may have reduced flow, or loss of tributary access, from irrigation withdrawals. High summer water temperatures are also prevalent. Climate change has and will cause earlier snow melt timing, reduced summer flows, and higher air temperatures; all of which will exacerbate the low flows and high water temperatures for juvenile SRB steelhead. This DPS is also considered to have only moderate capacity to adapt to climate change impacts. Given the extrinsic factors currently increasing the vulnerability of many populations to climate change impacts, it is unclear whether their adaptability would be sufficient to mitigate the risk climate change poses to the persistence of this DPS. The risk to SRB steelhead persistence from climate change has increased since the previous 2016 5-year review.

- An anomalous marine heatwave led to an onshore and northward movement of warm stratified waters into the California Current ecosystem, causing changes in the plankton community composition and structure, suggesting that forage fish diets are considerably less nutritional. In addition, Crozier et al. (2019) asserted in their vulnerability analysis that sea surface temperature and ocean acidification (as well as freshwater stream temperatures) were the most broadly identified climate-related stressors likely to impact populations. The risk to SRB steelhead persistence from the climate change effects of sea surface temperature, ocean acidification, and freshwater stream temperatures has increased since the previous 2016 5-year review.
- In general, hatchery programs can provide short-term demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks, including increased competition, predation, disease, genetic, broodstock collection, and facility effects (NMFS 2018b). Recent ESA consultations on Hatchery and Genetic Management Plans for every steelhead hatchery program in the Snake River basin concluded that hatchery programs in the Snake River basin are not likely to appreciably reduce the likelihood of survival and recovery of the Snake River Basin Steelhead DPS (NMFS 2017b). The main area of uncertainty regarding hatchery effects is the relative proportion and distribution of hatchery-origin spawners in natural spawning areas at the population level, particularly for SRB steelhead (Ford 2022). Information is needed to determine where, and to what extent, unaccounted-for hatchery steelhead are interacting with ESA-listed populations, particularly in Idaho (Ford 2022). The proportion and distribution of hatchery-origin spawners in natural spawning areas remain uncertain and similar to the previous 5-year review period. The risk to SRB steelhead persistence from hatcheries remains uncertain and at moderate to high risk, and has not changed since the last review period.

2.4.1 Snake River Basin steelhead DPS delineation and hatchery membership

The Northwest Fisheries Science Center’s review (Ford 2022) found that no new information had become available that would justify a change in the delineation of the SRB steelhead DPS.

The West Coast Regional Office’s review of new information since the previous 2016 5-year review regarding the DPS membership status of various hatchery programs indicates no changes in the SRB steelhead DPS membership are warranted.

2.4.2 ESU/DPS viability and statutory listing factors

The Northwest Fisheries Science Center’s review of updated information (Ford 2022) does not indicate a change in the biological risk category of moderate for the SRB steelhead DPS since the time of the last 5-year review (NMFS 2016a). However, Ford (2022) notes that the updated population-level abundance estimates have made very clear the recent (last 5 years) sharp declines that are extremely worrisome, were they to continue.

Our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the SRB steelhead’s persistence is moderate to high and is increasing because of climate change.

3. Results

3.1 Classification

Listing status

Based on the information provided above, we determine that no reclassification for the SRB steelhead SRB is warranted. Therefore, the SRB steelhead DPS should remain listed as threatened.

ESU/DPS Delineation

The Northwest Fisheries Science Center's viability assessment (Ford 2022) found that no new information has become available that would justify a change in delineation for the SRB steelhead DPS.

Hatchery Membership

For the SRB steelhead DPS, we do not recommend any changes to the hatchery program membership.

3.2 New Recovery Priority Number

Since the previous 2016 5-year review, NMFS revised the recovery priority number guidelines and twice evaluated the numbers (NMFS 2019a, 2022). Table 4 indicates the number in place for the SRB steelhead DPS at the beginning of the current review (3C). In January 2022, the number remained unchanged.

As part of this 5-year review, we re-evaluated the number based on the best available information, including the new viability assessment (Ford 2022). We concluded that the current recovery priority number remains 3C.

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4. Recommendations for Future Actions

In our review of the listing factors, we identified several actions critical to improving the status of the SRB steelhead DPS. These include implementing the 2017 recovery plan (NMFS 2017b), the *U.S. v. Oregon* (in-river harvest) Management Agreement for 2018-2027, the 2020 Columbia River System biological opinion (NMFS 2020a), and biological opinion on hatchery operations within the DPS (NMFS 2017d).

Some of the greatest opportunities to advance recovery are to:

- Implement habitat restoration at a watershed scale. Implement habitat improvement actions consistent with best practices for watershed restoration (see, e.g., Beechie et al. 2010; Hillman et al. 2016; and Appendix A of NMFS 2020a). Prioritize projects that improve habitat resilience to climate change; specifically, projects that restore natural flow regimes, reduce water temperatures, and reconnect tributaries and floodplains in juvenile rearing areas (Beechie et al. 2013).
- Develop, support, and enhance local- to basin-scale frameworks to guide and prioritize habitat restoration actions and integrate a landscape perspective into decision making. Successful examples of these Atlas and other watershed-scale assessments and plans can be found in Section 2.3.2 Listing factor A.
- Reconnect stream channels with their floodplains in steelhead habitat (Beechie et al. 2013). Use low-tech process-based methods (Wheaton et al., eds. 2019), including reintroducing beaver (Pollock et al. 2017) to facilitate widespread, low-cost floodplain restoration across the DPS.
- Connect tributaries to mainstem migration corridors. Temperature refugia from tributaries is vital to successful migration and survival (Keefer et al. 2018; EPA 2021).
- Monitor impacts from research programs, pinniped predation, hatcheries, and habitat restoration.
- Monitor population VSP metrics where data are lacking for populations that must reach viable status for MPG and DPS recovery.

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5. References

5.1 Federal Register Notices

November 20, 1991 (56 FR 58612). Notice of Policy: Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon.

February 7, 1996 (61 FR 4722). Notice of Policy: Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act.

August 18, 1997 (62 FR 43937). Final Rule: Endangered and Threatened Species: Listing of Several Evolutionary Significant Units (ESUs) of West Coast Steelhead.

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June 28, 2005 (70 FR 37204). Final Policy: Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead.

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January 5, 2006 (71 FR 834). Final Rule: Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead.

August 15, 2011 (76 FR 50448). Notice of availability of 5-year reviews: Endangered and Threatened Species; 5-Year Reviews for 17 Evolutionarily Significant Units and Distinct Population Segments of Pacific Salmon and Steelhead.

May 26, 2016 (81 FR 33468). Notice of Availability of 5-year Reviews Endangered and Threatened Species; 5-Year Reviews for 28 Listed Species of Pacific Salmon, Steelhead, and Eulachon.

April 30, 2019 (84 FR 18243). Notice of Final Guidelines: Endangered and Threatened Species; Listing and Recovery Priority Guidelines.

October 4, 2019 (84 FR 53117). Notice of Initiation of 5-year Reviews: Endangered and Threatened Species; Initiation of 5-Year Reviews for 28 Listed Species of Pacific Salmon and Steelhead.

November 19, 2020 (85 FR 73620). Final Rule: U.S. Department of Agriculture, Forest Service (Agency) is adopting a final rule amending its National Environmental Policy Act (NEPA) regulations.

December 17, 2020 (85 FR 81822). Revisions to Hatchery Programs Included as Part of Pacific Salmon and Steelhead Species Listed Under the Endangered Species Act.

January 13, 2021 (86 FR 2744). Final Rule: Reissuance and Modification of Nationwide Permits.

December 7, 2021 (86 FR 69372). Revised Definition of “Waters of the United States”.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Oncorhynchus tshawytscha: Snake River S

Current Classification: Threatened

Recommendation resulting from the 5-Year Review

☐ Downlist to Threatened
☐ Uplist to Endangered
☐ Delist
☒ No change is needed

Review Conducted By (Name and Office):

West Coast Region Snake River Spring-Summer Chinook Salmon ESU Evaluation Team

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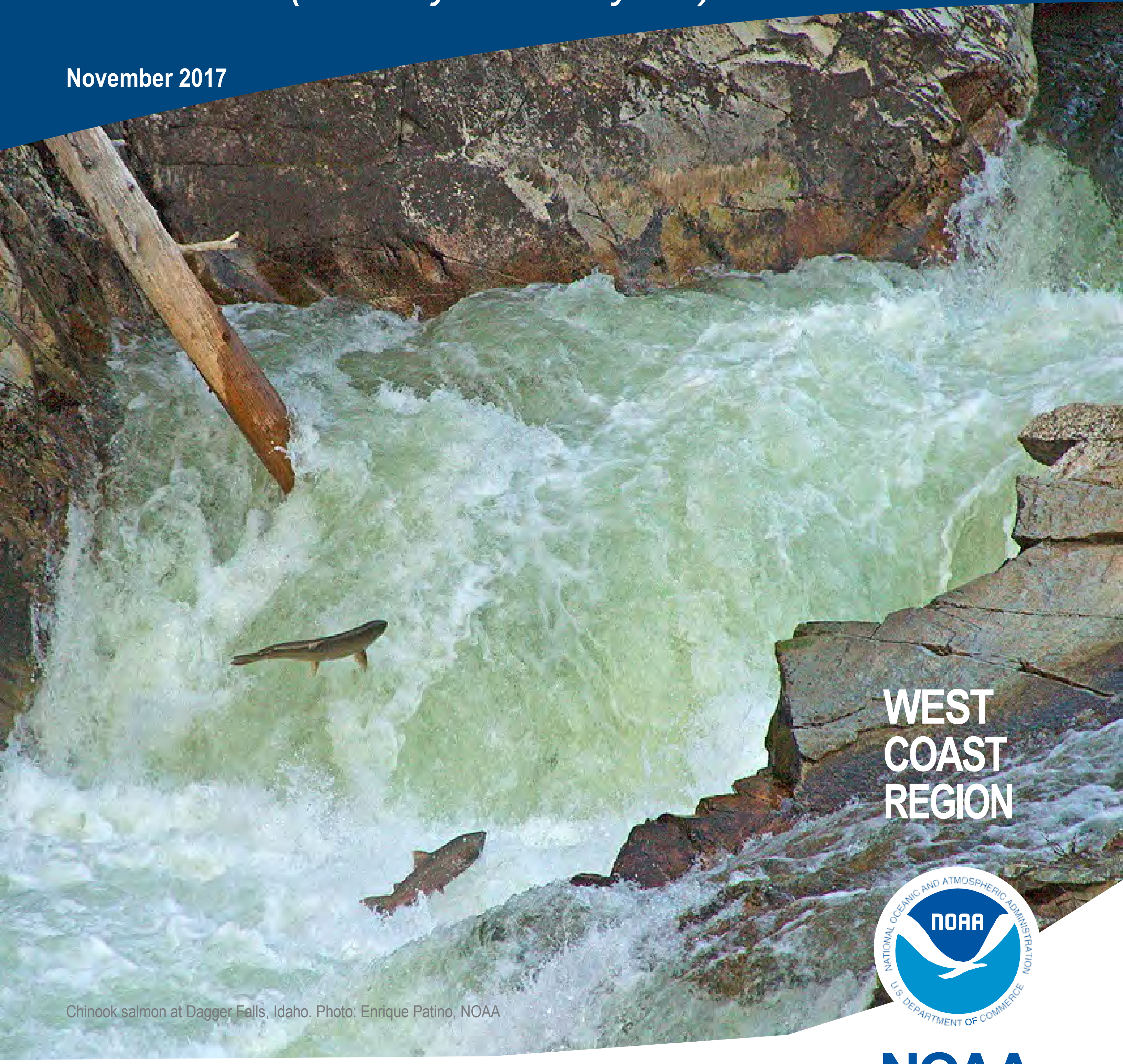
ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon *(Oncorhynchus tshawytscha)* & Snake River Basin Steelhead *(Oncorhynchus mykiss)*

November 2017



Chinook salmon at Dagger Falls, Idaho. Photo: Enrique Patino, NOAA

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Snake River Modules

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NMFS Snake River Harvest Module Authors
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Abbreviations and Acronyms

2008 SCA	2008 Supplemental Comprehensive Analysis
BACI	before after control influence
BiOp	Biological Opinion
BPA	Bonneville Power Administration
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CHaMP	Columbia Habitat Monitoring Program
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWT	Coded-wire tags
DDT	Dichlorodiphenyltrichloroethane
DPS	distinct population segment
ERTG	Expert Regional Technical Group
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FCRPS	Federal Columbia River Power System
FMEP	Fish Management and Evaluation Plan
GIS	geographic information system
GM	geometric mean
HGMP	Hatchery Genetic Management Plan
HSRG	Hatchery Scientific Review Group
ICTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IHOT	Integrated Hatchery Operations Team
ISDA	Idaho State Department of Agriculture
ISRP	Independent Scientific Review Panel
MCR	Middle Columbia River
MPG	major population group
NAWQA	National Water Quality Assessment
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NPDES	National Pollutant Discharge Elimination System
NPT	Nez Perce Tribe
NRCS	Natural Resources Conservation Service
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
OSC	Office of Species Conservation
PAHs	polycyclic aromatic hydrocarbons
PBDE	polybrominated diphenyl ethers
PBT	parental based tagging
PCBs	polychlorinated biphenyls

PIBO	Pacfish - Infish Biological Opinion
PIT	passive integrated transponder
PNI	proportionate natural influence
RIST	Recovery Implementation Science Team
RM	river mile
RME	research, monitoring, and evaluation
RPA	reasonable and prudent alternative
SAR	smolt-to-adult return
SBSTOC	Stanley Basin Sockeye Technical Oversight Committee
SBT	Shoshone Bannock Tribe
Sawtooth NRA	Sawtooth National Recreation Area
SR	Snake River
TCDDs	tetra-chlorinated dibenzo-p-dioxius
TDG	total dissolved gas
TMDL	total maximum daily load
TOC	Technical Oversight Committee
TRT	Technical Recovery Team
UCR	Upper Columbia River
UI	University of Idaho
USFS	U.S. Forest Service
USRT	Upper Snake River Tribes
VIC	variable infiltration capacity

Terms and Definitions

A-run steelhead	Steelhead referred to as “A-run” are smaller (usually 58 to 66 cm long), spend one year in the ocean, and begin their upriver freshwater migration earlier in the year than steelhead referred to as “B-run”.
Abundance	In the context of salmon recovery, abundance refers to the number of natural-origin adult fish returning to spawn.
Acre-feet	A common measure of the volume of water in the river system. It is the amount of water it takes to cover one acre (43,560 square feet) to a depth of one foot.
Action Agencies	The three agencies that operate the Federal Columbia River Power System: Bonneville Power Administration, U.S. Army Corps of Engineers and U.S. Bureau of Reclamation.
Adaptive Management	The process of adjusting management actions and/or directions based on new information.
All-H Approach	The idea that actions could be taken to improve the status of a species by reducing adverse effects of the hydropower system, predators, hatcheries, habitat, and/or harvest.
Anadromous Fish	Species that are hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.
B-run steelhead	Steelhead referred to as “B-run” are larger (>78 cm long), spend two years in the ocean, and appear to begin their upriver freshwater migration later in the year than steelhead referred to as “A-run”.
Baseline Monitoring	In the context of recovery planning, baseline monitoring is done before implementation, in order to establish historical and/or current conditions against which progress (or lack of progress) can be measured.
Biogeographical Region	An area defined in terms of physical and habitat features, including topography and ecological variations, where groups of organisms (in this case, salmonids) have evolved in common.
Broad Sense Recovery Goals	Goals defined in the recovery planning process, generally by local recovery planning groups, which go beyond the requirements for delisting, to address, for example, other legislative mandates or social, economic and ecological values.
Brood Cycles	Salmon and steelhead mature at different ages so their progeny return as spawning adults over several years. When all progeny at all ages have returned to spawn, the brood cycle is complete.
Compliance Monitoring	Monitoring to determine whether a specific performance standard, environmental standard, regulation, or law is met.
Conservation Gap	The difference between a population’s baseline status and its target status.

Contributing Population	A population for which some restoration will be needed to achieve the MPG-wide average viability recommended by the Interior Columbia Technical Recovery Team.
Critical Habitat	Specific areas that contain the physical or biological features that are essential for the conservation of endangered or threatened species, and that may require special management considerations or protection.
Delisting Criteria	Criteria incorporated into ESA recovery plans that define both biological viability (biological criteria) and alleviation of the causes for decline (threats criteria based on the five listing factors in ESA section 4[a][1]), and that, when met, would result in a determination that a species is no longer threatened or endangered and can be proposed for removal from the Federal list of threatened and endangered species.
Distinct Population Segment (DPS)	A listable entity under the ESA that meets tests of discreteness and significance according to USFWS and NOAA Fisheries policy. A population is considered distinct (and hence a “species” for purposes of conservation under the ESA) if it is discrete from and significant to the remainder of its species based on factors such as physical, behavioral, or genetic characteristics, it occupies an unusual or unique ecological setting, or its loss would represent a significant gap in the species’ range.
Diversion	Refers to taking water out of the river channel for municipal, industrial, or agricultural use. Water is diverted by pumping directly from the river or by filling canals.
Diversity	All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy versus lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.
Effectiveness Monitoring	Monitoring set up to test cause-and-effect hypotheses about reasonable and prudent alternative (RPA) actions intended to benefit listed species and/or designated critical habitat. Did the management actions achieve their direct effect or goal? For example, did fencing a riparian area to exclude livestock result in recovery of riparian vegetation?
Endangered Species	A species in danger of extinction throughout all or a significant portion of its range.
ESA Recovery Plan	A plan to recover a species listed as threatened or endangered under the U.S. Endangered Species Act (ESA). The ESA requires that recovery plans, to the extent practicable, incorporate (1) objective, measurable criteria that, when met, would result in a determination that the species is no longer threatened or endangered; (2) site-specific management actions that may be

	necessary to achieve the plan's goals; and (3) estimates of the time required and costs to implement recovery actions.
Essential Fish Habitat	As defined by the U.S. Congress in the Magnuson-Stevens Fishery Conservation and Management Act, Essential Fish Habitat (EFH) describes all waters and substrate necessary for fish for spawning, breeding, feeding, or growth to maturity.
Evolutionarily Significant Unit (ESU)	A group of Pacific salmon or steelhead trout that is (1) substantially reproductively isolated from other conspecific units and (2) represents an important component of the evolutionary legacy of the species. Equivalent to a distinct population segment (DPS) and treated as a species under the Endangered Species Act.
Extinct	No longer in existence. No individuals of this species can be found.
Extirpated	Populations that are entirely cut-off from anadromy and are locally extinct. Functionally extirpated populations are those of which there are so few remaining numbers that there are not enough fish or habitat in suitable condition to support a fully functional population.
Factors for Decline	Five general categories of causes for decline of a species, listed in the Endangered Species Act section 4(a)(1)(b): (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or human-made factors affecting its continued existence.
Fish Ladder	A series of stair-step pools that enables adult salmon and steelhead to migrate upstream past a dam. Swimming from pool to pool, adult salmon and steelhead work their way up the ladder to the top where they continue upriver.
Flow Augmentation	Water released from system storage at targeted times and places to increase streamflows to benefit migrating juvenile salmon and steelhead
Freshet	The heavy runoff that occurs in the river when streams are at their peak flows with spring snowmelt. Before the dams were built, these freshets moved spring juvenile salmon quickly downriver.
Functionally Extirpated	Describes a species or population that has so few remaining individuals that there are not enough fish or habitat in suitable condition to support a fully functional population.
Heterozygosity	The presence of different alleles at one or more loci on homologous chromosomes.
Hyporheic Zone	The hyporheic zone is a region beneath and alongside a stream bed where shallow groundwater and surface water mix.
Implementation Monitoring	Monitoring to determine whether an activity was performed and/or completed as planned.

Independent Population	Any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations.
Independent Scientific Review Panel (ISRP)	The Independent Scientific Review Panel reviews individual fish and wildlife projects funded by Bonneville Power Administration and makes recommendations to the Northwest Power and Conservation Council on matters related to those projects.
Indicator	A variable used to forecast the value or change in the value of another variable.
Intrinsic Potential	The estimated relative suitability of a habitat for spawning and rearing of anadromous salmonid species under historical conditions inferred from stream characteristics including channel size, gradient, and valley width.
Intrinsic Productivity	Productivity at very low population size; unconstrained by density.
Introgression	The incorporation of genes from one species into the gene pool of another as a result of hybridization.
Interoparity	The ability to reproduce more than once during a lifetime.
Jack and Jill salmon	Jack and Jill salmon return to freshwater one or two years earlier than their counterparts. They are usually smaller but are sexually mature and return to spawn at an earlier age.
Juvenile salmon	Juvenile salmon is the term applied to a salmonid fish between the egg and adult stages. Juvenile salmonid stages include sac fry or alevin, fry, parr, and smolts. The juvenile stage last until the fish are grown and sexually mature.
Large Woody Debris (LWD)	A general term for wood naturally occurring or artificially placed in streams, including branches, stumps, logs, and logjams. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape, and greater resistance to flooding.
Legacy Effects	Impacts from past activities (usually a land use) that continue to affect a stream or watershed in the present day.
Limiting Factors	Biological, physical, and chemical conditions (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) and associated ecological processes and interactions that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity).
Major Population Group (MPG)	An aggregate of independent populations within an ESU that share similar genetic and spatial characteristics.
Maintained Status	Population status in which the population does not meet the criteria for a viable population but does support ecological functions and preserve options for ESU recovery.

Management Unit	A geographic area defined for recovery planning purposes on the basis of state, tribal or local jurisdictional boundaries that encompass all or a portion of the range of a listed species, ESU, or DPS.
Metrics	Something that quantifies a characteristic of a situation or process; for example, the number of natural-origin salmon returning to spawn to a specific location is a metric for population abundance.
Morphology	The form and structure of an organism, with special emphasis on external features.
Natural-origin Fish	Fish that were spawned and reared in the wild, regardless of parental origin.
Northern Pikeminnow	A large member of the minnow family, the Northern Pikeminnow is native to the Columbia River and its tributaries. Studies show a Northern Pikeminnow can eat up to 15 young salmon a day.
Parr	The stage in anadromous salmonid development between absorption of the yolk sac and transformation to smolt before migration seaward.
Peak Flow	The maximum rate of flow occurring during a specified time period at a particular location on a stream or river.
Persistence Probability	The complement of a population’s extinction risk (i.e., persistence probability = 1 – extinction risk).
Phenotype	Any observable characteristic of an organism, such as its external appearance, development, biochemical or physiological properties, or behavior.
Photic Zone	The depth of the water in a lake or ocean that is exposed to sufficient sunlight for photosynthesis to occur.
Piscivorous	Describes any animal that preys on fish for food.
Primary Population	A population that is targeted for restoration to high or very high persistence probability.
Productivity	The average number of surviving offspring per parent. Productivity is used as an indicator of a population’s ability to sustain itself or its ability to rebound from low numbers. The terms “population growth rate” and “population productivity” are interchangeable when referring to measures of population production over an entire life cycle. Can be expressed as the number of recruits (adults) per spawner or the number of smolts per spawner.
Reach	A length of stream between two points.
Reasonable and Prudent Alternative	Recommended alternative actions identified during formal consultation that can be implemented in a manner consistent with the purposes of the action, that can be implemented consistent with the scope of the Federal agency’s legal authority and jurisdiction, that are economically and technologically feasible, and that the Service finds would avoid the likelihood of jeopardizing the

	continued existence of the listed species or the destruction or adverse modification of designated critical habitat.
Recovery Domain	An administrative unit for recovery planning defined by NMFS based on ESU boundaries, ecosystem boundaries, and existing local planning processes. Recovery domains may contain one or more listed ESUs.
Recovery Goals	Goals incorporated into a locally developed recovery plan. These goals may go beyond the requirements of ESA de-listing by including other legislative mandates or social values.
Recovery Scenarios	Scenarios that describe a target status for each population within an ESU, generally consistent with TRT recommendations for ESU viability.
Recovery Strategy	A statement that identifies the assumptions and logic—the rationale—for the species' recovery program.
Redd	A nest constructed by female salmonids in streambed gravels where eggs are deposited and fertilization occurs.
Resident Fish	Fish that are permanent inhabitants of a water body. Resident fish include trout, bass, and perch.
Residual Sockeye	Sockeye that are genetically aligned with the anadromous form of sockeye but have adopted a resident life-history pattern, remaining in freshwater to mature and reproduce.
Riparian Area	Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland. It includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.
River Reach	A general term used to refer to lengths along the river from one point to another, as in the reach from the John Day Dam to the McNary Dam.
Runoff	Precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water.
Salmonid	Of, belonging to, or characteristic of the family Salmonidae, which includes salmon, steelhead, trout, and whitefish. In this document, it refers to listed steelhead distinct population segments (DPS) and salmon evolutionarily significant units (ESU).
Self-sustaining	A self-sustaining viable population has a negligible risk of extinction due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year period and achieves these characteristics without dependence upon hatcheries. Hatcheries may be used to benefit threatened and endangered species and a self-sustaining population may include hatchery fish, but a self-sustaining population must not be dependent upon hatchery measures to achieve its viable characteristics. Hatcheries may

	contribute to but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.
Shoal	A shallow place in a lake or other body of water. Sockeye shoal spawners return to spawn along the shoreline of the lake.
Smolt	A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt from freshwater to a saltwater environment.
Smoltification	The transformation from parr to smolt. The transformation involves a series of physiological changes where juvenile salmonid fish adapt from living in freshwater to living in saltwater.
Spatial structure	The geographic distribution of a population or the populations in an ESU.
Spill	Water released from a dam over the spillway instead of being directed through the turbines.
Stabilizing Population	A population that is targeted for maintenance at its baseline persistence probability, which is likely to be low or very low.
Stakeholders	Agencies, groups, or private individuals with an interest in the recovery plan or the management of natural resources affected by the recovery plan and its implementation.
Stock	An aggregation of fish spawning in a particular stream or lake during a particular season which to a substantial degree do not interbreed with any group spawning at a different time.
Straying	Fish that return to locations that are not part of their population of origin. Straying occurs naturally and is only a concern when fish stray in areas where they present potential genetic and ecological risks.
Streamflow	Streamflow refers to the rate and volume of water flowing in various sections of the river. Streamflow records are compiled from measurements taken at particular points on the river, such as The Dalles, Oregon.
Technical Recovery Team (TRT)	Teams convened by NOAA Fisheries to develop technical products related to recovery planning. Technical Recovery Teams are complemented by planning forums unique to specific states, tribes, or regions, which use TRT and other technical products to identify recovery actions. See SCA section 7.3 for a discussion of how TRT information is considered in these biological opinions.
Threatened Species	A species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
Threat Reduction Scenario	A specific combination of reductions in threats from various sectors that would lead to a population achieving its target status.
Threats	Human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that

	cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.
Viability criteria	Criteria defined by NOAA Fisheries-appointed Technical Recovery Teams based on the biological parameters of abundance, productivity, spatial structure, and diversity, which describe a viable salmonid population (VSP) (an independent population with a negligible risk of extinction over a 100-year time frame) and which describe a general framework for how many and which populations within an ESU should be at a particular status for the ESU to have an acceptably low risk of extinction. See SCA section 7.3 for a discussion of how TRT information is considered in these biological opinions.
Viability Curve	A curve describing combinations of abundance and productivity that yield a particular risk of extinction at a given level of variation over a specified time frame.
Viable Salmonid Population (VSP)	An independent population of any Pacific salmon or steelhead that has a negligible risk of extinction due to threats from demographic variation (random or directional), local environmental variation, and genetic diversity change (random or directional) over a 100-year time frame.
VSP Parameters	Abundance, productivity, spatial structure, and diversity. These describe characteristics of salmonid populations that are useful in evaluating population viability. See NOAA Technical Memorandum NMFS-NWFSC-42, Viable salmonid populations and the recovery of evolutionarily significant units (McElhany et al. 2000).
Yearling	A fish that is in its second year of life; sometimes used synonymously with smolt.

1. Introduction

This is an Endangered Species Act (ESA) recovery plan (Plan or recovery plan) for Snake River spring- and summer-run Chinook salmon *(Oncorhynchus tshawytscha)* and Snake River Basin steelhead *(Oncorhynchus mykiss)*. NOAA's National Marine Fisheries Service (NMFS) is required, pursuant to section 4(f) of the ESA, to develop and implement recovery plans for species listed under the ESA. The Plan focuses on two species that spawn and rear in the Snake River basin, a main artery of the Columbia River in the northwest United States:

- Snake River spring/summer-run Chinook salmon, an evolutionarily significant unit (ESU),[1] was listed as a threatened species under the ESA on April 22, 1992 (57 FR 14658). NMFS reviewed the species' status in 2005 and, on June 28, 2005 (70 FR 37160), determined that the species should remain listed. We updated and made minor technical corrections to the listing on April 14, 2014 (79 FR 20802) (Figure 1-1). NMFS reviewed the species' status in 2015, and on May 26, 2016 (81 FR 33468), determined that the species should remain listed as threatened.
- Snake River Basin steelhead, a distinct population segment (DPS),[2] was originally listed as a threatened species under the ESA on August 18, 1997 (62 FR 43937). We reaffirmed this listing on January 5, 2006 (71 FR 834) and then updated and made minor technical corrections to the listing on April 14, 2014 (79 FR 20802) (Figure 1-2). NMFS reviewed the species' status in 2015, and on May 26, 2016 (81 FR 33468), determined that the species should remain listed as threatened.

Historically, the Snake River is believed to have been the Columbia River basin's most productive drainage for salmon and steelhead, supporting more than 40 percent of all Columbia River spring and summer Chinook salmon and 55 percent of summer steelhead (Fulton 1968; NMFS 1995). Strong runs of spring and summer Chinook salmon and steelhead returned each year to spawn and rear in mainstem and tributary reaches of the Snake River extending upstream to Shoshone Falls, a 212-foot-high natural barrier on the Snake River near Twin Falls, Idaho (RM 614.7). The fish also ranged into most Snake River tributaries stretching across the states of Oregon, Washington, Idaho, and into Nevada ─ including in the Owyhee, Bruneau, Boise, Payette, Weiser, Malheur, Burnt, Powder, Salmon, Clearwater, Grande Ronde, Imnaha, and Tucannon Rivers.

Today, as they did historically, these salmon and steelhead cover vast areas and rely on habitats across a wide geographic range during their life cycle. They begin life in the gravel of freshwater streams of the Snake River basin, up to 900 miles inland from the Pacific Ocean and 6,500 feet above sea level, and rear in these freshwater areas for their first year. As juveniles, they travel hundreds of miles downstream from their natal streams, through the Snake and Columbia Rivers

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[1] An ESU or DPS is a group of Pacific salmon or steelhead, respectively, that is discrete from other groups of the same species and that represents an important component of the evolutionary legacy of the species. Under the Endangered Species Act, each ESU or DPS is treated as a species.

[2] The species was originally listed as an ESU. It was delineated as an anadromous steelhead-only DPS in 2006. A DPS is defined based on discreteness in behavioral, physiological, and morphological characteristics, whereas the definition of an ESU emphasizes genetic and reproductive isolation.

to the ocean, passing up to eight major hydroelectric dams and undergoing extraordinary metabolic changes as they adapt to salt water. After one to five years traveling long distances in the Pacific Ocean, the adult fish retrace their journey up the Columbia and Snake Rivers, and through the mainstem hydropower system, returning to their natal streams to spawn a new generation.

Currently, both fish species remain at risk of becoming endangered within 100 years.[3] Multiple threats across their life cycles contribute to their current weakened status. These various threats need to be addressed to ensure that Snake River spring/summer Chinook salmon and steelhead can be self-sustaining in the wild over the long term. This recovery plan provides a strategy designed to take them to levels where they are again self-sustaining in the wild and no longer need the protections of the ESA.

1.1 Historical Context ─ Declines, Listings, and Recent Improvements

The once strong Snake River Chinook salmon and steelhead runs, revered by Native Americans and local communities and prized by fisheries, began to decline in the late 1800s. The runs continued to weaken through the 1900s. Many populations became extinct.

1.1.1 Factors Contributing to Species' Declines

Several factors have contributed to the species' declines since the late 1800s: Rates of harvest on the runs soared in the late 1800s and early 1900s and, while reduced through regulation, remained high until the 1970s. At the same time, increasing numbers of European-American settlers moved into the area, resulting in the deterioration of habitat conditions due to logging, mining, grazing, farming, hydropower development and other practices. Settlers also dammed and dredged tributaries, reducing access to spawning and rearing areas and contributing sediment to the streams. Construction and operation of irrigation systems reduced instream flows, increased stream temperatures, and created partial or complete migration barriers.

The fish lost access to large blocks of their historical habitat. In 1901, construction of Swan Falls Dam on the Snake River blocked access to mainstem and tributary habitat above river mile (RM) 457.7. More historical habitats (above RM 247) on the mainstem Snake River were lost after construction of the three-dam Hells Canyon Complex from 1955 to 1967. Dam construction also blocked and/ or hindered fish access to historical habitat in major tributaries. In the Clearwater River basin, Lewiston Dam,[4] built on the lower Clearwater River in 1927 and removed in 1973, is believed to have caused the extirpation of native Chinook salmon, but not steelhead, in the drainage above the dam site. Steelhead populations in the North Fork Clearwater River subbasin were eliminated in the early 1970s following construction of Dworshak Dam. In the Salmon

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[3] Under the ESA, a species is considered "endangered" if it is in danger of extinction throughout all or a significant portion of its range.

[4] Lewiston Dam, constructed in 1927 on the lower Clearwater River, allowed steelhead to access areas above the dam but blocked Chinook salmon until the fish ladder was improved in the 1950s. The dam was removed in the early 1970s, following construction of Dworshak Dam on the lower North Fork Clearwater River and Lower Granite Dam on the lower Snake River.

River basin, Sunbeam Dam, constructed on the Salmon River below the mouth of the Yankee Fork (RM 368) in 1910, was a serious impediment to migration of anadromous fish and may have been a complete block in at least some years before its partial removal in 1934 (Waples et al. 1991). Many smaller dams, and some temporary dams, were also built on tributaries at this time without fish passage facilities and had the same effects, though on much smaller scales. The loss of this historical habitat significantly reduced the spatial structure that was once available to the species.

Construction of large hydropower and water storage projects associated with the Federal Columbia River Power System (FCRPS) further affected salmonid migratory conditions and survival rates. The production of Snake River spring/summer Chinook salmon and steelhead was especially impacted by the development of eight major federal dams and reservoirs in the mainstem lower Columbia/ Snake River migration corridor between the late 1930s and early 1970s: four on the lower Columbia River (Bonneville, The Dalles, John Day and McNary Dams) and four on the lower Snake River (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams). All eight dams provide fish passage, but fish survival and productivity is affected by their operations and configurations.

Together, these and other factors seriously affected spring and summer Chinook salmon and steelhead production in the Snake River basin. By the early 1990s, abundance of naturally produced Snake River spring/summer-run Chinook salmon had dropped to a small fraction of historical levels, and projections expected a continued downward trend in the short term (Matthews and Waples 1991). Snake River Basin steelhead, while in somewhat better shape, were also on the decline.

1.1.2 Listing of Species under the ESA

The decline in these runs by the 1990s led NMFS to list Snake River spring/summer Chinook salmon under the ESA in 1992, and then to ESA-list Snake River Basin steelhead in 1997.

Snake River Spring and Summer-Run Chinook Salmon ESU

The Snake River spring/summer-run Chinook salmon ESU includes all naturally spawned spring/summer Chinook salmon originating from the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins (Figure 1-1). Also, spring/summer Chinook salmon from 11 hatchery programs: Tucannon River Program, Lostine River Program, Catherine Creek Program, Lookingglass Hatchery Program, Upper Grande Ronde Program, Imnaha River Program, Big Sheep Creek Program, McCall Hatchery Program, Johnson Creek Artificial Propagation Enhancement Program, Pahsimeroi Hatchery Program, and Sawtooth Hatchery Program (70 FR 20802).[5]

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[5] NMFS is currently reviewing the hatchery programs included in the ESU and may make changes during future rulemaking. The Plan will be updated based on any changes NMFS makes to the list of hatchery programs as needed.

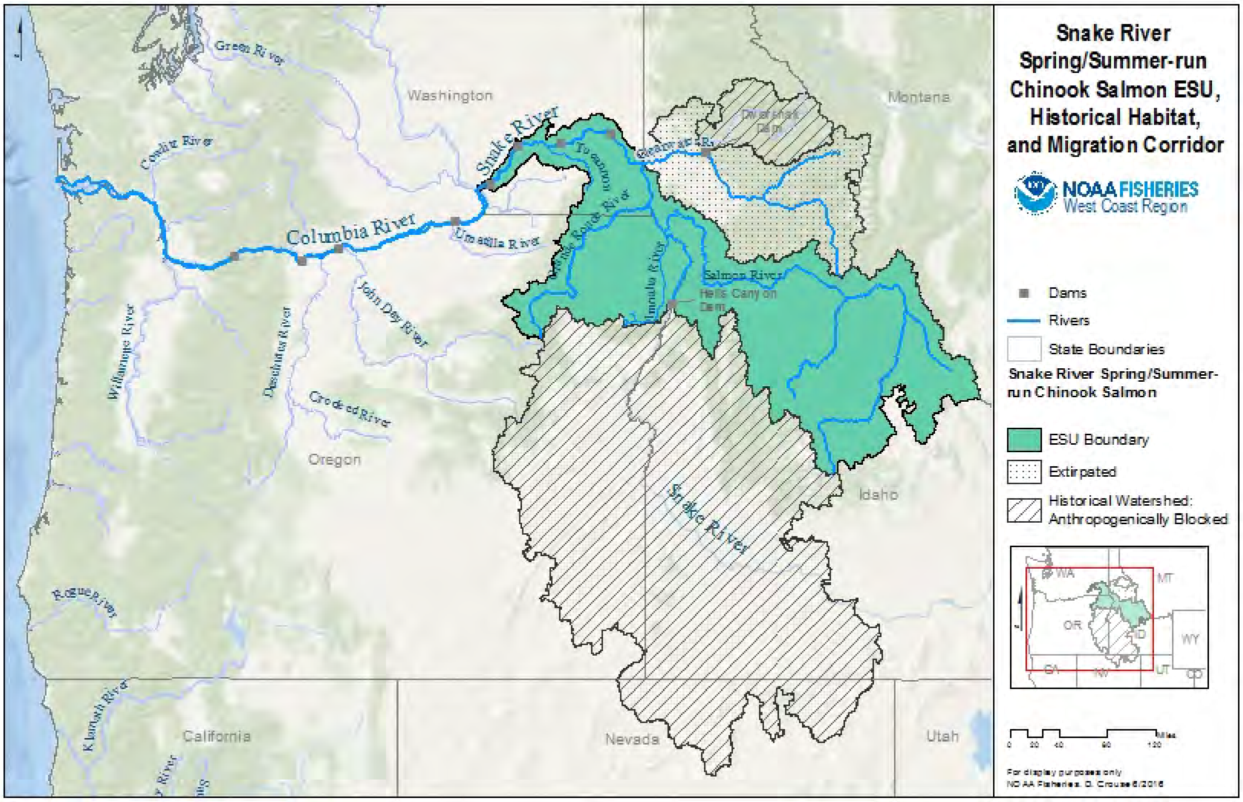

Figure 1-1. Snake River Spring/Summer-Run Chinook Salmon Evolutionarily Significant Unit, historical habitat, and migration corridor.

NMFS listed Snake River spring/summer-run Chinook salmon under the ESA in 1992 after a 1991 status review by its team of scientists (Matthews and Waples 1991) found the ESU at risk of becoming endangered. The review determined that while the historical run in the Snake River likely exceeded one million fish annually in the late 1800s, the run had declined to near 100,000 adults per year by the 1950s. Counts of spring and summer Chinook salmon adults at the lower Snake River dams declined further in the 1960s, with the run at Ice Harbor Dam reaching an average of 58,798 fish in 1962–1970 and a low of 11,855 fish in 1979. The adult counts gradually increased during the 1980s but then declined further, reaching a low of 2,200 fish in 1995. Factors cited in the 1991 status review as contributing to the species' decline since the late 1800s include overfishing, irrigation diversions, logging, mining, grazing, obstacles to migration, hydropower development, and questionable management practices and decisions (Matthews and Waples 1991).

A 1998 status review by NMFS' biological review team (Myers et al. 1998) updated the 1991 review. The 1998 review determined that the species remained at risk due to the impact of mainstem hydropower development, including altered flow regimes and impacts on estuarine habitats; regional habitat degradation; and increased hatchery production and use of outside hatchery stocks in major sections of the Grande Ronde River basin and some other Snake River tributaries. Subsequent status reviews by NMFS' West Coast Region and the Northwest

Fisheries Science Center (NWFSC) found that the species remained at high risk of becoming endangered (Good et al. 2005; Ford 2011; NWFSC 2015).

Snake River Basin Steelhead DPS

The Snake River Basin steelhead DPS includes all naturally spawned anadromous *O. mykiss* (steelhead) originating below natural and manmade impassable barriers in the Snake River basin (Figure 1-2). Also, steelhead from six hatchery programs: Tucannon River Program, Dworshak National Fish Hatchery (NFH) Program, Lolo Creek Program, North Fork Clearwater Program, East Fork Salmon River Program, and the Little Sheep Creek/Imnaha River Hatchery Program (Oregon Department of Fish and Wildlife stock #29) (79 FR 20802).[6]

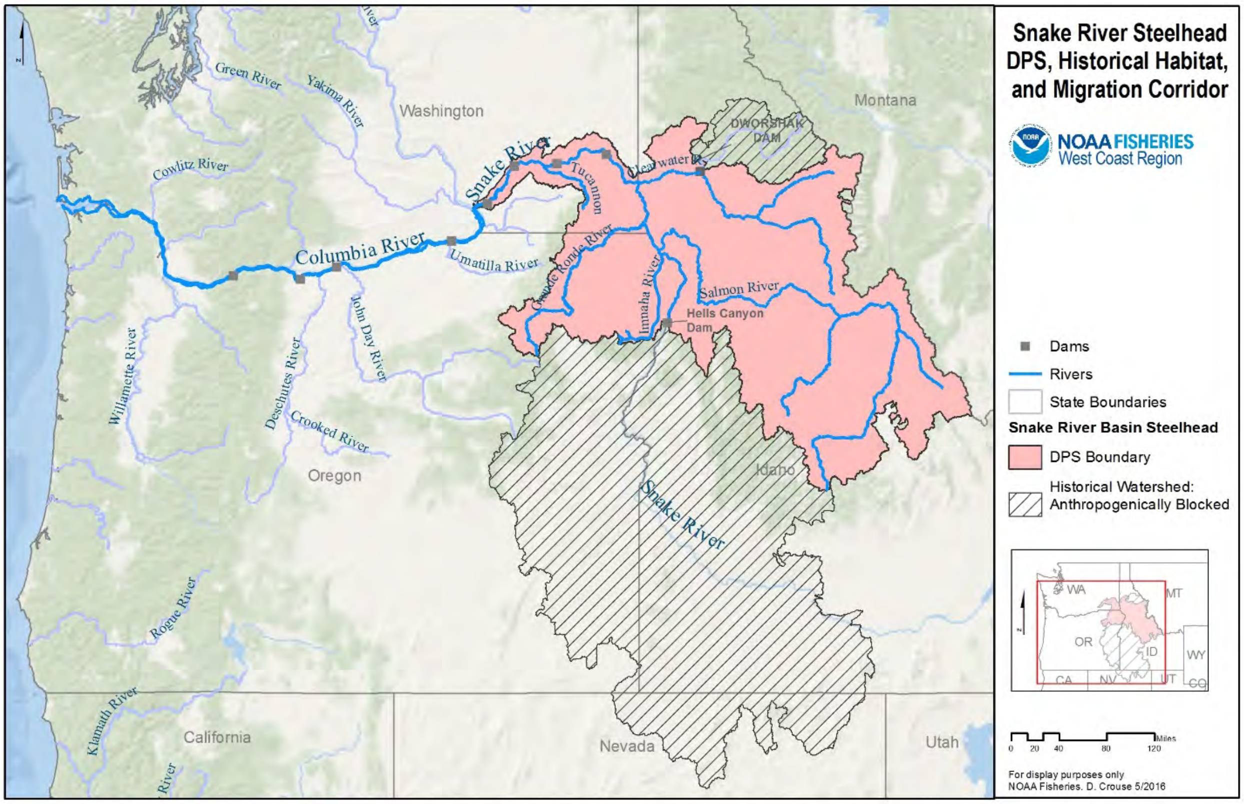

Figure 1-2. Snake River Basin Steelhead Distinct Population Segment, historical habitat, and migration corridor.

The steelhead are commonly referred to as "A-run" and "B-run" fish based on size and life-history expression. A-run steelhead are smaller, spend less time in the ocean, and often begin their upriver migration earlier in the year than do B-run steelhead. Research indicates that A-run steelhead spawn throughout the DPS but B-run steelhead only reproduce in the Clearwater and lower and middle Salmon River basins. Section 2.2.2 provides more information on these two run types and their distribution in the DPS.

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[6] NMFS is currently reviewing the hatchery programs included in the DPS and may make changes during future rulemaking. The Plan will be updated based on any changes NMFS makes to the list of hatchery programs as needed.

The 1997 ESA listing of Snake River Basin steelhead as likely to become endangered within the foreseeable future followed a decline in species abundance. Previous accounts estimated annual adult returns of 40,000 to 60,000 steelhead above Lewiston Dam on the lower Clearwater River in the early 1960s (Cichosz et al. 2001), 15,000 and 4,000 steelhead to the Grande Ronde and Imnaha Rivers in the 1960s (ODFW 1991), and 3,000 steelhead to the Tucannon River in the mid-1950s (Thompson et al. 1958). The Snake River steelhead run at Ice Harbor Dam in 1962 included 108,000 adults, and the run averaged approximately 70,000 adults annually until 1970. At the time of listing in 1997, the total recent-year average (1990–1994) escapement for Snake River steelhead above Lower Granite Dam had dropped to approximately 71,000 adults, with a natural component of 9,400 (7,000 A-run and 2,400 B-run) fish (Good et al. 2005).

NMFS’ 1997 listing determination for Snake River Basin steelhead noted the widespread habitat blockage from hydropower system management and the potentially deleterious genetic effects of straying and introgression of hatchery fish as factors leading to the species’ decline. A 1998 status review by its biological review team (Myers et al. 1998) also cited losses from hydropower development in the Snake and Columbia River basins, as well as widespread habitat degradation and flow impairment. In addition, it found a sharp decline in natural-origin returns beginning in the mid-1980s, and recognized that the high proportion of hatchery fish in the run threatened the run’s genetic integrity.

Subsequent status reviews by NMFS’ West Coast Region and the Northwest Fisheries Science Center (Good et al. 2005; Ford 2011; NWFSC 2015) found that the species remained at risk of becoming endangered. The 2005 review cited the continued relatively depressed status of the B-run steelhead populations as a particular threat. It recognized several key uncertainties due to lack of long-term information on spawning escapements in the individual populations, and the relative proportion of hatchery fish in natural spawning areas (Good et al. 2005). The 2010 review concluded that the status of most populations in the DPS remained highly uncertain, and that there was little evidence of substantial change in DPS status since the 2005 review (Ford 2011). Most recently, the 2015 status review (NWFSC 2015) found that while better status information existed than in previous reviews, it did not indicate a change in the species’ biological risk status; although one of the five major population groups was tentatively rated as viable. The review team noted that a great deal of uncertainty remains regarding the proportion of hatchery fish in natural-origin spawning areas near major hatchery release sites within individual populations (NWFSC 2015).

1.1.3 Improvements since ESA Listing

While efforts to reverse the decline of Snake River salmon and steelhead runs began before the ESA listings, the pace and magnitude of efforts accelerated after their listings under the ESA in the 1990s. Today, thanks to the combined effects of improvements made throughout the life cycle, natural-origin spring/summer Chinook salmon and steelhead populations and habitats are generally in better shape than at the time of ESA listing. Structural and operations improvements at mainstem Columbia and Snake River hydropower projects have boosted adult and juvenile survival through the mainstem corridor. Multiple habitat protection and restoration efforts in tributary and estuary reaches, and increased regulation, continue to improve spawning, rearing and migratory conditions. Collectively, the efforts are increasing habitat complexity, providing passage to historical habitats, and improving stream flows and water quality. Increased restrictions and coordinated efforts by fishery managers have reduced losses to harvest. Improved hatchery practices have decreased straying of hatchery fish, and increased natural abundance of some populations using hatchery supplementation. Research, monitoring, and evaluation (RM&E) activities now provide key information on the runs, remaining problem areas, and the effectiveness of different actions.

Nevertheless, while the combined efforts are moving us toward recovering the fish populations, we recognize that it will take time before the benefits from some of the actions are fully realized, particularly given the species' complex life cycle. At the same time, much more work is needed to address the multiple threats across the life cycle that contribute to the species' weakened status. We also need to gather more information to better understand the specific issues that affect the fish now, or might influence their recovery in the future, and how best to address them.

1.2 Purpose of the Plan

The goal of ESA recovery, and NMFS' goal in this Plan, is to improve the viability of Snake River spring/summer Chinook salmon and steelhead, and the ecosystems upon which they depend, to the point that the ESU and DPS are self-sustaining in the wild and no longer require ESA protection. This recovery plan provides a roadmap for ESA recovery that builds on past and current efforts to recover the species. It sets out where we need to go and defines a path to guide our steps based on the best available science. It identifies strategies and actions that can be implemented now to address limiting factors and improve species' viability. It also targets RM&E to address critical uncertainties and provides a framework that uses newly gained knowledge to alter our course strategically to achieve recovery.

The Plan includes the following parts, consistent with ESA requirements (see Section 1.3):

- Description of the context and process of plan development and how NMFS intends to use the Plan (Chapter 1);
- Background on Snake River spring/summer Chinook salmon and steelhead life histories, historical and current distribution, and the relationship of this Plan to other programs and processes (Chapter 2);
- Recovery goals and delisting criteria (Chapter 3);
- Assessment of the current status of the ESU and DPS, and gaps between current and target status (Chapter 4);
- Summary of the threats and limiting factors and how they are affecting species status (Chapter 5);

- Strategies and actions for recovery of the ESU and DPS and their major population groups (Chapter 6);
- An adaptive management framework (Chapters 6 and 7);
- Research, monitoring and evaluation to support adaptive management (Chapter 7);
- Time and cost estimates to achieve recovery (Chapter 8); and
- Framework for implementation of the Plan and coordination through an adaptive management process (Chapter 9).

The recovery plan focuses on the Snake River spring/summer Chinook salmon and steelhead populations that occupy remaining accessible Snake River habitats across the states of Oregon, Washington, and Idaho. Major tributaries still available to the fish runs include the Grande Ronde and Imnaha Rivers in Oregon, the Salmon River and parts of the Clearwater River in Idaho, and the Tucannon River in Washington.

The Plan includes several separate management unit plans and modules that provide important specific information and direction for Snake River spring/summer Chinook salmon and steelhead in the states of Oregon, Washington, and Idaho. All three management unit plans ─ for Northeast Oregon, Southeast Washington, and Idaho ─ were developed in coordination with respective state, federal, and local agencies, tribes, and others (see Section 1.4.2). Four modules provide additional detail of conditions that affect these and other Snake River species, including the hydropower system, estuary, harvest, and nearshore ocean and plume (see Section 1.4.3). The three management unit plans and four modules serve as appendices to this ESU- and DPS-level Plan for Snake River spring/summer Chinook salmon and steelhead.

Partnerships for Species Recovery

This Plan aims to build on related ongoing and planned efforts, not to duplicate them. We recognize that recovering Snake River spring/summer Chinook salmon and steelhead requires far-reaching actions that address the many factors that challenge their survival. The long-term biological success of these species reflects their ability to make use of diverse habitats from high mountain streams to the ocean. Thus, their resilience in the face of change depends on maintaining genetic, phenotypic, and behavioral diversity over a wide geographic area. At the same time, humans also have needs for the water and habitats that support these fish species. Some human activities have threatened the species' survival by dramatically changing the conditions encountered by the fish during their life cycle. Although many of the harmful effects on fish habitat are due to past practices, current human uses of the land and river systems continue to threaten the viability of Snake River salmon and steelhead across much of their range. Our intent is to provide a scientific understanding of what the species need to be viable and to provide guidance that will lead to development of comprehensive, multi-faceted actions that together will bring the species to recovery while also recognizing human needs.

Improving conditions to boost fish survival through the lower Snake River and the Columbia River and its estuary is particularly important for the Snake River species because of the length of their migration. Juvenile Snake River spring/summer Chinook salmon and steelhead must pass up to eight major dams as they travel downstream from natal tributary habitats through 320 miles of the Columbia and Snake River migration corridor. They pass the dams again as adults on their return journey through the migration corridor, and then swim on into the altered waters of the Snake River and its tributaries. These waters, however, are also important to the human populations living near them, for transportation, irrigation, and recreation. Balancing these often-competing uses is a challenge for recovery planning.

Recovery planning provides an opportunity to search for common ground, to organize protection and restoration of salmonid habitat, and to secure the economic and cultural benefits of healthy watersheds and rivers.

Fortunately, scientific understanding of the threats to Snake River spring/summer Chinook salmon and steelhead is growing, as is interest in aligning hydropower operations, land use, hatchery priorities, and harvest practices with conservation objectives for salmon and steelhead. Ongoing collaborations between federal, state, tribal, and local entities continue to improve salmonid survival throughout the Columbia and lower Snake Rivers, and restore estuary habitats that are essential for juvenile fish to feed, grow, and make the transition to saltwater. An increasing number of people in the Snake River basin recognize the opportunities and benefits of actively protecting and restoring stream corridors, wetlands, stream flows, and other natural features that support native fish and wildlife populations. Management of upland areas is changing to protect and restore watershed function. Cities are undertaking urban watershed protection and restoration.

1.3 Endangered Species Act Requirements

The ESA requires NMFS to develop and implement plans for the conservation and survival of species listed as endangered or threatened under the ESA. Section 4(f) of the ESA refers to these plans for conservation and survival as recovery plans. Recovery plans identify actions needed to restore threatened and endangered species to the point where they are again self-sustaining in the wild and no longer need the protections of the ESA.

ESA section 4(a)(1) lists five factors for determining whether a species is endangered or threatened. These five factors must be addressed in a recovery plan:

A. The present or threatened destruction, modification, or curtailment of [the species'] habitat or range;
B. Over-utilization for commercial, recreational, scientific or educational purposes;
C. Disease or predation;
D. The inadequacy of existing regulatory mechanisms; and
E. Other natural or human-made factors affecting its continued existence.

These listing factors, or threats, need to be addressed to the point that the species may be removed from the list and the removal is not likely to result in re-emergence of the threats and a need to re-list the species.

ESA section 4(f)(1)(B) directs that recovery plans, to the maximum extent practicable, incorporate:

1. A description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species;
2. Objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this chapter, that the species be removed from the list; and
3. Estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal.

In addition, it is important for recovery plans to provide the public and decision makers with a clear understanding of the goals and strategies needed to recover a listed species and the science underlying those conclusions (71 FR 834).

Once a species is deemed recovered and therefore removed from a listed status, section 4(g) of the ESA requires monitoring of the species for a period of not fewer than five years to ensure that it retains its recovered status.

1.4 Plan Development

This recovery plan is the product of a collaborative process initiated by NMFS and strengthened through regional and local participation. The goal was to produce a recovery plan that would meet NMFS' ESA requirements for recovery plans as well as broader needs. Throughout the recovery planning process, NMFS collaborated with the states of Idaho, Oregon, and Washington, as well as with other federal agencies, tribal and local governments, representatives of industry and environmental groups, other stakeholders, and the public.

The collaborative process reflects NMFS' belief that ESA recovery plans for salmon and steelhead should be based on state, regional, tribal, local, and private conservation efforts already underway throughout the region. Local support of recovery plans by those whose activities directly affect the listed species, and whose actions will be most affected by recovery efforts, is essential to plan implementation.

NMFS developed this ESU/DPS-level recovery plan by synthesizing material from (1) three geographically based and locally developed recovery plans for Oregon, Idaho, and Washington populations of Snake River spring/summer Chinook salmon and steelhead (discussed in Section 1.4.2); (2) the related recovery plan modules (discussed in Section 1.4.3); (3) the work of the Interior Columbia Technical Recovery Team; and (4) additional analyses by technical experts, as needed. The draft Plan went through multiple reviews and revisions in response to comments from technical reviewers, committee members, and the public.

1.4.1 Recovery Domains and Technical Recovery Teams

Snake River spring/summer Chinook salmon and steelhead are not the only salmon and steelhead runs in the Pacific Northwest that are in trouble. Currently, 28 evolutionarily significant units (ESUs) and distinct population segments (DPSs) of Pacific salmon and steelhead are listed under the ESA as endangered or threatened throughout the NMFS West Coast Region (the states of California, Oregon, Washington, and Idaho).

For the purpose of recovery planning for these species, the NMFS West Coast Region identified geographically based "recovery domains." Figure 1-3 shows these domains in Oregon, Washington, and Idaho: Puget Sound, Willamette/Lower Columbia, Oregon Coast, Southern Oregon/Northern California, and the Interior Columbia. The Interior Columbia domain is divided into three sub-domains: the Middle Columbia River, Upper Columbia River, and Snake River. The spawning and rearing ranges for the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS are in the Snake River sub-domain. Two other ESA-listed species also spawn and rear in the Snake River basin: the Snake River fall Chinook salmon ESU and the Snake River sockeye salmon ESU.[7]

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[7] These species are addressed in separate recovery plans. Snake River sockeye salmon are addressed in the *ESA Recovery Plan for Snake River Sockeye Salmon (Oncorhynchus nerka)* (NMFS 2015) and Snake River fall Chinook salmon are addressed in the *ESA Recovery Plan for Snake River Fall Chinook Salmon (Oncorhynchus tshawytscha)* (NMFS 2017b).

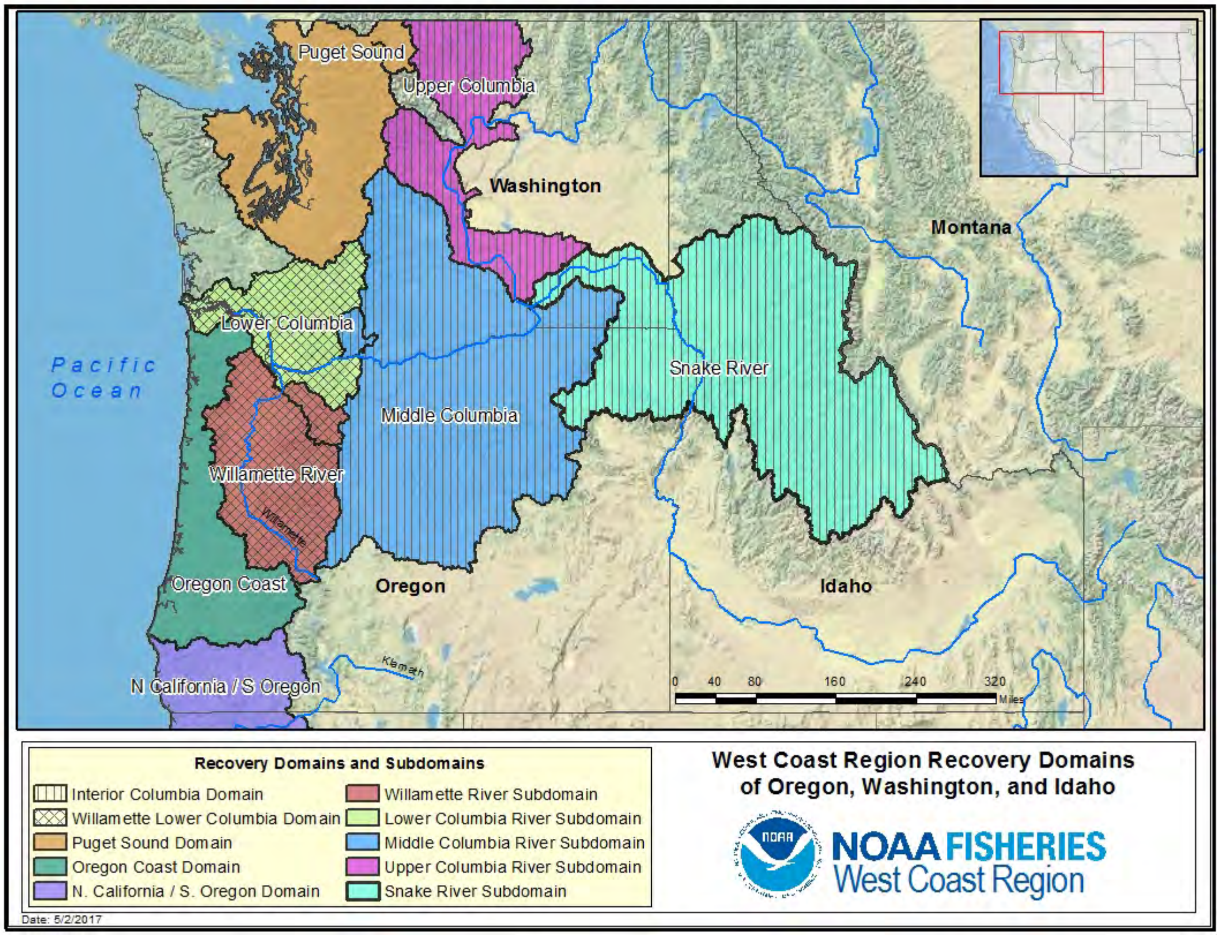

Figure 1-3. NMFS West Coast Region recovery domains of Oregon, Washignton, and Idaho.

Interior Columbia Technical Recovery Team

For each domain, NMFS appointed a team of scientists, called a technical recovery team, to provide a solid scientific foundation for recovery planning. These scientists were appointed for their geographic, species, and/or topical expertise. The technical recovery team responsible for Snake River spring/summer Chinook salmon and steelhead, the Interior Columbia Technical Recovery Team (ICTRT), included biologists from NMFS, state and tribal entities, and academic institutions.[8] NMFS directed each technical recovery team to define the historical population structure of each ESU and DPS, develop recommendations on biological viability criteria for each species and its component populations, provide scientific support to local and regional recovery planning efforts, and conduct scientific evaluations of proposed recovery plans. The ICTRT also addressed the two other Snake River listed species: Snake River fall Chinook salmon and Snake River Sockeye salmon.

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[8] ICTRT members were Thomas Cooney (NMFS Northwest Fisheries Science Center) (co-chair), Michelle McClure, (NMFS Northwest Fisheries Science Center) (co-chair), Casey Baldwin (Washington Department of Fish and Wildlife), Richard Carmichael (Oregon Department of Fish and Wildlife), Peter Hassemer (Idaho Department of Fish and Game), Phil Howell (U.S. Forest Service), Howard Schaller (U.S Fish and Wildlife Service), Paul Spruell (University of Montana), Charles Petrosky (Idaho Department of Fish and Game), Dale McCullough (Columbia River Inter-tribal Fish Commission), and Fred Utter (University of Washington).

The ICTRT and other technical recovery teams used a common set of biological principles to develop their recommendations for species and population viability criteria ─ the criteria that will be used, along with criteria based on mitigation of the factors for decline, to determine whether a species has recovered sufficiently to be down-listed or delisted. The biological principles are described in NMFS' technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). McElhany et al. describe viable salmonid populations (VSPs) in terms of four population parameters: abundance, population productivity or growth rate, population spatial structure, and diversity. Each technical recovery team made recommendations using the VSP framework. Their recommendations were also based on data availability, the unique biological characteristics of the species and the habitats in the domain, and the members' collective experience and expertise. NMFS encouraged the technical recovery teams to develop species-specific approaches to evaluating viability, while using the common VSP scientific foundation.

NMFS and local recovery planning groups used the ICTRT's recommendations to develop ESA recovery goals and biological viability criteria for the recovery plans. As the agency with ESA jurisdiction for salmon and steelhead, NMFS makes final determinations of ESA delisting criteria.

1.4.2 Management Unit Plans and Integration of Management Unit Plans

NMFS divided the Snake River recovery domain into different "management units" for recovery planning based on jurisdictional boundaries, as well as areas where local planning efforts were underway (Figure 1-4). The three separate management units for spring/summer Chinook salmon and steelhead include: the Northeast Oregon unit, Southeast Washington unit, and Idaho unit.

Separate management unit plans have been developed for each of the management units. All three plans were developed in coordination with respective state, federal, and local agencies, tribes, and others. This ESU-level and DPS-level recovery plan synthesizes relevant information from the three management unit plans for Northeast Oregon, Southeast Washington, and Idaho.

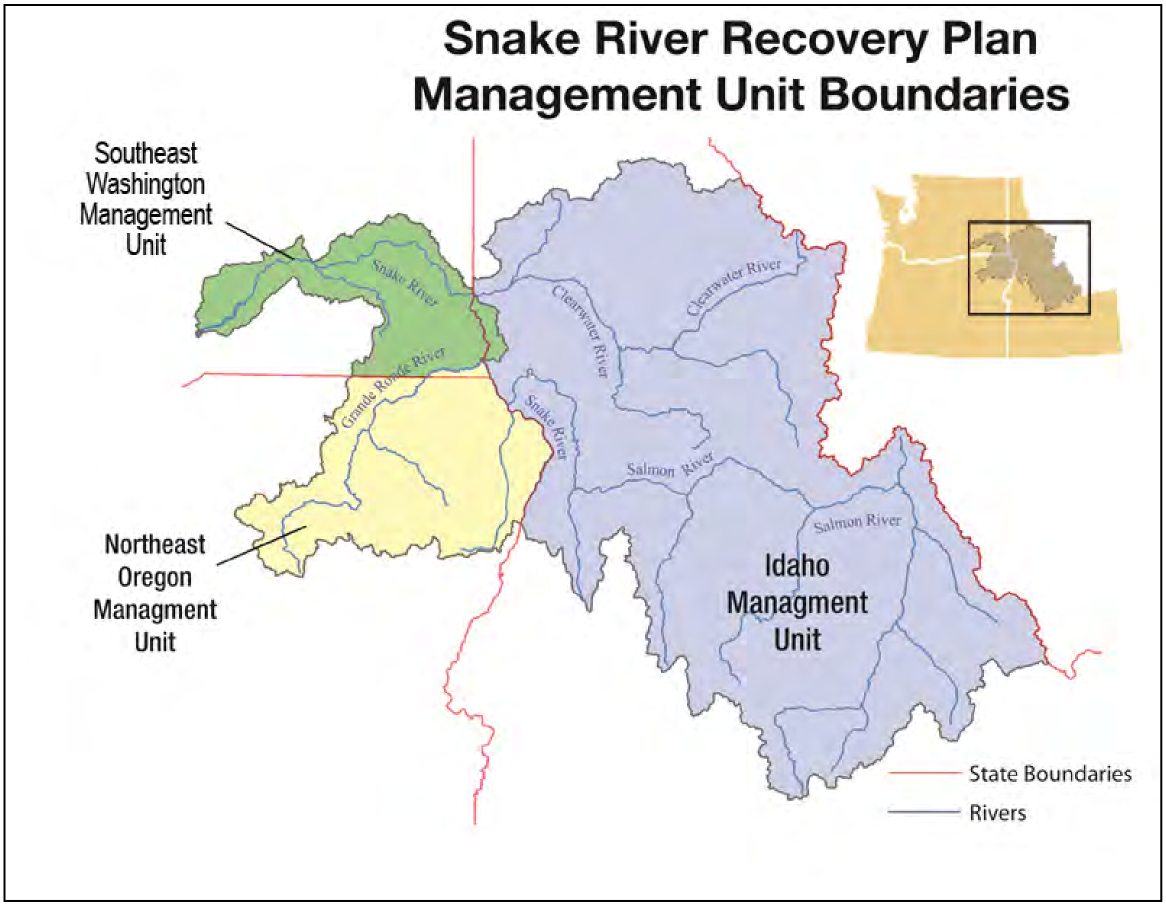

Figure 1-4. Snake River Recovery Domain Displaying the Idaho, Northeast Oregon, and Southeast Washington Management Units.

Northeast Oregon Snake River Salmon and Steelhead Recovery Plan

The recovery plan for the Northeast Oregon Management Unit covers Oregon's portion of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS, and a small corner of Southeast Washington. The populations occupy habitats in the Grande Ronde River and Imnaha River subbasins. The management unit plan was produced through a collaborative process initiated by NMFS and involving wide participation by natural resource agency staff and others. Participants in the process included the Oregon Governor's Natural Resource Office, the Grande Ronde Model Watershed, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, U.S. Bureau of Reclamation, U.S. Forest Service, Oregon Department of Forestry, Oregon Department of Agriculture, the Nez Perce Tribe, the Confederated Tribe of the Umatilla Indian Reservation, Soil and Water Conservation Districts, Wallowa Resources, The Nature Conservancy, Hells Canyon Preservation Council, Farm Bureau, Natural Resources Conservation Service, and others. A sounding board and technical team played key roles in the management unit plan's development. The resulting management unit plan is meant to serve both as a federal recovery plan under the ESA and a state of Oregon conservation plan under Oregon's Native Fish Conservation Policy (OAR 635-007-0502-0509). The management unit plan also influences actions implemented for the Oregon Plan for Salmon and Watersheds (ORS 541.898), including those actions coordinated by the Oregon Watershed Enhancement Board. This ESU/DPS-level plan includes the *Recovery Plan for Oregon Spring/Summer Chinook Salmon and Steelhead Populations in the Snake River Spring and Summer Chinook Salmon Evolutionarily Significant Unit and Snake River Basin Steelhead Distinct Population Segment* as Appendix A.

Southeast Washington Snake River Salmon and Steelhead Recovery Plan

The recovery plan for the Southeast Washington Management Unit covers the portion of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS in Washington. The management unit plan addresses the spring/summer Chinook salmon and steelhead populations that spawn and rear in Washington tributaries to the lower Snake River, including Asotin Creek and the Tucannon, Walla Walla, and Touchet Rivers. The management unit plan also defines actions for recovery of bull trout populations in Southeast Washington, which are ESA-listed by U.S. Fish and Wildlife Service.

The Snake River Salmon Recovery Board led this recovery planning effort. The board is comprised of government and tribal representatives, landowners, and private citizens. It operates through several committees including a lead entity project review and ranking committee, a regional technical team, and an executive committee. NMFS and the Snake River Salmon Recovery Board developed the management unit plan to be consistent with state of Washington habitat conservation plans, habitat preservation programs, conservation reserve enhancement programs, watershed plans, and other documents and efforts. Besides serving as a federal recovery plan under the ESA, the management unit plan will be shared with state and local natural resource agencies and stakeholders to inform future actions to recover the species and their habitats. This ESU-level plan includes the *Snake River Salmon Recovery Plan for Southeast Washington* as Appendix B.

Idaho Snake River Salmon and Steelhead Recovery Plan

The recovery plan for the Idaho Management Unit covers the portion of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS that occurs in Idaho. NMFS led the development of the Idaho management unit plan in coordination with the state of Idaho Governor's Office of Species Conservation, Idaho Department of Fish and Game, Nez Perce Tribe, Shoshone-Bannock Tribes, Clearwater Technical Group, Upper Salmon Basin Watershed Program, and other stakeholders. The Idaho management unit plan addresses recovery needs for Snake River spring/summer Chinook salmon populations in the Salmon River basin, and Snake River Basin steelhead populations in the Salmon and Clearwater basins. NMFS and the state of Idaho used information and criteria provided by the ICTRT to identify the specific populations of Idaho Snake River spring/summer Chinook salmon and steelhead. They then defined strategies and actions to focus recovery efforts for the salmonid populations. The agencies solicited comments from stakeholders and other interested parties during the planning process and revised the management unit plan to address comments from the various entities. NMFS and the state of Idaho will work with other federal and state agencies, tribal and local governments, and other parties to implement recovery efforts. This ESU/DPS-level plan includes the *Recovery Plan for Idaho Snake River Spring/Summer Chinook Salmon and Steelhead* as Appendix C.

Relationship between Management Unit Plans and ESU/DPS-level Plan

This recovery plan for the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS synthesizes information in the Northeast Oregon, Southeast Washington, and Idaho management unit plans. The ESU/DPS-level recovery plan provides a regional-level perspective on the baseline status of the Snake River ESU and DPS, goals and delisting criteria, limiting factors, scenarios for reducing threats, recovery actions, implementation, and research, monitoring, and evaluation. As required by the ESA, this recovery plan fully addresses the recovery needs of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS, throughout their life cycle and across their geographic range, which encompasses multiple management units.

The more detailed Northeast Oregon, Southeast Washington, and Idaho management unit recovery plans are part of this ESU/DPS-level plan, which includes them as appendices. By doing so, the ESU/DPS-level plan endorses the management unit plans' recommendations and acknowledges that certain recovery decisions (such as decisions about site-specific habitat actions) should be left to local recovery planners and implementers, as represented in the management unit plans.

1.4.3 Recovery Plan Modules and Other Documents and Processes

Because of the complexity of the salmonid life cycle, some regional issues that affect the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS are beyond the scope of any one management plan. NMFS developed several additional documents, referred to as "modules" to address these regional issues and assist in recovery planning. The following modules are incorporated into the Plan as appendices: (1) *Module for the Ocean Environment* (*hereafter* Ocean Module) (Fresh et al. 2014), (2) *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (*hereafter* Estuary Module) (NMFS 2011a), (3) *Snake River Harvest Module* (*hereafter* Harvest Module) (NMFS 2014b), and (4) 2017 *Supplemental Recovery Plan Module for Snake River Salmon and Steelhead, Mainstem Columbia River Hydropower Projects* (*hereafter* 2017 Hydro Module) (NMFS 2017). These modules contain information specific to the four ESA-listed Snake River Salmon ESUs and Steelhead DPS. NMFS will update the modules periodically to reflect new data.

Ocean Module

The Ocean Module (Fresh et al. 2014) uses the latest science to (a) synthesize what is known about how each of the four listed Snake River species uses ocean ecosystems, (b) identify major uncertainties regarding their use of the ocean environment, and (c) define the role of the ocean in recovery planning and implementation for each species. The module is included with this Plan as Appendix D and is also available on the NMFS web site: http://www.westcoast.fisheries.noaa.

gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/ocean_module.pdf

Estuary Module

The Estuary Module (NMFS 2011a) discusses limiting factors and threats that affect all salmonid populations in the mainstem Columbia River estuary and plume, and presents actions to address these factors. The Estuary Module was prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc. (subcontractor). It provides the basis of estuary recovery actions for ESA-listed salmon and steelhead in the Columbia River basin. The module is included with this Plan as Appendix E and is available on the NMFS web site: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/estuary-mod.pdf. This recovery plan summarizes actions identified in the Estuary Module to address threats to Snake River spring/summer Chinook salmon and steelhead. The Estuary Module discusses these actions in more detail.

Harvest Module

The 2014 Harvest Module describes fishery policies, programs, and actions affecting the four ESA-listed Snake River species (NMFS 2014b). The Harvest Module (NMFS 2014b) is included with this Plan as Appendix F and is also available on the NMFS web site: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/harvest_module_062514.pdf

Hydro Module

The 2017 Supplemental Hydro Module (NMFS 2017) supplements the 2008 Hydro Module for Snake River anadromous fish species listed under the ESA (NMFS 2008a). The 2008 Hydro Module overviews limiting factors, summarizes current recovery strategies, and provides survival rates associated with the Federal Columbia River Power System (FCRPS). The FCRPS, which is discussed in Section 1.7.1, consists of Columbia and Snake River hydropower and water storage projects that are operated as a coordinated system for power production, flood control, and other purposes. The 2017 Hydro Module provides new information relevant to the Snake River species, including the most recent survival estimates and discussion of latent and delayed mortality. The 2017 Hydro Module (NMFS 2017) is included with the Plan as Appendix G and is also available on the NMFS web site: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/2017_hydro_supplemental_recovery_plan_module.pdf.

Northwest Fisheries Science Center Documents

This recovery plan draws upon the resources of NOAA's Northwest Fisheries Science Center, which supports research and publishes technical memoranda pertinent to salmon and steelhead recovery plans for the Columbia River basin and Snake River basin species.

Other Related Processes

Many different conservation and recovery planning processes in Oregon, Washington, Idaho, and the larger Pacific Northwest region influenced the development of the ESU/DPS-level recovery plan. Efforts made through the recovery planning processes attempted to achieve consistency with these other plans and planning processes to the extent possible. The recovery plan is based on information and direction from these other planning processes, including tribal resource management plans, local watershed assessments, Northwest Power and Conservation Council subbasin plans, actions implemented through the FCRPS biological opinion, Columbia River Hatchery Scientific Review Group efforts and actions identified in related Hatchery Genetic Management Plans, and federal land management plans and research. Each of these planning efforts reflects the authorities, policies, and objectives of the specific organization, government or entity that develop these products; however, actions identified and implemented through these different parties often overlap salmonid recovery efforts. These efforts will continue during recovery plan implementation. The implementation processes identified in this ESU/DPS-level plan and the three management unit plans provide for continued coordination and communication across the different planning efforts.

1.5 Tribal Trust and Treaty Responsibilities

The salmon and steelhead that were once abundant in the watersheds throughout the Snake River basin were critically important to Native Americans throughout the region. Pacific Northwest Indian tribes today retain strong economic, cultural, educational, and spiritual ties to salmon and steelhead, reflecting thousands of years of use of this resource for subsistence, religious and/cultural ceremonies, and commerce. Many Northwest Indian tribes have legally enforceable treaties reserving their right to fish in usual and accustomed places, including within the geographic areas covered by this recovery plan. Article VI of the U.S. Constitution states: “This Constitution, and the laws of the United States which shall be made in pursuance thereof; and all treaties made, or which shall be made, under the authority of the United States, shall be the supreme law of the land; and the judges in every state shall be bound thereby, anything in the Constitution or laws of any State to the contrary notwithstanding.”

Treaty tribes within the range of Snake River spring/summer Chinook salmon and steelhead in the Columbia and Snake River basins include the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation (the Walla Walla, Cayuse, and Umatilla tribes), the Shoshone-Paiute Tribes, the Shoshone-Bannock Tribes, the Confederated Tribes and Bands of the Yakama Nation, and the Confederated Tribes of the Warm Springs Reservation of Oregon.

The U.S. District Court for the District of Oregon in the case of *United States v. Oregon* (*U.S. v. Oregon*) (Case No. 68-513, U.S. District Court, Oregon) affirmed language in the “Stevens treaties,”[9] i.e., “the right of taking fish at all usual and accustomed grounds and stations, in

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[9] Isaac Stevens, governor of Washington Territory from 1853 to 1857, presided at treaty councils with Indians west of the Cascade Mountains between December 25, 1854, and February 26, 1855, and with tribes east of the mountains between May 21 and October 17, 1855.

common with all citizens of the Territory" (Article III, Treaty with the Yakama, 1855; 12 Stat., 951), and later reserved for the tribal parties to this case up to 50 percent of the harvestable surplus of fish passing through their usual and accustomed fishing areas.

Tribal parties to *U.S. v. Oregon* case include the Shoshone Bannock Tribes, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, and the Confederated Tribes and Bands of the Yakama Nation, often referred to as "the Columbia River Treaty Tribes." Also party to the case are the states of Oregon, Washington, and Idaho, and the United States. All parties have developed the *U.S. v. Oregon* Management Agreement to provide a framework within which they may exercise their sovereignty in a coordinated manner to protect, rebuild, and enhance Columbia River fish runs while providing harvest for both treaty Indian and non-treaty fisheries.

The Stevens Treaties include the Treaty with the Yakama Tribe, the Umatilla Tribe, the Nez Perce Tribe, and the Tribes of Middle Oregon. The Shoshone and Bannock Tribes entered into peace treaties in 1863 and 1868, known today as the Fort Bridger Treaty. The Fort Bridger Treaty defined a reservation for the Shoshone and Bannock Tribes, and confirmed "hunting" rights as follows: "they [Indians] shall have the right to hunt on the unoccupied lands of the United States so long as game may be found thereon" (Article 4, 15 Stat., 673). In 1972, in *State of Idaho v. Tinno,* the Idaho Supreme Court ruled that the Shoshone word for "hunt" also included "to fish."[10]

Additionally, four Washington coastal tribes, the Makah, Quileute, Quinault, and Hoh, have treaty rights to ocean salmon harvest that may include some fall Chinook salmon destined for the Snake River basin. These Columbia Basin and Washington Coast treaty tribes are co-managers of salmon stocks, and participate in management decisions, including those related to hatchery production and harvest.

Other tribes in the Columbia River basin do not have treaties that were ratified by the U.S. government. Although these tribes do not have reserved treaty rights, they do have a trust relationship with the federal government and an interest in salmon and steelhead management, which includes harvest and hatchery production. The trust relationship between federal agencies and the tribes includes a "trust responsibility," which recognizes the federal duty to protect tribal lands, resources, and the native way of life. Each federal agency is bound by this trust responsibility and must respond to its independent obligations while carrying out statutory programs that affect the tribes (Wood 1995). The trust responsibility stands independent of treaties for the benefit of all tribes, treaty and non-treaty alike. For example, in the Upper and Middle Snake River basins, the Burns Paiute Tribe, Shoshone Paiute Tribes of the Duck Valley Reservation, and the Fort McDermitt Paiute-Shoshone Tribe have reservations that were created by Executive Order. These tribes have common vested interests to protect rights reserved through the United States Constitution, federal unratified treaties (e.g., the Fort Boise Treaty of

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[10] *State of Idaho v Tinno*, 94 Idaho (1972).

1864 and the Bruneau Treaty of 1866), executive orders, inherent rights, and aboriginal title to the land, which has never been extinguished by these tribes. These rights, resources, cultural properties, and practices may not be limited solely to hunting, fishing, gathering, and subsistence uses. Federal agencies must take these, and other tribal interests, into consideration when developing salmon recovery strategies.

Restoring and sustaining a sufficient abundance of salmon and steelhead for harvest while achieving viable escapements is important in fulfilling tribal fishing needs. NMFS is committed to meeting federal treaty and trust responsibilities to the tribes. It is our policy that the recovery of salmon and steelhead achieve two goals: (1) the recovery and delisting of salmonids listed under the provisions of the ESA; and (2) the restoration of salmonid populations, over time, to a level to provide a sustainable harvest sufficient to allow for the meaningful exercise of tribal fishing rights.[11]

Thus, it is appropriate for recovery plans to acknowledge treaty-reserved rights, trust responsibilities, and tribal harvest goals and to include strategies that support those goals in a manner that is consistent with recovery of naturally spawning populations. NMFS believes that our partnership with the Pacific Northwest tribes is critically important to the region's future success in recovery of listed Pacific salmon.

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[11] Garcia, Terry D., 1998. U.S. Department of Commerce, Office of the Assistant Secretary for Oceans and Atmosphere. Letter to Ted Strong, Executive Director, Columbia River Inter-Tribal Fish Commission, July 21.

1.6 How NMFS Intends to Use the Plan

The ESA clearly envisions recovery plans as the central organizing tool for guiding each species' recovery process. Accordingly, NMFS intends to use this recovery plan to organize and coordinate recovery of Snake River spring/summer Chinook salmon and steelhead in partnership with state, tribal, and federal resource managers, and with local stakeholders. Recovery plans are guidance, not regulatory, documents and their implementation is largely voluntary, except when recovery plan actions are incorporated into regulatory or permitting processes, such as under ESA sections 7, 10, and 4(d).

Recovery plans are important tools that provide the following guidance:

- A context for regulatory decisions;
- A guide for decision making by federal, state, tribal, and local jurisdictions;
- A basis and criteria for evaluating species status and delisting decisions;
- A structure to organize, prioritize, and sequence recovery actions;
- A structure to organize, prioritize, and sequence research, monitoring, and evaluation efforts; and
- A framework for adaptive management that uses the results of research, monitoring, and evaluation to update priority actions.

NMFS encourages federal agencies and non-federal jurisdictions to use the recovery plans as they make decisions to allocate resources. For example:

- Actions carried out by federal agencies to meet ESA section 7(a)(1) obligations to use their programs in furtherance of the purposes of the ESA and to carry out programs for the conservation of threatened and endangered species;
- Actions that are subject to ESA sections 4d, 7(a)(2), or 10;
- Hatchery Genetic Management Plans and permit requests;
- Harvest plans and permits;
- Selection and prioritization of habitat protection and restoration actions;
- Development of research, monitoring, and evaluation programs;
- Revision of land use and resource management plans; and
- Other natural resource decisions at the federal, state, tribal, and local levels.

NMFS emphasizes this recovery plan information in ESA section 7(a)(2) consultations, section 10 permit development, and application of the section 4(d) rule by considering:

- The nature and priority of the effects that will occur from an activity;
- The level of effect to, and importance of, individuals and populations within an ESU/DPS;
- The level of effect to, and importance of, the habitat for recovery of the species;
- The cumulative effects of all actions to species and habitats at a population scale; and
- The current status of the species and habitat.

In implementing these programs, recovery plans will be used as a reference for best available science and a source of context for evaluating the effects of actions on listed species, expectations, and goals. Recovery plans and recovery plan actions do not pre-determine the outcomes of any regulatory reviews or actions.

1.7 Related Programs, Partnerships and Efforts since Listing

As discussed earlier, a variety of existing forums in the habitat, hydropower, harvest, and hatchery sectors are taking steps that contribute to salmon and steelhead recovery. Together these various forums ─ each with their own distinct mandates and make up of appropriate federal, state, tribal, industry, and local representatives ─ are developing and implementing actions and programs that are improving Snake River salmon and steelhead runs and habitats. Many of these actions were spurred by the ESA listings. The ESA prohibits the take of listed species with some exemptions for activities pursuant to ESA section 4, section 7, and section 10. Regulations that apply to Snake River spring/summer Chinook salmon and steelhead today include NMFS' December 28, 1993, ESA section 4(b)(2) critical habitat designation (58 FR 68543) and the July 10, 2000, 4(d) rule (65 FR 42422), which contains regulations deemed necessary and advisable for the conservation of the species. The 4(d) rule addresses habitat, harvest, hatchery, and research and monitoring activities.

Furthermore, upon listing, all federal activities authorized, funded, or carried out by federal agencies that may affect the species require ESA section 7 consultations to ensure that they do not jeopardize the continued existence of the species nor adversely modify its critical habitat. Section 10(a) mandates regulatory reviews and permits for any take for scientific purposes or to enhance the propagation of the species. The objective of all ESA regulatory actions is to conserve the listed species and its ecosystems. Thus, even though a recovery plan has not been in place to provide context, many changes have collectively led to improved survival.

This section summarizes the recent history of partnerships, programs, and efforts that have influenced Snake River spring/summer Chinook salmon and steelhead survival since listing, and that provide the foundation for our recovery strategy.

1.7.1 Federal Columbia River Power System

The Federal Columbia River Power System (FCRPS) comprises 31 federally owned multipurpose projects on the Columbia River and its tributaries (i.e., the Willamette River, lower Snake River, etc.). The system is managed collaboratively by three federal agencies: the Bonneville Power Administration (BPA), U.S. Army Corps of Engineers (Corps), and U.S. Bureau of Reclamation (USBR) (hereinafter referred to as the Action Agencies). The FCRPS ESA section 7 consultation focuses on 14 of these projects, which are operated as a coordinated water management system: Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak Dams (operated and maintained by the Corps) and the Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee Dam (operated by the USBR). The FCRPS consultation also includes the mainstem effects of other tributary projects in the Columbia Basin.

Collectively, the Action Agencies maximize the use of the Columbia River by generating power, protecting fish and wildlife, managing flood levels, providing irrigation and navigation, and sustaining cultural resources. The federally owned multipurpose projects in the Columbia basin that comprise the FCRPS provide about 60 percent of the region's hydroelectric generating capacity. The FCRPS supplies irrigation water to more than a million acres of land in Washington, Oregon, Idaho, and Montana. As a major river navigation route, the Columbia-Snake Inland Waterway provides shipping access from the Pacific Ocean to Lewiston, Idaho, 465 miles inland. Water storage at all projects (federal, non-federal, and Canadian) on the major tributaries and mainstem of the Columbia totals 55.3 million acre-feet, much of which enhances flood control.

In 1993, NMFS and the FCRPS Action Agencies completed their first ESA section 7 consultation on the FCRPS and NMFS issued a biological opinion. NMFS and the Action Agencies were sued on that biological opinion. Judge Marsh, the presiding judge stated, "The situation literally cries out for a major overhaul" (Marsh 1994). More than two decades of ESA consultations and ongoing litigation involving multiple diverse plaintiffs ─ including environmental organizations, river users, states, and tribes - have ensued. NMFS issued a FCRPS biological opinion in 2008 and supplemented it in 2010 and 2014 (NMFS 2008b, 2010, 2014c).[12]

On May 4, 2016, U.S. District Court Judge Michael Simon ruled on litigation concerning the 2008 FCRPS biological opinion and its supplements. Though he did not vacate the 2008 biological opinion or its supplements, Judge Simon's order does require NMFS to prepare a new biological opinion. It also requires the Action Agencies to prepare a new, comprehensive environmental impact statement (EIS) under the National Environmental Policy Act (NEPA). On

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[12] It is the state of Oregon's position that additional and/or alternative actions to the FCRPS biological opinion should be taken in mainstem operations of the FCRPS to improve passage, survival, and habitat quality in the mainstem Columbia and Snake Rivers for ESA-listed salmon and steelhead. Some additional or alternative actions recommended by Oregon, while considered, were not included in NMFS' FCRPS biological opinion. At this time, Oregon is a plaintiff in litigation against the FCRPS agencies and NMFS, challenging the adequacy of the measures contained in the current (2008 as supplemented in 2010 and 2014) FCRPS biological opinions.

July 6, 2016, the court adopted the federal agencies' proposed schedule for these tasks. Under the court-ordered schedule, the Corps, USBR, and BPA are to complete a final EIS no later than March 26, 2021, and issue records of decision no later than September 24, 2021. NMFS must complete a biological opinion correcting the deficiencies identified in the court's May 4, 2016, ruling on or before December 31, 2018. NMFS will coordinate with the federal agencies as they develop their NEPA analysis and integrate the long-term decision that will result from the NEPA process under ESA section 7. NMFS is expected to complete a subsequent biological opinion following the selection of a preferred alternative in the final EIS.

This EIS will address the operation, maintenance, and configuration of 14 federal dam and reservoir projects that are operated as a coordinated water management system.[13] The EIS is referred to as the Columbia River System Operations EIS. As part of this process, BPA, the Corps, and the USBR (i.e., the "co-lead agencies" for the EIS) will evaluate a range of alternatives, including a no-action alternative (current system operations and configuration). Other alternatives will also be developed, and will likely include an array of alternatives for different system operations and additional structural modifications to existing projects to improve fish passage, including breaching one or more dams. Alternatives will include those within the EIS co-lead agencies' current authorities, as well as certain actions that are not within the co-lead agencies' authorities, based on the court's observations about alternatives that could be considered, and on comments received during the scoping process. In addition, the EIS will evaluate alternatives to insure that the prospective management of the Columbia River system is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of designated critical habitat, including evaluating mitigation measures to address impacts to listed species. The EIS will allow federal agencies and the region to evaluate the costs, benefits and tradeoffs of various alternatives as part of reviewing and updating the management of the Columbia River system.

In April 2017, the United States District Court for the District of Oregon, ordered the litigation parties to confer on a process to develop a spill implementation plan for increased spring spill for juvenile fish passage at the Corps' lower Snake River and lower Columbia River projects for the 2018 migration season. The parties were directed to consider an appropriate protocol and methodology for spill at each dam, incorporating the most beneficial spill patterns. The Regional Implementation Oversight Group (RIOG) is the forum where parties are collaborating on the development of recommendations for a 2018 spill implementation plan. Through the collaboration process, the federal agencies, state, and tribal representatives formed working groups. One working group is conducting a project-by-project review to identify potential constraints associated with increased spring spill. This review will help identify information that may reveal harmful effects where spilling to the "gas cap" levels could result in dam spillway erosion, blocking or delay of adult passage, or increased predation of juveniles, among other unintended consequences. A second working group is conducting spill pattern development on

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[13] These 14 projects are: Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak Dams (operated and maintained by the Corps), and the Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee (operated by the USBR).

physical models at the Corps' Engineer Research and Development Center in Vicksburg, Mississippi. The physical models will allow the teams to conduct trial and error simulations with spill gate combinations in concert with powerhouse turbine unit priorities to mitigate or eliminate harmful effects from increased spill. The RIOG forum will also consider potential unintended consequences of increasing spring spill for fish passage on biological monitoring (e.g. PIT tag detections) and power system reliability. Periodic status conferences with the Court are scheduled to ensure that the parties are making sufficient progress toward a spring spill implementation plan for the 2018 migration season. The Action Agencies will continue to implement all other actions required by the 2008 FCRPS biological opinion and its supplements through 2018.

Overall, since ESA-listing the Action Agencies have made significant structural and operational changes to the FCRPS projects in the lower Columbia and Snake Rivers to improve fish passage and survival. These changes include improvements and additions to fish passage facilities; operational changes in flow and spill; implementation of a juvenile transportation program; and increased off-site mitigation through tributary and estuarine habitat improvement, predator control, and hatchery reform. Actions implemented under the FCRPS biological opinions have contributed, and will continue to contribute, to improving the status of Snake River spring/summer Chinook salmon and steelhead, which must navigate six to eight FCRPS projects both as out-migrating juveniles and as returning adults.[14] In future FCRPS biological opinions, we anticipate that the actions benefitting Snake River spring/summer Chinook salmon and steelhead will be evaluated based on new information and that their implementation will either continue or be updated as appropriate and in consideration of recovery goals.

Structural and Operational Improvements

Primarily through the Corps' Columbia River Fish Mitigation Project, structural improvements have been added to improve fish passage at the six or eight dams that Snake River spring/summer Chinook salmon and steelhead navigate. Over $1 billion has been invested since the mid-1990s in baseline research, development, and testing of prototype improvements, and construction of new facilities and upgrades.

The configuration and operational improvements at the lower Snake and Columbia River dams, along with improved flow management programs and cool water releases from Dworshak Dam on the North Fork Clearwater River to reduce summer water temperatures, and along with other measures described in this section, have increased both juvenile survival rates through the mainstem rivers and the number of returning adults. The configurations and operations at the dams are designed to achieve the 2008 FCRPS biological opinion hydropower dam passage performance standards of 96 percent survival for yearling Chinook and steelhead migrants.

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[14] There are four federal dams on the lower Snake River mainstem (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) and four on the lower and mid-Columbia River mainstem (McNary, John Day, The Dalles, and Bonneville). Most Snake River spring/summer Chinook salmon and steelhead pass all eight projects; fish from the Tucannon River, which joins the Snake River downstream from Little Goose Dam, pass only six of the projects.

These and other changes have improved smolt survival in recent years, but hydropower system impacts remain.

Sections 5.2.3 and 6.3.3 in this Plan, and the 2017 Hydro Module (Appendix G), discuss recent changes by the Action Agencies, and improvements in ESA-listed salmon and steelhead passage rates as adult passage facilities have become more effective. In addition, the FCRPS Action Agencies Endangered Species Act Federal Columbia River Power System Annual Progress Reports and Comprehensive Evaluations, detail the implementation and progress of the 2008 biological opinion actions (USACE et al. 2009, 2010, 2011, 2012, 2013, 2015, 2017).

Juvenile Transportation

Since the late 1970s, managers have used barges or trucks to transport some juvenile salmon and steelhead past the lower Snake River dams. The intent of these transportation programs is to eliminate mortality the juveniles would otherwise experience by passing multiple dams, and thereby to achieve higher rates of juvenile survival.

Managers continue to evaluate the value of transportation as a strategy to improve juvenile survival. Before 2005, the FCRPS Action Agencies did not provide any voluntary spill at the Snake River dams during the summer migration season, and transport was considered essential. In 2005, the Action Agencies began providing spill at the lower Snake River projects during the summer months to enhance juvenile migration and survival. As a result, in-river migration survival has increased. Additional information is being collected to evaluate the effects of juvenile in-river vs. transport strategies on overall survival rates, including reach survival estimates and smolt-to-adult return rates (NMFS 2014c).

Offsite Mitigation: Habitat Improvement, Predator Control. And Hatchery Reform

The Action Agencies also implement other actions through the FCRPS biological opinions to provide offsite mitigation for mainstem hydropower impacts that remain after dam operations and structural improvements. Thus, they have been funding and working with various partners to implement substantial tributary and estuary habitat restoration programs, predator control for avian predators and northern pikeminnow in the mainstem Columbia and Snake Rivers, and hatchery reform actions. These offsite mitigation actions are described in the reasonable and prudent alternative for the 2008 FCRPS biological opinion and in the 2010 and 2014 FCRPS supplemental biological opinions. Implementation is summarized in the Action Agencies' Annual Progress Reports and Comprehensive Evaluations (USACE et al. 2009, 2010, 2011, 2012, 2013, 2015, 2017). The hatchery reform actions in the 2008 FCRPS biological opinion will help to ensure use of best management practices at hatcheries and provide funding for Snake River spring/summer Chinook salmon and steelhead research.

1.7.2 Columbia River Fish Accords

Many of the 2008 FCRPS biological opinion actions depend on cooperation with states and tribes. To promote regional collaboration and supplement the FCRPS biological opinion, the FCRPS Action Agencies entered into the 2008 Columbia Basin Fish Accords with three states

(Idaho, Montana, and Washington), five tribes (Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Colville Reservation, and the Shoshone-Bannock Tribes), and the Columbia River Inter-Tribal Fish Commission. The Accords provide firm commitments to hydropower performance standards and operations and habitat and hatchery actions. They also provide greater clarity regarding biological benefits and secure funding. The Accords directly addressed long-standing issues between the tribes and the FCRPS agencies.

1.7.3 Columbia Basin Fish and Wildlife Program

The Northwest Power and Conservation Council (Council), an interstate compact agency of Idaho, Montana, Oregon, and Washington, was established under the authority of the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act). The Northwest Power Act directs the Council to develop a program to "protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat, on the Columbia River and its tributaries … affected by the development, operation, and management of [hydroelectric projects] while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply." It also directs the Council to ensure widespread public involvement in the formulation of regional power and fish and wildlife policies. As a planning, policy-making, and reviewing body, the Council develops its Fish and Wildlife Program, and then monitors its implementation by BPA, the Corps, and the Federal Energy Regulatory Commission (FERC) and its licensees. The Council updates its Fish and Wildlife Program every five years.

The Council emphasizes implementation of fish and wildlife projects based on needs and actions described in the FCRPS biological opinion, ESA recovery plans, and the 2008 Columbia Basin Fish Accords. The Council also sponsors independent science review of Columbia Basin Fish and Wildlife Program actions proposed for funding, and follows up with science reviews of the actions from the Independent Scientific Review Panel. It also sponsors the Independent Scientific Advisory Board, which serves NMFS, Columbia River tribes, and the Council by providing independent scientific advice and recommendations regarding specific scientific issues.

1.7.4 Additional Mainstem and Estuary Programs and Actions

Numerous efforts have been implemented and continue to restore habitat conditions in the Columbia River and its estuary. These efforts include removing dikes and pilings, reconnecting side channels and floodplains, improving water quality, relocating nesting sites for birds that prey on migrating juvenile salmonids, and implementing other actions that improve migratory and rearing conditions for Snake River spring/summer Chinook salmon and steelhead and other salmonids. Some of these actions, such as FCRPS biological opinion actions and many other section 7 consultations, were prompted by ESA listings. Individually, these consultations have resulted in actions that avoided jeopardy to the species and adverse modification of its critical habitat within the individual action areas. Collectively, these consultations have protected mainstem habitat from getting worse and in many cases have improved the habitat.

Other voluntary and regulatory actions have also been implemented to protect and improve estuarine habitats over the last twenty or more years. Many of these efforts are being implemented through the Lower Columbia Estuary Partnership, a National Estuary Program working to improve the health of the estuary. The efforts bring together collective groups of federal, state, tribal, local, and private parties to plan, implement, and monitor habitat restoration efforts. The various partnerships and actions are discussed in the Estuary Module (Appendix E) and in the Lower Columbia River Estuary Partnership's Year in Review reports, available since 1999. See the reports at: http://www.estuarypartnership.org/.

1.7.5 Tributary Habitat Programs and Actions

Different parties across the Snake River basin continue to work diligently to protect and restore tributary habitat conditions in Oregon, Washington, and Idaho. These parties include regional recovery boards and watershed councils, whose constituents have substantial opportunity and authorities pertaining to habitat; tribal, state, and federal agencies with habitat management responsibilities; and non-governmental and other private organizations and landowners that implement individual habitat restoration projects (see Table 1-1). Given that Snake River spring/summer Chinook salmon and steelhead populations rely on such a large, interconnected area of spawning, rearing, and migration habitats for viability, the future work by these various parties will play a critical role in recovery.

Together, these various parties have already implemented numerous habitat restoration projects on private, public, and tribal lands. Activities implemented to improve habitat conditions include instream wood placement, riparian planting, fencing, floodplain reconnection, artificial passage barrier removal, off-channel stock water development, and culvert replacement. Often, the efforts involve substantial pooling of coordination, resources, and funds by the various groups, and rely heavily on the sweat equity provided by volunteers.

Table 1-1. Tribes, Public Agencies and Organizations, and Private Groups Involved in Efforts Contributing to Recovery of Snake River Spring/summer Chinook Salmon and Steelhead and Their Habitats.

Entities* Involved in Efforts Contributing to Recovery of Snake River Spring/summer Chinook Salmon and Steelhead	
Tribes	**Federal Agencies**
Burns Paiute Tribe	U.S. Army Corps of Engineers
Columbia River Inter-Tribal Fish Commission	Bonneville Power Administration
Confederated Tribes of the Umatilla Indian Reservation	U.S. Bureau of Land Management
Confederated Tribes and Bands of the Yakama Nation	U.S. Bureau of Reclamation
Confederated Tribes of the Warm Springs Reservation	Environmental Protection Agency
Nez Perce Tribe	Federal Highway Administration
Shoshone-Bannock Tribes	Natural Resources Conservation Service
Shoshone-Paiute Tribes	NOAA National Marine Fisheries Service
State Agencies	Northwest Power Conservation Council
Idaho Dept. of Agriculture	U.S. Fish and Wildlife Service
Idaho Dept. of Environmental Quality	U.S. Forest Service
Idaho Dept. of Fish and Game	U.S. Geological Service
Idaho Dept. of Transportation	**County and City Agencies**
Idaho Dept. of Water Resources	County Soil and Water Conservation Districts
Idaho Governor's Office of Species Conservation	Representatives from counties and cities in Northeast Oregon, Southeast Washington and Idaho
Clearwater Technical Group	
Upper Salmon Basin Watershed Program	**Interested Public — Organizations and Individuals**
Idaho Soil and Water Conservation Commission	Freshwater Trust
Oregon Dept. of Agriculture	Grande Ronde Model Watershed
Oregon Dept. of Environmental Quality	Hells Canyon Preservation Council
Oregon Dept. of Fish and Wildlife	Lemhi Regional Land Trust
Oregon Dept. of Forestry	Palouse-Clearwater Environmental Institute
Oregon Farm Bureau	Native Fish Society
Oregon Governor's Office	Salmon Valley Stewardship
Oregon Watershed Enhancement Board	The Nature Conservancy
Snake River Salmon Recovery Board	Trout Unlimited
Washington Dept. of Ecology	Tri-State Steelheaders
Washington Dept. of Ecology	
Washington Dept. of Fish and Wildlife	
Washington Governor's Salmon Recovery Office	
*These tribes, agencies and groups have participated in developing this recovery plan. This list is not meant to be inclusive of all partners or organizations that are working on salmon recovery in the Snake River basin.	

In addition, NMFS has reviewed hundreds of federal actions through section 7 consultations since the listings, and also issued section 10 permits on non-federal activities in the tributaries. These consultations and permits have reduced threats of further impacts associated with mining, dredging, agriculture, grazing, forestry, and industry, and in many cases, contributed to healing ecosystem functions in the tributaries.

1.7.6 Harvest Programs and Actions

Snake River spring/summer Chinook salmon and steelhead are subject to incidental harvest in both ocean and in-river fisheries. The ocean fisheries are primarily managed pursuant to the provisions of the Pacific Salmon Treaty between the U.S. and Canada. The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) is the primary law governing marine fisheries management in U.S. federal waters, extending out to 200 nautical miles from shore. Fisheries in the Columbia River basin, particularly in the mainstem of the

Columbia River, are managed pursuant to harvest plans developed by the parties to *U.S. v. Oregon*, under the continuing jurisdiction of the federal district court. Regulations for recreational fisheries in the tributaries of the Columbia and Snake Rivers are developed by Idaho, Washington, and Oregon for their respective waters. Each tribe regulates tributary fisheries under their respective jurisdictions.

Since ESA listing, state, tribal, and federal fishery managers have worked together to substantially reduce the mortality of ESA-listed species in both ocean and in-river fisheries. Snake River spring and summer Chinook salmon and steelhead continue to encounter fisheries in the ocean, mainstem Columbia and Snake Rivers, and tributaries during their migration, but most harvest on the species now occurs during tribal and nontribal mainstem Columbia River fisheries. The states and tribes manage the fisheries in the Columbia River estuary, mainstem Columbia River, Snake River, and tributaries to focus on different stocks and populations while adhering to the guidelines and constraints of the ESA administered by NMFS, the Columbia River Compact, and management agreements negotiated between the parties to *U.S. v. Oregon*. Consistent with *U.S. v. Oregon*, a stock is an aggregation of fish spawning in a particular stream or lake during a particular season which to a substantial degree do not interbreed with any group spawning at a different time. Chapters 5, 6, and 7 and the Harvest Module (Appendix F) provide more information on the various fisheries, their impact, and existing programs and actions to address them.

1.7.7 Hatchery Programs and Actions

Hatchery programs for Snake River spring/summer Chinook salmon and steelhead populations serve the dual purpose of providing fish for fisheries and supplemental spawners to help rebuild depressed natural populations (Tables 1-2 and 1-3). The management of hatchery programs to support species recovery and meet requirements of the Endangered Species Act is complicated because of needs to simultaneously address other legal agreements regarding production levels, agreements regarding mitigation levels, harvest agreements, tribal trust responsibilities, and scientific uncertainty. The states, tribes, and federal agencies manage the hatchery programs to enhance fisheries while promoting conservation of listed species. NMFS continues to regulate the hatchery actions under the ESA, and they are reviewed and modified by existing forums to support survival of natural-origin populations.

The hatchery programs are authorized under the Lower Snake River Compensation Plan and other mitigation programs. Production goals, release sizes, release locations, release priorities, life stage, and marking of released fish for Snake River spring/summer Chinook salmon and steelhead hatchery programs are all established through the *U.S. v. Oregon* management process. The programs must comply with section 4(d) protective regulations under the ESA. The hatchery programs are discussed in Sections 5.2.5 and 6.3.5 of this recovery plan and within the individual management unit plans.

Table 1-2. Snake River Spring/summer Chinook Salmon Hatchery Programs in Washington (WA), Oregon (OR), and Idaho (ID) and ESA Status.

Program Stock Origin	Hatchery Program	Run	Program Operator*	Watershed Location of Release (State)	Currently in Listed ESU/DPS?
Snake River Spring/Summer-run Chinook Salmon ESU					
Tucannon	Tucannon River	Spr/Sum	WDFW	Tucannon River (WA)	Yes
Lostine	Lostine River	Spr/Sum	ODFW	Lostine River (OR)	Yes
Catherine Creek	Catherine Creek	Spr/Sum	ODFW	Catherine Creek (OR)	Yes
Lookingglass	Lookingglass Hatchery Reintroduction	Spr/Sum	ODFW	Lookingglass Cr (OR)	Yes
Up. Grande Ronde	Up. Grande Ronde	Spr/Sum	CTUIR	U. Grande Ronde R. (OR)	Yes
Imnaha	Imnaha River	Spr/Sum	ODFW	Imnaha River (OR)	Yes
SF Salmon	McCall Hatchery	Summer	IDFG	SF Salmon River (ID)	Yes
	Dollar Cr. SBT	Spring	SBT	SF Salmon River (ID)	No**
Johnson Creek	Johnson Cr. Artificial Propagation Enhancement	Summer	NPT	EF/SF Salmon River (ID)	Yes
Pahsimeroi	Pahsimeroi Hatchery	Summer	IDFG	Salmon River (ID)	Yes
	Panther Creek	Summer	SBT	Salmon River (ID)	No**
Sawtooth	Sawtooth Hatchery	Spring	IDFG	Up. Main Salmon R. (ID)	Yes
Sawtooth/Pahsimeroi	Yankee Fork SBT	Spring	SBT	Yankee Fork (ID)	No**
Rapid	Rapid River Hatchery	Spring	IDFG	Little Salmon River (ID)	No
Dworshak stock/ Clearwater River	Dworshak NFH	Spring	USFWS/NPT	NF Clearwater (ID)	No
	Kooskia	Spring	NPT	Mainstem Clearwater (ID)	No
	Clearwater Hatchery	Spring	IDFG	Mainstem Clearwater (ID)	No
	Nez Perce Tribal Hatchery	Spring	NPT	Mainstem Clearwater (ID)	No

* Program operators: Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Idaho Dept. of Fish and Game (IDFG), Nez Perce Tribe (NPT), Oregon Department of Fish and Wildlife (ODFW), Shoshone-Bannock Tribes (SBT), U.S. Fish and Wildlife Service (USFWS), and Washington Dept. of Fish and Wildlife (WDFW). Although one agency is a primary operator, decisions regarding programs are made by co-managers through the *U.S. v. Oregon* Agreement and Annual Operating Plan meetings.

** NMFS (2016) recommends that three new spring/summer Chinook salmon hatchery programs (Yankee Fork, Panther Creek, and Dollar Creek) be considered for inclusion in the ESU because the programs were initiated with currently listed stocks and the propagated fish are being released within the ESU's range (Jones 2015, as cited in NMFS 2016). Such changes would occur when NMFS completes future rulemaking.

Table 1-3. Snake River **Basin** Steelhead Hatchery Programs in Washington (WA), Oregon (OR), and Idaho (ID) and ESA Status.

Program Stock Origin	Hatchery Program	Run	Program Operator*	Watershed Location of Release (State)	Currently in Listed ESU/DPS?
Snake River Basin Steelhead DPS					
Tucannon	Tucannon River	Summer	WDFW	Tucannon River (WA)	Yes
Imnaha	Little Sheep Cr. – Imnaha R. Hatchery	Summer	ODFW	Imnaha River (OR)	Yes
EF Salmon	EF Salmon River	A-run	IDFG	EF Salmon River (ID)	Yes
NF Clearwater/ Dworshak stock	Dworshak NFH	B-run	USFWS/NPT	Clearwater River (ID)	Yes
	Lolo Creek	B-run	IDFG	Clearwater River (ID)	Yes
	Clearwater Hatchery	B-run	IDFG	NF Clearwater River (ID)	Yes
	EF Salmon River	B-run	IDFG	EF Salmon River (ID)	No
	Squaw Creek	B-run	IDFG	Squaw Creek (ID)	No
	Little Salmon River	B-run	IDFG	Little Salmon River (ID)	No
SF Clearwater	SF Clearwater (localized)	B-run	IDFG	SF Clearwater (ID)	Yes
Wallowa stock	Lyons Ferry NFH	Summer	WDFW	Tucannon River (WA)	No
	Cottonwood Pond	Summer	ODFW	Grande Ronde R. (OR)	No
	Wallowa Hatchery and Big Canyon Satellite Pond	Summer	ODFW	Wallowa River (OR)	No
Hells Canyon/ Oxbow	L. Snake and Hells Canyon Mitigation	A-run	IDFG	Snake River (ID)	No
Sawtooth/ Pahsimeroi	Pahsimeroi Hatchery	A-run	IDFG	Pahsimeroi River (ID)	No
	Sawtooth Hatchery	A-run	IDFG, SBT	Upper Salmon River (ID)	No
	Streamside Incubator Proj.	A-run	SBT, IDFG	Upper Salmon River (ID)	No
	Little Salmon steelhead	A-run	IDFG	Little Salmon River (ID)	No
	Yankee Fork	A-run	SBT, IDFG	Upper Salmon River (ID)	No

* Program operators: Idaho Dept. of Fish and Game (IDFG), Nez Perce Tribe (NPT), Oregon Department of Fish and Wildlife (ODFW), Shoshone-Bannock Tribes (SBT), U.S. Fish and Wildlife Service (USFWS), and Washington Dept. of Fish and Wildlife (WDFW). One agency is a primary operator, but decisions regarding programs are made by co-managers through the *U.S. v. Oregon* agreement and Annual Operating Plan meetings.

1.7.8 Relationship of Existing Programs to Recovery Plan

The overall recovery strategy for Snake River spring/summer Chinook salmon and steelhead integrates the work of the forums discussed in this section and builds on their collective achievements. NMFS intends to continue our cooperative relationships with these partners during recovery plan implementation. For example, if limiting factors involving agriculture are identified in the Salmon or Clearwater River subbasin, the partnership may include NMFS, the Natural Resources Conservation Service, the Idaho Soil Conservation Commission, local soil and water conservation districts, the Clearwater Technical Group, the Upper Salmon Basin Watershed Program, as well as landowners and water managers. Or, to address hatchery- and harvest-related limiting factors, NMFS will work with parties to the *U.S. v. Oregon* agreement and other appropriate forums. Our intent is to work within the framework of existing efforts whenever possible and not create duplicative efforts that may conflict with state or local programs.

Also, while the recovery plan is not intended to be regulatory or binding, it incorporates existing programs that have undergone ESA section 7 consultation or section 10 permit review or that NMFS has otherwise formally agreed to. This is because those programs play a significant role in conserving the species. Chapter 6 provides more detail on the recovery strategy and actions.

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2. Biological Background

This chapter provides context for understanding the characteristics that define the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS. It describes the geographic landscape that supports the two species and discusses the biological, distribution, and life-history traits that make them unique. It describes key concepts in salmonid biology, i.e., the biological hierarchical structure of salmonid species from independent population to ESU/DPS, and the parameters that influence its viability: abundance, productivity, spatial structure and diversity. It also defines the critical habitat that has been designated for the species, presents the biological criteria that the ICTRT recommended for use in assessing species and population viability, and briefly summarizes methods and benchmarks the ICTRT recommends for evaluating individual population status. The ESA recovery goals in this Plan and the population biological recovery goals identified in the management unit plans, as well as NMFS' criteria for delisting the Snake River species, are all based on the ICTRT recommendations. (See Chapter 3 for recovery goals and delisting criteria.)

2.1 Geographic Setting

The Snake River basin covers approximately 107,000 square miles, roughly half of the entire Columbia River basin (219,000 square miles) (Figure 2-1). The Snake River is the 13th longest river system in the United States and the largest and longest tributary of the Columbia River. It extends over 1,000 miles from its headwaters in Yellowstone National Park, Wyoming, and drops nearly 7,000 feet in elevation before joining the Columbia River near Pasco, Washington. The river system drains approximately 87 percent of the state of Idaho, over 18 percent of the state of Washington, and about 17 percent of the state of Oregon.

Currently, naturally spawned populations of Snake River spring/summer Chinook salmon and steelhead inhabit streams in the Grande Ronde River and Imnaha River region in Northeast Oregon), the Tucannon River and lower Snake River in Southeast Washington, and the Salmon River and parts of the Clearwater River basin (steelhead only) in Idaho. At one time, however, the populations ranged over a much larger area. Historically, spring/summer Chinook salmon and steelhead traveled up the Snake River into areas of the middle Snake River drainage upstream of the current site of Hells Canyon Dam. The spring and summer Chinook salmon and steelhead runs also historically returned to several areas in the Clearwater River drainage, including the North Fork Clearwater River. Access to these areas was blocked or inundated by hydroelectric dam development; in all, approximately 2,500 miles of historical anadromous fish habitat have been lost to barrier dams and inundation (IDFG 1985). Thurow et al. (2000) estimated that only 20 to 30 percent of historically occupied Snake River subwatersheds are currently occupied by Snake River spring/summer Chinook salmon and steelhead.

The ICTRT has determined that several additional steelhead populations historically existed in areas above Hells Canyon Dam on the mainstem Snake River, including in the Powder, Burnt, and Weiser Rivers. Information is not available to assess the relationships among steelhead populations in this extirpated area, but it is possible that one or more additional DPSs may have existed in the area above Hells Canyon Dam (ICTRT 2007). Habitat analyses and historical records also indicate that the area above Hells Canyon Dam likely supported several additional spring/summer Chinook salmon populations; however, no biological data are currently available to assess the historical relationships among populations in the extirpated areas (ICTRT 2008). NMFS did not include these extirpated populations in the recovery scenarios for the species; however, based on future research and adaptive management options, rebuilding in blocked areas through reintroduction may contribute to broad sense goals described in Section 3.1. This recovery plan is limited to the Snake River basin and its tributaries below Hells Canyon Dam, an impassible barrier and ESU/DPS boundary on the mainstem Snake River.

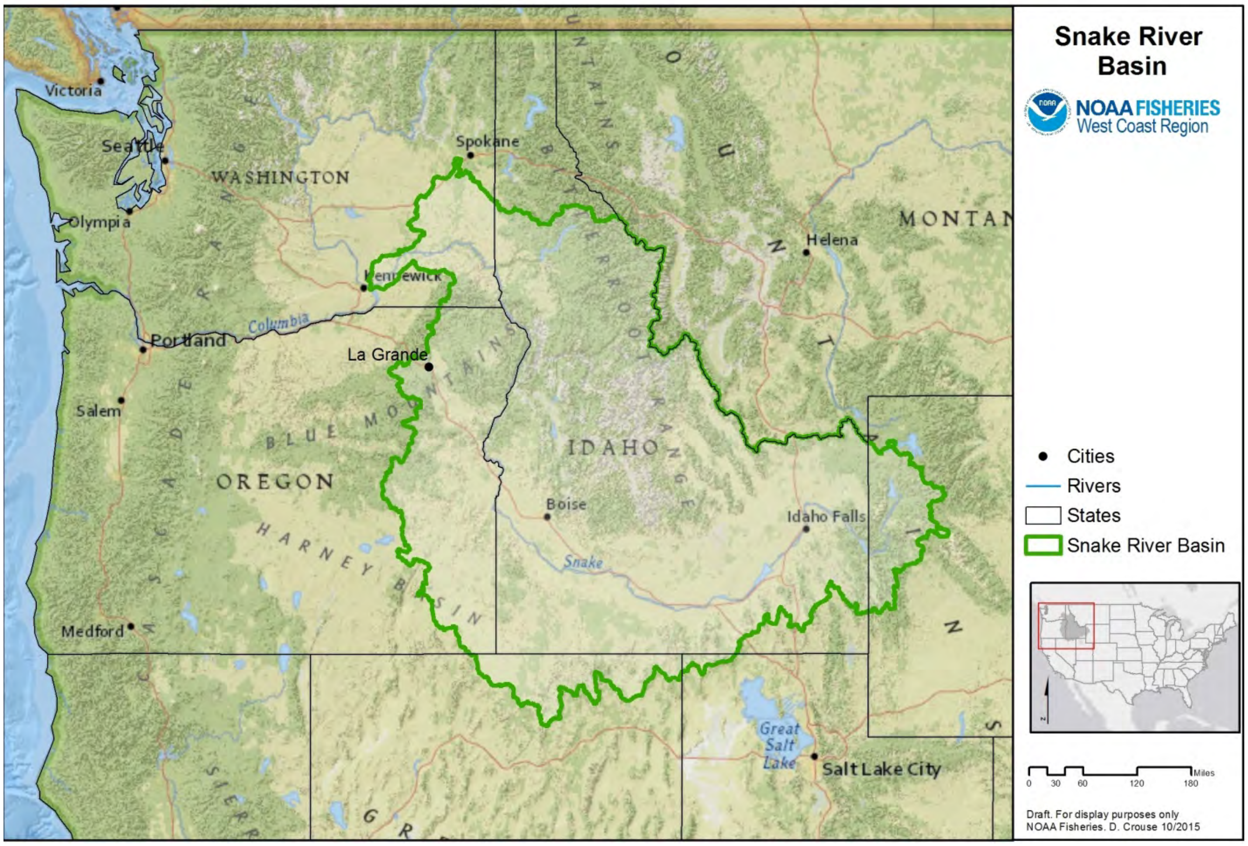

Figure 2-1. Snake River basin, geographic setting.

2.1.1 Topography and Land Use

The Snake River basin is characterized by dramatic changes in elevation, dropping from 12,662 feet at Mount Borah in the headwaters for the Pahsimeroi River to 340 feet at the Snake's confluence with the Columbia River. The basin contains diverse conditions: high elevation deserts, alpine peaks, temperate rain forests, and the deepest river canyon in North America (Hells Canyon). Temperatures and precipitation vary widely, usually depending on elevation, with cooler and wetter climates in the mountainous areas and warmer and drier climates in the lower elevations of the province.

Within the Snake River basin, land use ranges from agriculture and rangeland, to cities and to recreation in the largest contiguous wilderness in the lower 48 states. Of the 31,862 square miles of land in the Snake River recovery domain, 69.4 percent is federally owned, 24.3 percent is privately held, and 6.5 percent is partitioned for state and tribal use. Human populations in the basin are growing more slowly than are other areas in the Pacific Northwest, but development continues and tends to be concentrated in the valley bottoms. Figure 2-2 shows land use and cover in the Snake River basin. The individual recovery plans for the Idaho, Oregon, and Washington management units describe the areas diverse geographic characteristics and land use in more detail.

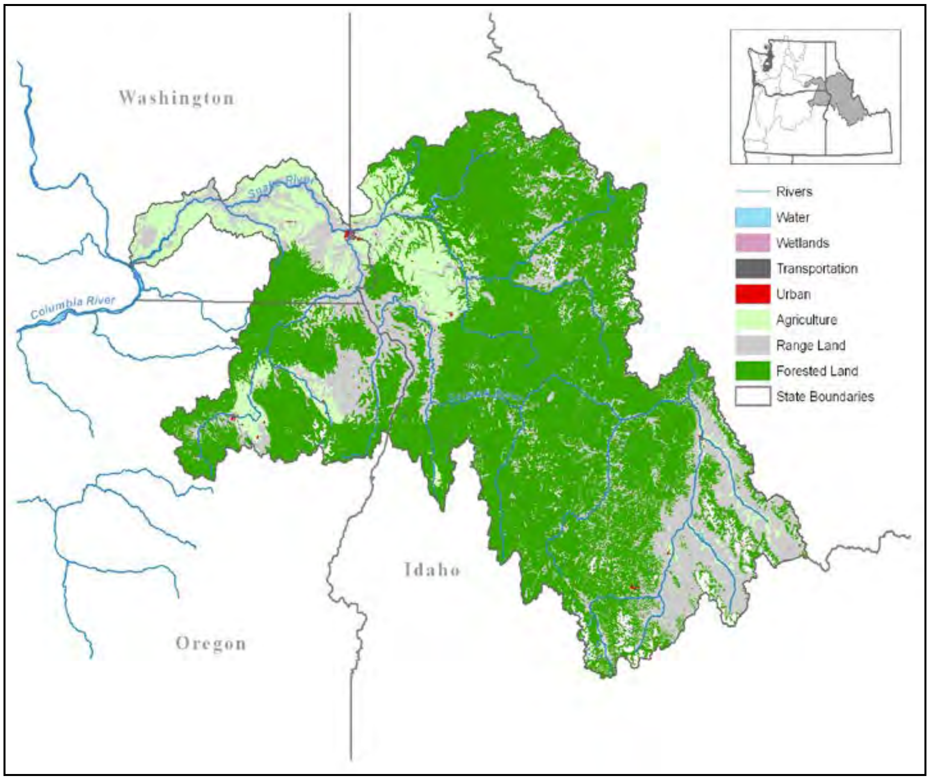

Figure 2-2. Land use and cover in the Snake River basin.

2.2 Species Descriptions and Life Histories

2.2.1 Snake River Spring and Summer Chinook Salmon

Spring/summer-run Chinook salmon from the Snake River basin represent two of four different seasonal (i.e., spring, summer, fall, or winter) "races" or “runs” in the Chinook salmon migration from the ocean to freshwater. These runs reflect the timing of when adult Chinook salmon enter freshwater to begin their spawning migration. The runs differ in the degree of maturation at the time of river entry, the thermal regime and flow characteristics of their spawning site, and their actual time of spawning. Freshwater entry and spawning timing are generally related to local temperature and water flow regimes.

The different seasonal migration strategies among Chinook salmon also reflect the evolution of two distinct juvenile life histories: a "stream-type" Chinook salmon resides in freshwater for a year or more following emergence; an "ocean-type" Chinook salmon migrates to the ocean predominantly within their first year. Snake River spring and summer Chinook salmon generally exhibit a stream-type life history (Figure 2-3), but populations have developed specialized life histories in order to utilize a variety of habitats.

By definition, adult spring-run Chinook salmon destined for the Snake River return to the Columbia River from the ocean in early spring and pass Bonneville Dam beginning in early March and ending May 31st. Snake River summer-run Chinook salmon return to the Columbia River from June through July. Adults from both runs hold in deep pools in the mainstem Columbia and Snake Rivers and the lower ends of the spawning tributaries until late summer, when they migrate into the higher elevation spawning reaches. Generally, Snake River spring-run Chinook salmon spawn in mid- through late August. Snake River summer-run Chinook salmon spawn approximately one month later than spring-run fish and tend to spawn lower in the tributary drainages, although their spawning areas often overlap with those of spring-run spawners.

The eggs that Snake River spring and summer Chinook salmon deposit in late summer and early fall incubate over the following winter, and hatch in late winter and early spring. Juveniles rear through the summer, overwinter, and typically migrate to sea in the spring of their second year of life, although some juveniles may spend an additional year in freshwater. Depending on the tributary and the specific habitat conditions, juveniles may migrate extensively from natal reaches into alternative summer-rearing or overwintering areas.

Most Snake River spring/summer Chinook salmon migrate to the ocean as yearlings, averaging 73-134 mm depending on the river system, but the species does exhibit diversity in its freshwater life-history strategy. For example, in the Salmon River basin juveniles may spend less than one year (migrating as subyearlings), one year, or two years rearing in freshwater habitats before migrating to the ocean (Copeland and Venditti 2009). The outmigrants generally pass downstream of Bonneville Dam from late April through early June. The average date of passage at the dam (50 percent of the fish from 2003 to 2012) was May 18 for all of the yearlings (wild fish and hatchery-origin fish) and May 17 for wild fish only (http://www.cbr.washington.edu/dart). Most yearling fish are thought to spend relatively little time in the estuary compared to sub-yearling ocean-type fish, often travelling from Bonneville Dam (RKm 235, RM 146) to a sampling site at RKm 70 (RM 43) in one to two days (Appendix D). McMichael et al. (2013) found that most of the yearling Chinook salmon (68.3 percent) that they tagged with acoustic transmitters (no stock origin was provided) stayed near the mouth of the Columbia River (an area defined by a polygon beginning downstream of RKm 8 (RM 5) and extending about 15 km west, north and south) for less than a day. Nevertheless, there is considerable variation in residence times in different habitats and in the timing of estuarine and ocean entry among individual fish. Such variation is important, providing the ESU with resilience to changing environmental conditions (McElhany et al. 2000; Holsman et al. 2012).

Once the yearlings enter the Northern California Current, they can initially disperse in any direction but they quickly begin to migrate along the coast to the north. Snake River spring/summer-run Chinook salmon range over a large area in the northeast Pacific Ocean, including coastal areas off Washington, British Columbia, and southeast Alaska, the continental shelf off central British Columbia, and the Gulf of Alaska (Appendix D). Most of the fish spend two or three years in the ocean before returning to tributary spawning grounds primarily as 4- and 5-year-old fish. A small fraction of the fish spend only one year in the ocean and return as 3-year-old “jacks,” heavily predominated by males (Good et al. 2005).

Returning adult spring Chinook salmon are abundant in the lower Columbia River estuary in April and May, but are also present in March and June (Appendix D). Time spent in the estuary varies: studies show that tagged adult Snake River spring/summer Chinook salmon took an average of 18.1 days to reach Bonneville Dam in 2001 and 15.4 days in 2010, with travel times for individual fish ranging from 7 to 57 days (Wargo-Rub et al. 2012a, 2012b). The date when the adults pass Bonneville Dam often varies as a function of river of origin, and median passage dates can range up to 20 days depending on the destination of the fish (Hess et al. 2014). For example, from 1996 to 2001, median date of passage at Bonneville Dam ranged from April 23 for fish destined for the Tucannon River to May 29 for fish destined for the Imnaha River (Keefer et al. 2004).

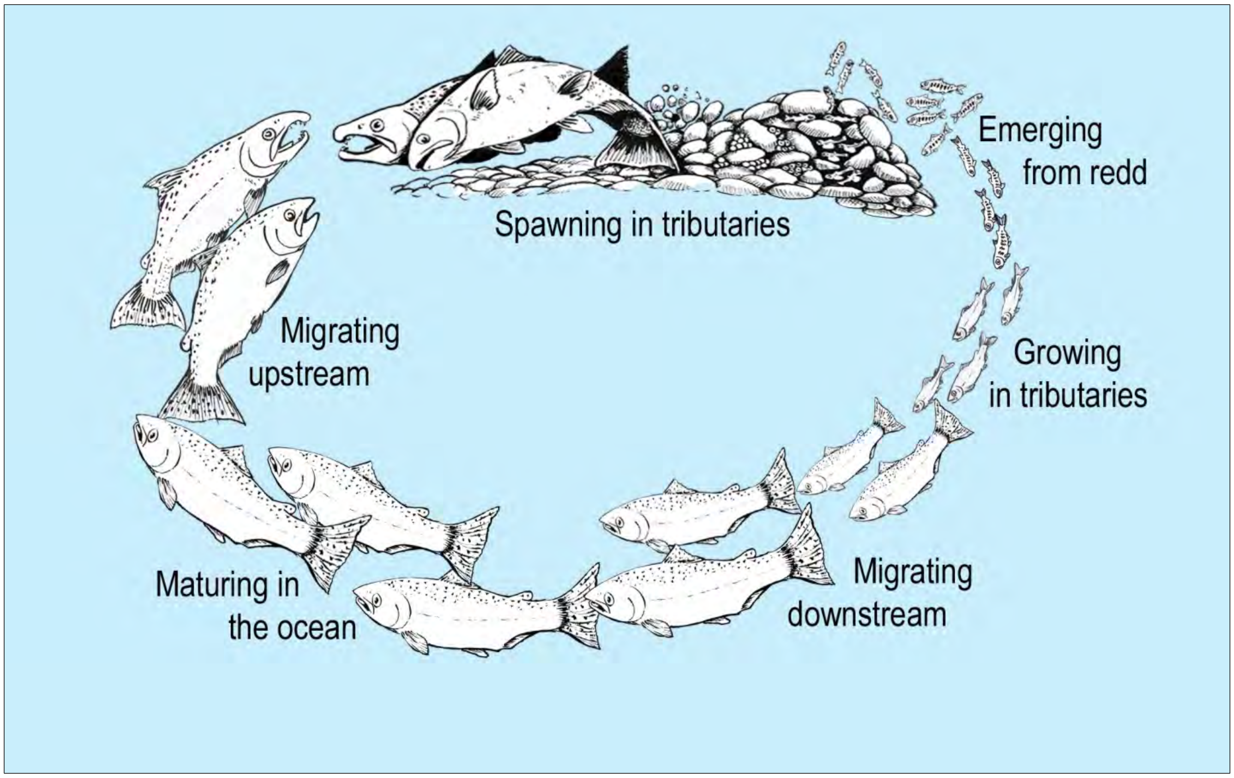

Figure 2-3. Anadromous Salmon and Steelhead Stream-type Life Cycle.

2.2.2 Snake River Basin Steelhead

Snake River Basin steelhead express a summer-run spawning migration strategy, one of four seasonal migration strategies from the ocean to freshwater (winter, spring, summer, or fall). Steelhead with different migration strategies differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics in the spawning areas, and time of spawning. Summer-run steelhead are sexually immature when they return to freshwater between May and October, and require several months to mature and spawn. For this reason they are also categorized as stream-maturing, as opposed to ocean-maturing steelhead. The latter type is typical of winter-run steelhead, which enter freshwater between November and April with well-developed gonads and spawn shortly thereafter.

A 2015 review by NMFS' Northwest Fisheries Science Center has improved our understanding regarding Snake River Basin steelhead life-history expressions and adaptation to varying natal habitat conditions. Previously, the steelhead stocks were commonly referred to as either "A-run" or "B-run" based on migration timing and differences in age and size at return. Generally, A-run steelhead are smaller (<78 cm [usually 58 to 66 cm] long), spend one year in the ocean, and begin their upriver freshwater migration earlier in the year than B-run steelhead. In comparison, the B-run steelhead are larger (many >78 cm long), spend two years in the ocean, and appear to begin their upriver freshwater migration later in the year. A-run steelhead occur throughout the steelhead-bearing streams in the Snake River basin and inland Columbia River, while research indicates that B-run steelhead occur in the Clearwater and Salmon River basins (NWFSC 2015) (Table 2-1).

The NWFSC recently determined that some Snake River Basin steelhead populations support both A-run and B-run life-history expressions (NWFSC 2015). The NWFSC updated the Snake River Basin steelhead life-history pattern designations based on initial results from genetic stock identification (GSI) studies of natural-origin returns (e.g. Ackerman et al. 2014; Vu et al. 2015). Using this new information, the NWFSC designated the populations as A-run or B-run based on length (less or more than 78 cm), but further assigned the populations with both A-run and B-run steelhead to different categories reflecting their mixtures of the run types (NWFSC 2015). The NWFSC determined that all but one of the populations previously designated by the ICTRT as A-run steelhead populations had no or negligible B-run returns and should remain as A-run populations (Table 2-1). It reassigned the Lower Clearwater River population as a B-run based on analyses showing a mix of A-run and B-run steelhead in the population. The remaining populations were assigned to one of three different B-run categories reflecting the relative contribution of fish exceeding the B-run size threshold (High >40 percent, Moderate 15 to 40 percent, Low <15 percent) (NWFSC 2015). Research indicates that these broad categories may mask a genetic and life-history diversity that influences population dynamics and contributes to the viability of wild steelhead populations (Copeland et al. 2017). Copeland et al. (2017) found that there was broad overlap among the steelhead populations in several respects, forming a gradient in life-history characteristics rather than a dichotomous break. For example, all populations produced adults <78 cm and had adults returning after August 25. Median lengths of assumed B-run populations were close to the length criterion that was supposed to be a defining characteristic. In contrast, few A-run populations produced many adults ≥78 cm (Copeland et al. 2017).

Table 2-1. Updated major life-history category designations for Snake River Basin Steelhead DPS populations based on initial results from genetic stock identification studies. Designated A-run population have no or negligible B-run size returns in stock group samples. B-run population category designations reflect relative contribution of fish exceeding B-run size threshold (High >40%, Moderate 15-40%, Low <15%) (NWFSC 2015).

Major Population Group	Population	2007 ICTRT Major Life-History Pattern	Change?	2015 Assessment Update to Major Life-History Pattern
Lower Snake River MPG	Tucannon River	A		A
	Asotin Creek	A		A
Grande Ronde River MPG	Joseph Creek	A		A
	Up. Grande Ronde River	A		A
	Lo. Grande Ronde River	A		A
	Wallowa River	A		A
Imnaha River MPG	Imnaha River	A		A
Clearwater River MPG	Lower Clearwater Mainstem	A	Provisional	Low B
	South Fork Clearwater River	B	Yes	High B
	Selway River	B	Yes	High B
	Lochsa River	B	Yes	High B
	Lolo Creek	A/B	Yes	High B
Salmon River MPG	South Fork	B	Yes	High B
	Secesh River	B	Yes	High B
	Lo. Middle Fork Salmon River	B	Yes	Moderate B
	Up. Middle Fork Salmon River	B	Yes	Moderate B
	North Fork Salmon River	A		A
	Panther Creek	A		A
	Pahsimeroi River	A		A
	Lemhi River	A		A
	Up. Salmon River Mainstem	A		A
	Up. Salmon East Fork	A		A
	Chamberlain Creek	A		A

Adult Snake River Basin summer steelhead generally return to the Columbia River from June to August. Once the fish enter the Columbia River estuary, their timing of upstream migration at Bonneville Dam varies with age, size, and distribution of the fish. Most wild fish pass the dam earlier than hatchery fish. The peak passage of Snake River Basin steelhead has shifted by about two weeks from late July to early August, probably in response to warming temperatures and reduced flows in the river (NMFS 2014c). Snake River Basin steelhead can delay their migration up the Columbia and Snake Rivers, and pull into cooler tributaries for temporary holding.

Most Snake River Basin steelhead arrive in the Snake River and tributaries in early fall. After holding over the winter, summer-run steelhead spawn the following spring (typically from March to May), but potentially into June in some higher elevation watersheds in central Idaho. Snake River steelhead migrate a substantial distance from the ocean and use high-elevation tributaries (typically 1,000–2,000 m above sea level) for spawning and juvenile rearing that are colder than many lower elevation tributaries. Figure 2-3 displays the stream-type life cycle of the Snake River steelhead. Steelhead are iteroparous, or capable of spawning more than once before death. Iteroparity as a life-history trait remains in several tributaries of the Snake River basin. Recent studies conducted by Colotelo et al. (2013, 2014) indicate that the availability of spill weirs and other surface bypass routes at all eight mainstem dams since 2010, and the requirement for 24-hour spill, is improving the survival of downstream adult steelhead migrants (termed "kelts"). These measures, however, are too recent to have improved productivity at the species level. Resident *O. mykiss* are also present in many of the drainages used by Snake River Basin steelhead.

Steelhead emergence in the Snake River basin generally occurs by early June in low elevation streams and by mid-July or later at higher elevations. In the South Fork Salmon River, one study showed that steelhead emergence was not complete until early August (Thurow 1987). Snake River steelhead usually smolt at age-2 or age-3 years. Juvenile outmigrating steelhead often reach Bonneville Dam by mid-May, with May 19 the average median date of passage for natural-origin fish. Most juvenile steelhead travel rapidly (<5 days) through the estuary and into the ocean. McMichael et al. (2013) found that most (83 percent) of the tagged steelhead remained near the river's mouth (below Rkm 8) for less than a day. However, there is considerable variation in travel times and timing of estuarine and ocean entry between individual fish. For example, McMichael et al. (2013) found that residence time of juvenile steelhead at the mouth of river ranged from 0.1 days to 10.8 days. Differences in ocean entry date of days to weeks could affect the survival of fish in the ocean and the species' ability to adapt to changing environmental conditions (Scheuerell et al. 2009; Holsman et al. 2012).

After leaving the estuary and plume, Snake River Basin steelhead can disperse in all directions (McMichael et al. 2013), with the proportion of fish moving in any direction as a function of time of year. McMichael et al. (2013) reported that in early spring most fish initially dispersed south and west while later in the spring fish mostly were dispersing north and west. They speculated that this difference in dispersal patterns is a function of local ocean currents. Regardless of direction the fish initially go, information from ocean trawl catches indicate steelhead migrate rapidly through the plume and near coastal region, and are beyond the continental shelf in a matter of days (Appendix D). The fish generally leave the Northern California Current off the state of Washington by June (Daly et al. 2014). There is little known about their life in the ocean; however, Snake River steelhead distribute themselves in a broad band across the North Pacific, with most fish found between 40° N and 50° N latitude and from the North American Coast to 165° W (west of the date line) (Myers et al. 1996). In general, ocean distribution appears to be highly dependent on temperature (Welch et al. 1998; Atcheson et al. 2012; Appendix D). The fish typically reside in marine waters for one to three years before returning to their natal stream to spawn at four or five years of age.

2.3 Biological Structure of Salmonid Populations

Historically, most salmon and steelhead species contained multiple populations connected by some small degree of genetic exchange that reflected the geography of the river basins in which they spawned, and with some spawners straying in from other areas. Thus, the overall biological structure of the species is hierarchical; spawners in the same area of the same stream share more characteristics than they do with those in the next stream over. Fish whose natal streams are separated by hundreds of miles generally have less genetic similarity due to long-term adaptation to their different environments. The species is essentially a metapopulation defined by the common characteristics of populations within a geographic range. Recovery planning efforts focus on this biologically based hierarchy, which extends from the species level to a level below a population, and reflects the degree of connectivity between the fish at each geographic and conceptual level.

McElhany et al. (2000) formally identified two levels in this biological hierarchy for listing, delisting and recovery planning purposes: the evolutionarily significant unit (ESU) or distinct population segment (DPS) and the independent population. The ICTRT identified an additional level in the hierarchy between the population and ESU/DPS levels, which they call a major population group (MPG) (McClure et al. 2003). The three levels in the hierarchy are defined below. Figure 2-4 shows the relationship between the three levels.

- **Evolutionarily Significant Unit & Distinctive Population Segment:** A salmon ESU or steelhead DPS is a distinctive group of Pacific salmon or steelhead that is uniquely adapted to a particular area or environment. An ESU is equivalent to a DPS and treated as a species under the ESA. Two criteria define an ESU of salmon listed under the ESA: (1) it must be substantially reproductively isolated from other conspecific units, and (2) it must represent an important component of the evolutionary legacy of the species (Waples et al. 1991). Two similar, but slightly different, criteria define a DPS of steelhead listed under the ESA: (1) discreteness of the population segment in relation to the remainder of the species to which it belongs, and (2) significance of the population segment to the species to which it belongs. ESUs and DPSs may contain multiple populations that are connected by some degree of migration, and hence may have a broad geographic range across watersheds, river basins, and political jurisdictions.
- **Major Population Groups:** Within an ESU/DPS, independent populations can be grouped into larger aggregates that share similar genetic, geographic, and/or habitat characteristics (McClure et al. 2003). These “major population groups” are groupings of populations that are isolated from one another over a longer time scale than that defining the individual populations, but retain some degree of connectivity greater than that between different ESUs or DPSs.

- **Independent Populations:** McElhany et al. (2000) defined an independent population as: "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season." For our purposes, not interbreeding to a "substantial degree" means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame.

  The independent populations exhibit different population attributes that influence their abundance, productivity, spatial structure and diversity. Independent populations are the units that will be combined to form alternative recovery scenarios for MPGs and ESU/DPS viability ─ and, ultimately, are the objects of recovery efforts.

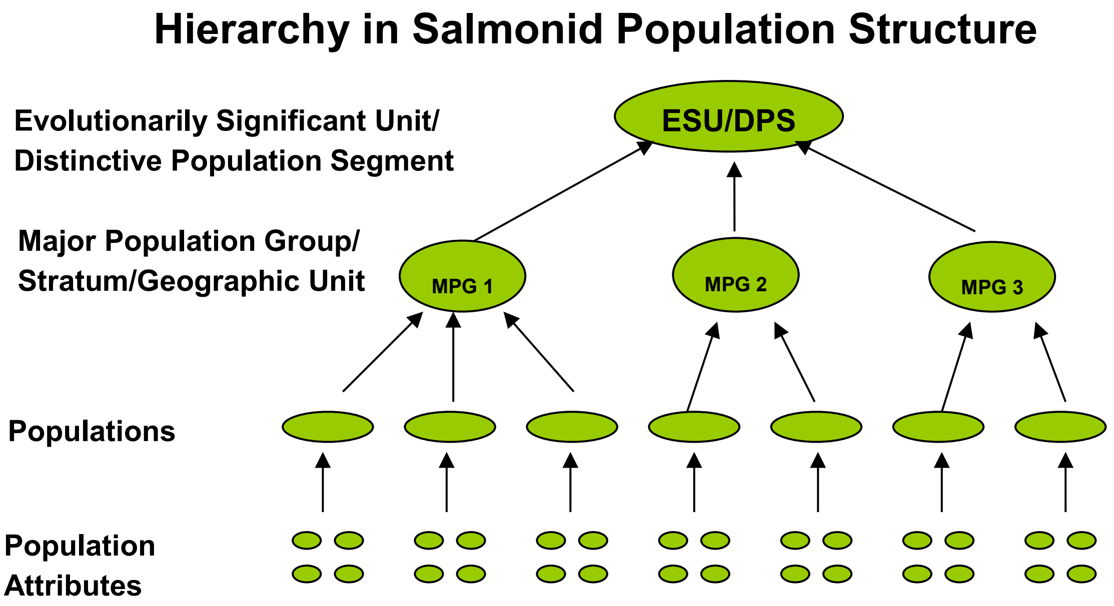

Figure 2-4. Hierarchical levels of salmonid species structure as defined by the ICTRT for ESU/DPS recovery planning.

2.3.1 Population Structure Adopted for Recovery Planning

NMFS adopted the ESU/DPS, Major Population Group, and population structure defined by the ICTRT for purposes of Snake River spring/summer Chinook salmon and steelhead recovery planning. NMFS and the ICTRT identified the population groups of Snake River spring/summer Chinook salmon and steelhead based on geography, migration rates, genetic attributes, life-history patterns, phenotypic characteristics, population dynamics, and environmental and habitat characteristics (Myers et al. 2006), as well as an understanding of the characteristics of viable salmonid populations (McElhany et al. 2000).

Snake River Spring/Summer Chinook Salmon Populations

The Snake River spring/summer Chinook salmon ESU includes all naturally spawned populations of spring/summer Chinook salmon originating from the mainstem Snake River and the Tucannon River, Grand Ronde River, Imnaha River, and Salmon River subbasins. The Salmon River system contains especially productive habitats for spring and summer Chinook salmon, and may have once contributed more than 40 percent of the total return of spring/summer Chinook salmon to the entire Columbia River (Fulton 1968).

The ICTRT identified five MPGs in the Snake River spring/summer Chinook salmon ESU (ICTRT 2003). Together, as shown in Figure 2-5, the MPGs contain 28 extant independent naturally spawning populations, three functionally extirpated populations, and one extirpated population (ICTRT 2003).[15] The Upper Salmon River MPG contains eight extant populations and one extirpated population. The Middle Fork Salmon River MPG contains nine extant populations. The South Fork Salmon River MPG contains four extant populations. The Grande Ronde/Imnaha Rivers MPG contains six extant populations, with two functionally extirpated populations. The Lower Snake River MPG contains one extant population and one functionally extirpated population. The South Fork and Middle Fork Salmon Rivers currently support most of the natural spring/summer Chinook salmon production in the Snake River drainage.

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[15] Extirpated populations are considered to be locally extinct. The ICTRT considers extirpated populations to be those that are entirely cut off from anadromy. Functionally extirpated populations are those where there are not enough fish or habitat in suitable condition to support a fully functional population.

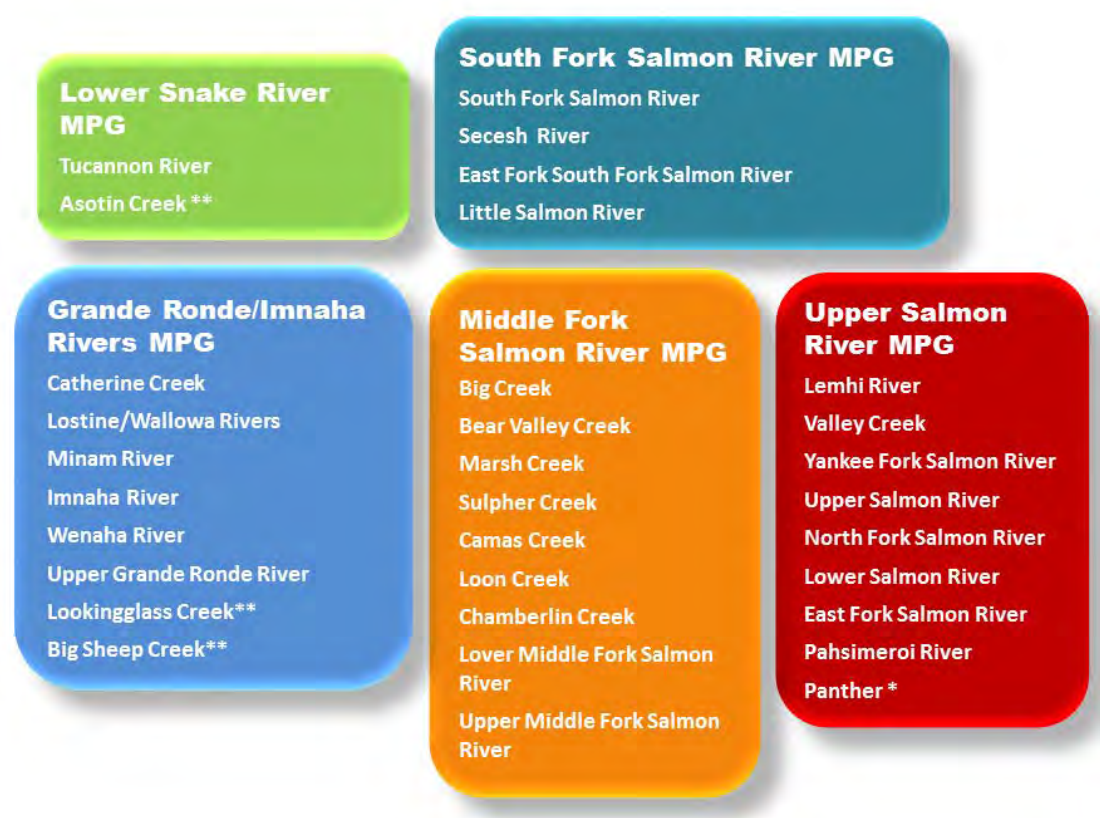


Figure 2-5. Major Population Groups and Populations of Snake River Spring/Summer Chinook Salmon. *extirpated populations **functionally extirpated populations.

Historically, Snake River spring/summer Chinook salmon also ranged into several areas that are no longer accessible (Figure 2-6). Habitat analyses and historical records of fish presence indicate that the Clearwater River basin and the area above Hells Canyon Dam, including some major tributaries, supported several additional anadromous populations. No biological data, however, are available to assess the historical relationships among populations in the extirpated areas above the Hells Canyon Complex, including the potential that one or more additional ESUs may have existed (ICTRT 2007). Current runs to the Clearwater River also are not part of the Snake River spring/summer Chinook salmon ESU. Lewiston Dam, constructed on the lower Clearwater River in 1927, blocked salmon and steelhead passage until the early 1940s (Matthews and Waples 1991). Biologists have concluded that even if a few native salmon survived the hydropower dams on the Clearwater River, the massive outplantings of nonindigenous hatchery stocks to the Clearwater system since the late 1940s have presumably substantially altered, if not eliminated, the original gene pool (Matthews and Waples 1991).

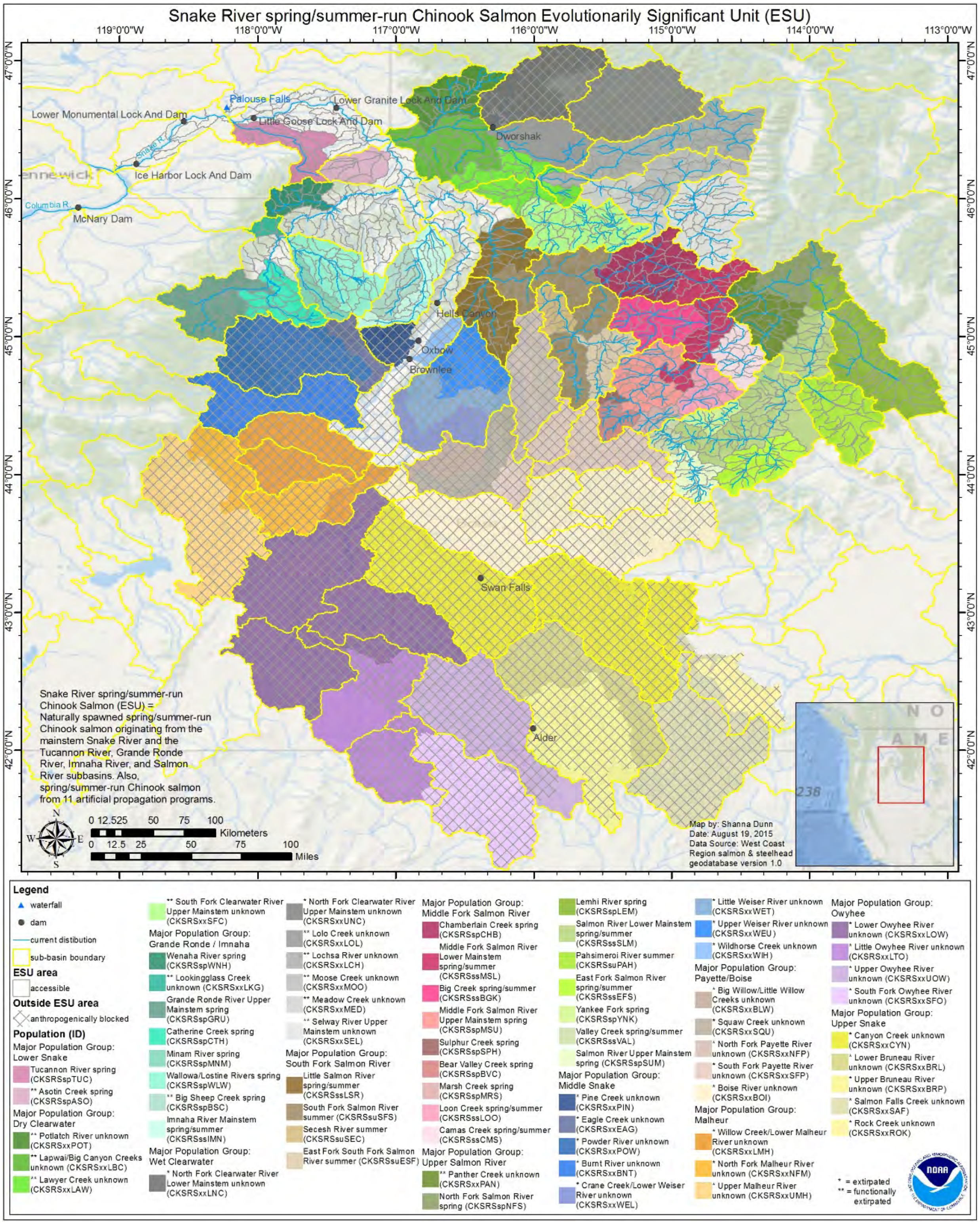


Figure 2-6. Snake River spring/summer Chinook salmon ESU and lost historical production areas above Hells Canyon Dam and in the Clearwater River drainage.

Snake River Basin Steelhead Populations

The ICTRT identified six historical MPGs in the Snake River Basin steelhead DPS ─ Clearwater River, Salmon River, Grande Ronde River, Imnaha River, Lower Snake River, and Hells Canyon Tributaries (ICTRT 2008). Together, the five extant MPGs in the DPS support 24 extant independent naturally spawning steelhead populations (ICTRT 2008). As shown in Figure 2-7, the five steelhead MPGs with extant populations are: Lower Snake River MPG (two populations); the Grande Ronde MPG (four populations); the Imnaha River MPG (one population); the Clearwater River MPG (five extant populations and one extirpated); and the Salmon River MPG (11 extant populations and one extirpated population).

Figure 2-7. Major Population Groups and Populations of Snake River Basin steelhead. *extirpated populations **functionally extirpated populations.

Historically, Snake River Basin steelhead also spawned and reared in areas above the Hells Canyon Complex on the Snake River and in the North Fork Clearwater River drainage (Figure 2-8). Steelhead are currently blocked from historical habitat in these areas. The ICTRT identified one historical MPG for the area above the Hells Canyon Complex, the Hells Canyon MPG, but the historical independent populations in the MPG are considered extirpated. Small tributaries entering the mainstem Snake River below Hells Canyon Dam likely were historically part of the Hells Canyon MPG, with a core area currently cut off from anadromous access.

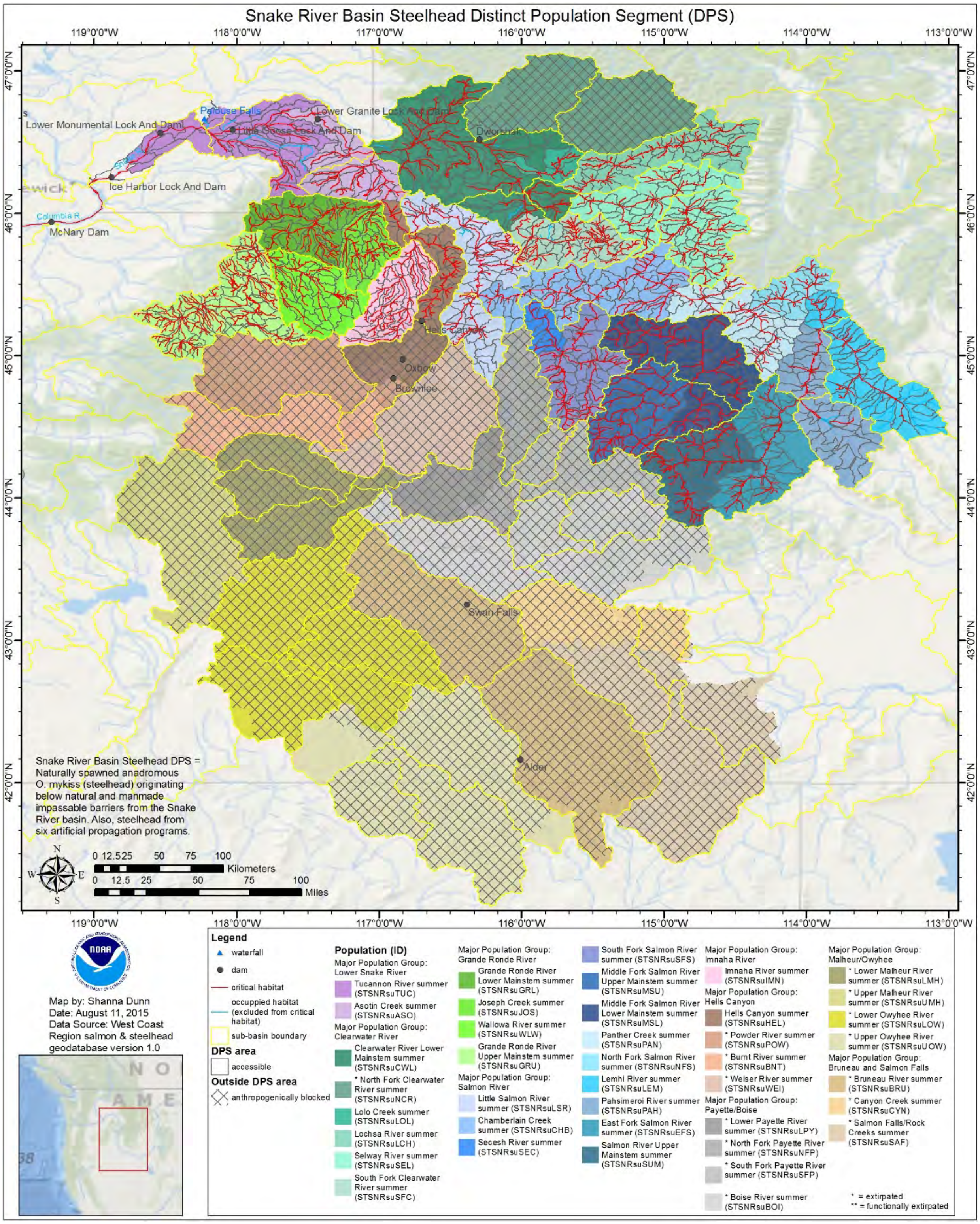


Figure 2-8. Snake River Basin steelhead DPS and historical production areas above Hells Canyon Dam and in the Clearwater River drainage.

2.4 Viable Salmonid Populations

Viability is a key concept within the context of the Endangered Species Act. NMFS' technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units,* (McElhany et al. 2000) provides guidance for assessing viability. It describes a Viable Salmonid Population as an independent population of any Pacific salmon or steelhead that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic changes over a 100-year time frame (McElhany et al. 2000). NMFS scientists measure salmon recovery in terms of four parameters, called viable salmonid population (VSP) parameters that influence the biological viability and long-term resilience of a salmonid population: abundance, productivity, spatial structure, and diversity. These parameters are closely associated, such that improvements in one parameter typically cause, or are related to, improvements in another parameter. For example, improvements in productivity might depend on increased diversity or habitat quality, and be accompanied by increased abundance and spatial structure.

2.4.1 Abundance and Productivity

Abundance and productivity are linked. Populations with low productivity can still persist if they are sufficiently large, and small populations can persist if they are sufficiently productive. A viable population needs sufficient abundance to maintain genetic health and to respond to normal environmental variation, and sufficient productivity to enable the population to quickly rebound from periods of poor ocean conditions or freshwater perturbations.

Abundance is expressed in terms of natural-origin spawners (adults on the spawning ground), measured over a time series, i.e., some number of years. The ICTRT often used a recent 10-year geometric mean of natural-origin spawners as a measure of current abundance.

Productivity of a population (the average number of surviving offspring per parent) is a measure of the population's ability to sustain itself. Productivity can be measured as spawner-to-spawner ratios (returns per spawner or recruits per spawner, or adult progeny to parent), annual population growth rate, or trends in abundance. Population-specific estimates of abundance and productivity are derived from time series of annual estimates, typically subject to a high degree of annual variability and sampling-induced uncertainties.

McElhany et al. (2000) offers abundance (size) and productivity guidelines for viable salmonid populations. These guidelines are shown in the box below.

Viable Salmonid Populations Abundance and Productivity Guidelines

(McElhany et al. 2000)

Abundance

1. Be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.
2. Be sufficiently large to provide resilience to environmental and anthropogenic disturbances.
3. Be sufficiently large to maintain genetic diversity over the long term.
4. Be sufficiently abundant to provide important ecological functions throughout its life cycle.
5. Population status evaluations should take uncertainty regarding abundance into account.

Productivity

1. Demonstrate sufficient natural productivity to maintain abundance above viable levels (support a net replacement rate of 1:1 or higher at abundance levels established as long-term targets).
2. Demonstrate sufficient productivity from naturally produced spawners to maintain abundance at or above viability thresholds in absence of hatchery subsidy. (Natural return ratio around 1.0, indicating negligible hatchery influence on the population.)
3. Exhibit sufficient productivity during freshwater life history stages to maintain abundance at or above viable thresholds—even during poor ocean conditions.
4. Should not exhibit sustained declines in abundance that span multiple generations and affect multiple brood year-cycles.
5. Should not exhibit trends or shifts in traits that portend declines in population growth rate.
6. Population status evaluations should take into account uncertainty in estimates of population growth rate and productivity-related parameters.

2.4.2 Spatial Structure and Diversity

A population’s spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Spatial structure refers to the amount of habitat available, the organization and connectivity of habitat patches, and the relatedness and exchange rates of adjacent populations. Diversity refers to the distribution of life-history, behavioral, and physiological traits within and among populations. Some of these traits are completely genetically based, while others, including nearly all morphological, behavioral, and life-history traits, vary as a result of a combination of genetic and environmental factors (McElhany et al. 2000). Spatial structure and diversity considerations are combined in the evaluation of a salmonid population’s status because they are so interrelated.

Spatial structure influences the viability of salmon and steelhead because populations with restricted distribution and few spawning areas are at a higher risk of extinction as a result of catastrophic environmental events, such as a landslide, than are populations with more widespread and complex spatial structures. A population with a complex spatial structure, including multiple spawning areas, experiences more natural exchange of gene flow and life-history characteristics. (Excessive exchange of migrants above historical levels can impede the process of local adaptation.)

Population-level diversity is similarly important for long-term persistence. Populations exhibiting greater diversity are generally more resilient to short-term and long-term environmental changes. Phenotypic diversity, which includes variation in morphology and life-history traits, allows more diverse populations to use a wider array of environments, and protects populations against short-term temporal and spatial environmental changes. Underlying genetic diversity provides the ability to survive long-term environmental changes.

Because neither the precise role that diversity plays in salmonid population viability nor the relationship of spatial processes to viability is completely understood, the ICTRT adopted the principle from McElhany et al. (2000) that historical spatial structure and diversity should be taken as a “default benchmark,” on the assumption that historical, natural populations did survive many environmental changes and therefore must have had adequate spatial structure and diversity.

McElhany et al. (2000) offers spatial structure and diversity guidelines for viable salmonid populations. These guidelines are shown in the box below.

Viable Salmonid Populations Spatial Structure and Diversity Guidelines

(McElhany et al. 2000)

Spatial Structure

1. Habitat patches should not be destroyed faster than they are naturally created.
2. Natural rates of straying among subpopulations should not be substantially increased or decreased by human actions.
3. Some habitat patches should be maintained that appear to be suitable or marginally suitable, but currently contain no fish.
4. Source subpopulations should be maintained.
5. Analyses of population spatial processes should take uncertainty into account.

Diversity

1. Human-caused factors such as habitat changes, harvest pressures, artificial propagation, and exotic species introduction should not substantially alter variation in traits such as run timing, age structure, size, fecundity, morphology, behavior, and molecular genetic characteristics.
2. Natural processes of dispersal should be maintained. Human-caused factors should not substantially alter the rate of gene flow among populations.
3. Natural processes that cause ecological variation should be maintained.
4. Population status evaluations should take uncertainty about requisite levels of diversity into account.

For all four of the viable salmonid population parameters, the guidelines recommend that population-specific status evaluations, goals, and criteria take into account the level of scientific uncertainty about how an individual parameter relates to a population's viability (McElhany et al. 2000).

2.5 ICTRT Biological Viability Criteria and Approach

One of the main tasks that NMFS assigned to the ICTRT for recovery planning was to recommend biologically based viability criteria specifically adapted to Interior Columbia salmon and steelhead listed under the ESA. The viability criteria developed by the ICTRT represent a consistent framework that follow VSP guidelines recommended by McElhany et al. (2000), expressed in terms of population-level abundance, productivity, spatial structure and diversity. They identify characteristics and conditions that, when met, will describe viable populations and viable species. The viability criteria also identify the metrics and thresholds that may be used to determine the status of a population and the viability risk. Thus, the biological viability criteria provided an important foundation for use in determining recovery goals and delisting criteria for Snake River spring/summer Chinook salmon and steelhead, described in Chapter 3.

The ICTRT's biological viability criteria are hierarchical. They are designed to assess risk for abundance/productivity and spatial structure/diversity at the population level. These assessments are then "rolled up" to arrive at composites for the MPG and ESU levels. The criteria reflect the best available science and consist of a combination of general statements and metrics that characterize viability.

The viability criteria are summarized below and outlined in more detail in the ICTRT's draft technical report, *Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs* (ICTRT 2007). The report is available at: http://www.nwfsc.noaa.gov/trt/col/trt_viability.cfm. The three management units describe how the criteria were used to inform decisions during the recovery planning process.

2.5.1 ESU- and DPS-Level Viability Criteria

The ESU/DPS-level viability criterion focuses on ensuring the preservation of basic historical metapopulation processes needed to maintain a viable ESU or DPS in the face of long-term ecological and evolutionary processes. These characteristics include (1) genetic exchange across populations within an ESU/DPS over a long time frame; (2) the opportunity for neighboring populations to serve as source areas in the event of local population extirpations; and (3) populations distributed within an ESU/DPS so that they are not all susceptible to a specific localized catastrophic event.

ESU/DPS Viability Criterion (ICTRT 2007)

All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU or DPS should be at low risk (Viable).

The ESU/DPS viability criterion targets major population group viability. It recognizes that since MPGs are geographically and genetically cohesive groups of populations, they are critical components of ESU/DPS-level spatial structure and diversity. Having all MPGs within an ESU or DPS at low risk provides the greatest probability of persistence of any ESU/DPS.

The ICTRT viability criteria allow for some flexibility in which populations will be targeted for a particular recovery level to achieve a viable ESU/DPS. The ICTRT recognized that in addition to some extant populations being in better shape than others, there are often one or more extirpated populations within an ESU/DPS. The ICTRT recommended that extirpated populations be included in the total number of populations in the ESU or DPS (for calculating minimum number of populations in the MPG), but that the initial focus of recovery efforts be put on extant populations, with scoping efforts for re-introductions of extirpated populations conducted concurrently.

2.5.2 MPG-Level Viability Criteria

The ICTRT's MPG-level criteria are designed to ensure robust functioning of metapopulation processes and provide resilience in case of catastrophic loss of one or more populations. The criteria take into account the level of risk associated with the MPG's component populations. They assume that MPG viability depends on the number, spatial arrangement, and diversity associated with its component populations.

MPG-Level Viability Criteria (ICTRT 2007)

The following six criteria should be met for an MPG to be regarded as at low risk (Viable):

1. At least one-half of the populations historically within the MPG (with a minimum of two populations) should meet viability standards.
2. At least one population should be classified as "Highly Viable."
3. Viable populations within an MPG should include some populations that are classified (based on historical intrinsic potential) as "Very Large," "Large," or "Intermediate" generally reflecting the proportions historically present within the MPG. In particular, Very Large and Large populations should be at or above their composite historical fraction within each MPG.
4. All major life-history strategies (e.g., spring and summer run timing) that were present historically within the MPG should be represented in populations meeting viability requirements.
5. Remaining MPG populations should be maintained with sufficient abundance, productivity, spatial structure, and diversity to provide for ecological functions and to preserve options for ESU/DPS recovery.
6. For MPGs with only one population, this population must be Highly Viable.

The MPG-level criteria follow NMFS' recommendations (McElhany et al. 2000) that the presence of viable populations in each extant MPG and some number of highly viable populations distributed throughout the ESU or DPS should result in sustainable production across a substantial range of environmental conditions. This distribution would preserve a high level of diversity within the ESU or DPS, and would promote long-term evolutionary potential for adaptation to changing conditions. The presence of multiple, relatively nearby, highly viable, viable, and maintained populations acts as protection against long-term impacts of localized catastrophic loss by serving as a source of re-colonization. These criteria are consistent with recommendations for other ESUs in the Pacific Northwest (e.g., McElhany et al. 2006; Ruckelshaus et al. 2002; ICTRT 2007).

2.5.3 Population-Level Viability Criteria

The ICTRT population-level criteria define the viability status of the individual populations that make up an MPG and an ESU/DPS. The ICTRT's criteria describe a viable population based on the four VSP parameters (abundance, productivity, spatial structure, and diversity). As discussed in Section 2.4, these parameters are important indicators of population extinction risk ─ or, conversely, a population's probability of persistence. The ICTRT grouped the population-level criteria into two categories: measures addressing abundance and productivity, and measures addressing spatial structure/diversity considerations.

Abundance and Productivity

Abundance refers to the number of natural-origin adult fish returning to spawn, measured over a time series. The ICTRT used a recent 10-year geometric mean of natural-origin spawners as a measure of current abundance. Productivity, or population growth rate, is the average number of surviving offspring per parent. Productivity is used as an indicator of a population’s ability to sustain itself, or its ability to rebound from low numbers. The term refers to the performance of the population over time in terms of number of recruits (adults) per spawner or the number of smolts produced per spawner. Together, the abundance and productivity parameters drive extinction risk.

The ICTRT identified the following objective for population abundance and productivity based on guidance from McElhany et al. 2000:

> *Abundance should be high enough that (1) in combination with intrinsic productivity, declines to critically low levels would be unlikely assuming recent historical patterns of environmental variability; (2) compensatory processes provide resilience to the effects of short-term perturbations; and, (3) subpopulation structure is maintained (e.g., multiple spawning tributaries, spawning patches, life-history patterns).*

The ICTRT (2007) provided a simple method for estimating current intrinsic productivity using spawner-to-spawner return pairs from low-to-moderate escapements over a recent 20-year period (ICTRT 2007). However, the ICTRT also recognized that there could be situations where alternative methods could be employed to estimate productivity, especially in circumstances where the simple method would be based on relatively few annual return-per-spawner estimates.

The ICTRT developed a quantitative tool, called a “viability curve,” for evaluating the abundance and productivity (A/P) of a population (ICTRT 2007). A viability curve describes those combinations of abundance and productivity that yield a particular risk or extinction level at a given level of variation. Viability curves are generated using a population viability analysis. The ICTRT developed different viability curves corresponding to a range of extinction risks over a 100-year period: less than 1 percent (very low) risk, 1-5 percent (low) risk, 6-25 percent (moderate) risk, and greater than 25 percent (high) risk. The ICTRT targeted population-level recovery strategies to achieve less than a 5 percent (low) risk of extinction in a 100-year period. This is consistent with the VSP guidelines and conservation literature (McElhany et al. 2000; NRC 1996; ICTRT 2007). The ICTRT considers a population with less than 5 percent risk of extinction in 100 years to be viable, and a population with a less than 1 percent risk of extinction during the period to be highly viable. Figure 2-9 shows an example of an abundance/productivity viability curve used to test viability.

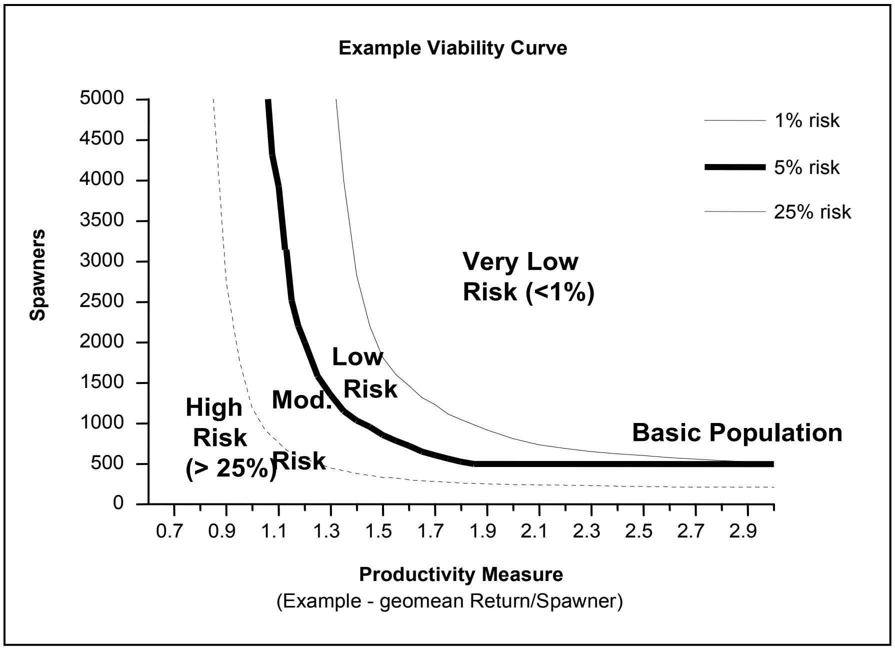


Figure 2-9. Example of an Abundance/Productivity Viability Curve.

The ICTRT (2007) identified and incorporated "minimum abundance and productivity thresholds" into the viability curves for the salmon and steelhead populations using four different population size categories: Basic, Intermediate, Large, and Very Large. The minimum abundance thresholds reflect the viable salmonid principles provided by McElhany et al. (2000), as well as estimates of the relative amount of historical spawning and rearing habitat associated with each population. They represent the number of spawners needed for a population of the given size category to achieve the 5 percent (low) risk level at a given productivity.

The ICTRT decided that abundance levels below 500 individuals for any population would pose unacceptable risk for inbreeding depression and other genetic characteristics (McClure et al. 2003). It established a minimum abundance threshold of 500 individual spawners for the small Basic-size population. For populations that cover a larger geographic area, the ICTRT identified higher minimum abundance levels that would be necessary to meet the full range of VSP criteria. The minimum abundance thresholds for the Snake River spring/summer Chinook salmon and steelhead populations are shown in Table 2-2 (Chinook salmon) and Table 2-3 (steelhead). For spring/summer Chinook salmon, minimum abundance thresholds are 500, 750, 1000, and 2000 for population sizes of Basic, Intermediate, Large, and Very Large, respectively, with productivity thresholds of 2.21, 1.76, 1.58, and 1.34, respectively. For steelhead, minimum abundance thresholds are 500, 1000, 1500, and 2500 for population sizes of Basic, Intermediate, Large, and Very Large, respectively, with productivity thresholds of 1.27, 1.14, 1.10, and 1.08, respectively.

The ICTRT (2007) incorporated the minimum abundance and productivity thresholds into the viability curves generated for each Snake River spring/summer Chinook salmon and Snake River Basin steelhead population. The ICTRT's individual population-level abundance/productivity viability curves for Snake River spring/summer Chinook salmon and steelhead are included in the management unit plans for Northeast Oregon, Southeast Washington, and Idaho. Importantly, the ICTRT envisioned its viability curve concept as adaptable. The curves can be generated specific to the form of stock-recruit relationship and type of time series data available for a particular population of set of populations. The ICTRT (2007) provided guidance for updating a viability curve and for assessing current status relative to the curve. The ICTRT (2007) also recognized that there could be situations when alternative means of assessing productivity may be needed. For example, in some cases the use of life cycle models or other tools may provide a more robust and reasonable way to estimate current population abundance and productivity. Such potential methods for estimating abundance and productivity using life cycle models are now under development. The ICTRT generated viability curves for application to populations within each ESU/DPS based on a simple Hockey-Stick stock recruitment relationship. Estimates of current equilibrium spawning abundance and intrinsic productivity from other forms (e.g., Beverton Holt) can be directly compared to the ICTRT viability curves if the productivity term is expressed as steepness (expected productivity from parent spawning escapement at 20 percent of estimated equilibrium). Alternatively, viability curves can be generated that are specific to the form of stock-recruit relationship and type of time series data available for a particular population of set of populations. The ICTRT (2007) provided guidance to adapt the approach to accommodate the biological characteristics and available data for Snake River spring/summer Chinook salmon and steelhead populations.

Table 2-2. Minimum Abundance and Productivity Thresholds for Snake River Spring/Summer Chinook Salmon. Populations with combinations of abundance and productivity meeting or exceeding these minimum thresholds would be considered viable and at low risk with a 95% probability of persistence over 100 years (ICTRT 2007).

Major Population Group	Population	Population Size	Minimum Abundance Threshold*	Minimim Productivity Threshold**
Grande Ronde/ Imnaha Rivers MPG	Wenaha River	Intermediate	750	1.76
	Minam River	Intermediate	750	1.76
	Catherine Creek	Large***	750	1.76
	Lookingglass Creek (Extirpated)	Basic	500	2.21
	Lostine/Wallowa Rivers	Large	1,000	1.58
	Up. Grande Ronde River	Large	1,000	1.58
	Imnaha River	Intermediate	750	1.58
	Big Sheep Creek (Extirpated)	Basic	500	2.21
Lower Snake River MPG	Tucannon River	Intermediate	750	1.76
	Asotin Creek (Extirpated)	Basic	500	2.21
South Fork Salmon River MPG	Little Salmon River	Intermediate	500	2.21
	Secesh River	Intermediate	750	1.76
	South Fork Salmon River	Large	1,000	1.58
	EF South Fork Salmon River	Large	1,000	1.58
Middle Fork Salmon River MPG	Chamberlain Creek	Intermediate	500	2.21
	Big Creek	Large	1,000	1.58
	Lower MF Salmon River	Basic	500	2.21
	Camas Creek	Basic	500	2.21
	Loon Creek	Basic	500	2.21
	Upper MF Salmon River	Intermediate	750	1.76
	Sulphur Creek	Basic	500	2.21
	Bear Valley Creek	Intermediate	750	1.76
	Marsh Creek	Basic	500	2.21
Upper Salmon River MPG	North Fork Salmon River	Basic	500	2.21
	Lemhi River	Very Large	2,000	1.34
	Upper Salmon River Lower Main	Very Large	2,000	1.34
	Pahsimeroi River	Large	1,000	1.58
	East Fork Salmon River	Large	1,000	1.58
	Yankee Fork Salmon River	Basic	500	2.21
	Valley Creek	Basic	500	2.21
	Upper Salmon River Upper Main	Large	1,000	1.58
	Panther Creek (functionally extirpated)	Intermediate	750	1.76

* Minimum Abundance Threshold is based on estimated historical tributary spawning and rearing habitat available to a population. Current abundance is measured as the 10-year geometric mean of the natural origin spawners for comparison to the minimum abundance threshold. The ICTRT recognized that there are alternative life cycle modeling based approaches to estimate abundance.

** Minimum Productivity Threshold is derived from the ICTRT population viability curves, where the intrinsic productivity value on the curve corresponds to the population's minimum abundance threshold. A population's intrinsic productivity represents the geometric mean of estimates associated with low to moderate parent escapements. The ICTRT recognized alternative methods for estimating current intrinsic productivity, including using a simple geometric mean of return-per-spawner estimates from low to moderate parent escapements over the most recent 20 brood cycles.

***As described by the ICTRT, the overall size category for the Catherine Creek population is Large, including Indian Creek and associated mainstem spawning areas. The smaller Catherine Creek “core emphasis area” has a minimum abundance threshold of 750 spawners.

Table 2-3. Minimum Abundance and Productivity Thresholds for Snake River Basin Steelhead. Populations with combinations of abundance and productivity meeting or exceeding these minimum thresholds would be considered viable and at low risk with a 95% probability of persistence over 100 years (ICTRT 2007).

Major Population Group	Population	Population Size	Minimum Abundance Threshold*	Minimum Productivity Threshold**
Grande Ronde River MPG	Joseph Creek	Basic	500	1.27
	Wallowa River	Intermediate	1,000	1.14
	Upper Grande Ronde River	Large	1,500	1.10
	Lower Grande Ronde River	Intermediate	1,000	1.14
Imnaha River MPG	Imnaha River	Intermediate	1,000	1.14
Lower Snake River MPG	Tucannon River	Intermediate	1,000	1.14
	Asotin Creek	Basic	500	1.27
Clearwater River MPG	Lower Main Clearwater River	Large	1,500	1.10
	NF Clearwater River (Extirpated)	Large	-	-
	Lolo Creek	Basic	500	1.27
	Lochsa River	Intermediate	1,000	1.14
	Selway River	Intermediate	1,000	1.14
	South Fork Clearwater River	Intermediate	1,000	1.14
	Little Salmon River	Basic	500	1.27
	South Fork Salmon River	Intermediate	1,000	1.14
	Secesh River	Basic	500	1.27
	Chamberlain Creek	Basic	500	1.27
	L. Middle Fork Salmon River	Intermediate	1,000	1.14
	U. Middle Fork Salmon River	Intermediate	1,000	1.14
	Panther Creek	Basic	500	1.27
	North Fork Salmon River	Basic	500	1.27
	Lemhi River	Intermediate	1,000	1.14
	Pahsimeroi River	Intermediate	1,000	1.14
	East Fork Salmon River	Intermediate	1,000	1.14
	Upper Salmon River	Intermediate	1,000	1.14
Hells Canyon Tributaries MPG***	Lower Hells Canyon tribs (Remnant?)	Basic	--	--
	Powder River	--	--	--
	Burnt River	--	--	--
	Weiser River	--	--	--

* Minimum Abundance Threshold is based on estimated historical tributary spawning and rearing habitat available to a population. Current abundance is measured as the 10-year geometric mean of the natural origin spawners for comparison to the minimum abundance threshold. The ICTRT recognized that there are alternative life cycle modeling based approaches to estimate abundance.

** Minimum Productivity Threshold is derived from the ICTRT population viability curves, where the intrinsic productivity value on the curve corresponds to the population's minimum abundance threshold. A population's intrinsic productivity represents the geometric mean of estimates associated with low to moderate parent escapements. The ICTRT recognized alternative methods for estimating current intrinsic productivity, including using a simple geometric mean of return-per-spawner estimates from low to moderate parent escapements over the most recent 20 brood cycles.

***The historical Hells Canyon Tributaries MPG contained three independent populations above the site of Hells Canyon Dam. All three populations are now extirpated. Steelhead are present in the tributaries below Hells Canyon Dam; however, the ICTRT does not consider any of these tributaries (or all combined) to be large enough to support an independent population. The MPG is not expected to contribute to DPS recovery.

Spatial Structure and Diversity

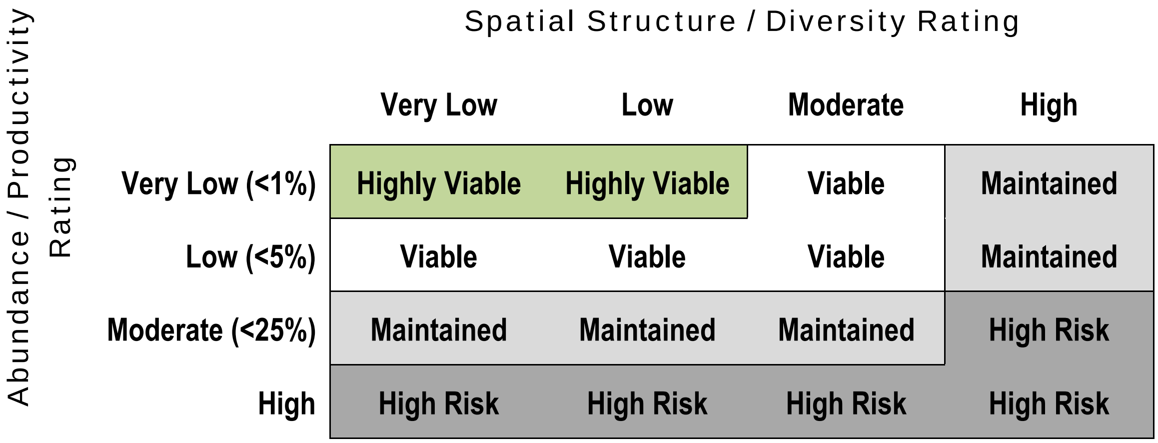
The spatial structure and diversity criteria are specific to each population, and based on historical spatial distribution and diversity, to the extent these can be known or inferred. The ICTRT cautions that there is a good deal of uncertainty in assessing the status of spatial structure and diversity in a population (ICTRT 2007; McElhany et al. 2000).

The ICTRT identified two primary goals, or biological or ecological objectives, that spatial structure and diversity criteria should achieve:

- Maintain natural rates and levels of spatially mediated processes. This goal serves (1) to minimize the likelihood that populations will be lost due to local catastrophe, (2) to maintain natural rates of recolonization within the population and between populations, and (3) to maintain other population functions that depend on the spatial arrangement of the population.
- Maintain natural patterns of variation. This goal serves to ensure that populations can withstand environmental variation in the short and long terms (ICTRT 2007).

Integrating the Four VSP Parameters

The ICTRT developed a simple matrix approach for integrating all four VSP parameters (Figure 2-10). The abundance and productivity risk level combines the abundance and productivity VSP criteria using a viability curve (see Figure 2-9). The spatial structure and diversity risk level integrates across 12 measures of spatial structure and diversity, defined in ICTRT 2007, which are related to achieving the two primary goals. The overall viability rating for a population is determined using two guiding principles. First, the VSP concept (McElhany et al. 2000) provides a 5 percent risk criterion to define a viable population. Therefore, any population that scores moderate or high risk in the abundance/productivity criteria would not meet the recommended viable standards. In addition, any population that scores high risk in the spatial structure/diversity criteria would not be considered viable. Second, populations with a very low risk rating for abundance and productivity and at least a low risk rating for spatial structure and diversity would be considered “highly viable.” Populations with a low risk rating for abundance and productivity and a moderate rating for spatial structure and diversity would be considered “viable.” This integration approach places greater emphasis on the abundance and productivity criteria. These individual ratings are then integrated to determine the viability of major population groups within an ESU/DPS. The assessments of individual MPGs are aggregated to assess the ESU/DPS as a whole (ICTRT 2007).



Abundance / Productivity Rating	Spatial Structure / Diversity Rating			
	Very Low	Low	Moderate	High
Very Low (<1%)	Highly Viable	Highly Viable	Viable	Maintained
Low (<5%)	Viable	Viable	Viable	Maintained
Moderate (<25%)	Maintained	Maintained	Maintained	High Risk
High	High Risk	High Risk	High Risk	High Risk

Figure 2-10. Matrix used to assess population viability across VSP criteria. Percentages for abundance and productivity scores represent the probability of extinction in a 100-year time period (ICTRT 2007).

2.6 Critical Habitat

The ESA, section 3(5), requires NMFS to designate critical habitat for any species it lists under the ESA. The Act defines critical habitat as areas that contain physical or biological features that are essential for the conservation of the species, and that may require special management considerations or protection. Critical habitat designations must be based on the best scientific information available, and must be made in an open public process and within specific timeframes. Under section 4(b)(2) of the ESA, NMFS may exclude areas from critical habitat if the benefits of exclusion outweigh the benefits of designation, unless excluding the area will result in the extinction of the species concerned. Before designating critical habitat, NMFS must carefully consider economic, national security, and other relevant impacts of the designation.

A critical habitat designation does not set up a preserve or refuge, and does not affect activities on private land unless federal permitting, funding, or direct action is involved, or activities on private land result in the unlawful take of the listed species. Under section 7 of the ESA, all federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify its designated critical habitat.[16]

NMFS defines critical habitat as consisting of four types of sites: (1) spawning and juvenile rearing areas, (2) juvenile migration corridors, (3) areas for growth and development to adulthood, and (4) adult migration corridors. Essential features of spawning and rearing areas include adequate spawning gravel, water quality, water quantity, water temperature, food, riparian vegetation, and access. Essential features of juvenile migration corridors include adequate substrate, water quality, water quantity, water temperature, water velocity,

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[16] Regulations finalized in 2016 addressed this section 7 analysis by defining destruction or adverse modification of critical habitat as “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).

cover/shelter, food, riparian vegetation, space, and safe passage conditions. The adult migration corridors are the same areas as the juvenile migration corridors, and the essential features are the same, with the exception of adequate food (since adults do not eat on their return migration to natal streams) (58 FR 68543). Because Pacific Ocean areas used by listed salmon for growth and development to adulthood are not well understood, NMFS has not defined essential features of these areas or designated habitats in the ocean and nearshore (58 FR 68543; 70 FR 52630).[17] Table 2-4 summarizes the physical and biological features considered essential for anadromous salmon and steelhead.

By designating these essential features as critical habitat, NMFS recognizes that portions of the designated critical habitat is in a degraded condition. These physical and biological features have been designated because of their potential to develop or improve and eventually provide the needed ecological functions to support species' recovery. Other portions of critical habitat have been designated because, even in a degraded condition, the value they provide is essential to species survival and recovery.

Table 2-4. Types of sites and essential physical and biological features designated as PCEs for anadromous salmonids, and the life stage each PCE supports (70 FR 52630).

Site	Essential Physical and Biological Features	ESU/DPS Life Stage
Freshwater spawning	Water quality, water quantity, and substrate	Spawning, incubation, and larval development
Freshwater rearing	Water quantity and floodplain connectivity	Juvenile growth and mobility
	Water quality and forage	Juvenile development
	Natural cover[a]	Juvenile mobility and survival
Freshwater migration	Free of artificial obstructions, water quality and quantity, and natural cover[b]	Juvenile and adult mobility and survival
Estuarine areas	Free of obstruction, water quality and quantity, and salinity	Juvenile and adult physiological transitions between salt and freshwater
	Natural cover[a], forage[b] and water quantity	Growth and maturation
Nearshore marine areas	Free of obstruction, water quality and quantity, natural cover[a] and forage[b]	Growth and maturation, survival
Offshore marine areas	Water quality and forage[b]	Growth and maturation

[a] Natural cover includes shade, large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

[b] Forage includes aquatic invertebrate and fish species that support growth and maturation.

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[17] Recent data and analyses are beginning to provide new information on ocean use. This information is summarized for the plume and nearshore ocean in the Ocean Module (Appendix D) and in Section 5.2.6.

NMFS designated critical habitat for Snake River spring/summer Chinook salmon on December 28, 1993 (58 FR 68543) and revised it slightly on October 25, 1999 (64 FR 57399). The designation consists of river reaches of the Columbia, Snake, and Salmon Rivers and all the tributaries of the Snake and Salmon Rivers (except the Clearwater River) presently or historically accessible to Snake River spring/summer Chinook salmon (except above natural falls and the Hells Canyon Dam). NMFS is currently working to produce a map showing critical habitat for this ESU and will add the map to the recovery plan when it becomes available.

NMFS published a final rule designating critical habitat for Snake River Basin steelhead and 12 other species of salmon and steelhead (not including Snake River spring/summer Chinook salmon) on September 2, 2005 (70 FR 52630). These critical habitat designations, which total 8,049 miles of stream, became effective January 2, 2006. The Critical Habitat Assessment Review Team (CHART) (70 FR 52630) made critical habitat designations for this group of ESUs and DPSs by rating the conservation value of all 5th-field hydrologic unit codes (HUCs) supporting populations of Snake River spring/summer Chinook salmon and Snake River Basin steelhead. Figure 2-11 shows the critical habitat designated for Snake River Basin steelhead.

The Columbia River estuary is among the areas of high conservation value to these species because it connects every population with the ocean and is used by rearing/migrating juveniles and migrating adults.

NMFS recognizes that salmon habitat is dynamic and that current understanding of areas important for conservation will likely change as recovery planning sheds light on areas that can and should be protected and restored. NMFS will update the critical habitat designations as needed based on the best information available, including information developed during recovery plan implementation.

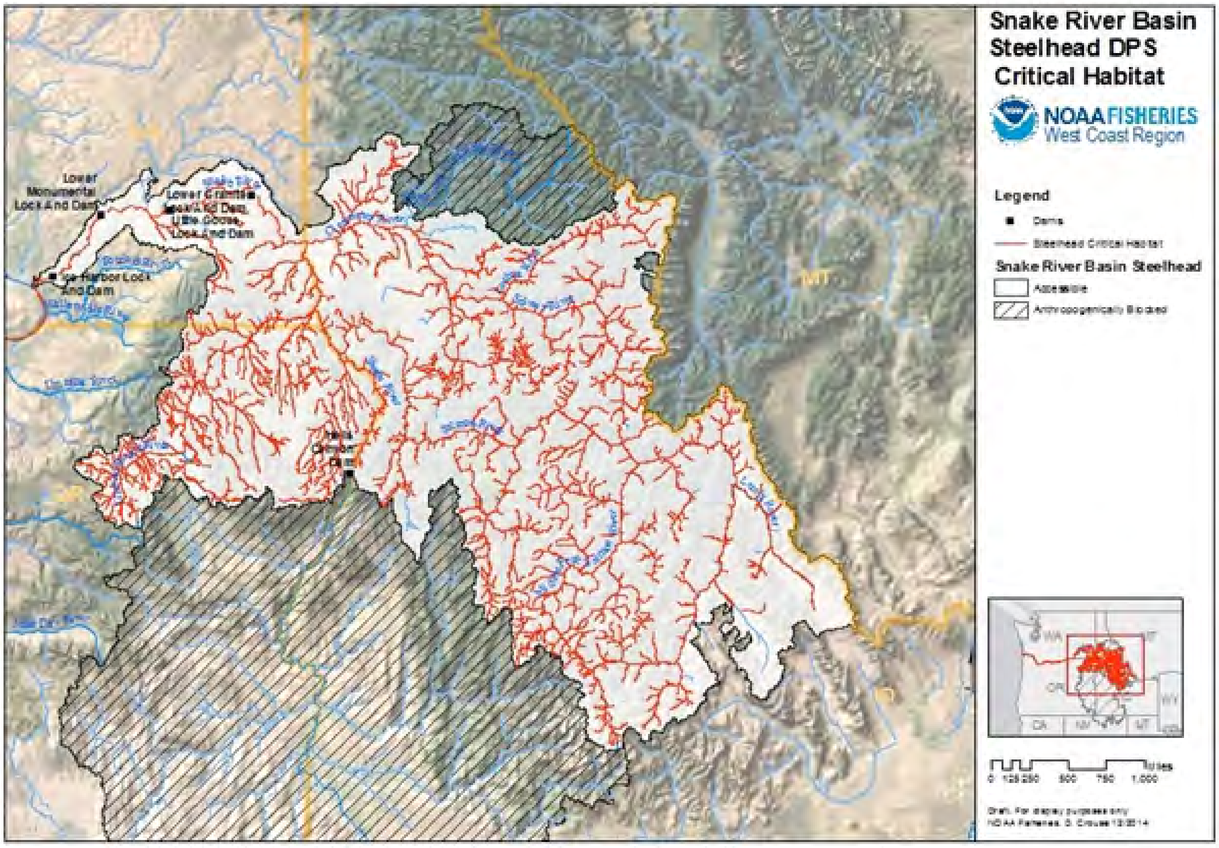

Figure 2-11. Designated critical habitat for Snake River Basin steelhead DPS.

3. Recovery Goals and Delisting Criteria

This chapter describes NMFS' recovery goals and criteria for ESA recovery (delisting) of Snake River spring/summer Chinook salmon and steelhead. The ESA recovery goal provides a general statement of conditions that would support delisting. The ESA recovery, or delisting, criteria are the "objective, measurable criteria" (ESA section 4(f)) that NMFS will use to evaluate the status of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS, and determine whether the species should be removed from the list of threatened and endangered species. NMFS applies two kinds of delisting criteria: biological viability criteria, which describe population or demographic parameters, and threats criteria, which relate to the five listing factors in ESA section 4(a)(1). This discussion is supplemented by additional detail at the species and major population group levels in Chapter 6.

The chapter also summarizes the recovery goals identified in the Oregon, Washington, and Idaho management unit plans. These management unit-level goals include biological recovery goals that are intended to be consistent with the ESA recovery goal and delisting. They also include broad sense goals that go beyond delisting under the ESA to address other legislative mandates or provide social, cultural, ecological, and economic benefits that are derived from having healthy, diverse salmon and steelhead populations. NMFS includes the broad sense goals in recovery plans to provide additional direction to strategic approaches to ESA recovery and to inform management for the species after delisting occurs.

3.1 ESU/DPS-Level Recovery Goals

3.1.1 ESA Recovery Goal

ESA recovery should support conservation of natural fish and the ecosystems upon which they depend. Thus, the ESA recovery goal for Snake River spring/summer Chinook salmon and steelhead is that:

> *The ecosystems upon which Snake River spring /summer Chinook salmon and steelhead depend are conserved such that the ESU and DPS are self-sustaining in the wild and no longer need ESA protection.*

A self-sustaining viable ESU or DPS depends on the status of its major population groups and component populations, and the ecosystems (e.g. habitats) that support them. A self-sustaining viable population has a negligible risk of extirpation due to reasonably foreseeable changes in circumstances affecting its abundance, productivity, spatial structure, and diversity characteristics over a 100- year time frame and achieves these characteristics without dependence upon hatcheries. Hatcheries may be used to benefit threatened and endangered species, and a self-sustaining population may include hatchery fish, but a self-sustaining population must not be dependent upon hatchery measures to achieve its viable characteristics. Hatchery production may contribute to recovery, but is not a substitute for addressing the underlying factors (threats) causing or contributing to a species' decline.

3.1.2 Broad Sense Goals

This Plan is founded on a belief that citizens throughout the region value and enjoy the substantial ecological, cultural, social, and economic benefits that are derived from having healthy, diverse salmon and steelhead populations. NMFS believes that while the Plan's goal is to ensure that the ESU and DPS are self-sustaining in the wild and no longer need ESA protection, it is important to achieve ESA recovery in a manner that is consistent with other federal legal obligations, mitigation goals, and other broad sense goals to provide social, cultural, economic, and ecological values. Although the broad sense scope exceeds the definition of delisting provided by the ESA, broad sense goals incorporate many of the traditional uses, as well as rural and Sovereign Tribes values, that are important in the Pacific Northwest. NMFS is supportive of the broad sense recovery goals in the management unit plans and believes that the most expeditious way to achieve them is by achieving viability of natural populations and delisting. Upon delisting, NMFS will continue to work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations.

NMFS has ultimate responsibility for final recovery plans and delisting decisions, and must take into account all relevant information, including, but not limited to, biological and policy considerations developed in the recovery planning process.

3.2 Management Unit Plan Recovery Goals

Snake River spring/summer Chinook salmon and steelhead spawn in Oregon, Washington, and Idaho, and are covered under the three separate management unit plans. Each management unit plan includes biological goals that local planners believe are consistent with delisting,[18] as well as broad, conceptual statements of purpose. The biological recovery goals are designed to support conservation of natural fish and the ecosystems upon which they depend, and are intended to be consistent with the ESA recovery goal and delisting. The components of the biological recovery goals in the management unit plans rely heavily on the biological viability criteria developed by the ICTRT. The broader, "broad sense," goals go beyond the requirements for delisting under the ESA and the purpose of this Plan to address other legislative mandates or social, economic, and ecological values.

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[18] Section 3.2 discusses NMFS' view of the management unit plans' recovery goals.

3.2.1 Management Unit Plan Biological Recovery Goals

The goal of the management unit plans is recovery of the populations and MPGs to the point that the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS can be delisted. Recovery planners at the management-unit level largely followed the ICTRT's guidelines in assessing the viability of Snake River spring/summer Chinook salmon and steelhead populations, MPGs, and ESUs/DPSs for the purposes of setting biological recovery goals.

The management unit plans adopt the ICTRT's definition of a viable ESU or DPS. All the plans also adopt the ICTRT's criteria described in Section 2.5. In addition, the management unit planners relied heavily on the ICTRT's guidelines regarding abundance and productivity, spatial structure, and diversity in setting viability goals for individual populations. The management unit plans lay out steps to meet the biological viability criteria, threats criteria, and other requirements that may be set by NMFS for delisting. Detail on methodologies can be found in the individual management unit plans. Chapter 6 presents MPG and population-specific goals, such as abundance and productivity targets.

3.2.2 Management Unit Plan Broad Recovery Goals

The management unit plans include broad, conceptual statements of purpose for the recovery of their Snake River spring/summer Chinook salmon and steelhead populations. Generally, most of the planning entities and citizen groups agree that while delisting salmon and steelhead is an important goal, ultimately the "broad sense" goal is to have thriving, abundant fish populations that provide ecological, social, cultural, and economic benefits in perpetuity for all citizens, as well as sufficient harvest to meet federal treaty obligations. The Oregon and Washington management unit plans include goals that go beyond delisting to provide for other socio-economic values. Such goals have not yet been identified for the Idaho management unit plan.

Northeast Oregon Management Unit Plan

The broad sense goal for the salmon and steelhead populations in the Northeast Oregon management unit was defined during a series of workshops held by the Oregon Snake River Stakeholders Group, which included local representatives of communities, agricultural water users, land managers, and industry and environmental interests. The management unit plan describes a goal for the Northeast Oregon populations that goes beyond delisting.

> *The naturally spawning Snake River Chinook and steelhead populations are sufficiently abundant, productive, and diverse (in terms of life histories and geographic distribution) throughout historical habitats so that they provide significant ecological, social, cultural, and economic benefits.*

To achieve benefits for current and future generations, the Northeast Oregon management unit plan seeks first to restore Snake River Chinook salmon and steelhead populations in Oregon subbasins to the point where their protection under the ESA is no longer needed. When this is achieved, efforts will move beyond the minimum steps necessary to delist the species to provide for other legislative mandates or social, economic, and ecological values.

The Oregon Department of Fish and Wildlife's broad sense goals include restoring passage and production of extirpated Oregon spring/summer Chinook salmon and steelhead populations above Hells Canyon Dam in the Powder, Malheur, and Owyhee River drainages to sustainable and harvestable levels. Priority tributaries for reintroduction include Pine Creek and the Powder River basin (Eagle, Daly, and Goose Creeks). They also include working with landowners to restore functionally extirpated populations in Big Sheep and Lookingglass Creeks.

Southeast Washington Management Unit Plan

The Southeast Washington management unit plan states that the ultimate goal of the fish restoration effort is to create conditions allowing the establishment of salmonid populations that are viable, harvestable, and of sufficient abundance to meet other socio-economic goals. Thus, delisting the salmonid populations is only the first step on the road to restoring populations within the management unit. The Snake River Salmon Recovery Board developed a vision statement based largely on statements from the Northwest Power and Conservation Council (NPCC 2004) subbasin plans for the Lower Snake River Mainstem, Tucannon River, Asotin Creek, and Walla Walla River. The statement describes broad sense goals for the Board's recovery plan for the Southeast Washington management unit.

> *Develop and maintain a healthy ecosystem that contributes to the rebuilding of key fish populations by providing abundant, productive, and diverse populations of aquatic species that support the social, cultural, and economic well-being of the communities both within and outside the recovery region.*

The vision statement includes: (1) meeting recovery goals established by NMFS for listed populations of anadromous fish species, (2) achieving sustainable harvests of key species within the recovery region and the Columbia River, and (3) realizing these objectives while recognizing that local culture and economies (agriculture, urban development, logging, power production, recreation, and other activities) are beneficial to the health of the human environment within the recovery region.

Idaho Management Unit Plan

The Idaho management unit plan does not identify broad sense goals that reach beyond achieving population levels that support delisting. Instead, the Idaho management unit plan focuses on improving the viability of the two species to the point that ESA protection is no longer required.

Tribal and Other Broad Sense Goals

Other parties, including Northwest tribes, also have broad sense goals that go beyond needs for ESA recovery and delisting. For example, part of the vision of the Nez Perce Tribe is that all species and populations of anadromous and resident fish and their habitats will be healthy and harvestable within Nez Perce usual and accustomed areas. The Nez Perce Tribe Department of Fisheries Resources Management Plan describes an approach to achieve this vision consistent with the Nimiipúu way of life and beliefs (available at www.nptfisheries.org). NMFS respects the broader goals of all our partners and the Plan is intended to be inclusive of these different goals.

3.3 Recovery Scenarios for ESU and DPS

The status levels targeted for populations within an ESU or DPS are referred to collectively as the "recovery scenario" for the ESU or DPS. The ICTRT recommends that all MPGs in an ESU/DPS should be viable before the ESU or DPS is considered at low risk of extinction. However, the ICTRT recognizes that a variety of recovery scenarios may lead to a viable ESU/DPS. These various recovery scenarios may reflect different combinations of viable populations and policy choices regarding acceptable risk levels.

Compatible with the ICTRT criteria, an ESU or DPS recovery scenario will likely have some populations meeting viability standards close to each other, and some populations meeting viability standards relatively distant from each other. The major objectives of the ICTRT's ESU/DPS- and MPG-level viability criteria are to ensure preservation of basic historical metapopulation processes: (1) genetic exchange across populations within an ESU or DPS over a long timeframe; (2) the opportunity for neighboring populations to serve as source areas in the event of local population extirpations; and (3) distribution of populations throughout an ESU or DPS so that they are not all susceptible to a specific localized catastrophic event (McElhany et al. 2000; ICTRT 2007).

The ICTRT incorporated the viability criteria into viable recovery scenarios for each Snake River spring/summer Chinook salmon and steelhead MPG (see Tables 3-1 and 3-2). The criteria (explained in Section 2.5) should be met for an MPG to be considered viable, or low (5 percent or less) risk of extinction, and thus contribute to the larger objective of ESU or DPS viability. These criteria are:

- At least one-half the populations historically present (minimum of two populations) should meet viability criteria (5 percent or less risk of extinction over 100 years).
- At least one population should be highly viable (less than 1 percent risk of extinction).
- Viable populations within an MPG should include some populations classified as "Very Large'" or "Large," and "Intermediate" reflecting proportions historically present.
- All major life-history strategies historically present should be represented among the populations that meet viability criteria.
- Remaining populations within an MPG should be maintained (25 percent or less risk of extinction) with sufficient abundance, productivity, spatial structure, and diversity to provide for ecological functions and to preserve options for ESU or DPS recovery.

- For MPGs with only one population, this population must be highly viable (less than 1 percent risk of extinction).

For each Snake River MPG, the ICTRT offered a detailed discussion of possible recovery scenarios that would allow each ESU or DPS to meet the viability criteria (ICTRT 2008). The ICTRT selected these combinations of target viability levels based on the populations' unique characteristics, such as run timing, population size, or genetics; major production areas in the MPG; and spatial distribution of the populations. However, although the ICTRT criteria provide that at least one population in each MPG should reach highly viable status, in most cases the team did not indicate which population that should be, because of the uncertainties of any population's response to recovery efforts. The ICTRT cautioned against prematurely closing off the options for any population.

Further, while not all populations in an MPG need to meet the viability criteria under most viable-MPG scenarios, the ICTRT strongly advised planners to attempt to improve more than the minimum number of populations to reach viable status. There are two primary reasons for this: First, based on current population dynamic theory, the ICTRT has recommended that all extant populations be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e., the less robust areas should not serve as significant population sinks). In fact, many populations will need to be improved from their current status to meet "maintained" status. Second, although the possible population sets suggested by the ICTRT would meet viability criteria for the ESUs, achieving recovery will likely require attempting recovery in more than those populations, because of the uncertainty of success of recovery efforts. A low-risk strategy will, thus, target more populations than the minimum for viability (ICTRT 2008).

While the management unit plans have adopted the ICTRT recovery scenarios, there are still choices to be made in designing recovery strategies, actions, and implementation plans. Where the ICTRT noted options, management unit planners have made decisions based on best available science concerning how to proceed and whether to target one population or another for viable or highly viable status. Even so, NMFS and the management unit planners recognize that the ICTRT's targeted recovery scenarios are not finite, and that the best options for achieving ESU and DPS viability, and thus delisting, may change over time based on fish response to recovery actions and natural factors, such as climate change. Thus, the recovery scenarios for the ESU and DPS remain flexible and will be updated in the future. Any viable MPG scenario satisfying the criteria in Section 2.5 is acceptable for achieving the recovery goal.

3.3.1 Recovery Scenario for Snake River Spring/Summer Chinook Salmon ESU

Table 3-1 shows the recovery scenario for the Snake River spring/summer Chinook salmon ESU. The table identifies each population in an MPG, its characteristics, and proposed role in a viable MPG recovery scenario. The proposed roles reflect a population's characteristics and current status; however, the recovery scenario remains flexible and will be updated in the future depending on population response to changes over time. Any MPG scenario that satisfies the viability criteria in Section 2.5 is acceptable to support recovery.

Table 3-1. Recovery Scenarios: Application of ICTRT Viability Criteria to Snake River Spring/Summer Chinook MPGs: Options for Viability (ICTRT 2007; NMFS 2016).

MPG & Population	Size Category	Adult Life History Type	Role in Scenario	Considerations
Lower Snake River Spring/Summer Chinook Salmon MPG: Applying ICTRT viability criteria, for this MPG to be viable, two populations should be viable, and one highly viable. Initial recovery efforts should focus on the extant population. Scoping efforts for potential reintroduction should be conducted as recovery planning progresses.				
Tucannon River	Intermediate	Spring	Highly Viable	The only extant population in the MPG.
Asotin Creek (functionally extirpated[19])	Basic	Spring	Consider for reintroduction as recovery efforts progress	ICTRT recommends that initial recovery efforts focus on extant populations, with scoping efforts for reintroduction conducted concurrently.
Grande Ronde/Imnaha Rivers Spring/Summer Chinook Salmon MPG: Applying ICTRT viability criteria, for this MPG to be viable at least four populations should meet viability criteria, with at least one highly viable; the rest should meet maintained status. The Imnaha River population has a unique life-history strategy and should meet the viability criteria. The Lostine/Wallowa River population and at least one from each of the following pairs: Catherine Creek or Upper Grande Ronde (both Large size), and Minam or Wenaha (both Intermediate size) should meet viability criteria. Distributing viable "Large" populations throughout the subbasin is preferable to having them clumped or contiguous. Hatchery supplementation programs are ongoing in the Imnaha, Wallowa-Lostine, Catherine Creek, and Upper Grande Ronde populations.				
Wenaha River	Intermediate	Spring	Viable or Highly Viable	Wenaha R. is most downstream, providing connectivity with other MPGs. Population has little spatial structure or diversity impairment. Wenaha R. and Minam R. populations are currently the most unaffected by hatchery fish.
Minam River	Intermediate	Spring	Viable or Highly Viable	Minam R. has have little spatial structure or diversity impairment. Wenaha R. and Minam R. populations are currently the most unaffected by hatchery fish.
Lostine/Wallowa Rivers	Large	Spring	Viable or Highly Viable	One of the populations that would likely achieve viability with least improvement.
Lookingglass Creek (functionally extirpated)	Basic	Spring	Consider options as ongoing reintroduction efforts progress	ICTRT recommends that initial recovery efforts focus on extant populations. Efforts to re-establish natural production are currently underway.
Catherine Creek	Large	Spring	Viable or Highly Viable	Large population, would likely require less improvement than the Upper Grande Ronde population to achieve viability. ICTRT recommends initial focus on Catherine Creek core area (equivalent to Intermediate population.)
Upper Grande Ronde River	Large	Spring	Viable or Maintained	Population has the poorest abundance/productivity status of all populations in MPG, would likely require the most improvement to achieve viability.

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[19] The ICTRT considers extirpated populations to be those that are entirely cut off from anadromy. Functionally extirpated populations are those of which there are so few remaining numbers that there are not enough fish or habitat in suitable condition to support a fully functional population.

MPG & Population	Size Category	Adult Life History Type	Role in Scenario	Considerations
Imnaha River	Intermediate	Spring/Summer	Viable or Highly Viable	Only population with spring/summer life history.
Big Sheep Creek (functionally extirpated)	Basic	Spring	Consider for reintroduction as recovery efforts progress	ICTRT recommends that initial recovery efforts focus on extant populations, i.e., the adjacent Imnaha River population, with scoping efforts for re-introduction conducted concurrently. Currently hatchery releases into Big Sheep Creek are from the adjacent Imnaha River population.
South Fork Salmon River Spring/Summer Chinook Salmon MPG: Applying ICTRT viability criteria, for MPG viability at least two populations should meet viability criteria and one should be highly viable; the rest should be maintained. MPG-level criteria require that the Little Salmon River population meet viability criteria because it is the only population in the MPG with spring/summer life history; however, the ICTRT recommends that recovery efforts focus on populations in the South Fork drainage because of the Little Salmon population's small size and high level of potential hatchery integration. Since two of the populations are classified as Large and two are classified as Intermediate, at least one population from each size class or the two Large populations must achieve viability.				
Little Salmon River (includes Rapid River)	Intermediate	Spring/Summer	Maintained	Only population with spring/summer life history. Size category is driven by small, adjunct tributaries where the spring life history is represented in the population, although minor. Location outside main drainage. Population is greatly influenced by Rapid River Hatchery production and releases.
South Fork Salmon River	Large	Summer	Viable or Highly Viable	Targeted for viability to achieve large-size requirement.
Secesh River	Intermediate	Summer	Viable or Highly Viable	Targeted for high viability. No supplementation and satisfies Intermediate-size requirement for MPG.
East Fork South Fork Salmon River	Large	Summer	Viable or Maintained	Ongoing supplementation exists in this population (Johnson Creek).
Middle Fork Salmon River Spring/Summer Chinook Salmon MPG: Applying ICTRT viability criteria, for this MPG to be viable, at least five populations should meet viability criteria, with one meeting highly viable status; remaining populations should be maintained. Big Creek should meet viability criteria as the only Large population. Two of the three Intermediate populations should meet viability criteria. All of the populations have high quality spawning and rearing habitat.				
Middle Fork Salmon below Indian Creek	Basic	Spring/Summer	Maintained	
Big Creek	Large	Spring/Summer	Viable or Highly Viable	Targeted for high viability. The only Large population in this MPG. Supports spring and summer run fish.
Camas Creek	Basic	Spring	Viable or Maintained	
Loon Creek	Basic	Spring/Summer	Viable or Highly Viable.	Targeted for viability because of geographic distribution in MPG and historic production potential.
Middle Fork Salmon above Indian Creek	Intermediate	Spring	Viable or Maintained	Upper Middle Fork mainstem is composed of a number of small tributaries (rather than a core, contiguous spawning area).
Sulphur Creek	Basic	Spring	Maintained	
Bear Valley Elk Creek	Intermediate	Spring	Viable or Highly Viable	Targeted for viability because of historical production potential and opportunity.
Marsh Creek	Basic	Spring	Viable or Highly Viable	Targeted for viability due to geographic distribution in MPG and historic production potential.
Chamberlain Creek	Intermediate	Spring	Viable or Highly Viable	Targeted for viability. Significant geographic position provides connectivity between MPGs. Population has unique, apparently persistent genetic characteristics.

MPG & Population	Size Category	Adult Life History Type	Role in Scenario	Considerations
Upper Salmon River Spring/Summer Chinook Salmon MPG: Applying ICTRT viability criteria, for this MPG to be viable, at least five populations should meet viability criteria and at least one should be highly viable; the rest should be maintained. At least three Large or Very Large populations should meet viability criteria. One Intermediate or larger population should meet viability criteria.				
North Fork Salmon River	Basic	Spring	Maintained	The most downstream population. However, relatively few data are available, and there have been substantial anthropogenic effects on population and habitat.
Panther Creek (functionally extirpated)	Intermediate	Spring	Not included in initial recovery strategies*	Functionally extirpated, but the only Intermediate population. A large population could be substituted for this population to meet viability criteria.
Lemhi River	Very Large	Spring	Viable or Highly Viable	Targeted for viability to provide proportional representation of class size. Lemhi historically may have had summer Chinook salmon production. Lemhi provides important connectivity to other MPGs, as a large, downstream population.
U. Salmon River Lower Mainstem, below Redfish Lake	Very Large	Spring/Summer	Maintained	
Pahsimeroi River	Large	Summer	Viable or Highly Viable	Targeted for viability. Only extant population in this MPG with summer life history.
East Fork Salmon River	Large	Spring/Summer	Viable or Highly Viable	Targeted for viability.
Yankee Fork	Basic	Spring	Maintained	Currently occupied by non-native stock.
Valley Creek	Basic	Spring	Viable or Highly Viable	Targeted for viability. Historically had larger production than most Basic populations.
U. Salmon River Upper mainstem, above Redfish Lake	Large	Spring	Viable or Highly Viable	Targeted for high viability. Population is at the geographic end of the ESU and MPG and provides proportional representation of class size.

* Because the ICTRT (2003) defined the Panther Creek population as functionally extirpated, the population is not included in the initial recovery strategies for achieving a viable MPG or a viable ESU. Thus the recovery plan does not designate a proposed status for this population. The primary recovery function of the population will be to contribute to the abundance, productivity, and spatial structure of the Upper Salmon River MPG and the ESU. However, as more information is gathered about the spring/summer Chinook salmon spawning in Panther Creek, it is possible that NMFS will select Panther Creek as one of the Upper Salmon River populations to reach low risk status as part of the MPG recovery strategy. This determination would then be integrated into the recovery plan.

3.3.2 Recovery Scenario for Snake River Basin Steelhead DPS

Table 3-2 shows the recovery scenario for the Snake River Basin steelhead DPS. It identifies each population in an MPG, its characteristics, and proposed role in a viable MPG recovery scenario. The proposed roles reflect a population's characteristics and current status; however, the recovery scenario remains flexible and will be updated in the future depending on population response to changes over time. Any MPG scenario that satisfies the viability criteria in Section 2.5 is acceptable to support recovery.

Table 3-2. Recovery Scenarios: Application of ICTRT Viability Criteria to Snake River Basin Steelhead MPGs: Options for Viability (ICTRT 2007; NMFS 2016).

MPG & Population	Size Category	Adult Life History Type	Role in Scenario	Considerations
Lower Snake River Steelhead MPG: Applying ICTRT viability criteria, for this MPG to be viable, two populations should be viable and one should be highly viable.				
Tucannon River	Intermediate	A-Run	Viable or Highly Viable	Currently rated as Maintained.
Asotin Creek	Basic	A-Run	Viable or Highly Viable	Currently rated as Maintained.
Clearwater River Steelhead MPG: Applying ICTRT viability criteria, for this MPG to be viable at least three populations should be viable and one of these should be highly viable; the rest should meet criteria for maintained. Since NF Clearwater population is extirpated, Lower Clearwater populations, as only Large or Very Large population, should meet viability criteria. At least two of three Intermediate populations should meet viability criteria (viable or highly viable). At least one A-run and one B-run population should meet viability criteria.				
Lower Main Clearwater River	Large	Low B-Run	Viable or Highly Viable	Targeted for viability. The only extant Large population. Contains A-run and B-run fish with B-run making up <15% of population.
South Fork Clearwater River	Intermediate	High B-Run	Viable or Maintained	High degree of hatchery influence. B-run steelhead make up >40% of population.
North Fork Clearwater River	Large		Not part of recovery scenario.	Population is extirpated.
Lolo Creek	Basic	High B-Run	Viable or Highly Viable	B-run steelhead constitute >40% of Lolo Creek population.
Selway River	Intermediate	High B-Run	Viable or Maintained	Targeted for viability. B-run fish make up >40% of population. Very little hatchery influence. Much of habitat in wilderness protection.
Lochsa River	Intermediate	High B-Run	Viable or Highly Viable	Targeted for High Viability. B-run fish constitute >40% of population. Very little hatchery influence. Much of habitat in wilderness protection. Area accessible for data collection using current monitoring programs.
Grande Ronde River Steelhead MPG: Applying ICTRT viability criteria, for this MPG to be viable at least two populations should be viable, with one highly viable; the rest should meet criteria for maintained. The Upper Grande Ronde mainstem is the only Large population and needs to be part of the viability scenario.				
Lower Grande Ronde River	Intermediate	A-Run	Viable or Maintained	Lower Grande Ronde population receives hatchery releases. The population would contribute to spatial structure in the lower MPG.
Joseph Creek	Basic	A-Run	Viable, Highly Viable or Maintained	Recently rated as highly viable. Joseph Creek population has the least hatchery influence. The population contributes to spatial structure in the lower MPG.
Wallowa River	Intermediate	A-Run	Viable or Maintained	Wallowa includes multiple core areas and some unique habitat characteristics (e.g. Eagle Cap), but supports a hatchery (with little straying)
Upper Grande Ronde River	Large	A-Run	Viable or Highly Viable.	Recently tentatively rated as viable. This is the only Large population in the MPG. Currently receives no hatchery releases.
Imnaha River Steelhead MPG: Applying ICTRT viability criteria, for this MPG to be viable, the MPG's one population should meet highly viable criteria.				
Imnaha River	Intermediate	A-Run	Highly Viable	Targeted for high viability. Only population in MPG.

MPG & Population	Size Category	Adult Life History Type	Role in Scenario	Considerations
Salmon River Steelhead MPG: Applying ICTRT viability criteria, for this MPG to be viable at least six of the twelve populations should meet viability criteria, with at least one highly viable; the rest should meet maintained criteria. At least four of the Intermediate populations should meet viability criteria. At least two of the six viable populations should be B-run. Spatial structure should be a strong consideration in this large MPG. Populations meeting viability criteria should spread across Upper Salmon, Middle Fork, South Fork, and Lower Salmon. A-run populations should also be represented since they made up two-thirds of the total populations in this MPG. Where possible, maintaining the distribution of A and B run populations would most closely mirror historical (lower-risk) conditions.				
Little Salmon and Rapid Rivers	Intermediate	A-Run	Viable or Maintained	Population has some hatchery influence, which tends to be out-of-MPG (Dworshak B, Hells Canyon A). There has been little monitoring of the population except Rapid River.
South Fork Salmon River	Intermediate	High B-Run	Viable or Highly Viable	Targeted for viability. One of two populations in MPG with a strong B-run component (>40% of population). No hatchery influence or effects. Natural river system characteristics. Located at downstream end of MPG. Would provide geographic distribution of viable populations.
Secesh River	Basic	High B-Run	Viable or Maintained	One of two populations in MPG with a strong B-run (>40% of population). Genetically distinct. No hatchery influence or effects. Natural river system characteristics.
Lower Middle Fork Salmon River Tributaries	Intermediate	Moderate B-Run	Viable or Highly Viable	Targeted for viability. Moderate B-run component (15-40%) of population with very little hatchery influence. Natural river system within the wilderness boundaries.
Upper Middle Fork Salmon River	Intermediate	Moderate B-Run	Viable or Highly Viable.	Targeted for viability. Moderate B-run component (15-40%) of population. Very little hatchery influence. Geographic separation from other targeted populations. Natural river system within wilderness boundaries.
Chamberlain Creek	Basic	A-Run	Viable or Highly Viable	Targeted for viability. A-run life-history strategy with very little hatchery influence. Natural river system characteristics. Population provides connectivity between populations in the South Fork, Middle Fork, and Upper Salmon River drainages
Panther Creek	Basic	A-Run	Viable or Maintained	Targeted for viability. Some hatchery influence, likely from out-of-MPG. Watershed is publically owned, could become very productive. Fewer water withdrawals than other populations.
North Fork Salmon River	Basic	A-Run	Viable or Maintained	Some hatchery influence from out-of-MPG stock.
Lemhi River	Intermediate	A-Run	Viable or Maintained	Targeted for viability. Population has some hatchery influence from out-of-MPG. There has been little monitoring of the population.
Pahsimeroi River	Intermediate	A-Run	Viable or Maintained	Population has some hatchery influence from out-of-MPG. There has been little monitoring of the population. Active hatchery supplementation.
East Fork Salmon River	Intermediate	A-Run	Viable or Maintained	Population has hatchery influence, with some from out-of-MPG. There has been little monitoring of the population.
Upper Salmon River	Intermediate	A-Run	Viable or Maintained	Population has some hatchery influence, with some from out-of-MPG. There has been little monitoring of the population.
Hells Canyon Steelhead MPG: This MPG is not part of the Snake River Basin steelhead DPS recovery scenario. With the possible exception of several small tributaries below Hells Canyon Dam, this MPG is largely extirpated. Fish that currently occupy the small tributaries below the dam may be the only remnants of this MPG. A key research need is to determine whether these are remnants or hatchery strays. The state of Oregon has a broad sense goal to restore passage and production above Hells Canyon Dam.				
Tribs. below Hells Canyon D.			Not part of recovery scenario	Do not appear large enough (separate or combined) to support independent population.
Powder River (extirpated)			Not part of recovery scenario	
Burnt River (extirpated)			Not part of recovery scenario	
Weiser River (extirpated)			Not part of recovery scenario	

3.4 NMFS Delisting Criteria and Decisions

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS from the Federal List of Endangered and Threatened Wildlife and Plants, NMFS must determine that the ESU or DPS, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, "…to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12…)." NMFS applies two kinds of these criteria: biological viability criteria, which deal with population or demographic parameters, and "threats" criteria, which relate to the five listing factors detailed in the ESA section 4(a)(1). The threats criteria define the conditions under which the listing factors, or threats, can be considered to be addressed or mitigated. Together, the biological viability and threats criteria make up the "objective, measurable criteria" required under section 4(f)(1)(B) for the delisting decision.

The delisting criteria are based on the best available scientific information (including the ICTRT's biological viability criteria) and incorporate the most current understanding of the ESU/DPS and the threats it faces. As this recovery plan is implemented, additional information will likely become available that can increase certainty about whether the threats have been ameliorated, whether improvements in population and ESU/DPS status have occurred, and whether linkages between threats and changes in salmon or steelhead status are understood. These criteria will be reviewed periodically, as new information becomes available.

3.4.1 Biological Viability Criteria

To remove the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS from the list of threatened and endangered species, NMFS must determine that the ESU and DPS have met criteria for low risk or viable status. NMFS has considered the ICTRT's biological viability criteria (see Section 2.5) (ICTRT 2007), the principles presented in the Viable Salmonid Populations paper (McElhany et al. 2000), the recovery scenarios (summarized in Tables 3-1 and 3-2), population-level information and goals in the management unit plans, and the best available information on population and ESU/DPS status and new advances in risk evaluation methodologies. NMFS has concluded that the ICTRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the management unit plan recovery scenarios (summarized in Tables 3-1 and 3-2 of this recovery plan) and population-level abundance, productivity goals (see Chapters 6 and 7) and has concluded that they also adequately describe the characteristics of an ESU/DPS that no longer needs the protections of the ESA. NMFS endorses the recovery scenarios and population-level goals in the management unit plans (summarized here in Tables 3-1 and 3-2 and Sections 6.2 and 7.2) as one of multiple possible scenarios consistent with delisting.

NMFS therefore proposes the following biological viability criteria for the listed ESU and DPS, as defined by the ICTRT (2007):

ESU/DPS Viability Criterion

- All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU or DPS should be at low risk.

MPG-Level Viability Criteria

- An MPG meeting the ICTRT (2007) viability criteria described in Section 2.5 and Section 3.3 would be at low risk. The recovery scenarios in Tables 3-1 and 3-2 are consistent with these biological viability criteria.

3.4.2 Listing Factors/Threat Criteria

Threats, in the context of salmon recovery, are understood as the activities or processes that cause the biological and physical conditions that limit salmon survival (the limiting factors). Threats also refer directly to the listing factors detailed in section 4(a)(1) of the ESA. Listing factors are those features that are evaluated under section 4(a)(1) when initial determinations are made whether to list species for protection under the ESA.

ESA section 4(a)(1) listing factors are the following:

A. The present or threatened destruction, modification, or curtailment of the species’ habitat or range;
B. Over-utilization for commercial, recreational, scientific, or educational purposes;
C. Disease or predation;
D. Inadequacy of existing regulatory mechanisms; and
E. Other natural or human-made factors affecting the species’ continued existence.

At the time of a delisting decision for the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS, NMFS will examine whether the section 4(a)(1) listing factors have been addressed. To assist in this examination, NMFS will use the listing factors (or threats) criteria described below, in addition to evaluation of biological recovery criteria and other relevant data and policy considerations. The threats need to have been addressed to the point that delisting is not likely to result in their re-emergence.

NMFS recognizes that perceived threats, and their significance, can change over time due to changes in the natural environment or changes in the way threats affect the entire life cycle of salmon. Indeed, this has already happened. As discussed earlier, some threats perceived as significant effects on Snake River spring/summer Chinook salmon and Snake River Basin steelhead at the time of listing, such as harvest mortality, have since been addressed through management adjustments and now pose little danger to species viability. Other threats, such as the mainstem hydropower system, continue to affect survival through the migration corridor. At the same time, new threats, such as those posed by climate change, are emerging. Consequently, NMFS expects that the relative priority of threats will continue to change over time and that new threats may be identified. During its 5-year reviews, NMFS will review the listing factor criteria as they apply at that time.

The specific criteria listed below for each of the relevant listing/delisting factors help to ensure that underlying causes of decline have been addressed and mitigated before a species is considered for delisting. NMFS expects that if the actions described in the Plan are implemented, they will make substantial progress toward meeting the following listing factor (threats) criteria for Snake River spring/summer Chinook salmon and Snake River Basin steelhead. Chapter 5 discusses the regional-level threats and limiting factors that currently affect Snake River spring/summer Chinook salmon and Snake River Basin steelhead viability. The three management unit plans discuss limiting factors and threats specific to populations in the management units.

NMFS will use the listing factor criteria below in determining whether an ESU or DPS has recovered to the point that it no longer requires the protections of the ESA:

A: The present or threatened destruction, modification, or curtailment of a species' habitat or range

To determine that the ESU/DPS is recovered, threats to habitat should be addressed as outlined below:

1. Passage obstructions (e.g., dams and culverts) are removed or modified to improve survival and restore access to historically accessible habitat where necessary to support recovery goals.
2. Flow conditions that support adequate rearing, spawning, and migration are achieved through management of mainstem and tributary irrigation and hydropower operations, and through increased efficiency and conservation in other consumptive water uses such as municipal supply.
3. Passage conditions through mainstem hydropower systems (including dams, reservoirs and transportation) consistently meet or exceed performance standards from associated biological opinions and (a) accurately account for total mortality (i.e., juvenile passage and adult passage mortalities) and constrain mortality rates to levels that are consistent with recovery; and (b) are implemented in such a way as to avoid deleterious effects on populations or negative effects on the distribution of populations.

4. Water quality (including temperature, dissolved oxygen, total dissolved gas, and turbidity parameters) is adequate to support spawning, rearing, and migration consistent with maintaining viability.
5. Shallow-water habitat in the Columbia River estuary is protected and restored to provide adequate feeding, growth, and refuge from predators during smolt transition to salt water.
6. Forest management practices that protect watershed and stream functions are implemented on federal, state, tribal, and private lands.
7. Agricultural practices, including grazing, are managed in a manner that protects and restores riparian areas, floodplains, and stream channels, and protects water quality from sediment, pesticide, herbicide, and fertilizer runoff.
8. Urban and rural development (including land use conversion from agriculture and forestland to residential uses) does not reduce water quality or quantity, or impair natural stream conditions so as to impede achieving recovery goals.
9. The effects of toxic contaminants on salmonid fitness and survival are understood and are sufficiently limited so as not to affect recovery.
10. Channel function (including vegetated riparian areas, canopy cover, stream-bank stability, off-channel and side-channel habitats, natural substrate and sediment processes, and channel complexity) are restored to provide adequate rearing and spawning habitat.
11. Floodplain function and the availability of floodplain habitats for salmon are restored to a degree sufficient to support a viable ESU/DPS. This restoration should include connectedness between river and floodplain and the restoration of impaired sediment delivery processes.
12. Routine construction and maintenance practices are managed to reduce or eliminate mortality of listed species.

B: Over-utilization for commercial, recreational, scientific or educational purposes

To determine that the ESU/DPS is recovered, any utilization for commercial, recreational, scientific, or educational purposes should be managed as outlined below:

1. Fishery management plans are in place that (a) accurately account for total fishery mortality (i.e., both landed catch and non-landed mortalities) and constrain mortality rates to levels that are consistent with recovery; and (b) are implemented in such a way as to avoid deleterious genetic effects on populations or negative effects on the distribution of populations.
2. Federal, tribal, and state rules and regulations are effectively enforced.
3. Technical tools accurately assess the effects of the harvest regimes so that harvest objectives are met but not exceeded.

4. Handling of fish is minimized to reduce indirect mortalities associated with educational or scientific programs, while recognizing that monitoring, research, and education are key actions for conservation of the species.

C: Disease or predation

To determine that the ESU/DPS is recovered, any disease or predation that threatens its continued existence should be addressed as outlined below:

1. Hatchery operations do not subject targeted populations to deleterious diseases and parasites and do not result in increased predation rates of wild fish.
2. Predation by avian predators is managed in a way that allows for recovery of salmon and steelhead populations.
3. The northern pikeminnow and other fish predators are managed to reduce predation on the targeted populations.
4. Populations of introduced exotic predators such as smallmouth bass, walleye, and catfish are managed such that competition or predation does not impede recovery.
5. Predation below Bonneville Dam by marine mammals does not impede achieving recovery.
6. Physiological stress and physical injury that may cause disease or increase susceptibility to pathogens during rearing or migration is reduced during critical low flow periods (e.g. low water years) or poor passage conditions (e.g. at diversion dams or bypasses).

D: The inadequacy of existing regulatory mechanisms

To determine that the ESU/DPS is recovered, any inadequacy of existing regulatory mechanisms that threatens its continued existence should be addressed as outlined below:

1. Adequate resources, priorities, regulatory frameworks, plans, binding agreements and coordination mechanisms are established and/or maintained for effective enforcement of:
    a. Land and water use regulations that protect and restore habitats, including water quality and water quantity;
    b. Hydropower system operations;
    c. Flood control and other water use systems;
    d. Hatchery operations; and
    e. Effective management of fisheries.
2. Habitat conditions and watershed functions are protected through land-use planning that guides human population growth and development.

3. Habitat conditions and watershed function are protected through regulations, land use plans, and binding agreements that govern resource extraction such as timber harvest and gravel mining.
4. Regulatory, control, and education measures to prevent additional exotic plant and animal species invasions are in place.
5. Sufficient priority instream water rights for fish habitat are in place.

E: Other natural or human-made factors affecting [the species'] continued existence

To determine that the ESU/DPS is recovered, other natural and manmade threats to its continued existence should be addressed as outlined below:

Hatcheries:

1. Hatchery programs are being operated in a manner that is consistent with maintaining viability of the ESU/DPS, including use of appropriate criteria for integration of hatchery populations and extant natural-origin populations inhabiting watersheds where the hatchery fish return.
2. Hatcheries operate using appropriate ecological, genetic, and demographic risk containment measures for (1) hatchery-origin adults returning to natural spawning areas, (2) release of hatchery juveniles, (3) handling of natural-origin adults at hatchery facilities, (4) withdrawal of water for hatchery use, (5) discharge of hatchery effluent, and (6) maintenance of fish health during their propagation in the hatchery.
3. Monitoring and evaluation plans are implemented to measure population status, hatchery effectiveness, and ecological, genetic, and demographic risk containment measures.
4. Nutrient enrichment programs are implemented where it is determined that nutrient limitations are a significant limiting factor for steelhead production and that nutrient enrichment will not impair water quality.

Climate Change:

1. The potential effects of climate change have been evaluated and incorporated into management programs for hydropower, flood control, instream flows, water quality, fishery management, hatchery management, and reduction and elimination of exotic plant and animal species invasions.

3.5 Delisting Decision

The biological viability criteria (described in Section 3.4.1) and the listing factors (threats) criteria (described in Section 3.4.2), define conditions that, when met, would result in a determination that the Snake River Spring/Summer Chinook salmon ESU and Snake River Basin Steelhead DPS are not likely to become endangered within the foreseeable future throughout all or a significant portion of its range. NMFS will update the criteria, as appropriate, if new information becomes available.

In accordance with our responsibilities under section 4(c)(2) of the Act, NMFS will conduct reviews of Snake River spring/summer Chinook salmon and Snake River Basin steelhead every five years to evaluate the status of the species and gauge progress toward delisting. Status reviews could be conducted in less than five years if conditions warrant. Status reviews will be based on the best scientific information available at that time and take into account the following:

- The biological viability criteria (ICTRT 2007) and listing factor (threats) criteria described above.
- The management programs in place to address the threats.
- Principles presented in the Viable Salmonid Populations paper (McElhany et al. 2000).
- Best available information on population and ESU/DPS status and new advances in risk evaluation methodologies.
- Other considerations, including: the number and status of extant spawning groups; the status of the major spawning groups; linkages and connectivity among groups; the diversity of life history and phenotypes expressed; and considerations regarding catastrophic risk.

4. Current Status Assessment

This chapter summarizes the current status of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS, and their MPGs and populations, based on ICTRT viability assessment results (ICTRT 2007 and 2008, updated in 2010), the Northwest Fisheries Science Center's recent 2015 *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest* (NWFSC 2015), and NMFS' *5-Year Review: Summary and Evaluation of Snake River Sockeye, Snake River Spring-Summer Chinook, Snake River Fall-Run Chinook, and Snake River Basin Steelhead* (NMFS 2016). It also describes the gaps between current status and proposed status. The NWFSC assessed the current status of each population using the biological criteria and assigned a current viability rating. In some cases, the chapter also summarizes findings of other status reviews and NMFS publications, including the Northwest Fisheries Science Center's previous *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). The management unit plans for the Northeast Oregon, Southeast Washington, and Idaho populations provide more information on MPG and population status.

4.1 Current Status of Snake River Spring/Summer Chinook Salmon ESU

This section describes the current status of the Snake River spring/summer Chinook salmon ESU. Section 4.1.1 summarizes the viability assessment results for independent populations in each MPG. Section 4.1.2 discusses the gap between the current and proposed status.

4.1.1 Current Status

Currently, the majority of extant spring/summer Chinook salmon populations in the Snake River spring/summer Chinook salmon ESU remain at high overall risk of extinction, with a low probability of persistence within 100 years.[20] Since the 2010 status review (Ford 2011), one of the Chinook salmon populations (Chamberlain Creek in the Middle Fork Salmon River MPG) improved to an overall rating of maintained due to increased abundance. Natural-origin abundance in most other populations in the ESU also increased in recent years, but the increases were not substantial enough to change the viability ratings. Relatively high ocean survival in recent years is believed to have been a major contributing factor to recent abundance patterns (NWFSC 2015). Natural-origin spawning abundance remains below the minimum thresholds set by the ICTRT. As a result, all five of the MPGs comprised by these populations also fail to achieve the ICTRT's criteria for viability (NWFSC 2015).

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[20] As described in Section 2.3, the ICTRT recommended methods for evaluating the status of salmon and steelhead populations in the Interior Columbia domain. The ICTRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity, and then integrating these assessments into an overall assessment of population risk and persistence probability. Management unit recovery planners and the ICTRT followed this approach to assess the current status of the populations. Information from these assessments and NMFS' latest status review is summarized here. The information is consistent with conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest* (NWFSC 2015).

Low abundance and poor productivity remain the primary obstacles to viability for all of the Snake River spring/summer Chinook salmon populations. Most of the populations also exhibit reduced spatial structure and diversity. The latest status review shows that ten Snake River spring/summer Chinook salmon 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 Middle Fork Salmon River MPG, decreased in both abundance and productivity (NWFSC 2015). The relatively low natural production rates and spawning levels below minimum abundance thresholds remain a major obstacle to viability for populations across the ESU. The ability of populations to be self-sustaining in the wild through normal periods of relatively low ocean survival continues to be uncertain.

Recent conclusions regarding the status of the Snake River spring/summer Chinook salmon ESUs five MPGs are summarized below from the *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest* (NWFSC 2015) and *5-Year Review: Summary & Evaluation of Snake River Sockeye, Snake River Spring-Summer Chinook, Snake River Fall-Run Chinook, and Snake River Basin Steelhead* (NMFS 2016). The three management unit plans describe the status of the populations.

Lower Snake River MPG

The biological viability criteria (discussed in Section 3.4.1) call for both populations in this MPG to be restored to viable status, with one highly viable. Current abundance and productivity remain the major obstacle for viability of the Tucannon River population, the only extant population in this MPG. Natural spawning abundance (10-year geometric mean) for the population has increased but persists well below the minimum abundance threshold. Natural productivity has decreased since the previous 2010 review (Ford 2011) and continues to limit population viability. Research indicates that prespawn mortality in the Tucannon River has been relatively high recently; efforts continue to quantify and identify potential causes of this loss (Bumgarner and Dedloff 2015; NWFSC 2015). The Tucannon River also has an ongoing supplementation program and hatchery returns have constituted about a third of spawning in natural areas in recent years. The population is rated at high risk for abundance/productivity and moderate risk for spatial structure/diversity, with an overall rating of high risk (NWFSC 2015).

The Asotin Creek population is functionally extirpated, and it is uncertain whether the population is critical to the functioning of the MPG. The ICTRT recommended evaluating the potential for reintroducing production in Asotin Creek as recovery planning progresses.

Grande Ronde/Imnaha Rivers MPG

The biological viability criteria call for a minimum of four populations in this MPG to achieve viable status, with at least one highly viable. Currently, all populations in this MPG are rated at overall high risk. All extant populations in the MPG, with the exception of the Wenaha River population, have shown increases in natural-origin spawner abundance in recent years, although each population lingers below their respective minimum abundance thresholds. Three of the populations (Lostine/Wallowa Rivers, Catherine Creek, and Upper Grande Ronde River) have exhibited moderately positive trends in total spawning abundance since 1995, and the other three have had slightly positive (Minam River and Imnaha River) or negative (Wenaha River) trends. All of the populations have also seen a recent increase in natural-origin productivity; however, geometric mean productivity estimates continue to be relatively low for all populations in the MPG (NWFSC 2015).

All six extant populations in this MPG are rated at moderate risk for diversity. The extant populations had relatively high hatchery spawner proportions in the 1990s, reflecting the large-scale use of out-of-basin stock (Rapid River) in local releases during that period. Release programs for the populations were transitioned to incorporate local natural-origin broodstock in the mid-1990s. Lookingglass Creek, although considered an extirpated population, has an integrated hatchery recovery program, with the long-term goal to reintroduce and restore locally adapted spring summer Chinook salmon into Lookingglass Creek. Currently, five of the six extant population tributaries and Lookingglass Creek have targeted hatchery releases. The current local broodstock-based hatchery programs in three of the basins are designed to supplement natural spawning while contributing to meeting mitigation objectives for harvest. The Minam River and Wenaha River populations do not have direct supplementation programs. (NWFSC 2015). The Imnaha River has an ongoing integrated hatchery program that incorporates natural-origin broodstock.

For spatial structure/diversity, the Catherine Creek population is rated at moderate risk and the Upper Grande Ronde River population is at high risk. The Upper Grande Ronde River population's rating of high risk for spatial structure contributes to its high risk for spatial structure/diversity. The remaining extant populations (Wenaha River, Minam River, and Imnaha River) are rated at moderate risk for spatial structure/diversity.

South Fork Salmon River MPG

The viability criteria call for two of the four populations in this MPG to achieve viable status, with at least one highly viable. Currently, all four spring/summer Chinook salmon populations in the South Fork Salmon River MPG remain at overall high risk of extirpation. Natural spawning abundance has increased in recent years for three of the populations (the South Fork Salmon River, East Fork South Fork Salmon River, and Secesh River populations), but the increases were lower than in the Middle Fork Salmon River and Upper Salmon River MPGs, with the exception of the East Fork South Fork Salmon River population. The high relative increase in abundance for the East Fork South Fork Salmon River population may partially reflect a significant level of direct hatchery supplementation. The latest status review indicates that productivity has decreased in the South Fork Salmon River and East Fork Salmon River populations, with no change in the Secesh River population. Productivity estimates for the three populations, however, are generally higher than estimates for populations in other Snake River spring/summer Chinook salmon MPGs. Combined estimates for abundance and productivity show that viability ratings remain at high risk, although survival/capacity gaps relative to moderate and low risk are smaller than for other ESU populations (NWFSC 2015).

Three of the four populations in the South Fork Salmon River MPG have ongoing hatchery programs, although hatchery proportions for two of the three populations decreased marginally in the most recent 5-year update (NWFSC 2015). The Secesh River continues to show low hatchery proportions, reflecting some straying for hatchery programs in adjacent populations. Spatial structure/diversity risks are currently rated moderate for the South Fork Salmon River population (relatively high proportion of hatchery spawners) and low for the Secesh, East Fork South Fork, and Little Salmon River populations. The Little Salmon River population includes returns from large-scale hatchery releases but some of its side tributary spawning sites likely have low hatchery contributions.

Middle Fork Salmon River MPG

The viability criteria call for at least five or the nine populations in this MPG to achieve viable status, with at least one highly viable. Currently, all but one population (Chamberlain Creek) in the Middle Fork Salmon River MPG rate at overall high risk of extirpation. The Chamberlain Creek population rates as maintained, primarily due to an increase in natural-origin abundance. The other eight populations in this MPG remain at high risk for abundance/productivity. Natural spawner abundance also increased in the Big, Camas, Sulphur, Marsh, and Bear Creek populations and Upper Middle Fork Salmon River population since the last status review, but the increases were not enough to lower their abundance/productivity risk. Sulphur Creek was the only population to show increases in both abundance and productivity between the 2010 and 2015 status reviews, but both metrics remain extremely low for this population and far below viability levels. One population, Loon Creek, decreased in both abundance and productivity. As in the previous ICTRT assessment, abundance/productivity estimates for Bear Valley Creek and Chamberlain Creek (limited data series) are the closest to meeting viability minimums among the populations.

The Chamberlain, Marsh, and Bear Valley Creek populations achieved a spatial structure/diversity rating of low risk. Spatial structure/diversity risk ratings for the other Middle Fork Salmon River populations are moderate, driven largely by moderate ratings for genetic structure assigned by the ICTRT because of uncertainty arising from the lack of direct samples from within the component populations. Hatchery proportions for populations in the Middle Fork Salmon River MPG are based on carcass recoveries and remain very low, indicating straying rates as there are no direct hatchery release programs in the river basin. The Lower Middle Fork Salmon River Mainstem population remains at high risk for spatial structure loss.

Upper Salmon River MPG

The viability criteria call at least five of the nine populations in this MPG to achieve viable status, with at least one highly viable. Currently all eight extant populations in the Upper Salmon River MPG remain at overall high risk. The latest status review showed strong positive abundance and productivity trends for most populations in the MPG; with the exception of the Salmon River Lower Mainstem population, which saw a decline in abundance, and the Lemhi River population which has shown a relatively flat trend in total abundance since 1995. The Upper Salmon River Upper Mainstem population (above Redfish Lake Creek) and Pahsimeroi River population have the highest abundance/productivity of the populations. The estimated productivity for the Yankee Fork Salmon River population decreased since the prior review, and was the lowest of all populations in the MPG. All of the populations remain at high abundance/productivity risk (NWFSC 2015).

Spatial structure and diversity ratings vary considerably across the MPG. Four of the eight populations (North Fork Salmon River, Upper Salmon River Lower Mainstem, Valley Creek, and Upper Salmon River Upper Mainstem) are rated at low or moderate risk for overall spatial structure/diversity and could achieve viable status with improved abundance and productivity. The high spatial structure/diversity risk rating for the Lemhi River population is driven by a substantial loss of access to tributary spawning and rearing habitats, and the associated reduction in life-history diversity. High spatial structure/diversity ratings for the Pahsimeroi River, East Fork Salmon River, and Yankee Fork Salmon River populations reflect a combination of habitat loss and reduced diversity. Four of the seven populations in the MPG with sufficient information to directly estimate hatchery contributions had very low hatchery proportions (Lemhi River, East Fork Salmon River, Valley Creek, and Upper Salmon River Lower Mainstem). The most recent five-year mean for the Pahsimeroi River population was also relatively low (NWFSC 2015). Hatchery contributions to the Yankee Fork Salmon River population have increased substantially in recent years, reflecting returns from a large-scale supplementation effort.

4.1.2 Gap between Current and Proposed Status

Table 4-1 shows the current and proposed status for each Snake River spring/summer Chinook salmon population. Management unit recovery planners coordinated with NMFS in making decisions about the proposed status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities.

Table 4-1. Snake River Spring/Summer Chinook Salmon ESU Recovery Strategy and Current and Proposed Population Status.

Major Population Group	Population	Contribution to Recovery	Current Status[1]	Proposed Status
Lower Snake River MPG	Tucannon River	Primary	High Risk	Highly Viable
	Asotin Creek	Consider reintroduction	Functionally extirpated	
Grande Ronde/ Imnaha Rivers MPG	Wenaha River	Primary	High Risk	Viable or Highly Viable
	Minam River	Primary	High Risk	Viable or Highly Viable
	Lostine/Wallowa Rivers	Primary	High Risk	Viable or Highly Viable
	Lookingglass Creek	Consider reintroduction	Functionally extirpated	
	Catherine Creek	Primary	High Risk	Viable or Highly Viable
	U. Grande Ronde River	Supporting	High Risk	Viable of Maintained
	Imnaha River	Primary	High Risk	Viable or Highly Viable
	Big Sheep Creek	Consider reintroduction	Functionally extirpated	
South Fork Salmon River MPG	Secesh River	Primary	High Risk	Highly Viable
	EF South Fork Salmon	Supporting	High Risk	Maintained
	South Fork Salmon	Primary	High Risk	Viable
	Little Salmon River	Supporting	High Risk	Maintained
Middle Fork Salmon River MPG	MF Salmon below Indian Cr	Supporting	High Risk	Maintained
	Big Creek	Primary	High Risk	Highly Viable
	Camas Creek	Supporting	High Risk	Maintained
	Loon Creek	Primary	High Risk	Viable
	MF Salmon above Indian Cr	Supporting	High Risk	Maintained
	Sulphur Creek	Supporting	High Risk	Maintained
	Bear Valley Elk Creek	Primary	High Risk	Viable
	Marsh Creek	Primary	High Risk	Viable
	Chamberlain Creek	Primary	Maintained	Viable
Upper Salmon River MPG	North Fork Salmon River	Supporting	High Risk	Maintained
	Lemhi River	Primary	High Risk	Viable
	Salmon River Lower Mainstem	Supporting	High Risk	Maintained
	Pahsimeroi River	Primary	High Risk	Viable
	East Fork Salmon River	Primary	High Risk	Viable
	Yankee Fork Salmon River	Supporting	High Risk	Maintained
	Valley Creek	Primary	High Risk	Viable
	Salmon River Upper Mainstem	Primary	High Risk	Viable or Highly Viable
	Panther Creek	Consider reintroduction	Functionally extirpated	

[1] Population status is based on viability criteria: highly viable (less than 1% risk of extinction in 100 years), viable (5% or less risk of extinction), maintained (6 to 25% risk of extinction), high risk (more than 25% risk of extinction).

The most recent status review indicates that very large improvements will be needed to bridge the gap between the current status and proposed status for many of the populations to support recovery of the Snake River spring/summer Chinook salmon ESU (NWFSC 2015). Currently all but one of the populations in the ESU are rated at high overall risk, with a low probability of persistence in 100 years. Chamberlain Creek, in the Middle Fork Salmon River MPG, improved to an overall rating of maintained due to an increase in abundance. Natural-origin abundance has also increased recently in most other populations in the ESU, but larger increases are needed to improve overall viability ratings.

There is a considerable range in the relative improvements to life cycle survivals or limiting life stage capacities required for the different populations to attain viable status. In general, populations within the South Fork Salmon River MPG have the lowest gaps among MPGs. The other multiple population MPGs each have a range of relative gap levels. Targeted populations for each MPG recovery strategy will need to decrease their abundance/productivity risk to reach their proposed status, whether it is highly viable with very low (<1 percent) risk, viable with low (1-5 percent) risk, or maintained with moderate (6-25 percent) risk. The current spatial structure/diversity risk for many of the populations will also need to improve for many of the populations to meet their proposed status. Four populations from the three MPGs (Catherine Creek, and the Upper Grande Ronde, Lemhi, and Lower Middle Fork Salmon River populations) currently remain at high risk for spatial structure loss. Further, populations in three of the four MPGs are undergoing active supplementation with local broodstock hatchery programs. Efforts to evaluate key assumptions and impacts are underway for several of the programs. Improvements in all viable salmonid population parameters will increase the ability of the target populations to become self-sustaining through normal periods of fluctuating ocean survival and future habitat transformations posed by climate change.

At this time, no single population is targeted for highly viable status in the Grande Ronde/ Imnaha Rivers MPG. The ICTRT determined that the Minam River and Catherine Creek populations would require the least improvement in survival to achieve this proposed status, however, all the populations are currently at high risk and it is unclear how they will respond individually to recovery efforts. Thus, NMFS will continue to track progress and improvements in viability. Future monitoring results showing changes in population performance will be used to determine which population(s) in the MPG can best achieve highly viable status. This approach also applies for the other MPGs. The populations targeted for viable and highly viable status may change in any of the MPGs depending on how the populations ─ all currently rated at high risk ─ respond to recovery efforts.

4.2 Current Status of Snake River Basin Steelhead DPS

This section describes the current status of the Snake River Basin steelhead DPS. Section 4.2.1 summarizes the viability assessment results for independent populations in each MPG. Section 4.2.2 discusses the gap between the current and proposed status.

4.2.1 Summary of New Data Available for Review

Information gained in the last five years has improved our understanding of the status of the Snake River Basin steelhead DPS. In the past, adult abundance data series for the Snake River Basin steelhead DPS were limited to a set of aggregate estimates ─ total A-run and B-run counts at Lower Granite Dam, estimates for two Grande Ronde River MPG populations (Joseph Creek and Upper Grande Ronde River), and index area and weir counts for subsections of several other populations. Generally, it can be difficult to attain accurate estimates of adult steelhead abundance using current methods because of high and turbid flows on spawning grounds. Obtaining estimates of annual abundance and information on the relative distribution of hatchery spawners for additional populations within the DPS has been a high priority.

Additional monitoring programs instituted in the early 2000s now provide better information on natural-origin abundance and life-history diversity across the populations than was available for the previous review. Two projects based on representative sampling of adult returns at Lower Granite Dam have provided estimates of the number of natural returns for additional populations or groups of populations for spawning years 2009-14 (QCI 2013; Copeland et al. 2015). In addition, ODFW has refined sampling methods for redd count-based population estimates for Joseph Creek and the Upper Grande Ronde River. A weir-based mark/recapture project on Joseph Creek now provides more direct estimates of adult steelhead migrants to the creek. NMFS used these various sources of information to evaluate status for the different Snake River Basin steelhead populations.

The Northwest Fisheries Science Center recently used the new information to update the ICTRT’s 2007 life-history pattern assignments for the Snake River Basin steelhead populations (see Table 2-1) (NWFSC 2015). The new assignments reflect recent information from genetic stock identification assessment findings that no populations fell exclusively into the B-run size category, although there were clear differences among the population groups in the relative contributions of the larger B-run life-history type (Ackerman et al. 2014; Vu et al. 2015). Under the new life-history pattern designations, all but one of the populations that the ICTRT previously assigned as A-run steelhead retained their A-run designation. The remaining populations were separated into three B-run categories based on the percentage of fish exceeding the B-run size threshold of >78 cm: High >40 percent, Moderate 15 to 40 percent, and Low <15 percent. Steelhead assigned to the Upper Clearwater River, South Fork Salmon River, and South Fork Clearwater River had the highest proportion of B-run lengths, while the Middle Fork Salmon River drainage population group had an intermediate level of contributions of fish exceeding the B-run length threshold. The remaining populations had low or very low contributions from the B-run size category. The Lower Clearwater River population, previously designated as an A-run, includes a small B-run component and was provisionally reassigned as a Low B-run population (NWFSC 2015).

4.2.2 Current Status

Overall, the NWFSC’s latest status review (2015) did not indicate a change in the Snake River Basin steelhead DPS’s general biological status from the previous BRT and ICTRT reviews. The review found that four out of the five MPGs are not meeting the specific objectives in the recovery plan. The Grande Ronde MPG is tentatively rated viable, although more specific data on spawning abundance and the relative contribution of hatchery spawners for Lower Grande

Ronde and Wallowa River populations is needed. The status of many individual populations remains uncertain (NWFSC 2015).

Information available in the latest status review showed that the most recent five-year geometric mean abundance estimates increased for the two populations with long-term data series (Joseph Creek and Upper Grande Ronde River Mainstem), with each population increasing an average of 2 percent per year over the past 15 years. Hatchery-origin spawner estimates for both populations continued to be low (NWFSC 2015). Counts of aggregated runs of natural-origin steelhead at Lower Granite Dam also increased from prior years. The 2011-2014 geometric mean count of natural-origin A-run steelhead at the dam was over twice the estimate from the previous review, and the updated B-run steelhead geometric mean was over 50 percent higher than previously. The hatchery-origin runs to Lower Granite Dam were lower than in the previous review. As a result, the geometric mean estimates of the A-run and B-run components of the total run (including natural-origin and hatchery-origin fish) were down from the previous review (7 percent and 15 percent, respectively) (NWFSC 2015).

The latest status review rated all Snake River Basin steelhead populations, except one, at low or very low risk for spatial structure, given available evidence for distribution of natural production with the populations. The exception was Panther Creek, which was given a high risk rating for spatial structure because of the lack of spawning in the upper reaches. Evaluating the occupancy of major spawning areas remains problematic given that redd surveys are not routine due to adverse environmental conditions that affect count accuracy (NWFSC 2015).

Updated information on hatchery spawner fractions and life-history diversity contributed to revised ratings of diversity risk across the DPS. Generally, however, a great deal of uncertainty still remains regarding the relative proportion of hatchery fish in natural spawning areas near major hatchery release sites within some individual populations. The distribution of these potential hatchery-origin spawners relative to natural-origin spawners is not well understood, and this remaining uncertainty contributed to higher risk ratings. Additional information on the distribution of hatchery-origin spawners could change some current diversity ratings.

Recent conclusions regarding the status of the Snake River Basin steelhead DPS's five extant MPGs are summarized below from the *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest* (NWFSC 2015). Appendix H to this Plan, *Snake River Basin Steelhead DPS: Updated Viability Curves and Population Abundance/Productivity Status*, provides additional information on new data and updates the viability curves for the populations. The three management unit plans describe the status of the MPGs and local populations in more detail.

Lower Snake River MPG

The viability criteria call for both populations in this MPG (Tucannon River and Asotin Creek) to achieve viable status, with at least one highly viable. Each of these populations includes a core drainage (Tucannon River or Asotin Creek) as well as several smaller tributaries to the mainstem Snake River. For example, the ICTRT identified Alpowa Creek and Almota Creek as major and minor spawning areas within the general Asotin Creek population. Currently, both steelhead populations are rated at moderate risk overall; however, it is possible that the Tucannon River population could be at high risk for abundance and productivity, which would increase its overall rating to high risk (NWFSC 2015). The viability ratings for both populations reflect a combination of known conditions and uncertainties about key factors, primarily average natural-origin abundance and productivity, and hatchery influences.

Population-level spawner escapement estimates are not available for the Tucannon River population but research indicates that numbers of spawning steelhead in the system are low (e.g., Bumgarner and Dedloff 2013). An apparent high overshoot rate of returning steelhead adults may be a contributing factor. Analysis of returning PIT-tagged adults (2005-2012 return years) indicates that an average of 30.7 percent of returning adults enter the Tucannon River directly, while 59.3 percent overshoot the Tucannon River pass Lower Granite Dam. Of the overshoots, 21.2 percent return to the Tucannon River after overwintering, while the remaining 44.6 percent apparently remain above Lower Granite Dam, with a likely significant portion spawning in Asotin Creek (Bumgarner and Dedloff 2013). Hatchery-origin adults of endemic and Lyons Ferry stock in the Tucannon River show similar straying rates (NWFSC 2015).

The recent 10-year geometric mean abundance of natural-origin spawners in the Upper Asotin Creek subarea alone (a core population area) exceeds the abundance threshold (500 spawners) for the population. Asotin Creek, however, receives substantial input of adult returns from the Tucannon River and potentially other areas (both natural-origin and hatchery-origin) in the lower Snake River region. The actual proportional contribution of hatchery-origin spawners to total spawning is not known. Spatial structure and diversity are currently rated at moderate risk for the two populations. This rating is driven by phenotypic patterns and hatchery influence (NWFSC 2015).

Grande Ronde River MPG

The Grande Ronde River steelhead MPG is tentatively rated as achieving viable status (NWFSC 2015). The MPG provisionally meets the viability criteria, which call for at least two populations to reach viable status, with at least one highly viable. The other two populations should meet criteria for maintained.

Population-level abundance data for this MPG include long-term estimates for two MPG populations (Joseph Creek and Upper Grande Ronde River) and more recent natural spawner abundance estimates for the two other populations (Lower Grande Ronde River and Wallowa River). The data indicates that the Joseph Creek steelhead population’s overall viability rating remains as highly viable, with abundance/productivity and spatial structure/diversity rated at low risk. Data for the Upper Grande Ronde River population indicate that the population’s overall risk rating is viable. Average abundance levels in both populations have dropped from the prior

2010 review period, but the geometric mean natural-origin spawner abundance and productivity levels remain above the 1 percent viability curves for their respective population size categories (NWFSC 2015).

The Wallowa and Lower Grande Ronde populations are provisionally rated as maintained. Estimates of mean adult abundance for the two populations based on general returns of A-run steelhead suggest that the populations may rate at moderate risk for abundance/productivity; however, more specific information on annual returns is needed to assign specific abundance and productivity ratings for the two populations.

The NWFSC's latest spatial structure/diversity risk ratings for the Grande Ronde River steelhead populations reflect new data that suggests that hatchery fish may be contributing to spawning in the Lower Grande Ronde River and Wallowa River populations at significant levels (Copeland et al. 2015; NWFSC 2015). The NWFSC concluded that more information is needed to determine the distribution and levels of hatchery contribution in the two populations, but in the interim the hatchery risk ratings for the two populations were increased to moderate risk (NWFSC 2015). The 2015 NWFSC review updated the previous status review (Ford 2011) that gave all four populations in this MPG low-risk ratings for spatial structure/diversity.

Imnaha River MPG

The viability criteria call for the Imnaha River steelhead population, the only population within the Imnaha River MPG, to achieve a rating of highly viable for this single population MPG to be considered viable. Available information suggests that the population is currently at maintained status, with moderate risk ratings for abundance/productivity and spatial structure/diversity (NWFSC 2015).

Information for the population includes results from the genetic stock identification project, and available PIT-tag based estimates of steelhead returns to the Imnaha River from 2011 and 2012. The data suggests that natural steelhead production in the Imnaha River may be exceeding the ICTRT minimum threshold of 1,000 spawners for the population. However, data from a parental-based tagging (PBT) hatchery study indicates that a substantial number of returning hatchery fish may also spawn in the basin. Limited available information indicates that most of the returning hatchery fish do not mix with the natural population, but instead are concentrated in one area (Big Sheep Creek). Still, there is uncertainty about the proportions of hatchery-origin vs natural-origin spawners, particularly in the lower mainstem Imnaha River (NWFSC 2015).

Clearwater River MPG

The viability criteria call for at least three of the five extant populations in this MPG to achieve viable status, with at least one at highly viable status. Results from NMFS' latest status review indicate that although steelhead populations in the Lower Clearwater, Lochsa, and Selway Rivers are improved overall in status relative to prior reviews, they remain below viable status but likely achieve maintained status. The Lolo Creek and South Fork Clearwater populations remain at high risk due in part to uncertainties regarding productivity and hatchery spawner composition (NWFSC 2015).

The current ratings for the Clearwater River steelhead populations reflect recent status review findings (NWFSC 2015) based on a genetic stock composition analysis for stock groups. The data indicates that the Lochsa and Selway River populations currently rate at moderate abundance/productivity risk. Results from the genetic stock composition analysis for the Lower Clearwater River population are less clear than those for the Upper Clearwater group, but the information suggests that the population also rates at moderate abundance/productivity risk. Analyses for the Lolo Creek and South Fork Clearwater River populations, generated based on the genetic stock composition analysis and one year of estimates for the Lower Granite natural-origin PIT-tag project (2012), indicate that the two populations remain at high risk for abundance/productivity (NWFSC 2015). These recent ratings update previous ratings for the populations that reflected a lack of available data on natural spawning abundance to determine abundance and productivity. Because of the insufficient data, in the previous review all the Clearwater River steelhead populations were rated at high risk for abundance/productivity, with the exception of the Lower Mainstem Clearwater River population, which was rated at moderate risk.

Spatial structure and diversity risks continue to rate as low for the Lower Mainstem Clearwater River, Selway River, and Lochsa River steelhead populations. The South Fork Clearwater River and Lolo Creek populations retain their previous rating of moderate risk for spatial structure and diversity, largely due to the high risk for spawner composition (NWFSC 2015).

Salmon River MPG

The viability criteria call for at least six of the twelve populations in this large MPG to achieve viable status, with at least one highly viable. The proposed recovery scenario includes certain populations: the two Middle Fork Salmon River populations, and the South Fork Salmon River, Chamberlain Creek, Panther Creek, and North Fork Salmon River populations. Results of the latest review, including data from the genetic stock composition study, indicate that all of the steelhead populations in the Salmon River MPG currently rate at moderate risk for abundance/productivity. The spawning abundance and derived productivity estimates for four of the Salmon River steelhead populations (the South Fork Salmon, Secesh, Upper Middle Fork Salmon, and Lower Middle Fork Salmon River populations) are based on relatively strong genetic differentials and there is empirical evidence supporting low hatchery contributions. The remaining populations are provisionally rated as moderate risk for abundance/productivity, although they have higher levels of potential genetic discrimination error and many have high potential for hatchery contributions in natural spawning areas.

For spatial structure/diversity, five of the populations (South Fork Salmon, Secesh, Lower Middle Fork Salmon, and Upper Middle Fork Salmon Rivers and Chamberlain Creek) rated at low risk, and five populations (Little Salmon, North Fork Salmon, Lemhi, Pahsimeroi, and

Upper Mainstem Salmon Rivers) rated at moderate risk. One population (Panther Creek) rated at high risk. These combined ratings for abundance/productivity and spatial structure/diversity indicate that all but one of the Salmon River MPG's steelhead populations rate an overall status of maintained. The remaining population (Panther Creek) has an overall rating of high risk (NWFSC 2015).

4.2.2 Gap between Current and Proposed Status

Table 4-2 shows the current and proposed status for each Snake River Basin steelhead population to support MPG-level viability. Management unit recovery planners coordinated with NMFS in making decisions about the proposed status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities.

Table 4-2. Snake River Basin Steelhead DPS Recovery Strategy and Gaps between Current and Proposed Population Status (NWFSC 2015).

Major Population Group	Population	Contribution to Recovery	Current Status[1]	Proposed Status
Lower Snake River MPG	Tucannon River	Primary	High Risk??	Viable or Highly Viable
	Asotin Creek	Primary	Maintained/ High Risk?	Viable or Highly Viable
Grande Ronde River MPG[2]	L. Grande Ronde River	Primary	Maintained?	Viable or Highly Viable
	Joseph Creek	Primary	Highly Viable	Highly Viable
	Wallowa River	Primary	Maintained?	Viable or Highly Viable
	U. Grande Ronde River	Primary	Viable	Viable or Highly Viable
Imnaha River MPG	Imnaha River	Primary	Maintained?	Highly Viable
Clearwater River MPG	L. Mainstem Clearwater	Primary	Maintained?	Viable
	SF Clearwater	Supporting	Maintained/ High Risk?	Maintained
	Lolo Creek	Supporting	Maintained?	Maintained
	Selway River	Primary	Maintained?	Viable
	Lochsa River	Primary	Maintained?	Highly Viable
	NF Clearwater River	Not part of recovery scenario	Extirpated	
Salmon River MPG	Little Salmon River	Supporting	Maintained?	Maintained
	South Fork Salmon River	Primary	Maintained?	Viable
	Secesh River	Supporting	Maintained?	Maintained
	L. Middle Fork Salmon	Primary	Maintained?	Highly Viable
	U. Middle Fork Salmon	Primary	Maintained?	Viable
	Chamberlain Creek	Primary	Maintained?	Viable
	North Fork Salmon River	Supporting	Maintained?	Maintained
	Lemhi River	Primary	Maintained?	Viable
	Pahsimeroi River	Supporting	Maintained?	Maintained
	East Fork Salmon River	Supporting	Maintained?	Maintained
	U. Mainstem Salmon R.	Supporting	Maintained?	Maintained
	Panther Creek	Primary	High Risk?	Viable
Hells Canyon MPG	Hells Canyon Tributaries	Not part of recovery scenario.[3]	Extirpated	

[1] Population status is based on viability criteria: highly viable (less than 1% risk of extinction in 100 years), viable (5% or less risk of extinction), maintained (6 to 25% risk of extinction), high risk (more than 25% risk of extinction). Ratings followed by a question mark are tentative due to insufficient data.

[2] At this time, no single population is targeted for highly viable status in the Grande Ronde River steelhead MPG.

[3] While not part of the recovery scenario, passage and reintroduction to Hells Canyon MPG and Tributaries support state of Oregon broad sense goals.

The viability ratings for four of the five MPGs in the Snake River Basin steelhead DPS do not currently meet the ICTRT viability criteria. The Grande Ronde River MPG is tentatively considered viable, with two populations (Joseph Creek and Upper Grande Ronde River) meeting the criteria for viable or highly viable status (NWFSC 2015).

While information gained since the last status review has improved our ability to assess status in more detail, the gap between the current and proposed status for most steelhead populations in the DPS still remains unclear because of the lack of population-specific abundance data. A great deal of uncertainty also remains regarding the level of hatchery fish in natural-origin spawning areas within individual population areas. Obtaining annual estimates of population-level spawning abundance and hatchery/wild proportions remains among the highest priority opportunities for improved assessments of the populations. Results from ongoing and planned efforts to generate annual estimates of spawning escapement based on adult PIT-tag detections and other studies should continue to improve our understanding of current status for many of the populations and allow us to better target efforts needed to achieve proposed levels.

Better information regarding mortality due to threats posed at different stages in the life cycle is also needed. Smolt-to-adult return (SAR) rates available for outmigration years 1964 through 2011 show that year-to-year variations in SARs represent a major influence on the annual returns of Snake River natural-origin steelhead, although the pattern is complicated because multiple broods (predominately ages 3-6) contribute to each particular return year escapement. Generally, the series of the Snake River steelhead natural-origin run shows similarities to other Interior Columbia River steelhead DPSs and Chinook salmon ESUs in recent years, indicating that they may be subject to some of the same influences during the smolt-to-adult phase (Figure 4-1). The individual series show relative peaks in roughly the same time periods, although there are some differences in timing and magnitude of year-to-year variations (NWFSC 2015).

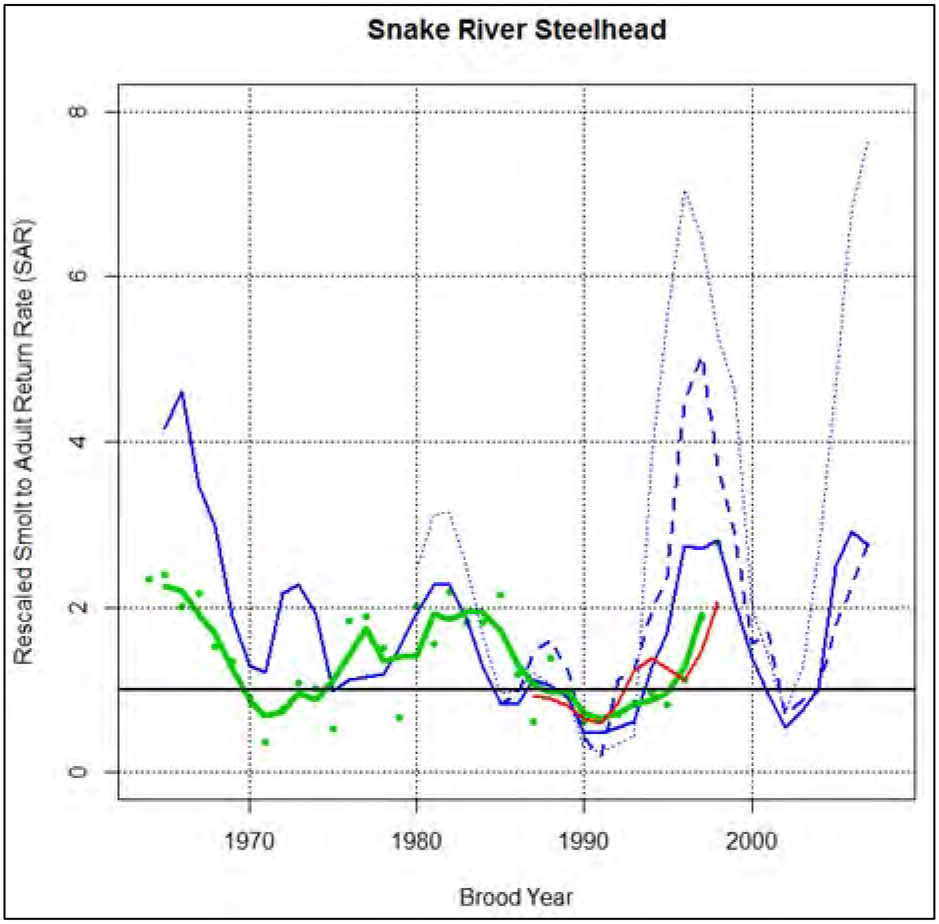

Figure 4-1. Snake River natural origin steelhead aggregate smolt to adult return rates (green points and heavy line). Aggregate SARs for other Interior Columbia basin ESUs and DPSs provided for comparison. Snake River aggregate spring/summer Chinook (solid blue), Tucannon spring Chinook (dotted blue), Upper Columbia spring Chinook (blue dashed line), Upper Columbia steelhead (green dashed line) and, Mid-Columbia steelhead (red line). Each SAR series is rescaled by dividing annual values by the corresponding series mean to facilitate relative comparison. Lines are three year moving averages.

5. Threats and Limiting Factors

This chapter provides an overview of the threats and limiting factors that contributed to the decline in Snake River spring/summer Chinook salmon and steelhead viability and/ or currently threaten the species' survival. Understanding these limiting factors and threats allows us to design recovery strategies and site-specific actions to effectively address remaining problems or gain key information to better focus our efforts. These limiting factors and threats are related to the five ESA section 4(a)(1) listing factors. They must be addressed to the point that delisting of the ESU and DPS is not likely to result in their re-emergence.

The management unit plans for Northeast Oregon, Southeast Washington, and Idaho discuss MPG and population-specific limiting factors and threats, and the recovery strategies and actions to address them.

5.1 Types of Limiting Factors and Threats

NMFS generally describes the reasons for a species' decline in terms of limiting factors and threats: NMFS defines *limiting factors* as the biological, physical, or chemical conditions and associated ecological processes and interactions that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity) (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources). We defines *threats* as those human activities or natural events that cause or contribute to the limiting factors. Threats may exist in the present or be likely to occur in the future. For example, removing the vegetation along the banks of a stream (threat) can cause higher water temperatures (limiting factor), because the stream is no longer shaded. The reasons for a species' decline are generally described in terms of limiting factors and threats.

What are limiting factors and threats?

Limiting factors are the biological, physical, or chemical conditions and associated ecological processes and interactions that result in reductions in VSP parameters (e.g., inadequate spawning habitat, high water temperature).

Threats are the human activities or natural events that cause or contribute to the limiting factors.

The term "threats" carries a negative connotation; however, threats are often legitimate and necessary activities that at times may have unintended negative consequences on fish populations. These activities can be managed to minimize or eliminate the negative impacts.

A single limiting factor may be caused by one or more threats. Likewise, a single threat may cause or contribute to more than one limiting factor and may affect more than one life stage. In addition, the impact of past threats may continue to contribute to current limiting factors through legacy effects. For example, current high water temperature could be the result of earlier practices that reduced stream complexity and shade by removing trees and other vegetation from the streambanks. Such activities often have the potential to be managed in ways that minimize or eliminate negative impacts. As discussed previously, there have been significant improvements in management activities that affect survival and viability of Snake River spring/summer Chinook salmon and steelhead since the species were listed.

Types of Limiting Factors

The factors that limit the viability of Snake River spring/summer Chinook salmon and Snake River Basin steelhead fall into 14 general categories. Table 5-1 describes these factors, their common characteristics, and the salmonid life stages they can affect. Seven of the factors relate directly to habitat conditions. Other factors relate to fish passage, the hydropower system, hatcheries, harvest, and pathogens/predation/competition.

Table 5-1. Limiting factors and common characteristics used to describe them.

Limiting Factor	Common Characteristics	Life Stages Affected
Impaired riparian condition	Loss, degradation, or impairment of riparian conditions important for production of food organisms and organic material, shading, bank stabilizing by roots, nutrient and chemical mediation, control of surface erosion, and production of large-sized woody material.	Egg-to-smolt survival, smolt migration, adult migration, pre-spawning
Reduced floodplain connectivity	Loss, degradation, or impairment of floodplain connectivity; access to previously available habitats (seasonal wetlands, off-channel habitat, side channels); and a connected and functional hyporheic zone. This factor includes reduced overwinter habitat and channel habitat.	Egg-to-smolt survival, smolt migration, adult migration, pre-spawning
Reduced stream habitat quantity/ complexity	Loss of structure (wood, boulders, etc.); poor hydrologic function; inadequate quantity or depth of pools; inadequate spawning substrate; and loss of instream roughness, channel morphology, and habitat complexity.	Egg-to-smolt survival, smolt migration, adult migration, pre-spawning
Altered hydrology/water quantity	Changes in the hydrograph that alter the natural pattern of flows over the seasons, causing inadequate flow, scouring flow, or other flow conditions that inhibit the development and survival of salmonids.	Egg-to-smolt survival, smolt migration, and adult migration
Impaired water quality	Impaired water quality due to abnormal temperature, dissolved oxygen, nutrients from agricultural runoff, heavy metals, pesticides, herbicides and other contaminants (toxic pollutants).	Egg-to-smolt survival, smolt migration, and adult migration
Excess fine sediment	Excessive fine sediment that reduces spawning gravel or increases embeddedness. This is caused by excess fine sediment input to streams and enhanced by inadequate sediment routing.	Egg-to-parr survival
Reduced channel structure/ stability	Loss, degradation, or impairment of channels and streambanks; loss of side and braided channels; a lack of suitable riffles and functional pool distribution.	Egg-to-smolt survival, smolt migration, and adult migration
Impaired fish passage	The total or partial human-caused blockage to previously accessible habitat that eliminates or decreases migration ability or alters the range of conditions under which migration is possible. This may include seasonal or periodic total migration blockage. This includes dams, culverts, thermal barriers, seasonal push up dams, unscreened diversions, and entrainment in irrigation diversions.	Smolt migration, adult migration, and juvenile upstream migration due to thermal blockage or water availability
Mainstem hydropower system related adverse effects	Altered stream flows; impaired water quality, high water temperatures; impaired fish passage and survival; reduced mainstem spawning and rearing; increased predation and competition; degraded estuary and altered Columbia River plume habitat quality and quantity; degraded floodplains	Egg-to-smolt survival, smolt migration, adult migration

Limiting Factor	Common Characteristics	Life Stages Affected
Hatchery related adverse effects	Increased competition for food and space; increased predation; disease transfer; loss of genetic diversity	Egg-to-smolt survival, smolt migration, adult migration
Harvest related adverse effects	Decreased adult abundance (number of spawners or adult recruits) and productivity; influenced diversity and spatial structure through selective removal based on size, age, distribution or run timing	Egg-to-smolt survival, adult survival
Pathogens	Pathological condition in naturally produced fish resulting from infection.	Early rearing and smolt migration
Predation	Consumption of naturally produced fish by one or more species (does not include fishery mortality).	Early rearing and smolt migration
Competition	Adverse interaction between naturally produced fish and hatchery fish or other species, both of which need some limited environmental factor (e.g., food or space).	Early rearing and smolt migration

Types of Threats

The “threats” contributing to the limiting factors and causes for a species’ decline are often described in terms of the “four Hs” – habitat (usually relating to the effects of land use and tributary water use, or natural events such as climate change), hydropower development and operations, harvest and fishery management, and hatchery management. These often represent the primary threats to the species. They may be associated with one or more specific life cycle stages and may occur in the past, present, or future.

- Habitat-related threats are human actions (e.g., agriculture, roads, timber harvest, etc.) or natural events (e.g., natural barriers, fire, etc.) that cause or contribute to limiting factors.
- Hydropower-related threats include dams and projects for hydropower, flood control, and/or storage that alter river conditions for migrating juvenile and adult steelhead and cause both direct and indirect mortality.
- Hatchery-related threats include hatchery programs that present genetic or ecological risk to natural-origin populations. Hatchery management can focus primarily on production of fish for harvest, on conservation and recovery, or both. Depending on how they are used, hatcheries may increase or decrease the viability of listed fish populations.
- Fishery-related threats include harvest rates, methods and timing, bycatch, and indirect mortality from catch and release fisheries. All of these threats can affect fish survival.

5.2 Current Limiting Factors and Threats to Species Viability

Background

As discussed in Chapter 1, many human activities contributed to the decline of Snake River spring/summer Chinook salmon and steelhead. NMFS’ 1997 listing determination and 1998 status review concluded that the decline of the ESU and DPS was the result of losses from hydropower development in the Snake and Columbia River basins, widespread habitat degradation and flow impairment, historical commercial fisheries, and threats posed to the genetic integrity of natural-origin populations by past and current hatchery operations. Table 5-2 shows the history of human activities that have contributed to the current status of Snake River spring/summer Chinook salmon and Snake River Basin steelhead.

Today, some threats that contributed to the original listings of the species now present less harm to the ESU and DPS, and some others continue to threaten viability. Impacts from ocean and in-river fisheries are now better regulated through ESA-listed constraints and management agreements, significantly reducing harvest-related mortality. Land use practices have also improved in many areas, restoring habitat diversity in once degraded areas, and leaving more water in streams during critical periods for fish survival. Hatchery-related effects are being reduced through improved hatchery practices and release strategies. In addition, structural and operational changes to the mainstem Columbia and Snake River hydropower system have improved survival rates for the species since ESA-listing,

Still, repeated status reviews have concluded that there has not been a substantial change in the biological risk status of Snake River spring/summer Chinook salmon and Snake River Basin steelhead, and that many factors continue to limit the viability of the species (Good et al. 2005; Ford 2011; NWFSC 2015). Tributary habitat conditions remain degraded in many reaches, and caution and uncertainty persist concerning the influence of hatchery fish on the genetic integrity and fitness of natural-origin populations. The hydropower system continues to pose a significant threat to Chinook salmon and steelhead viability. In addition, new threats ─ such as those posed by toxic contamination, increased predation by non-native species, and effects due to climate change ─ are emerging. Further, the combined and relative effects of the different threats across the life cycles of these species remain poorly understood.

The threats and limiting factors affecting Snake River spring/summer Chinook salmon and steelhead operate across all stages of the life cycle. While each factor independently affects the viability of the ESU and/ or DPS, they also have synergistic and cumulative effects throughout the species' life cycle. Understanding these various limiting factors and threats, individually and collectively, through RM&E and life cycle modeling provides a critical foundation for developing effective recovery strategies and actions, and then adjusting actions and priorities as new information emerges.

During Plan implementation phase, NMFS will work with co-managers, tribes, and other parties to refine and prioritize the limiting factors based on available information, including information provided in NMFS' 5-year status reviews and new findings gained from life cycle modeling and other research. This will be a long-term, ongoing process in partnership with co-managers and others.

Table 5-2. History of activities contributing to Snake River spring/summer Chinook salmon and steelhead decline and recovery.

Date	Human Activities Affecting Snake River Spring/summer Chinook Salmon and Steelhead	Estimated Fish Abundance & Status
Late 1800s	Mainstem and tributary habitat degradation begins due to mining, timber harvest, agriculture, livestock production, beaver removal, and other activities.	Annual returns of s/s Chinook to Snake River likely over one million. SR steelhead over half entire Columbia R. steelhead run.
1883-1903	Commercial harvest of Columbia River salmon peaks at more than 42 million lbs in 1883. Spring Chinook salmon runs declines by 1903. Harvest in Columbia River turns to target fall Chinook.	Spring Chinook salmon run begins decline.
1901	Swan Falls Dam constructed on Snake River (RM 457.7). Access blocked to 157 miles of mainstem habitat and large reaches of historical tributary habitat in Idaho and Oregon.	Spring/summer Chinook and steelhead populations above dam site lost.
1904-1935	Commercial harvest effort moves from lower Columbia, where harvest was controlled, to above Celilo Falls (1904). Fish wheels outlawed in Oregon (1928) and Washington (1935).	Runs continue declines.
1927	Lewiston Dam constructed on Clearwater River (RM 6). Access blocked to habitat above dam from 1927-1973.	
1938-1947	Bonneville Dam completed on Columbia River (RM 146) in 1938.	
1950s	Two dams completed on Columbia River: McNary Dam (RM 292) in 1953, The Dalles Dam (RM 191.5) in 1957.	
1958-1975	Hells Canyon Complex dams constructed on middle Snake River: Brownlee (1958), Oxbow (1961), and Hells Canyon (1967) (RM 285, 273, and 247 respectively). John Day Dam completed in 1968 on Columbia River (RM 215.6). Lower Snake River dams constructed: Ice Harbor (1961), Lower Monumental (1969), Little Goose (1970), Lower Granite (1975). Lower mainstem Columbia spring-run Chinook fisheries annual harvest rates 20-40% through early 1970s.	SR s/s Chinook return drops to near 100,000/year by 1950s. Return to Ice Harbor Dam averages 58,800 s/s Chinook (1962-1970) and low of 11,855 in 1979. SR steelhead return of 108,000 in 1962 at Ice Harbor Dam; averages 70,000/ year until 1970.
1976-1980	Lower Snake River Compensation Plan begins producing hatchery fish to compensate for losses (1976).	SR s/s Chinook natural-origin return averages 27,000/ year (1976-1980), a 40% decrease from 1962-1966 average.
1980s	Hatchery production increases. Hatcheries begin to play major role in production.	SR steelhead natural-origin returns decline sharply in mid-1980s. Natural-origin SR s/s Chinook also continue decline.
1990-1995	SR s/s Chinook listed under ESA as threatened in 1992. Harvest impacts further reduced after ESA listing.	SR s/s Chinook natural-origin returns drops to 3,820 (1992-1996). Low of 2,200 fish in 1995. SR steelhead natural-origin returns av. 9,400/yr (1990-1994).
1996-2001	Actions in 1995 FCRPS BiOp implemented (1996) to improve dam passage/operations for migration. SR steelhead listed under the ESA as threatened in 1997.	Natural-origin SR sp. Chinook return to LGD exceed 3,700/year; SR sm. Chinook return below 5,000 (1997-2001).
2000-2007	Actions in 2000 FCRPS BiOp implemented to further improve dam passage/operations for migration (include increased summer spill). Incidental harvest of natural-origin SR fish averages 11% for s/s Chinook and under 10% for steelhead.	
2005-06	Snake River ESA listings reaffirmed: S/s Chinook in 2005, steelhead in 2006. Harvest agreements further reduce harvest impact from ocean/Columbia River fisheries.	2005 status: SR s/s Chinook returns variable but low. Steelhead at moderate risk.
2008-present	Actions in 2008 FCRPS BiOp implemented to improve dam passage/ operations for migration (with increased spill and final installations of surface passage routes (spillway weirs, sluiceways, corner collectors) at all mainstem dams. Adult survival from Bonneville to Lower Granite Dam improves for SR s/s Chinook salmon to 82% and SR steelhead to 81% (2008-12). Snake River ESA listings for species reaffirmed (2014).	2010 status: SR s/s Chinook - natural-origin levels up but all populations still at high risk. Steelhead - Status of most populations highly uncertain, but below target levels for viability. 2015 status: SR s/s Chinook- natural-origin levels up but most populations high risk. Steelhead- Status of many pops unclear. Grande Ronde MPG tentatively Viable, others still at risk.

Section Organization

The following sections discuss the different threats and limiting factors that affect Snake River spring/summer Chinook salmon and steelhead viability throughout their life cycle. The sections are organized by threat category (habitat, hydropower, harvest, hatcheries, etc.) and arranged to coincide with the five ESA section 4(a)(1) listing factors: (A) destruction, modification, or curtailment of habitat or range; (B) over-utilization for commercial, recreational, scientific or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; and (E) other natural or human-made factors. Section 3.4.2 of this Plan overviews the section 4(a)(1) listing factors and the associated listing factor (threats) criteria. Chapter 6 summarizes the recovery strategies and actions designed to achieve viability for the ESU and DPS. The management unit plans for Northeast Oregon, Southeast Washington, and Idaho discuss MPG and population-specific limiting factors and threats, and provide recovery strategies and actions to address them.

Information provided in the different sections describes the threats and limiting factors that affect the two species at different stages in their life cycles. Recovery planners identified the limiting factors for the species based on the results of a substantial body of research, monitoring and evaluation on the fish and their habitats, and through various related consultations. The sections reflect results to date from RM&E activities and from NMFS status reviews, ICTRT assessments, and various consultations. The discussions also reflect information from the Ocean Module (Appendix D); Estuary Module (Appendix E); Hydro Module (Appendix G); 2008 and 2014 FCRPS biological opinions (NMFS 2008c, 2014c); and Harvest Module (2014b).

- Sections 5.2.1 (Tributary Habitat), 5.2.2 (Estuary, Plume, and Ocean Habitat), and 5.2.3 (Hydropower and Mainstem Migration Corridor) discuss habitat-related limiting factors and threats that contribute to the destruction, modification, or curtailment of the species' habitat and range (ESA section 4(a)(1) listing factor A).
- Section 5.2.4 (Fisheries Management) describes threats and limiting factors related to harvest, and the threats contributing to over-utilization for commercial, recreational, scientific, or educational purposes (ESA section 4(a)(1) listing factor B).
- Section 5.2.5 (Hatchery Programs) discusses the effects of hatchery programs on natural-origin Snake River spring/summer Chinook salmon and steelhead. Hatcheries are one of the human-made factors that affect the species' continued existence (ESA section 4(a)(1) listing factor E).
- Section 5.2.6 (Predation, Competition, Disease, and Exposure to Toxic Pollutants) identifies threats and factors associated with predation and disease (ESA section 4(a)(1) listing factor C), as well as those associated with competition with hatchery fish and other species, and exposure to toxic pollutants (ESA section 4(a)(1) listing factor E, other human-made factors).
- Section 5.2.7 (Climate Change) discusses the influence of climate change on habitat conditions throughout the life cycle and is also associated with listing factor A.

Information provided in each of the sections also addresses ESA section 4(a)(1) listing factor D, the inadequacy of existing regulatory mechanisms.

Importantly, our understanding of the risks posed by the various threats and limiting factors continues to improve. Information gained through ongoing RM&E, and refined through use of life cycle models and other tools, should increase our understanding of how and where the different factors affect the species, as well as each factor's overall importance in relation to other threats across the species' life cycle or at a specific life stage.

5.2.1 Tributary Habitat

The loss and degradation of tributary habitats due to past and/or present land use continues to hinder Snake River spring/summer Chinook salmon and steelhead productivity. Both fish species spend long periods in tributary habitats and are very sensitive to changes in their freshwater ecosystems. The fish depend on a complex, interacting system of environmental conditions, with different conditions needed for each life stage. Optimal water temperature, for example, varies (within limits) for adult migration vs. egg incubation vs. juvenile rearing. In addition, the particular factors limiting production may vary across different sections of a tributary drainage. Together, the freshwater habitat conditions shape the viability of the populations over the long term by influencing abundance, productivity, spatial structure, and diversity.

Stream systems within areas of the Snake River basin that are protected, such as designated wilderness and roadless areas, often display better habitat conditions than do areas that are outside such protection. These areas support natural ecological processes and functions that create healthy, diverse habitats, and their long-term protection gives stability to safeguard the habitats during different periods of natural variation so the fish can be self-sustaining. Such areas in the Snake River basin include the majority of the Middle Fork Salmon River drainage, which is in the Frank Church River of No Return Wilderness area. Many sections of this wilderness area are in near-pristine condition due to limited influence from contemporary land use activities. Habitats in roadless areas of the Clearwater River drainage are also in near-natural condition.

In comparison, areas of the Snake River basin that have been compromised by past and/ or current land use activities, such as by overgrazing, mining, logging, agricultural practices, road construction, water withdrawals, urban development, and recreational use, often lack the necessary habitat conditions to support viable Chinook salmon and steelhead populations. Together, past and current land use activities have weakened the natural watershed processes that historically supported productive and sustainable fish populations. For example, parts of the Grande Ronde and Imnaha River drainages in Northeast Oregon, the Tucannon River drainage in Southeast Washington, and the lower Clearwater and South Fork Salmon River drainages in Idaho display impaired habitat conditions that reflect combined development and land use activities since the later 1800s, primarily in the early and mid-1900s. Prominent habitat issues include confinement of floodplain and channel meandering, loss of riparian trees, reduced stream flows during critical periods, high summer water temperatures, and excessive fine sediments. Degraded water quality also exists in a number of areas due to runoff from agricultural and livestock operations, industrial uses, sewage treatment, past mining activities, and other sources. In areas where stream flows are significantly reduced through water withdrawals, the low flow can result in high concentrations of contaminants.

Further, the removal of beaver has substantially altered the physical, chemical, and biological characteristics of many stream ecosystems across the Snake River basin. Beavers create and maintain complex stream ecosystems by constructing dams that impound water and capture sediment and organic materials. The removal of beaver and loss of beaver dams has often caused fish habitat quality and complexity to decline by lowering groundwater tables, reducing floodplain extent, reducing base flows in summer, altering water temperatures, and altering riparian plant communities (Pollock et al. 2015).

Tributary Habitat Limiting Factors

Currently, several interrelated limiting factors primarily reduce the viability of the Snake River spring/summer Chinook salmon and steelhead populations by lowering habitat carrying capacity:

- *Impaired fish passage.* Fish passage to historical habitats remains blocked or impaired in a number of tributary reaches. Barriers to fish passage include culverts, water diversions, weirs at hatchery facilities, and other human-made structures that restrict access. They can prevent returning adults from accessing upstream spawning habitat, and juvenile fish from migrating up or down stream. Unscreened diversions can entrain juvenile fish, transporting them along with the flow of water out of a stream and into a diversion where they become trapped.
- *Reduced stream complexity and channel structure.* Stream complexity ─ in the form of large wood, pool habitat, and connectivity to side channels and other areas ─ has been reduced in streams across the area relative to historic levels. Complexity is an important feature of natural stream morphology and is often maintained through connection to the surrounding landscape. Natural channel-forming processes and hydrologic regimes that create thermal refugia in summer and deep pools and connected side channels for cover in winter are particularly important, and are impaired through much of the area. Sufficient habitat capacity and complexity is critical to produce enough recruits-per-spawner to sustain population productivity.
- *Excess fine sediment.* Fine sediment levels in streams are above historic levels throughout the area, except in wilderness area watersheds, due to streambank and channel destabilization. The fine sediments can cover and clog substrate, reducing stream suitability for spawning and egg incubation.
- *Elevated summer water temperatures.* Summer water temperatures are elevated in many tributary stream reaches across the Snake River basin and exceed water quality standards. The elevated water temperatures restrict salmonid use of some historically suitable habitat areas, particularly summer rearing and migration habitat. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water all contribute to elevated stream temperatures. Elevated summer water temperatures affect

spring/summer Chinook salmon and steelhead in the mainstem Snake River above Lower Granite Dam and in tributary reaches. The high temperatures during holding in tributaries and during the latter stages of adult migration may lead to prespawning mortality or reduced spawning success as a result of delay or increased susceptibility to disease and pathogens. In addition, lethal temperatures (temperatures that kill fish) can cause mortality in the migration corridor or holding tributaries.

- *Diminished streamflow during critical periods.* Summer flows, often limited naturally, are lower than they were historically due to water withdrawals and land management practices. It is common for flow levels to be depleted by sequential small diversions that cumulatively contribute to low flow and high temperature problems, some reaches of small- and mid-sized tributaries that provide key rearing habitat often become dry or intermittent during the summer due to demand for surface water. The impact of cumulative water diversions can extend to mainstem reaches; for instance, reduced streamflow in individual tributaries of the Salmon River basin collectively diminishes the amount and function of available habitat in the mainstem Salmon River (NMFS 2015; Arthaud and Morrow 2007, 2013).

  Reduced flows during critical periods can affect adult and juvenile salmonids by blocking fish migration, stranding fish, reducing rearing habitat availability, and increasing summer water temperatures. Salmon and steelhead often cannot survive in warmer streams unless they can find deep pools and cold-water refugia that have an influx of cool water from springs or seepage through gravels. This cold-water refugia provides important habitat for salmonids during incubation, emergence, and early rearing.

- *Reduced floodplain connectivity and function.* Floodplain degradation and lost connectivity to streams has progressed across many parts of the basin over decades due to various land use activities. Healthy, connected floodplains provide complex habitats for juvenile and adult salmonids, including side channels and shallow-water refugia during flood conditions. Juveniles that have access to ephemeral floodplain habitats during flood events show higher growth and rates of survival (Sommer et al. 2001; Jeffres et al. 2008).

  Floodplains also play a critical role in forming and maintaining healthy stream conditions for salmonid development by expanding water storage during periods of high flow and slowing its release to recharge stream flows with cool water. Complex floodplains increase food availability by producing a variety of prey for juvenile fish. They provide streambank stability, reducing soil erosion and consequently excess sediment levels, and support development of healthy riparian vegetation. The loss of floodplain connectivity impacts all life stages, from incubating eggs and rearing juveniles to returning spawners.

- *Degraded riparian conditions.* Impaired riparian conditions affect many stream reaches. Disturbance of riparian functions and removal of riparian vegetation contribute significantly to the above conditions by reducing streambank stability, shade, and recruitment of large wood debris that creates stream complexity.

These interrelated habitat limiting factors exist in different concentrations across the Snake River watershed, depending on local land use activities and natural conditions. As discussed earlier, areas that are protected often display higher watershed and aquatic integrity compared to lower elevations and broad valley reaches with easier access for humans and development.

Tables 5-3 and 5-4 summarize the tributary habitat limiting factors for the Snake River spring/summer Chinook salmon and steelhead populations as identified in the three management unit plans. In some cases, the limiting factors identifies in the tables reflect habitat conditions present in some, but not all, parts of a population area. For example, habitat conditions for the Wallowa River steelhead population vary considerably, from nearly pristine in the Eagle Cap Wilderness to highly modified in valley floor streams impacted by past and current land use.

The three management unit plans provide detailed discussions of tributary habitat limiting factors and threats for individual fish populations. Some of the habitat descriptions in the management unit plans, however, are now out of date and do not accurately reflect current conditions, including where habitats are now protected and/or improved due to efforts such as the state of Washington’s Forest Practices Habitat Conservation Plan. The management unit plan descriptions of limiting factors, and actions to address them, will be updated during the Plan implementation phase.

Table 5-3. Widespread tributary habitat limiting factors for Snake River spring/summer Chinook salmon populations as identified in the three management unit plans.

Population	Tributary Habitat Limiting Factors						
	Stream Complexity	Excess Sediment	Passage Barriers	Altered/ Low Flows	Water Quality/ Temperature	Riparian Condition	Floodplain Connectivity
Lower Snake River MPG							
Tucannon River	√	√	√	√	√	√	√
Asotin Creek	√	√		√	√	√	√
Grande Ronde/ Imnaha Rivers MPG							
Wenaha River	√						
Minam River	√	√			√		
Lostine/ Wallowa R.	√	√	√	√	√	√	√
Lookingglass Creek	√	√	√			√	
Catherine Creek	√	√		√	√	√	√
Upper Grande Ronde R.	√	√		√	√	√	√
Imnaha River	√	√	√	√	√	√	√
Big Sheep Creek	√	√		√	√	√	√
South Fork Salmon River MPG							
Little Salmon River	√	√	√	√	√	√	√
South Fork Salmon R.	√	√			√	√	√
Secesh River		√	√				√
East Fork Salmon R.	√	√	√		√	√	√
Middle Fork Salmon River MPG							
Chamberlain Creek							
Big Creek	√	√	√	√			
Lower MF Salmon R							
Camas Creek	√		√	√		√	
Loon Creek			√				
Upper MF Salmon R.							
Sulphur Creek				√			

Population	Tributary Habitat Limiting Factors						
	Stream Complexity	Excess Sediment	Passage Barriers	Altered/ Low Flows	Water Quality/ Temperature	Riparian Condition	Floodplain Connectivity
Bear Creek		√					
Marsh Creek	√			√		√	
Upper Salmon River MPG							
North Fork Salmon R.	√	√	√	√		√	
Lemhi R.	√	√	√	√	√	√	
Up. Salmon R. L. Main	√	√	√	√	√	√	√
Pahsimeroi R.	√	√	√	√	√	√	
East Fork Salmon R.	√	√	√	√	√	√	
Yankee Fk Salmon R.	√					√	√
Valley Creek	√		√	√	√	√	√
Up. Salmon R. U. Main	√	√	√	√	√	√	
Panther Creek	√		√	√			

Table 5-4. Widespread tributary habitat limiting factors for Snake River steelhead populations as identified in the three management unit plans.

Population	Tributary Habitat Limiting Factors							
	Stream Complexity	Excess Sediment	Passage Barriers	Altered/ Low Flows	Water Quality/ Temperature	Riparian Condition	Floodplain Connectivity	Entrainment
Lower Snake River MPG								
Tucannon River	√	√		√	√	√	√	
Asotin Creek	√	√		√	√	√	√	
Grande Ronde River MPG								
Joseph Creek	√	√		√	√	√	√	
Lo. Grande Ronde R.	√	√	√	√	√	√	√	
Wallowa River	√	√	√	√	√	√	√	
Up. Grande Ronde R.	√	√		√	√	√	√	
Imnaha River MPG								
Imnaha River	√	√		√	√	√	√	
Clearwater River MPG								
Lo. Main Clearwater R.	√	√	√	√	√	√	√	
Selway River		√	√		√	√		
Lolo Creek	√	√	√		√	√		
Lochsa River	√	√	√		√	√		
SF Clearwater R.	√	√	√		√	√	√	
Salmon River MPG								
Little Salmon R.	√	√	√	√	√	√	√	
South Fork Salmon R.		√	√			√		
Secesh R.		√	√					
Chamberlain Creek	√	√	√		√	√		
Lower MF Salmon R		√	√			√		
Upper MF Salmon R.		√						
Panther Creek		√	√	√	√	√		√
North Fork Salmon R.	√		√	√		√		√
Lemhi R.	√	√	√	√	√	√	√	√
Pahsimeroi R.		√	√	√	√	√		√
East Fork Salmon R.	√	√	√	√	√	√	√	√
Upper Main Salmon R.	√	√	√	√	√	√	√	√

Need for Key Information

Lack of key information also continues to limit recovery efforts for Snake River spring/summer Chinook salmon and steelhead. Better information is needed to understand which life stages are currently hindered, and to focus in on the habitat limiting factors and ecosystem functions that need to be repaired to improve a population's survival and viability. More information is needed to better understand how the following key factors influence recovery efforts:

1. Where are the key tributary habitats that provide the highest survival for juveniles and adults ─ such as cold-water refugia in summer, and deep pools for cover and shallow floodplain refugia from flood conditions in winter ─ and, conversely, what population sinks need to be addressed? Such areas can also provide population resiliency against the potential effects of climate change, including the effects of increased winter flooding. Identifying these areas will aid in identifying appropriate habitat improvements to directly improve survival/productivity for increased cost/benefit. Importantly, not all of these areas are located in the Snake River basin; research indicates that adult steelhead from the Snake River basin use other cool-water tributaries and cold-water refugia during their migration in the lower Columbia River mainstem, and that these fish have lower rates of return to natal streams and higher rates of disappearance due to incidental mortality from fishing in refugia tributaries and other unknown reasons (Keefer et al. 2009).

2. How is impairment of natural habitat-forming processes affecting the fish populations? For instance, the effects of altered groundwater hydrology on steelhead populations are not well understood, yet may be an important limiting factor. We also need better information concerning the role increased/ decreased ice formation resulting from historic channel and floodplain alterations might be having on overwintering juveniles. Is increased ice formation resulting in increased juvenile fish stranding on winter floodplains, or is increased ice and associated bed scour contributing to decreased overwinter survival? Gaining additional information about the natural habitat- and channel-forming processes that limit the fish at different life stages will be critical to target habitat improvements effectively to increase tributary habitat function and carrying capacity, as well as adult returns.

   Of key importance is learning more regarding potential density dependence limitations on spring/summer Chinook salmon and steelhead productivity in freshwater habitats, including what is happening in the overwintering life stage. Currently, for example, while the number of spring/summer Chinook salmon spawners has increased in recent years, this increase has not resulted in additional smolt production. In addition, monitoring shows that abundance of juvenile Chinook salmon can be associated with reduced smolt size (ISAB 2015), indicating that food availability in freshwater habitat may be limiting growth and survival. More information is needed to better understand the natural potential of different stream systems, the relationship of density dependence to environmental conditions, and the ability of existing habitats to support desired spawning, parr, and smolt production.

3. What are the drivers that support species life-history diversity, such as yearling vs sub-yearling life-history strategies for spring/summer Chinook salmon or the relationship between A-run and B-run steelhead? More information is needed regarding the factors that influence and maintain the life-history diversity, and how the diversity contributes to viability.
4. Why, where, and to what extent are juvenile losses occurring during outmigration between natal rearing habitats and the mainstem hydropower system? PIT-tag studies for Snake River spring/summer Chinook salmon survival during migration from upstream hatcheries and smolt traps to Lower Granite Dam showed a significant negative linear relationship between migration distance and survival during 1998-2014 (R2 = 0.850, P = 0.003). Survival rates varied from a 17-year mean of 0.779 for smolts released from Dworshak Hatchery (116 km to Lower Granite Dam) to 0.444 for those released from the Salmon River Hatchery (747 km to Lower Granite Dam) (Faulkner et al. 2015). The survival probabilities of wild Chinook smolts during 2014 were also inversely related to the distance of the trap from Lower Granite Dam. More information is needed to determine the sources of mortality in these upstream areas, including in the mainstem Salmon River.

5.2.2 Estuary, Plume, and Ocean Habitat

The Columbia River estuary and plume and the Pacific Ocean are inter-connected habitats that have a major effect on the viability of Snake River spring/summer Chinook salmon and steelhead. These habitats, and their use by Snake River salmon and steelhead, as well as other species, are discussed in the Ocean Module (Appendix D) and Estuary Module (Appendix E) and summarized in this section.

Estuary and Plume

The estuary and plume provide salmon and steelhead with a food-rich environment where they can undergo the physiological changes needed to make the transition to and from saltwater and achieve the growth needed to bolster their marine survival (Appendix E; LCFRB 2010). Juvenile spring/summer Chinook salmon and summer steelhead from the Snake River basin currently spend less time in these estuarine habitats than some other species; they are stream-type fish, and generally move through the estuary in the main channel within a matter of days, in contrast to ocean-type salmonids, such as sub-yearling fall Chinook salmon, which rear in shallow water along the river margin. Nevertheless, the ecological conditions (water quality, availability of prey, refuge from predations) in the deeper estuarine channels and the Columbia River plume can be important in determining the survival of these species.

Although mean residencies in the estuary and nearfield plume outside the mouth of the river appear to be short, there is considerable variation in residence times in the different habitats and the timing of estuarine and ocean entry among individual fish. This variation may influence survival at later life stages and help provide resilience to the ESU and DPS (McElhany et al. 2000; Holsman et al. 2012; Appendix D).

Over the last 100 years, the estuary and plume have undergone significant change as a result of human development in the estuary itself and water management throughout the Columbia River basin. These changes have altered the function of these areas as habitat for salmon and steelhead (Appendix E; Fresh et al. 2005). The cumulative impacts of past and current land use (including dredging, filling, diking, and channelizing of lower Columbia River tributaries) and alterations to the Columbia River flow regimes by reservoir storage and release operations have reduced the quality and quantity of estuarine habitat, and at least the extent of the plume. The amount and accessibility of in-channel, off-channel, and plume habitat have been reduced as a result of habitat conversion for agricultural, urban, and industrial uses, hydropower regulation and flood control, channelization, and higher bank full elevations, which have been facilitated by diking, dredging, and filling. Where historically marshes, wetlands, and side channels along the lower river provided salmon and steelhead with food and refuge, most of these shallow water habitats have been diked off from the river. Corbett (2013) estimated losses of 70 percent for vegetated tidal wetlands and 55 percent for forested uplands. Much of this area has been converted for agriculture, but significant areas have also been lost to industrial, commercial, and residential uses. It is estimated that the surface area of the estuary has decreased by approximately 20 percent over the past 200 years (Fresh et al. 2005).

The quality of the habitat available to salmon and steelhead in the estuary also has been compromised. Water quality in the estuary and plume has been degraded by human practices from the estuary and from upstream sources. Elevated water temperatures and toxic contaminants both pose risks to salmon and steelhead in the estuary (Appendix E). Water temperatures above the upper thermal tolerance range for salmon and steelhead occur earlier and more often and are likely to continue to climb due to climate change (Independent Scientific Advisory Board 2007a, as cited in Appendix E). Exposure to toxic pollutants could also be affecting species viability; however, our current understanding of the effects on aquatic life impacts of many contaminants, alone or in combination with other chemicals (potential for synergistic effects) is incomplete.

Construction of revetments, disposal of dredged material, removal of large wood, and reductions in flow in the estuary have also altered the diet of juvenile salmon in the estuary by eliminating much of the vegetated wetlands that historically supplied insect prey for juvenile salmonids and macrodetrital inputs to the estuarine food web. The shift in diet has been compounded by increased microdetrital inputs to the estuary; microdetrital inputs originate in decaying phytoplankton delivered from upstream reservoirs and nutrient inputs from urban, industrial, and agricultural development. The microdetrital-based food web may be less efficient for salmon and steelhead and favor other fish species in the estuary, such as American shad. It is likely that estuarine food web dynamics are being further altered by the presence of native and exotic fish, introduced invertebrates, invasive plant species, and thousands of over-water and instream structures, which alter habitat in their immediate vicinity. These and other changes in habitat have left the estuary and plume in a degraded state compared to historical conditions (Appendix E).

Currently, more information is needed about the use of estuarine and plume habitats by juvenile Snake River spring/summer Chinook salmon and steelhead to identify potential bottlenecks that could be restricting productivity of natural-origin fish. It is possible that the carrying capacity and diversity of the Columbia River estuary has declined, or that the carrying capacity of the estuary might now be exceeded by current smolt (hatchery- and natural-origin) production (ISAB 2015). Such changes would likely intensify density dependent ecological interactions such as competition, predation, disease, and migration, depending on abundances of life-history types passing through the estuary at the same time.

Ocean

The conditions that juvenile and adult spring/summer Chinook salmon and steelhead experience in the ocean environment also have a significant effect on productivity and survival. Conditions in the ocean vary considerably between years; poor ocean conditions can result in poor salmonid survival and low returns to the Columbia River, while good ocean conditions can boost survival, health, and body size of returning fish. The Ocean Module (Appendix D) describes what we know about the ocean environment and its connection to the estuary, the use of this environment by different species, and the risks to salmon during their ocean life. Ocean-related limiting factors and threats are summarized here.

After Snake River spring/summer Chinook salmon and steelhead leave the Columbia Basin, they travel over a wide area of the North Pacific Ocean during their first year of ocean life. Snake River steelhead often cover a larger range than spring/summer Chinook salmon, moving from area to area in response to water temperature (Welch et al. 1998; Atcheson et al. 2012; Appendix D). In comparison, most spring/summer Chinook salmon are in the Gulf of Alaska by the end of their first year of ocean life (Teel et al. 2014). The early ocean period is often a critical period for both species, with early ocean growth often positively correlated to ocean survival and adult returns to Bonneville Dam. Little is known about either species once the fish enter their second year of ocean life. Potential limiting factors relate to the ocean's physical (e.g., temperature, circulation, stratification, upwelling), chemical (e.g., acidification, nutrient input, oxygen content), and biological (e.g., primary production, species distributions, phenology, food web structure, community composition, and ecosystem functions/services) components and processes. Most of these risk factors are very poorly understood (Appendix D).

The physical and biological relationships between habitat conditions in freshwater, the estuary, the plume, and the nearshore ocean remain unclear. It is likely that ocean growth and survival, especially during the time that salmon and steelhead spend in the Northern California Current, are influenced by characteristics of the fish (size, timing, condition) during their time in the estuary and plume; however, this relationship is not fully understood. Scheuerell et al. (2009) reported that timing of ocean entry was related to survival of Columbia River basin Chinook salmon and steelhead, with earlier migrating fish generally performing better than later migrating fish.

There is some evidence that flow during seaward migration through the mainstem Columbia River influences mortality rates. Studies by Petrosky and Schaller (2010) and Haeseker et al. (2012) correlated lower mainstem flows with reduced marine survival for Snake River spring/summer Chinook salmon; however, the mechanisms to explain these statistical relationships were unclear. Flow can influence arrival timing in the estuary (Scheuerell et al. 2009; Tomaro et al. 2012), but so can transportation, which has also been related to subsequent mortality (see summary in Williams et al. 2005). Flow also affects plume characteristics (Burla et al. 2010) with additional potential effects on salmon survival. For example, Miller et al. (2013) found that returns of Upper Columbia sub-yearling Chinook salmon to Priest Rapids Dam were related to plume volume at the time of emigration in most years studied.

5.2.3 Hydropower and Mainstem Migration Corridor

The multipurpose Federal Columbia River Power System (FCRPS) projects in the lower Snake and Columbia River mainstem corridor remain a primary threat to the viability of Snake River spring/summer Chinook salmon and steelhead. The system of dams and reservoirs continues to affect both species during their juvenile and adult migrations. The fish must pass up to eight large mainstem dams on their journey to the ocean and back: four federal dams on the lower Snake River mainstem (Lower Granite, Lower Monumental, Ice Harbor, and Little Goose Dams) and four federal dams on the Columbia River mainstem (McNary, The Dalles, John Day, and Bonneville Dams). This section summarizes the general effects of the mainstem hydropower system on Snake River spring/summer Chinook salmon and steelhead. The 2017 Hydro Module describes the impacts in more detail.

Salmon and steelhead survival is primarily affected by the operation and configuration of the mainstem lower Snake and Columbia River hydropower projects. The fish are also affected to a lesser degree by the management of water released from the Hells Canyon Complex on the Middle Snake River, Dworshak Dam on the North Fork Clearwater River, and other projects including upper basin storage reservoirs in the U.S. and Canada. While impacts on the species from hydropower system development and operations on the Columbia and Snake Rivers have been significantly reduced in recent years, especially for steelhead, they continue to affect the viability of both species.

Limiting factors and threats posed by the mainstem FCRPS projects include those related to dam passage mortality; loss of habitat due to conversion of riverine habitat to slower moving reservoirs with modified shorelines; and temperature regimes due to flow modifications in all mainstem reaches. Specific limiting factors that have impacted viability in recent years include direct and indirect mortality on downstream migrants (juveniles), alteration of the hydrograph (mainstem and estuary flow regime), degraded rearing habitat and food supplies for both presmolts and smolts, increased migrant vulnerability to predation in the Columbia River, elevated summer water temperatures that can delay upstream passage of adult steelhead or summer migrating Chinook salmon, and increased predation by pinnipeds of Chinook salmon below Bonneville Dam. These limiting factors and threats are summarized below.

Migrating Juveniles

The hydropower system can affect migrating Snake River spring/summer Chinook salmon and steelhead by delaying downstream juvenile passage and increasing direct and indirect mortality of juvenile migrants. Migrating juvenile spring/summer Chinook salmon and steelhead encounter a number of challenges in the mainstem corridor during their downstream migration. The hydropower projects have converted much of the once free-flowing migratory river corridor into a stair-step series of slower pools (though juveniles do feed and rear in the reservoirs). Construction of the mainstem dams increased the time it took for smolts to migrate through the lower Snake and Columbia Rivers. Migration delays are most pronounced in low flow years but still present in even the highest flow years (Williams et al 2005) (Figure 5-1). However, the addition of surface spillway weirs, and increased levels of spill at the dams during the last 10 years has greatly reduced delay for yearling fish, particularly for steelhead (Smith 2014) (Figure 5-2).

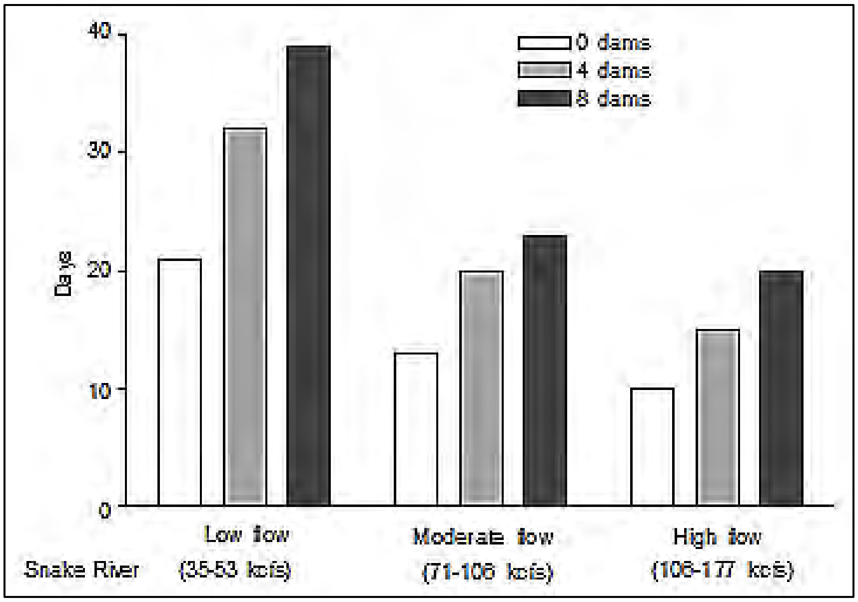

Figure 5-1. Estimated annual average travel times for yearling Chinook salmon through the section of the lower Snake and Columbia Rivers now inundated by mainstem hydropower dams (approximately from Lewiston, Idaho, to Bonneville Dam tailrace). Estimates for the 0- and 4-dam scenarios are derived after data in Raymond (1979). Data for 8 dams were derived from PIT-tagged fish between 1997 and 2003.

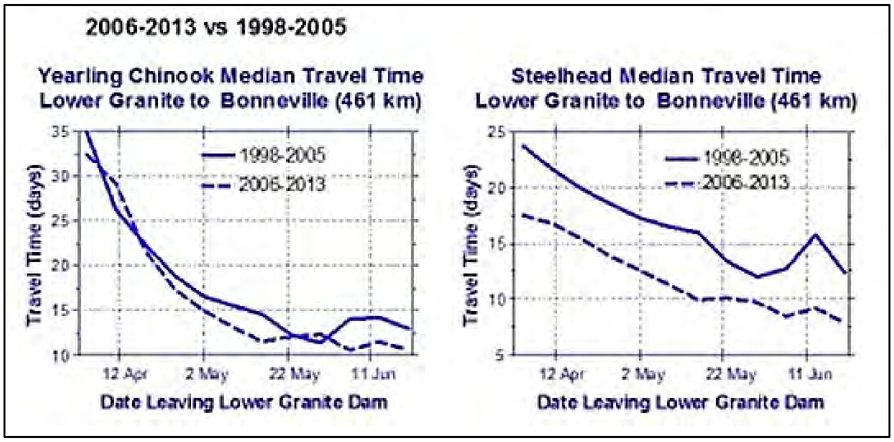

Figure 5-2. Comparison of estimated annual travel time of juvenile yearling chinook and steelhead to migrate from Lower Granite Dam to Bonneville Dam for an average of years when the projects were modified with surface weirs and increased levels of spill (2006-2013), versus years when the surface years were largely absent and spill volumes were lower (1998-2005).

The extent of this impact compared to before hydropower system development, however, can only be estimated because the methodologies used to monitor the fish during the 1960s and 1970s (freeze brands, etc.) were radically different from those used presently (PIT tags). Based on recent detections of PIT-tagged smolts, average travel times from Lower Granite Dam to Bonneville Dam range from about 13 to 16 days for yearling Chinook salmon and 11 to 15 days for steelhead (2010-2015 migration years) with earlier migrants (April) generally taking longer to migrate through this reach than later migrants (late May). These travel times are faster than those measured in 2007 and reflect substantial improvements (especially for steelhead smolts) at each of the mainstem Snake and Columbia River dams. While migration times have been reduced, delays likely continue to impact smolts by: (1) increasing their exposure to predation, disease, and thermal stress in the reservoirs; (2) disrupting their arrival time in the estuary; (3) depleting their energy reserves; and (4) for steelhead, substantial delay has been shown to cause residualism (a loss of migratory behavior).

Juvenile salmon and steelhead can be killed while migrating through the dams, both directly through collisions with structures and abrupt pressure changes during passage through turbines and spillways, and indirectly, through non-fatal injury and disorientation that leave fish more susceptible to predation and disease, resulting in delayed, or latent, mortality. A number of actions in recent years have improved these passage conditions in the migration corridor for all listed Columbia River salmon and steelhead species. By 2009, each of the eight mainstem lower Snake and lower Columbia River dams was equipped with a surface passage structure (spillbay weirs, powerhouse corner collectors, or modified ice and trash sluiceways) to improve passage of smolts, which primarily migrate in the upper 20 feet of the water column in the lower Snake and Columbia Rivers. Other improvements include the relocation of juvenile bypass system outfalls to avoid areas where predators collect, changes to spill operations, installation of avian wires to reduce juvenile losses to avian predators, and structures that reduce dissolved gas concentrations that might otherwise limit spill operations. Nevertheless, while these and other changes have improved smolt survival in recent years, dam passage impacts remain.

As recommended in NMFS' 2016 status review, continued monitoring is needed to gain a better understanding of smolt migration timing and mortality rates through the lower Snake and Columbia Rivers, including the effects of spring and summer spill operations on juvenile migrants. We also need a better understanding of juvenile mortality that occurs before the fish reach the head of Lower Granite Reservoir and the FCRPS system. As discussed earlier, substantial mortality of in-river migrating juveniles occurs between natal streams and the hydropower system (Faulkner et al. 2016).

The degree to which mortality in the estuary and ocean is caused by the prior experience of juveniles passing through the FCRPS (i.e., delayed or latent mortality) is unknown, and hypotheses regarding the magnitude of this effect vary greatly (ISAB 2007, 2012). Yearling smolts detected in bypass systems are less likely to return as adults than those migrating over a spillway. However, it is unclear whether this mortality reflects injury during passage through the bypass systems, or if fish that were already sick or injured are more likely to use these routes. The relative magnitude of delayed or latent effects, the specific mechanisms causing these effects, and the potential for interactions with other factors (ocean conditions, toxic pollutants, habitat modification or predation below Bonneville Dam, etc.) remain critical uncertainties. Answering these questions could improve the ability of hydropower system managers to improve survival (and potentially SARs) through additional structural improvements or operational modifications at the mainstem dams in future years (NMFS 2014c).

Additional information is needed on differential survival between populations of Snake River spring/summer Chinook salmon and steelhead migrating through the FCRPS. Research suggests that populations that spawn and rear at high elevations and produce relatively small yearling and sub-yearling smolts that migrate during June and July could be experiencing higher mortality rates in the mainstem portion of the migration corridor than populations that spawn at lower elevations and produce relatively large yearling smolts that migrate during the spring (NMFS 2016).

Migrating Adults

Except during recent years with high summer water temperatures, the migration rates of adults through the mainstem FCRPS projects is similar to that before the dams were built (Ferguson et al. 2005). Any delay that adults experience as they search for and navigate through fish ladder entrances is balanced by the faster rate of migration through the lower velocity reservoir environments.

Water management operations at large upstream flood control storage projects in the United States and Canada and the mainstem run-of-river reservoirs have combined with changing climate patterns to alter the thermal regime of the Snake and Columbia Rivers compared to the predevelopment period. In general, the mainstem Snake and Columbia Rivers now have higher minimum winter temperatures and are cooler later in the spring and warmer later in the fall (Perkins and Richmond 2001). The combined effects of these changes appear to benefit spring and summer Chinook salmon and early migrating sockeye salmon and steelhead, which migrate during the spring and much of the summer. However, late summer and fall migrating sockeye salmon and steelhead are exposed to elevated temperatures compared to the predevelopment period. The Corps operates Dworshak Dam on the North Fork Clearwater River during July, August, and September to maintain cooler summer temperatures in the lower Snake River in an effort to mitigate these effects of reservoir operations and warmer climate conditions.

Adult salmon and steelhead can pass each of the eight mainstem dams in the lower Snake and Columbia rivers volitionally at fish ladders (also called "fishways"). In general, we consider these adult passage facilities to be highly effective. For example, the current estimate of average adult Snake River spring/summer Chinook salmon survival (conversion rate estimates using known-origin adult fish after accounting for "natural straying" and mainstem harvest) between Bonneville and Lower Granite Dams (2012-2016) is approximately 87.3 percent (Table 5-5).[21]

Table 5-5. Adult Snake River spring/summer Chinook salmon and Snake River Basin steelhead survival estimates after correction for harvest and straying based on PIT tag conversion rates from Bonneville (BON) to McNary (MCN) Dam, McNary to Lower Granite (LGR) Dam, and Bonneville to Lower Granite Dam. Source: http://PTAGIS.org. Note: 2016 Harvest estimate unavailable, so 2011-2015 average harvest rate was used to correct the 2016 survival estimate.

Species	Years	BON to MCN	MCN to LGR	BON to LGR
SR Spr/Sum Chinook	2012-2016 Avg	93.1%	94.0%	87.3%
SR Steelhead	2012-2016 Avg	93.2%	94.3%	87.9%

More information is needed to aid managers in determining why/ where adult losses occur between Bonneville and Lower Granite Dams (e.g., adult fallback at spillways, unauthorized harvest, injuries from pinniped attacks, etc.) and in developing potential remedies. In addition, some returning adult spring/summer Chinook salmon and steelhead from the Tucannon River are "overshooting" the river and passing above Lower Granite Dam. More information is needed to determine why this is occurring and what can be done to improve passage conditions for the adults when they return downstream. The RM&E described in Chapter 7 of this Plan, the 2017 Hydro Module (Appendix G), and the 2014 Supplemental FCRPS Biological Opinion (NMFS 2014c) provide more discussion on these information needs.

Steelhead Kelt Passage

A small fraction of adult steelhead do not die after spawning and attempt to migrate back to the Pacific Ocean. Currently very few post-spawn adult steelhead, termed "kelts," survive downstream passage and ocean travel to return as repeat spawners. High mortality rates would be expected in a free-flowing river because the energy reserves of the outmigrating kelts are substantially depleted; however, fisheries managers expect that survival is lower because turbine bypass systems were not designed to safely pass adult fish (Appendix G). Kelt downstream

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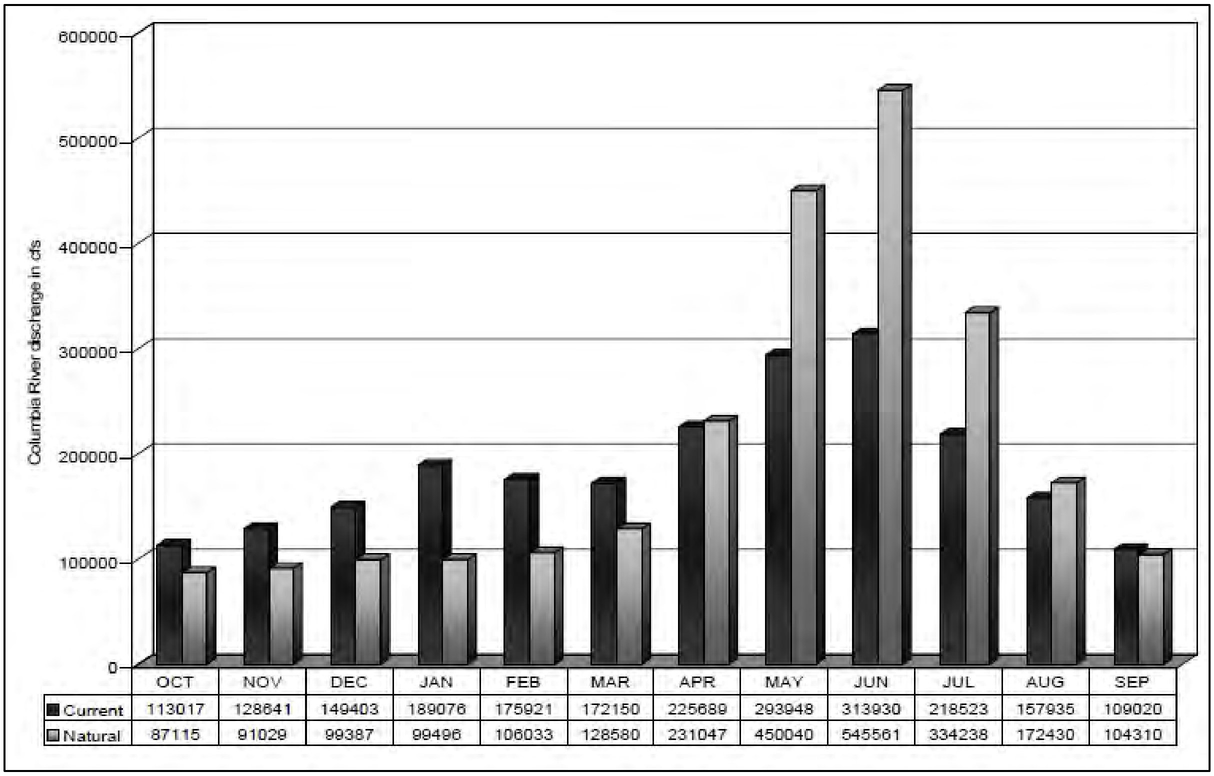
[21] These adult survival estimates capture all sources of mortality within the Bonneville to Lower Granite Dam reach, including those resulting from the existence and operation of the FCRPS, unquantified levels of mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal attacks, etc.), and unquantified levels of "natural' mortality (i.e., levels that would have occurred without the influence of human activities).

migrations are also delayed by the mainstem projects (Wertheimer and Evans 2005) in a manner similar to that previously described for juveniles (downstream survival rates are negatively affected because more energy and time are required to migrate through the reservoirs).

The installation of spill weirs and other surface passage routes at each of the mainstem FCRPS dams to improve juvenile fish passage has also benefited steelhead kelts. A study on steelhead kelt survival through the FCRPS found that about 40 percent of tagged kelts released at or above Lower Granite Dam survived to river kilometer 156 (downstream of Bonneville Dam) in 2012 (Colotelo et al. 2013). In 2013, the overall kelt survival rate through the reach was 27.3 percent; however, river discharge was lower in 2013 compared to 2012 and likely contributed to differences in migration success (Colotelo et al. 2014). In both study years, spillway weirs were the primary route of passage for steelhead kelts in the Snake River and survival estimates of kelts that passed via spillway weirs were higher than for kelts that passed using other routes (Colotelo et al. 2014). These rates compared to estimated survival rates of about 4 to 16 percent in 2001 and 2002. BPA and the U.S. Army Corps of Engineers are currently developing strategies to increase kelt survival through the hydropower system.

Altered Seasonal Flow and Temperature Regimes

The water impoundment and dam operations in Canada and the Upper Columbia and Snake River basins in the United States affect downstream hydrologic conditions and water quality characteristics that are important for salmonid survival. Today, average flows during the annual spring freshet are roughly the same in April, but about 35 to 40 percent lower than estimated unregulated flows in May and June when the great majority of steelhead and yearling Chinook salmon smolts migrate (Figure 5-3, from NMFS 2008c SCA). These flow reductions also contribute to the slower travel times noted above.



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
■ Current	113017	128641	149403	189076	175921	172150	225689	293948	313930	218523	157935	109020
▨ Natural	87115	91029	99387	99496	106033	128580	231047	450040	545561	334238	172430	104310

Figure 5-3. Changes in mean monthly Columbia River flow, current conditions compared to flows that would have occurred without water development (NMFS 2008c).

The effect of hydropower and water storage project operations on river temperatures is complicated. Large storage projects like Brownlee or Grand Coulee Dams, because of their thermal inertia, generally increase winter minimum temperatures, delay spring warming and delay fall cooling, resulting in higher late summer and fall water temperatures (Appendix G).

Hydropower and water storage development, water management operations, and climate change have generally increased the frequency of high water temperatures (20 °C) occurring while summer Chinook salmon and steelhead are migrating through the lower Snake River during late summer and fall (EPA 2001). Crozier et al. (2011) showed a rise of 2.6 °C in mean July water temperature in the lower Columbia River at Bonneville Dam between 1949 and 2010 (NMFS 2014c); however, high water temperatures (>20 °C) often occurred in the lower Snake River from July to mid-September prior to hydropower and water storage development (Perry and Bjornn 2002). The high water temperatures can cause migrating adult salmon to stop or delay their migrations, or increase fallback at a dam. Warm temperatures can also increase the fishes' susceptibility to disease. Warmer water temperatures can increase the foraging rate of predatory fish, thereby increasing smolt consumption.

Direct effects of high water temperatures on salmon and steelhead depend on the coincidence of sensitive life stages with the shifts in water temperature (Table 5-6). Since 1993, the U.S. Army Corps of Engineers has cooled rising water temperatures in the lower mainstem Snake River for migrating juvenile fish by drafting colder water from Dworshak Reservoir during summer months. The U.S. Bureau of Reclamation also provides flow augmentation from the upper Snake River basin that enhances flows (water quantity) in the lower Snake and Columbia Rivers. The agency seeks to release 487,000 acre feet of flow from the upper Snake River basin, but during drier water years water availability declines and limits flow releases to 427,000 acre feet or less. Most of the water from the upper Snake River basin is released to improve mainstem flows during July and August; however, since 2008 a portion of the upper Snake River water has been released in May and June to benefit spring migrants.

Table 5-6. Summary of potential thermal effects to salmonids in the Columbia Basin (NMFS 2008b).

Species	Life Stage	Timing	Potential for Thermal Effects
Snake River spring/summer Chinook Salmon	Adult Migration	April-June	
	Migration/Spawning	August-October	X
	Egg Incubation/Alevin	Throughout winter season	
	Emergence	March-May	
	Juvenile Rearing	1 year in freshwater	X
	Juvenile Outmigration	Spring	
Snake River Steelhead	Adult Migration	May-October	X
	Spawning	March-May	
	Incubation	May-June	X
	Emergence	May-June	X
	Juvenile Rearing	1-2 years in freshwater	X
	Juvenile Outmigration	Spring	

Migrating adult summer-run Chinook salmon and steelhead are particularly susceptible to potential high water temperatures in the Snake and Columbia Rivers. For example, in late July and September 2013 a combination of low summer flows, high air temperatures, and little wind created thermally stratified conditions in Lower Granite reservoir and the adult ladder, disrupting fish passage for more than a week. In response, the U.S. Army Corps of Engineers modified dam operations and pumped cooler water from deeper in the forebay to reduce water temperatures in the fish ladder. This change, along with cooler weather, allowed the fish to resume passage at the dam. Still, the events resulted in an estimated 15 percent of the migrating summer Chinook salmon and 12 percent of the migrating steelhead failing to pass Lower Granite Dam (Appendix G). Then in 2015 unusually hot weather resulted in very high tributary and mainstem temperatures in late June and July. Federal project managers responded by releasing cool water from Dworshak Dam several weeks earlier than usual. In addition, the U.S. Army Corps of Engineers operated temporary pumps at the Lower Granite Dam adult ladder to moderate temperatures, and, in coordination with NMFS and other co-managers, altered turbine unit and spill operations in an attempt to improve passage conditions (hydraulic attractiveness) in the fishway at Lower Granite and Little Goose Dams. The warm water conditions affected adult Snake River sockeye salmon more than other Snake River species, but Snake River summer

Chinook salmon were also significantly affected, especially during travel through the lower Columbia River between Bonneville and McNary Dams (NMFS 2016).

Table 5-7 summarizes the 2010 - 2015 survival estimates of PIT tagged Snake River spring/summer Chinook salmon which passed Bonneville Dam after June 1. Elevated water temperatures during June 2015 appear to have had a negative impact on Snake River spring/summer Chinook survival in both the Bonneville to McNary Dam reach and the McNary to Lower Granite Dam reach (where there is no harvest and survival is typically 90 percent+). An analysis of only those fish which passed Bonneville Dam after water temperatures exceeded 21 °C on June 21st (a subset of the 2015 analysis) showed even lower survivals in the Bonneville to McNary Dam reach. Survival was higher in the McNary to Lower Granite Dam reach, though this may be a result of the small sample size involved in this reach as there was no statistically significant difference (p=0.058) between the 2015 estimate and the subset of 2015 data.

The frequency of high water temperatures (20 °C) is likely to occur in the future in response to climate change; however, the impact of the temperature change is unclear because species response to climate change is complex and will vary by species and population (Crozier and Hutchings 2014; Munoz 2015; Mantua et al. 2015). Genetic variability in physiological tolerance of various traits can allow fish populations to adapt evolutionarily in response to a warming climate, and thus shift their timing of migration out of or into a river (Crozier 2016). This shift in migration timing in response to climate change has already occurred in the Snake River spring/summer Chinook salmon and steelhead life-history strategy, and is likely to continue in the future.

Table 5-7. Summary of 2010 - 2015 survival of Snake River spring/summer Chinook passing Bonneville Dam after June 1 (Bellerud 2016).

Year	BON to MCN*			MCN to LGR		
	Survival	95%ci[22]		Survival	95%ci	
2010	71.7%	68.5%	74.7%	95.2%	93.2%	96.8%
2011	63.2%	60.2%	66.0%	91.9%	89.6%	93.8%
2012	78.1%	74.1%	81.7%	89.1%	85.5%	92.1%
2013	79.0%	73.3%	84.0%	96.3%	92.5%	98.5%
2014	63.1%	58.1%	67.9%	89.9%	85.5%	93.4%
2015	53.0%	49.4%	56.5%	75.7%	71.3%	79.7%
2015 20°C+	41.8%	35.0%	48.9%	85.3%	76.5%	91.5%

*Bonneville Dam (BON), McNary Dam (MCN), Lower Granite Dam (LGD).

To improve salmon and steelhead survival during times of high water temperatures, the U.S. Army Corps of Engineers recently constructed a structure at Lower Granite Dam to move cooler water from deeper in the reservoir into the top (exit) of the adult fishway in time for the 2016 migration. This structure minimized temperature differentials within the fishway to improve

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[22] Ninety-five percent confidence interval.

passage conditions. The 2017 Hydro Module (Appendix G) and 2014 Supplemental FCRPS Biological Opinion (NMFS 2014c) describe these impacts in detail and identify actions to address them.

Blocked Areas

Historically, spring/summer Chinook salmon and steelhead ranged much further up the Snake River, as far as Shoshone Falls and also into several large middle mainstem tributaries. Seven of these tributaries ─ the Boise, Burnt, Malheur, Owyhee, Payette, Powder, and Weiser Rivers ─ may have provided hundreds of miles of spawning and rearing habitat, especially for steelhead. Dam construction blocked salmon and steelhead passage to this historical habitat. The species lost access to the Snake River and tributaries above RM 457 after construction of Swan Falls Dam in 1901. Construction of the Hells Canyon Complex of dams on the middle mainstem Snake River in the 1950s and 1960s further reduced access to historical habitat (USBR 1997). Many smaller dams, and some temporary dams, were also built without fish passage facilities and had the same effects, though on much smaller scales. For example, Sunbeam Dam, constructed on the Salmon River (near RM 368) in 1910, was a serious impediment to migration of anadromous fish and may have been a complete block in at least some years before its partial removal in 1934 (Waples et al. 1991). Today, as much as 210 miles of historical habitat in the mainstem Snake River above Hells Canyon Dam, and hundreds of additional miles of tributary habitat remain inaccessible.

Several dams also influence salmon and steelhead production in the Clearwater River drainage. Construction of Lewiston Dam on the lower Clearwater River mainstem in 1927 blocked Chinook salmon passage until the 1940s, and is believed to have caused the extirpation of native Chinook salmon, but not steelhead, in the Clearwater River above the dam site. Lewiston Dam was removed in the early 1970s, but Dworshak Dam, completed in 1971, caused the extirpation of steelhead and Chinook salmon runs to the North Fork Clearwater River. Harpster Dam, located on the South Fork Clearwater River, completely blocked steelhead and Chinook salmon from 1949 through 1963; however, the dam was removed in 1963 and fish passage was restored to approximately 500 miles of suitable spawning and rearing habitat.

5.2.4 Fisheries Management

Snake River spring/summer Chinook salmon and steelhead encounter fisheries in the ocean, Columbia River estuary, mainstem Columbia and Snake Rivers, and tributaries as they migrate from the ocean back to natal streams. Mortality and other indirect effects associated with the fisheries affect all Snake River spring/summer Chinook salmon and steelhead populations. This section summarizes these effects. The Harvest Module (Appendix F) provides more detail on the various fisheries, management processes, and other fisheries-related information. Limiting factors and threats specific to populations or major population groups are discussed in the management unit plans (Appendixes A, B, and C).

Fisheries have the potential to affect Snake River spring/summer Chinook salmon and steelhead by harvesting (killing) natural-origin adults and by producing selective pressure on migration timing, maturation timing, and size-at-age characteristics. Direct effects are defined as immediate mortality as a result of fisheries: fish that are caught and retained, or are fatally injured but not landed. The latter includes the small proportion of fish encountered by fishing gear. Indirect effects include delayed mortality for fish that are caught and released, or are injured by fishing gear but not landed. Other, indirect, fishery-related effects to Snake River spring/summer Chinook salmon and steelhead include reduced reproductive success when fish stressed by encounters with fishing gear do not spawn successfully because of their exposure, including those that are caught and released. Other effects result when fisheries selectively remove fish with specific population traits, such as their run timing or geographic distribution. Fisheries also reduce the number of adult salmonid carcasses in streambeds, which can impact the nutrient supply and carrying capacity of a stream system.

Direct and indirect effects associated with past and present fisheries continue to affect the abundance, productivity, and diversity of all Snake River spring/summer Chinook salmon and steelhead populations. However, while harvest-related mortality contributed significantly to the species' decline, these same fisheries are now managed to restrict the mortality of ESA-listed species. As a result, harvest impacts have been reduced substantially and have remained relatively constant in recent years.

The largest harvest-related effects on Snake River spring/summer Chinook salmon and steelhead result from the implementation of tribal and nontribal mainstem Columbia River fisheries. These fisheries target harvestable hatchery stocks migrating through Zones 1-6 in the lower portion of the mainstem Columbia River, extending from the river mouth to McNary Dam. Mortality associated with tributary fisheries also occurs in some areas. Mortality associated with ocean fisheries, which target fall-run Chinook salmon, is rare for the species.

Fishery managers use abundance-based management frameworks to define year-specific allowable harvest rates. The frameworks restrict annual mortality rates on ESA-listed salmon and steelhead while meeting various commercial, recreational, and tribal harvest goals. States and tribes manage fisheries in the Columbia River estuary, mainstem Columbia River, Snake River, Salmon River, and Clearwater River to focus on different stocks and populations while adhering to the guidelines and constraints of the Endangered Species Act administered by NMFS, the Columbia River Compact, and management agreements negotiated between the parties to *U.S. v. Oregon*. Consequently, mortality rates on natural-origin Snake River spring/summer Chinook salmon and steelhead are influenced by a combination of laws, policies, and guidelines.

Fishery managers develop long-term plans for managing fisheries to reduce potential effects on recovery of ESA-listed species. These Fishery Management and Evaluation Plans (FMEPs) and Tribal Resource Management Plans (TRMPs) are submitted to NMFS for authorization under the ESA and are implemented in accordance with a letter of concurrence from NMFS. The plans must meet criteria described in the ESA section 4(d) rule and regulations to reduce potential impacts on ESA-listed species. Accordingly, the mortality rates for natural-origin spring/summer Chinook salmon and steelhead as a result of the fisheries are managed at levels intended to support the recovery of natural-origin populations. The plans are under continuous review by NMFS. The fisheries are monitored annually according to processes and schedules identified in the plans.

Harvest exploitation rates have been relatively low on Snake River spring and summer Chinook salmon, generally below 10 percent, but have increased in recent years due to the continued large returns of hatchery spring Chinook salmon to the Columbia River basin. These large returns triggered increased allowable harvest rates under the abundance-driven sliding-scale harvest rate strategy guiding annual fishery management. The overall pattern of exploitation rates on Snake River spring Chinook is nearly identical to the rates on Upper Columbia River spring Chinook salmon, shown in Figure 5-4 and calculated by the *U.S. v. Oregon* Columbia River Technical Advisory Committee (NWFSC 2015). Steelhead encounters in the ocean and mainstem Columbia River fisheries are rare because the timing of the steelhead run occurs in the fall, well after the closure of the spring/summer Chinook salmon fisheries. (NMFS 2008d). Mainstem Columbia River fisheries are monitored annually to reduce impacts associated with the fisheries.

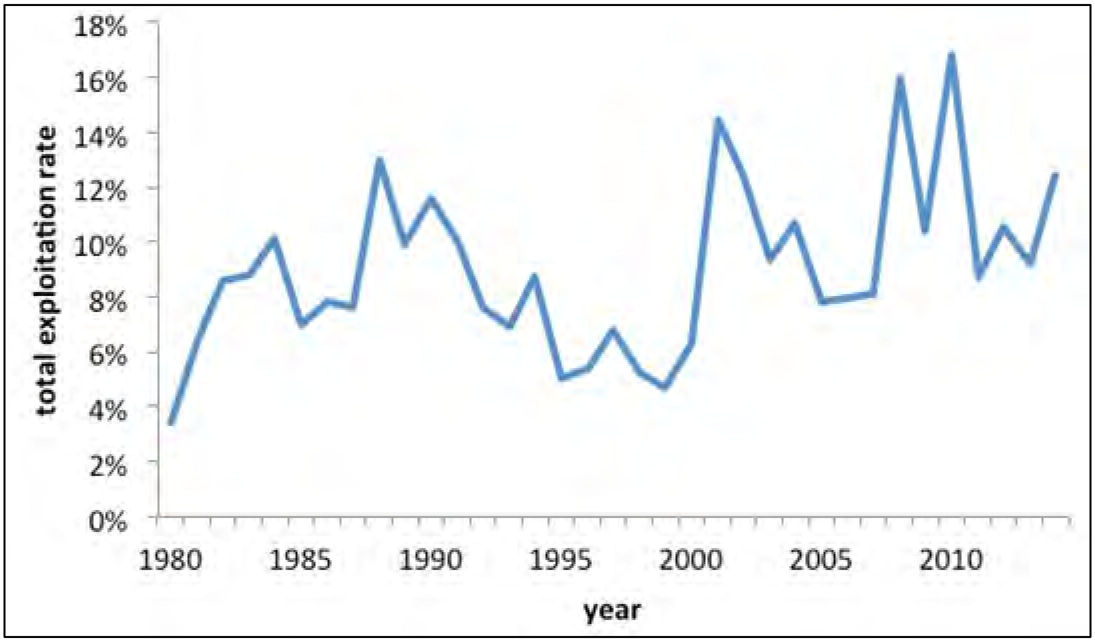

Figure 5-4. Total exploitation rate for Upper Columbia River spring Chinook salmon. Data from the *U.S. v. Oregon* Columbia River Technical Advisory Committee.

The majority of harvest on Snake River Basin steelhead occurs in tribal gillnet and dip net fisheries targeting Chinook salmon. The B-run component of the summer steelhead run, which returns to spawn in Idaho's Salmon and Clearwater River drainages, is more vulnerable to harvest in gillnet fisheries because of their larger size and consequently experiences higher fishing mortality than the A-run component. B-run steelhead also have a run timing and length distribution similar to fall-run Chinook salmon, and are susceptible to harvest in tribal fisheries directed at these fish (Copeland et al. 2017). In recent years, total exploitation rates on the A-run have been stable at around 5 percent while exploitation rates on the B-run have generally been in the range of 15 to 20 percent. Sport fisheries targeting hatchery-run steelhead with incidental impacts on wild returns also occur in the mainstem Columbia River and sections of the Snake, Clearwater, and Salmon Rivers (NWFSC 2015).

Ongoing fisheries management discussions are working toward abundance-based sliding-scale harvest rates for Snake River spring/summer Chinook salmon and steelhead. More fisheries data needs to be collected through PIT-tag detection and other studies to help managers better understand the sources of losses and improve harvest management. Impacts from harvest catch and release are also unclear.

5.2.5 Hatchery Programs

Hatchery programs can affect all four VSP parameters, and in so doing can be a source of benefits or risk to natural-origin populations. When natural-origin populations are chronically depressed, hatchery programs can benefit salmonid viability by reducing extinction risk and conserving genetic variability that would otherwise be lost through genetic drift. Hatchery programs can also support the reintroduction of salmon and steelhead into areas where they have been extirpated, thereby increasing their spatial distribution and reducing the threat posed by environmental variability and catastrophic events.

As natural-origin spawners increase and extinction risk decreases, hatchery propagation poses risks to natural-origin salmon and steelhead viability. Risks include genetic risks, such as disturbance of diversity patterns, reduced fitness of wild fish and altered life-history traits of the natural-origin populations. They also include ecological risks to natural-origin population abundance and productivity, such as increased competition for limited food and habitat, amplified predation, and by transferring diseases.

Thus, achieving ESA recovery for Snake River spring/summer Chinook salmon and steelhead will require (a) clearly identifying the recovery risks and uncertainties associated with hatchery operations, (b) effectively managing the genetic and ecological risks to natural-origin fish, and (c) robust monitoring to evaluate the uncertainties and further minimize risks to recover the populations to self-sustaining levels (HSRG 2009).

Generally, effects range from beneficial to negative for programs that use local fish for hatchery broodstock (Table 5-8). Even when a hatchery program uses genetic resources that represent the ecological and genetic diversity of the target or affected natural population(s), they may pose a risk to the fitness of the population based on the proportion of natural-origin fish being used as hatchery broodstock and the proportion of hatchery-origin fish spawning in the wild (Lynch and O'Hely 2001; Ford 2002). However, the benefits may outweigh these risks under circumstances where demographic or short-term extinction risk to the population is greater than risks to population diversity and productivity. Conversely, when hatchery programs use non-local broodstock that do not represent the ecological and genetic diversity of the targeted or affected natural population(s), effects may be negative. In these situations, isolating hatchery fish and avoiding co-occurrence of hatchery and natural-origin fish reduces the risks.

Table 5-8. Overview of the range in effects on natural population viability parameters from two categories of hatchery programs (NMFS 2016).

Natural population viability parameter	Hatchery broodstock originate from the local population and are included in the ESU or DPS	Hatchery broodstock originate from a non-local population or from fish that are not included in the same ESU or DPS
Productivity	**Positive to negative effect** Hatcheries are unlikely to benefit productivity except in cases where the natural population's small size is, in itself, a predominant factor limiting population growth (i.e., productivity) (NMFS 2004).	**Negligible to negative effect** Effect is dependent on differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish the greater the threat), the duration and strength of selection in the hatchery, and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible affect).
Diversity	**Positive to negative effect** Hatcheries can temporarily support natural populations that might otherwise be extirpated or suffer severe bottlenecks and have the potential to increase the effective size of small natural populations. Broodstock collection that homogenizes population structure is a threat to population diversity.	**Negligible to negative effect** Effect is dependent on the differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish the greater the threat) and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible affect).
Abundance	**Positive to negative effect** Hatchery-origin fish can positively affect the status of an ESU/DPS by contributing to the abundance and productivity of the natural populations in the ESU/DPS (70 FR 37204, June 28, 2005, at 37215).	**Negligible to negative effect** Effect is dependent on the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible affect), handling, RM&E and facility operation, maintenance and construction effects.
Spatial Structure	**Positive to negative effect** Hatcheries can accelerate re-colonization and increase population spatial structure, but only in conjunction with remediation of the factor(s) that limited spatial structure in the first place. "Any benefits to spatial structure over the long term depend on the degree to which the hatchery stock(s) add to (rather than replace) natural populations" (70 FR 37204, June 28, 2005 at 37213).	**Negligible to negative effect** Effect is dependent on facility operation, maintenance, and construction effects and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible affect).

This section summarizes the effects of hatchery programs on Snake River spring/summer Chinook salmon and steelhead populations. The three management unit plans discuss hatchery-related limiting factors and threats to individual populations and MPGs, and present strategies and actions to address these factors.

Hatchery programs for many Snake River Chinook salmon and steelhead populations serve the dual purpose of providing fish for fisheries and supplemental spawners to help rebuild depressed natural populations. Most hatchery production for Snake River spring/summer Chinook salmon and steelhead was initiated under the Lower Snake River Compensation Plan (LSRCP) as part of the Water Resources Development Act of 1976 (90 Stat. 2917). The LSRCP included a program to design and construct fish hatcheries to compensate for some of the losses of salmon and steelhead adult returns incurred as a result of the construction and operation of the four lower Snake River hydroelectric dams. Mitigation goals for the LSRCP program include 55,100 adult steelhead, 58,700 adult spring/summer Chinook salmon, and 18,300 fall Chinook salmon to the Snake River. The program is administered by the U.S. Fish and Wildlife Service. Production under the LSRCP generally began in the mid-1980s.

Other hatchery programs also produce salmon and steelhead. The Dworshak Dam mitigation program provides for hatchery production of steelhead as compensation for the loss of access to the North Fork Clearwater River. Dworshak Hatchery, completed in 1969, is the focus for that production. In addition, the Bonneville Power Administration funds the Nez Perce Tribal Hatchery as mitigation for the Federal Columbia River Power System. Hatchery fish are also produced as mitigation for fish losses caused by construction of the Hells Canyon Complex, a series of three retention dams, Brownlee, Hells Canyon, and Oxbow Dams, in the Snake River Hells Canyon area. None of the Hells Canyon Complex dams, which are owned and operated by Idaho Power Company, has fish passage facilities. The Idaho Power Company built four hatcheries to mitigate for the Hells Canyon Complex's effects on native fish populations: Oxbow, Rapid River, Niagara Springs, and Pahsimeroi Hatcheries. The four hatchery programs are managed by the Idaho Department of Fish and Game (IDFG). Several small-scale natural stock supplementation studies and captive breeding efforts have also been initiated in the Snake River basin since the mid-1990s.

The management of existing hatchery programs remains a threat for several Snake River spring/summer Chinook salmon and steelhead populations. The situation is complex, however, because several of the populations may have become extirpated if not for the benefit of hatchery supplementation. Further, the existence of locally derived hatchery stocks may help natural populations to bridge periods of adverse environmental conditions (as occurred in the 1990s).

Nevertheless, large releases of hatchery fish can pose risks to natural-origin fish in the Snake River spring/summer Chinook salmon and steelhead MPGs. For example, approximately four million B-run steelhead are released into the Salmon River and Clearwater River MPGs, primarily for harvest augmentation. These are large releases of hatchery fish relative to the likely size of natural production, and pose ecological and genetic risks (e.g., spawning site competition and hatchery-influenced selection). Further, some of the non-local B-run hatchery fish are released into areas where they are not the predominate life-history type. Other potential problems include using out-of-MPG stocks and releasing fish without acclimation, which may increase the risk of straying.

Achieving a balance between potential adverse impacts of hatchery programs with the long-term intent to reduce risk of extirpation requires careful management. It also requires continued research to clearly identify risks and uncertainties associated with hatchery operations. This management and a process for updating of hatchery programs is provided through the development and implementation of Hatchery and Genetic Management Plans (HGMPs) and Tribal Resource Management Plans (TRMPs), which are continuously under review and refinement. NMFS conducts ESA section 7 consultations on HGMPs and TRMPs to evaluate the effects of the hatchery programs on ESA-listed salmon and steelhead, and their designated critical habitat. It also evaluates the effect of the programs on Essential Fish Habitat, defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity," under the Magnuson-Stevens Fishery and Conservation Management Act. In 2016 and 2017, NMFS completed section 7 consultations and resulting biological opinions on six lower Snake River spring/summer Chinook salmon hatchery programs (NMFS 2016) and four Lower Snake River steelhead hatchery programs (NMFS 2017). In conclusion of the reviews, NMFS determined the hatchery actions were not likely to jeopardize the continued existence or recovery of the Snake River spring/summer Chinook salmon ESU or steelhead DPS, ore destroy or adversely modify designated critical habitat. The two documents provide further information on the NMFS reviews and findings, and are available at: http://www.westcoast.fisheries.noaa.gov/hatcheries/salmon_and_steelhead_hatcheries.html.

Several major uncertainties exist regarding the effects of hatchery programs on natural-origin Snake River spring/summer Chinook and steelhead populations. These uncertainties include the impact of hatchery releases on natural-origin population abundance, productivity, and genetic integrity. Importantly, they also include the ecological interactions that occur between hatchery and natural-origin ESA-listed fish in the tributary, mainstem, estuary, and ocean environments. Additional research will help managers assess demographic risk versus conservation benefit of hatchery supplementation, and the implications of hatchery programs.

One of the main areas where information is lacking is regarding the relative proportion and distribution of hatchery-origin spawners in natural spawning areas at the population level, particularly for Snake River steelhead (NWFSC 2015). Because of this lack of information, the status of most of the populations in the DPS remains highly uncertain. Information is needed to determine where and to what extent unaccounted for hatchery steelhead are interacting with depressed ESA-listed populations, particularly in Idaho (NWFSC 2015).

At a larger scale, information is also needed to determine the factors contributing to lower or greater reproductive success rates for hatchery fish, and the effects of total hatchery production on the listed salmon and steelhead populations. The potential effect of total hatchery production in the Columbia and Snake Rivers on natural-origin fish is unknown at this time.

5.2.6 Predation, Competition, Disease, and Exposure to Toxic Pollutants

Predation, competition, disease, and exposure to toxic pollutants all pose direct sources of mortality for Snake River spring/summer Chinook salmon and steelhead.

Predation

Anthropogenic changes in the Columbia River basin have altered the relationships between salmonids and other fish, bird, and pinniped species. Some species' abundance levels have increased dramatically, particularly in localized areas, increasing predation rates on steelhead and Chinook salmon juveniles and adults (NMFS 2014c). Consequently, predation by pinnipeds, birds, and piscivorous fish in the mainstem Columbia and Snake Rivers and some tributaries, while probably always a substantial source of mortality for salmonids, has increased to the point that it is now a contributing factor limiting the viability of Snake River spring/summer Chinook salmon and steelhead.

Bird Predation

Ecosystem alterations attributable to hydropower dams and changes in the mainstem hydropower system, and to modification of estuarine habitat, have increased bird predation on the populations, particularly by Caspian terns, double-crested cormorants, and a variety of gull species. Spring and summer-run Chinook salmon, summer steelhead, and other stream-type juvenile salmonids are most vulnerable to predation by Caspian terns and double-crested cormorants because the juveniles use deep-water habitat channels that have relatively low turbidity and are close to island tern habitats. Juvenile steelhead are particularly vulnerable to predation since they swim near the surface of the water (top of the water column) while juvenile Chinook salmon swim deeper in the water. A Columbia River basin-wide assessment of avian predation on juvenile salmonids indicates that the most significant impacts to smolt survival occur in the Columbia River estuary (Collis et al. 2009).

Two primary populations of double-crested cormorants prey on the juvenile migrants: Foundation Island, in the mainstem Columbia River near the mouth of the Snake, and East Sand Island, in the Columbia River estuary. The Foundation Island colony is relatively small. Colony size was estimated at 300 to 400 pairs over the years 2004-2010 (Roby et al. 2011), and at 390 pairs in 2014 (Evans et al. 2015). In comparison, studies indicate that the number of double-crested cormorants inhabiting colonies in the Columbia River estuary has increased in recent years, from an estimated 150 pairs in the early 1980s, to over 6,000 pairs in the late 1990s, and has varied from about 11,000 to 13,500 pairs during the past 10 years (Appendix E in NMFS 2014a). The East Sand Island colony of double-crested cormorants in the estuary was estimated at 11,000 nesting pairs in 2016 (Appy et al. 2017). Double-crested cormorant predation on juvenile salmon and steelhead has also increased, peaking in 2006, when double-crested cormorants are estimated to have consumed about 13 percent of the juvenile steelhead and over 4 percent of the juvenile yearling Chinook salmon in the lower Columbia River, including those from the Snake River ESUs and DPS (NMFS 2014c). Since 2006, consumption rates have been variable, but have remained high with an average juvenile steelhead and yearling Chinook consumption of about 9 percent and 3 percent, respectively, through 2013 when estimates were discontinued.

Caspian tern colonies also prey on juvenile migrants. East Sand Island in the Columbia River estuary has a Caspian tern colony that contained about 5,200 pairs in 2016. A second Caspian tern colony is located on the Blalock Islands in the mainstem Columbia River below McNary Dam. This colony recently increased in size from a 10-year average of about 58 pairs per year to 500 to 700 pairs annually in 2015 and 2016, respectively.

Presently, actions are being taken to reduce the number of Caspian terns nesting in the interior Columbia Basin and the number of Caspian terns and double-crested cormorants nesting in the Columbia River estuary. These actions are expected to improve future juvenile survival and adult return rates, especially for steelhead.

Non-salmonid Fish Predation

Non-salmonid fish also prey on spring and summer Chinook salmon and steelhead. Native northern pikeminnows are widely distributed throughout the Columbia River estuary, and congregate in the vicinity of dams in the mainstem Snake and Columbia Rivers and at hatchery release sites to feed on smolts. Introduced exotic fish species, such as smallmouth bass and walleye, are now abundant in the Columbia River basin, and are especially prevalent in the mainstem Snake and Columbia Rivers. These species are substantial predators of juvenile salmonids.

Predation and competition also affect spring/summer Chinook salmon and steelhead in some natal tributaries, including from northern pikeminnow, non-native smallmouth bass, brook trout, and native trout species. For example, in the upper Salmon River, brook trout may be reducing the potential production of spring/summer Chinook salmon populations through predation. The individual management unit plans discuss predation in tributary reaches.

Marine Mammal Predation

Marine mammals (pinnipeds or sea lions) prey on migrating adult salmon and steelhead in the lower Columbia River and as they attempt to pass over Bonneville Dam, primarily from January to May (USACE 2007). Pinniped predation remains a threat for listed species in Oregon and Washington due to a general increase in pinniped populations along the West Coast and in the lower Columbia River. California sea lions increased at a rate of 5.4 percent per year between 1975 and 2011 (NMFS 2015), while Steller sea lions increased at a rate of 4.18 percent per year between 1979 and 2010 (Allen and Angliss 2015). Harbor seals likely remain at or near carrying capacity in Washington and Oregon (Jefferies et al. 2003; Brown et al. 2005; respectively, as cited in NMFS 2014c).[23]

There has been a steady influx of pinnipeds (Figure 5-5), especially California sea lions, in the Columbia River basin in recent years with sharp increases in California sea lion presence in 2013

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[23] The last population estimates of harbor seals in Washington (coastal population) and Oregon was in 2003 and 2005 (Jefferies et al. 2003, Brown et al. 2005, respectively, as cited in NMFS 2014c), when the population growth rate was estimated at 7 percent (Appendix G).

of 750 animals, 1,420 animals in 2014,[24] and 2,340 animals in 2015.[25] Counts of the animals collected at the East Mooring Basin in Astoria hit an all-time high of 3,834 pinnipeds in 2016 (Brown et al. 2016).

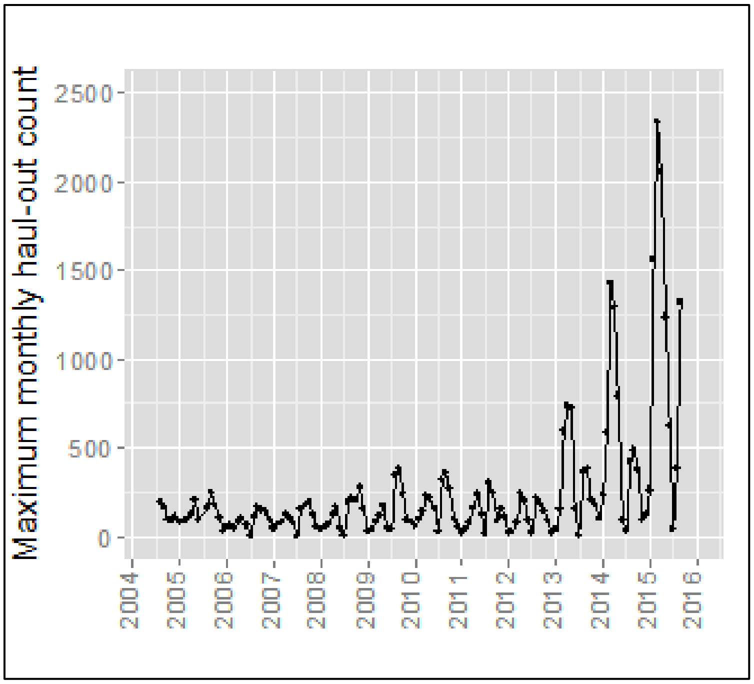

Figure 5-5. Estimated peak counts (spring and fall) of California sea lions in the East Mooring Basin in Astoria, Oregon, 2004 through 2015.

There has also been an increase in sea lion activity below Bonneville Dam (Figure 5-6). The U.S. Army Corps of Engineers has been monitoring pinniped presence, abundance, and activity at the dam since 2002. Findings show an increasing number of California sea lions at the dam, and also an increasing number of Steller sea lions. Since 2010, Steller sea lions have been observed at Bonneville Dam in increasing numbers, and are now present for 10 months of the year. They arrive during August and are present until May of the next year (USACE 2017). Most, but not all, California sea lions leave Bonneville Dam by the end of May, but a handful have taken residence in the area between the Bonneville Dam forebay and The Dalles Dam.

As pinniped numbers have increased in the Columbia River basin over the past 15 years (2002 through 2016), there has also been an increase in salmonid consumption. Besides seeing record-level sea lion abundance at Bonneville Dam in 2015 and 2016, the years also had the highest recorded consumption rates of salmonids. The largest single-year consumption rate occurred in 2015, and the level in 2016 was second highest to date (USACE 2017).

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[24] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, October 28, 2015.

[25] E-mail to Robert Anderson, NMFS, from Bryan Wright, ODFW, October 28, 2015.

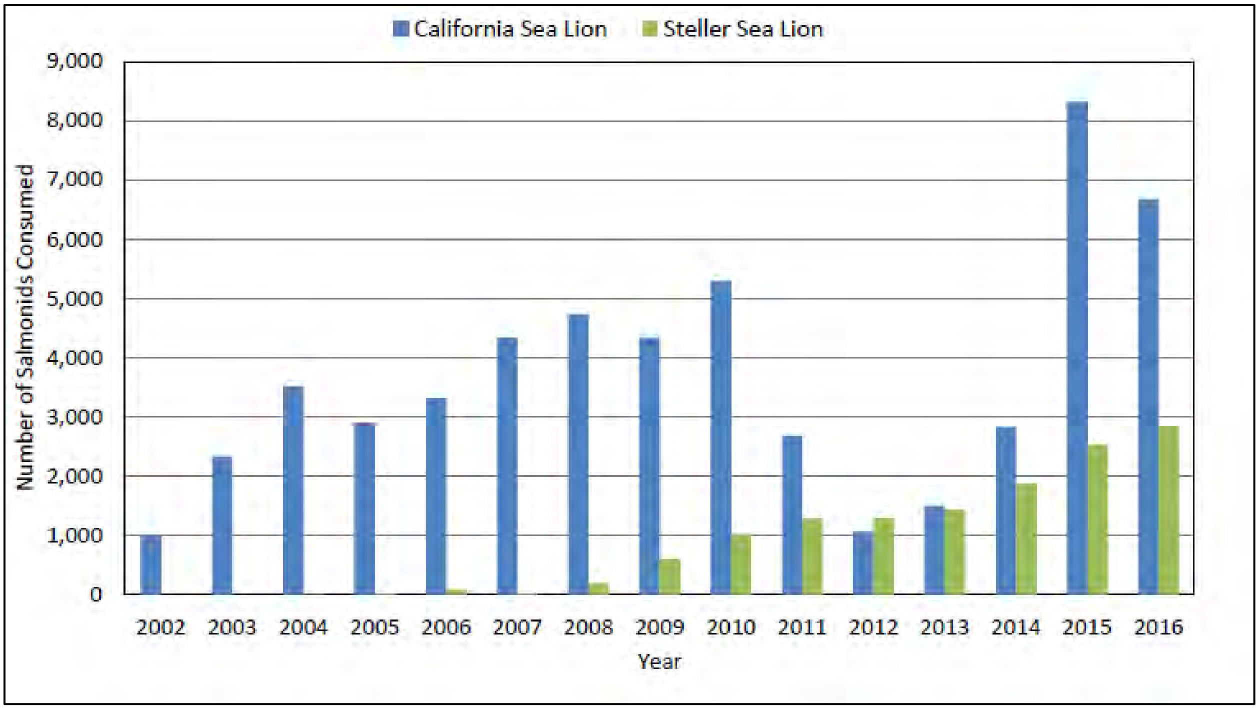

Figure 5-6. Adjusted estimates of salmonid consumption by California and Stellar sea lions at Bonneville Dam, from January 1 to May 31, 2002 to 2016. Expanded for hours not observed, and adjusted for unidentified fish catch (USACE 2017).

Overall, more than 40,000 fish from listed and non-listed salmon and steelhead stocks (listed stocks: Upper Columbia River spring-run Chinook salmon, Snake River spring/summer-run Chinook salmon, Upper Columbia River steelhead, Snake River basin steelhead, Middle Columbia River steelhead; non-listed stocks: Middle Columbia River spring-run Chinook salmon, Upper Columbia River summer-run Chinook salmon, Deschutes River summer-run Chinook salmon) have been consumed by California sea lions alone in the vicinity of Bonneville Dam (Stansell et al. 2014).

Ongoing research in the Columbia River (Wargo-Rub et al. 2014) suggests that 10 to 45 percent of the returning adult salmon are unaccounted for during the 146-mile migration between the Columbia River estuary and Bonneville Dam at the time when the California sea lions are present in the Columbia River in large numbers. If California sea lions are responsible for a substantial fraction of this estimated loss, then this additional source of pinniped predation (in addition to documented predation at Bonneville Dam) may represent a significant shift in the severity of pinniped predation to the recovery of listed Columbia River Basin salmon and steelhead stocks, in addition to anthropogenic threats (e.g., impacts from habitat loss, dams, etc.) (NMFS 2016).

While all up-river stocks are subject to pinniped predation in the vicinity of Bonneville Dam, the spring-run stocks are at greatest risk. Adult Snake River spring Chinook salmon, which return to the Columbia River in early spring, are therefore particularly vulnerable to these seasonal predators. In accordance with the procedures in Section 120 of the Marine Mammal Protection

Act, the National Environmental Policy Act, and the Endangered Species Act, NMFS authorized in 2008, 2012, and 2016 for the states of Oregon, Washington, and Idaho to remove or kill individual California sea lions that they determined to be having a significant negative impact. Combined, the three states' authorizations allow up to 92 animals to be removed per year. Since receiving removal authority in 2008, the states have permanently removed (to captivity or euthanized) 192 California sea lions. The states are currently operating under a Section 120 program authorization issued in 2016 that will expire on June 30, 2021. Adult losses have been reduced to some extent in the tailrace of Bonneville Dam as a result of hazing and lethal removal activities (NMFS 2014c). However, while the impact of marine mammal predation on Chinook salmon viability is unclear because available information is limited, it is likely a substantial threat.

More information is needed to understand the impact of California and Steller sea lion predation on Snake River spring/summer Chinook salmon and steelhead, both directly through predation and indirectly via injuries from attacks that can lead to increased prespawning mortalities and decreased fitness. Information is also needed to evaluate impacts on life cycle recruitment of targeted natural-origin populations, as well as on ESU and DPS viability.

Competition

Competition among salmonids, and between salmonids and other fish, can occur in the estuary, mainstem Columbia and Snake Rivers and reservoirs, as well as in tributary reaches. The intensity and magnitude of competition likely escalates when large numbers of salmonids inhabit an area at the same time and require similar habitat conditions and food. Competition also results when habitat capacity is limited and unable to support salmonids competing for key resources at the same time. For example, habitat loss in the Columbia River estuary over the last century has concentrated salmon and steelhead into more limited and fragmented regions (Bottom et al. 2005), which may have increased competition. However, the impact of habitat loss and the Columbia River estuary's capacity to support juvenile salmon and steelhead remains unknown (Bottom et al. 2005; ISAB 2015).

Competition between natural-origin and hatchery-origin salmonids and/or other native or invasive species fish also occurs in natal tributary reaches. Competition may restrict salmon and steelhead productivity in some tributary reaches because of limited habitat capacity and related density dependence. The individual management unit plans discuss competition in tributary reaches.

Information is needed regarding whether competition has increased in certain areas because habitat capacity is limited and unable to support salmonids competing for key resources at the same time ─ whether on the spawning grounds, in natal rivers and downstream reaches, in the estuary, or in the ocean (ISAB 2015). Information on how density dependence limits population growth and habitat carrying capacity is critical for setting appropriate biological goals and targeting actions effectively to reach recovery.

Disease

A range of viruses, bacteria, fungi, and parasites, collectively known as pathogens, have significant effects on salmon and steelhead populations through mortality or reduced fitness (morbidity). A number of factors have increased the potential for Snake River spring/summer Chinook salmon and steelhead to contract diseases. Impoundments and climate change have increased late summer water temperatures, creating conditions where levels of pathogens and severity of virulence of some pathogens are likely increased. In the mainstem Columbia and lower Snake Rivers, passage through the hydropower system also delays and stresses juvenile salmonids, increasing their exposure and potentially reducing their resistance to disease. In tributary reaches, warm summer water temperatures and low stream flows can also increase exposure and susceptibility of over-summering juvenile fish to disease. With regard to adults, Chinook salmon and steelhead migrating from July to September (either in mainstem reaches or tributary habitat) continue to be exposed to relatively high temperatures that could result in increased losses from pathogens. Introduction of exotic species and between-basin transfer of native fish create opportunities for the introduction of new pathogens, or for endemic pathogens to increase their range. Large-scale intensive hatchery culture provides conditions where pathogens could spread rapidly within the hatchery, and increases the risk of transfer of disease out of the hatchery through hatchery effluents and the release of infected fish. Changing environmental conditions have altered relationships between parasites and their hosts, potentially increasing the severity of parasitic infection. Handling and transport of fish at dams, though substantially reduced in recent years, still can result in fish being held at much higher densities than observed in the wild, increasing chances of disease transmission.

Exposure to Toxic Pollutants

A variety of toxic contaminants have been found in water, sediments, and salmon tissue in the Columbia and Snake River migration corridor, estuary, and some tributaries at concentrations above the estimated thresholds for health effects in juvenile salmon and steelhead. Exposure to these toxins can affect species abundance, productivity, and diversity by disrupting behavior and growth, reducing disease resistance, and potentially causing increased mortality.

The Columbia and Snake Rivers pass through agricultural lands and receive urban and industrial runoff in both mainstem and tributary reaches. In the estuary, the fish are particularly vulnerable to accumulation of contaminants because of its spatial position at the bottom of the watershed.

The Environmental Protection Agency's *Columbia River Basin State of the River Report for Toxics* (EPA 2009) highlighted the threat of toxic contaminants to salmon recovery in the Columbia River basin. The report identified several classes of contaminants that may have adverse effects on Snake River spring and summer Chinook salmon and steelhead: mercury, dichlorodiphenyltrichloroethane (DDTs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and polycyclic aromatic hydrocarbons (PAHs). These and other contaminants, including cooper, have received attention from NMFS because of their potential effects on listed salmonids (NMFS 2008b, 2010, 2011b). The contaminants are found at levels that could affect salmonids in many locations in the Columbia River and estuary, and throughout the Snake River basin, although some contaminant levels are declining in some areas. The contaminants are persistent in the environment, contaminate food sources, increase in concentration in fish and birds, and pose risk to both humans and wildlife (EPA 2009).

The State of the River Report for Toxics also identified other contaminants with potential effects on salmon (EPA 2009). These included metals such as arsenic and lead; radionuclides; combustion byproducts such as dioxin; and "contaminants of emerging concern" such as pharmaceuticals and personal care products. Additional information including geographically targeted studies on these contaminants is needed to evaluate their potential risk to threatened and endangered salmon and steelhead.

Pesticides, if not properly applied, could also reduce the viability of Snake River spring/summer Chinook salmon and steelhead. Pesticides in current use have been detected in the mainstem Columbia and Snake Rivers and estuary.

NMFS has performed a series of consultations on the effects of commonly applied chemical insecticides, herbicides, and fungicides which are authorized for use per EPA label criteria. All West Coast salmonids are identified as jeopardized by at least one of the analyzed chemicals; most are identified as being jeopardized by many of the chemicals. NMFS issued jeopardy biological opinions for Idaho (NMFS 2014d) and Oregon (NMFS 2012) for water quality standards for toxic substances. These consultations and biological opinions will result in promulgation of new standards for mercury, selenium, arsenic, copper, and cyanide in Idaho; and for cadmium, copper, ammonia, and aluminum in Oregon.

In summary, our understanding of the effects on aquatic life of many contaminants, alone or in combinations with other chemicals (potential for synergistic effects) is incomplete. While the effects are not well understood, the different compounds appear to pose risks to salmonid development, health, and fitness through endocrine disruption, bioaccumulative toxicity, or other means. Exposure to the chemical contaminants may disrupt behavior and growth, reduce disease resistance, and potentially cause mortality.

The Estuary Module (Appendix E) and FCRPS Biological Opinion (NMFS 2014c) discuss these impacts in more detail and identify actions to address them. Effects on specific populations and MPGs are discussed in the management unit plans.

5.2.7 Climate Change

Likely changes in temperature, precipitation, wind patterns, ocean acidification, and sea level height have implications for survival of Snake River spring/summer Chinook salmon and steelhead in their freshwater, estuarine, and marine habitats.

This section summarizes the expected climate change effects that may be pertinent to Snake River spring/summer Chinook salmon and steelhead. The information is based on findings in recent reviews, including relevant descriptions of expected changes in Pacific Northwest climate by Elsner et al. (2009), Mantua et al. (2009), Mote and Salathe (2009), Salathe et al. (2009), Mote et al. (2010), Chang and Jones (2010), and Crozier (2012, 2013). It also reflects reviews of the effects of climate change on salmon and steelhead in the Columbia River basin by the Independent Scientific Advisory Board (ISAB 2007), NMFS (2010), Hixon et al. (2010), Dalton et al. (2013), NMFS (2014c), and Crozier (2016b), as well as the NMFS Northwest Fisheries Science Center's 2015 *Status Review Update for Pacific Salmon and Steelhead* discussion of recent climate change science and recent trends in marine and terrestrial environments (NWFSC 2015). The NWFSC also produces annual updates (Crozier 2012, 2013, 2016b) describing new information regarding effects of climate change relevant to salmon and steelhead as part of the FCRPS Adaptive Management Implementation Plan.

Climatic conditions affect salmonid abundance, productivity, spatial structure, and diversity through direct and indirect impacts at all life stages. Importantly, however, the species have developed an adaptive ability over generations that has provided resiliency to a wide variety of climatic conditions in the past, and that could help them survive future changes in climate conditions in the absence of other anthropogenic stressors (NWFSC 2015).

Currently, the adaptive ability of these threatened and endangered species is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation. Without these natural sources of resilience, systematic changes in local and regional climatic conditions due to anthropogenic global climate change will likely reduce long-term viability and sustainability of populations in the Snake River basin. Species response to climate change is complex and will vary by species and population, and is context dependent (Crozier and Hutchings 2014; Munoz 2015; Mantua et al. 2015). Changes in phenology ─ the timing of migration out of or into a river ─ and reproduction, age at maturity, age at juvenile migration, growth, survival and fecundity are associated primarily with changes in temperature (Crozier and Hutchings 2014). Further research is needed regarding the strong behavioral plasticity and physiological capacity for change to help us understand the adaptive potential of Snake River spring/summer Chinook salmon and steelhead in response to climate change over time. Continued development and testing of comprehensive models of climate change susceptibility based on data from Snake River species and individual populations and the watersheds in which they reside is needed to understand the biological consequences of climate change.

Adapting to climate change may eventually involve changes in multiple life-history traits and/or local distribution, and some populations or life-history variants might die out. Importantly, the character and magnitude of these effects will vary within and among ESUs and DPSs (NWFSC 2015).

Freshwater Environments

Climate records show that the Pacific Northwest has warmed about 0.7 °C since 1900 (Dalton et al. 2013). As the climate changes, air temperatures in the Pacific Northwest are expected to continue to rise <1 °C in the Columbia Basin by the 2020s, and 2 °C to 8 °C by the 2080s

(Mantua et al. 2010). While total precipitation changes are uncertain (-4.7 percent to +13.5 percent, depending on the model), increasing air temperature will alter snow pack, stream flow timing and volume, and water temperatures in the Columbia and Snake River basin (Figure 5-7).

Globally, nationally and regionally, 2015 was a record-breaking climate year (Blunden and Arndt 2016). Crozier et al. 2016 analyzed adult spring/summer Chinook salmon migration through the lower Columbia River with regard to run timing, travel time, survival, and fallback for both Snake River and Upper Columbia River ESA-listed ESUs. The author reported that the lowest survival in all reaches studied occurred in the unusually warm year of 2015. Further analysis will help to clarify the impact of high temperatures and flows on arrival date, travel time, fallback, and survival.

Climate experts predict physical changes to rivers and streams in the Columbia River basin as a result of warmer temperatures that include:

- More precipitation falling as rain rather than snow.
- Higher likelihood of combined dry and warm years more likely, increasing the negative impacts of drought (Diffenbaugh et al. 2015).
- Declines in snowpack and total spring runoff, which contribute to drought conditions (Mao et al. 2015).
- Diminished snow pack and altered stream flow volume and timing.
- More winter flooding in transitional and rainfall-dominated basins.
- Lower late summer flows in historically transient watersheds.
- A trend toward loss of snowmelt-dominant and transitional basins in Idaho and eastern Washington, including the Snake River basin.
- Continued rise in summer and fall water temperatures.

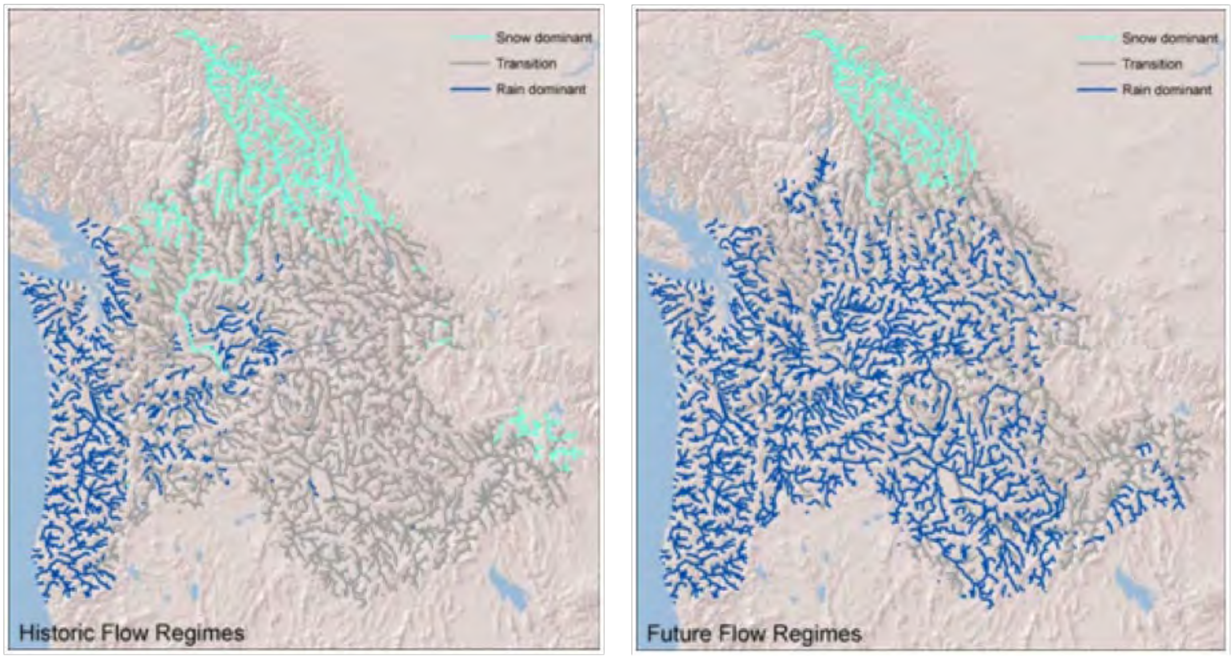

Figure 5-7. Preliminary maps of climate model results showing predicted hydrologic regime for (A) the period 1970-1999 and (B) the period 2070-2099 using emission scenario A1B and global climate model CGCM3.1 (T47), based on classification of annual hydrographs as in (Beechie et al. 2006). Data from University of Washington Climate Impacts Group (http://www.hydro.washington.edu/2860/).

These changes in air temperatures, river temperatures, and river flows are expected to cause general changes in salmon and steelhead distribution, behavior, growth, and survival. Climate change is anticipated to reduce the current range of native fish (Eby et al. 2014; Isaak et al. 2012; Wenger et al. 2011; Wenger et al. 2013) and could confound efforts to recover some extant populations (Munoz et al 2014). Modeling of climate change scenario effects on future stream temperature suggests high elevation areas of the Snake River basin, much of which are federally managed, are likely to provide long-term cold-water refugia important for the survival and recovery of native fish (Isaak et al. 2015), including Snake River salmon and steelhead. Thus, it will be important to preserve native biodiversity in these habitat areas and take pro-active steps to safeguard their long-term protection as “climate shields.”

The magnitude and timing of climate-related changes on Snake River spring/summer Chinook salmon and steelhead remain unclear. For example, recent stream inventories show that a number of small intermittent streams in the Clearwater River basin that provide important steelhead habitat (Banks and Bowersox 2015; Bowersox et al. 2011; Chandler 2013) are susceptible to effects of warmer winters that produce earlier, shorter snowmelt periods and lower summer flows than during normal years. The streams – and steelhead populations that rely on them – could be particularly vulnerable to climate effects that exacerbate these conditions, especially in areas where land use activities have reduced floodplain connectivity, increased stream flashiness, or interfered with natural pool-forming processes (NMFS 2016).

It is likely that the effects of climate change will vary among species and populations. They will depend on how increases in water temperatures and changes in river flow affect fish migration, spawning timing, emergence, dispersal, and rearing patterns. Presently, there is not a common understanding among managers about how the fish will respond. The degree to which phenotypic or genetic adaptations may partially offset these effects is being studied but is currently poorly understood. Information gained from research, monitoring and evaluation (described in Chapter 7) will help determine how the species respond, and how best to address changes that limit species' recovery.

Potential effects of climate change on Snake River spring/summer Chinook salmon and steelhead in freshwater areas include:

- Winter flooding in transient and rainfall-dominated watersheds may scour redds, reducing egg survival.
- Warmer water temperatures during incubation may accelerate the rate of egg development and result in earlier fry emergence and dispersal, which could be either beneficial or detrimental, depending on location and prey availability.
- Reduced summer and fall flows may reduce the quality and quantity of juvenile rearing habitat, strand fish, or make fish more susceptible to predation and disease.
- Reduced flows and higher temperatures in late summer and fall may decrease parr-to-smolt survival.
- Warmer temperatures will increase metabolism, which may increase or decrease juvenile growth rates and survival, depending on availability of food.
- Overwintering survival may be reduced if increased flooding reduces suitable habitat.
- Timing of smolt migration may be altered due to a modified timing of the spring freshet, such that there is a mismatch with ocean conditions and predators.
- Higher temperatures while adults are holding in tributaries and migrating to spawning grounds may lead to increased prespawning mortality or reduced spawning success as a result of delay or increased susceptibility to disease and pathogens.
- Increases in water temperatures in Snake and Columbia River reservoirs could increase consumption rates and growth rates of predators and, hence, predation-related mortality on juvenile spring/summer Chinook salmon and steelhead.
- Lethal water temperatures (temperatures that kill fish) may occur in the mainstem migration corridor or in holding tributaries, resulting in higher mortality rates.
- If water temperatures in the lower Snake River (especially Lower Granite Dam and reservoir) warm during late summer and fall sufficiently that they cannot be maintained at a suitable level by cold-water releases from Dworshak Reservoir, then migrating adult Snake River summer Chinook salmon and steelhead could have higher rates of mortality and disease.

Estuarine Environment

Climate change is also affecting the estuarine environment. Sea levels off Oregon could rise more than 1 meter in the next 100 years (Baptista and Rostaminia 2016). Salinity and other ocean influences could reach as far as the Willamette River under low to moderate river discharges, altering residence times and ecological function, and affecting salmon habitat. Mainstem temperatures through the estuary reach are already rising and may be affecting prey resources and the condition of juvenile salmon and steelhead as they enter the nearshore ocean.

Potential effects of climate change on Snake River spring/summer Chinook salmon and steelhead in the estuary include:

- Higher winter freshwater flows and higher sea levels may increase sediment deposition and cause wave damage within the estuary, possibly reducing the quality of rearing habitat.
- Lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of salmonid prey and predators.
- Increased temperature of freshwater inflows may increase predation by extending the range of non-native, warm-water species.

In all of these cases, the specific effects on Snake River spring/summer Chinook salmon and steelhead abundance, productivity, spatial distribution, and diversity are unclear. While many of these juvenile outmigrants move quickly through the estuary before reaching the ocean, others may spend considerably more time in these environments. Habitat restoration in the estuary, especially breaching dikes that isolate the mainstem from its historical floodplain, may result in the expression of juvenile life-history types that have been lost, improving the resilience of the listed species (Bottom et al. 2011).

Marine Environments

Varying conditions in the marine environment greatly influence the status of Snake River spring/summer Chinook salmon and steelhead. The conditions affect growth and survival rates, adult returns, and population variability. These effects are summarized here; the Ocean Module provides a more detailed discussion.

Changes in ocean conditions (shifts from good ocean years to bad ocean years) represent an important environmental factor that affects growth and survival of Snake River ESA-listed salmon and steelhead (Fresh et al. 2014). The changes in ocean conditions influence environmental conditions in both fresh and marine waters inhabited by Snake River spring/summer Chinook salmon and steelhead, and other Pacific Northwest salmon, and reflect, in large part, two ocean-basin scale drivers: the Pacific Decadal Oscillation (PDO; Mantua et al. 1997) and the El Niño-Southern Oscillation (El Niño or ENSO). Since late 2013, however, abnormally warm conditions in the Central Northeast Pacific Ocean known as the “warm blob” (Bond et al. 2015) have also had a strong influence on both marine and freshwater habitats.

Di Lorenzo and Mantua (2016) describe ocean temperature variability between the winters of 2013/14 and 2014/15 during the strong North American drought, resulting in the northeast Pacific Ocean experiencing the largest marine heatwave ever recorded. Enhanced by a strong El Niño, global annual surface temperature in 2015 topped records for the second year in a row, exceeding the pre-industrial average by over 1 °C for the first time. New records were also set for global ocean heat content, sea level, and minimum sea ice extent. Climate model simulations indicate that extreme conditions such as this are likely to increase with greenhouse gas forcing (Crozier 2016).

Snake River spring/summer Chinook salmon and steelhead and other stream type salmonids are particularly impacted by ocean conditions during the first weeks or months of marine life (Pearcy 1992; Pearcy and Wkinnell 2007). Accordingly, where the fish are during the first summer of ocean residence, and the conditions they experience, has a large impact on their overall marine survival. In general, salmon and steelhead from the Pacific Northwest can be grouped by their ocean migration patterns: sockeye and spring Chinook salmon move rapidly north along the continental shelf to Alaskan waters and reside in the Gulf of Alaska for most of their ocean residence, while fall Chinook remain in local waters (although their location during winter months is largely unknown). Steelhead generally exhibit a unique marine migration pattern and move directly offshore and apparently west across the North Pacific Ocean (Daly et al. 2014; Hayes et al. 2012; Myers et al. 1996).

Differences in migration patterns paired with diverse ocean conditions result in species and population differences in survival. Pacific salmon are a cold-water species and flourish in cold and productive marine ecosystems. Thus, elevated water temperatures can be detrimental to salmonid growth and survival, both directly and indirectly (Crozier et al. 2008; Wainwright and Weitkamp 2013). In marine environments, temperature changes are typically associated with different environmental conditions that have their own planktonic ecosystem, including salmon prey and predators. They can have a strong effect on the available food web, and the influence of this and other indirect effects is larger than those due directly to physiological effects of changing temperatures (Beauchamp et al. 2007; Trudel et al. 2002). For example, Snake River salmon and steelhead benefit from negative PDO (cool water off the Washington/Oregon coast) as do northern copepods and anchovy, which are part of their food web. Northern copepods have much higher lipid levels than southern copepods, and therefore likely produce food webs that promote high growth and survival in salmon (juvenile Chinook salmon and steelhead do not eat copepods directly) (Peterson et al. 2014). Species that prosper during positive PDOs (warmer waters) include southern copepods and sardines (Lindegren et al. 2013; Peterson and Schwing 2003; Shanks 2013).

The changing marine conditions that Snake River spring and summer Chinook salmon and steelhead encounter during their ocean journeys have and will continue to impact differences in species abundance and productivity. For example, the 1982/83 El Niño had much more severe impacts on Chinook salmon populations with southern distributions, than those with more northern distributions, such as Snake River spring Chinook salmon. Similarly, Snake River fall

Chinook salmon that entered the ocean in 2011 returned in record high numbers, while spring Chinook salmon entering in the same year had low returns (and below predictions). This difference is thought to be due to differences in ocean conditions encountered by the two runs: spring Chinook salmon migrate rapidly to Alaska, where ocean conditions were extremely unproductive in 2011, while fall Chinook salmon remained off the Washington/Oregon coast, where conditions were quite productive. A reverse situation to 2011 appears to have occurred in spring 2014. The exceptionally warm marine waters in 2014 and 2015 appear to have favored a subtropical food web that contributed to poor early marine growth and survival.

Climate-related changes in the marine environment are expected to alter primary and secondary productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids, although the degree of impact on listed salmonids is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and decreased incubation period) and altered upwelling could reduce marine survival rates. Ocean warming also may change migration patterns, increasing distances to feeding areas.

In addition, rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater and thus reducing the availability of carbonate for shell-forming invertebrates, including some that are prey items for juvenile salmonids. This process of acidification is under way, has been well documented along the Pacific coast of the United States, and is predicted to accelerate with increasing greenhouse gas emissions.

Ocean acidification has the potential to reduce survival of many marine organisms, including salmon. However, there is currently a paucity of research directly related to the effects of ocean acidification on salmon and their prey. Laboratory studies on salmonid prey taxa have generally indicated negative effects of increased acidification, but how this translates to the population dynamics of salmonid prey and the survival of salmon and steelhead is uncertain. Modeling studies that explore the ecological impacts of ocean acidification and other impacts of climate change concluded that salmon abundance in the Pacific Northwest and Alaska are likely to be reduced.

Summary for Climate Change

Snake River spring/summer Chinook salmon and steelhead are cold-water species: they flourish in cold streams and cold and productive marine ecosystems. Both freshwater and marine productivity tend to be lower for the species in warmer years than in cooler years. These trends suggest that many populations might decline as mean temperatures rise. However, the extent of climate change effects remains unclear. Both species have developed an adaptive ability over generations that has provided resiliency during a wide variety of climatic conditions in the past, and that could help them survive future changes in climate conditions. The historically high abundance of many southern populations is reflective of this adaptive ability and provides reason for optimism.

To the extent that climate change results in substantial effects to the species and challenges their phenotypic and genetic ability to adapt to change, additional survival improvements in any stage of their life cycle would be beneficial. This warrants considerable effort to restore the natural climate resilience of these species (NWFSC 2015). Remaining uncertainties regarding the effects that climate change will have on species abundance, productivity, spatial structure, and diversity reinforce the importance of monitoring, and the ability to adjust actions accordingly through adaptive management. Analysis of ESU- and DPS-specific vulnerabilities to climate change by life stage will be available in the near future, upon completion of the *West Coast Salmon Climate Vulnerability Assessment* by the Northwest Fisheries Science Center.

6. Recovery Strategy and Actions

This chapter describes the recovery strategy for Snake River spring/summer Chinook salmon and steelhead. It contains eight sections. Section 6.1 discusses the assumptions that we believe, if true and properly addressed, will lead to the delisting of the species. Section 6.2 describes our overall approach for recovery, including an adaptive management framework for prioritizing and updating future actions. Section 6.3 summarizes the recovery strategies and actions for the ESU and DPS to address limiting factors and threats. Section 6.4 identifies potential additional actions that will be considered in the future to improve species' viability. Section 6.5 examines the potential effectiveness of the actions and the need for continued RM&E and life cycle modeling. Section 6.6 summarizes the recovery strategies and actions identified to improve viability at the MPG level, and Section 6.7 provides links to the three supporting management unit plans that describe the site-specific actions for recovery of individual Snake River spring/summer Chinook salmon and Snake River Basin steelhead populations. Section 6.8 describes processes that will be used to identify contingency actions in case one or both species does not continue to move towards recovery in a timely manner, and/or if there are significant declines in status.

Overall, the recovery strategy is designed to rebuild the ESU and DPS to levels where they can be self-sustaining in the wild over the long term and can be delisted under the ESA. It aims to move the species toward meeting the recovery goals described in Chapter 3 by protecting recent improvements in the species' biological status, and by focusing actions and research to close the gaps between the species current status and the proposed status described in Chapter 4, and address the threats and limiting factors discussed in Chapter 5. The recovery strategy is also designed to be consistent with broader goals identified in Chapter 3 to help maintain tribal, commercial, and sport fisheries on a sustaining basis. NMFS developed this recovery strategy to achieve ESA recovery in a manner consistent with these other goals in the shortest practicable time frame.

Much work remains both at the regional level and at the local level before the recovery goal of delisting can be achieved. As discussed in Chapter 5, no single factor or threat accounts for the decline of Snake River spring/summer Chinook salmon and steelhead. Instead, the status of the ESU and DPS is the result of the cumulative impact of multiple limiting factors and threats.

Recovery of the ESU and DPS will require improvements throughout the life cycle: in tributaries, the Snake and Columbia River migration corridor, and in the estuary, plume, and ocean.

6.1 Assumptions

In designing an effective recovery strategy, we have made a number of assumptions that, if true and properly addressed, will lead to the delisting of the species. These assumptions include:

- *We have accurately identified the limiting factors and threats affecting the fish.*

  This recovery strategy reflects the best technical information available and our current understanding of the limiting factors and threats that affect ESU and DPS viability.

- *Addressing the combined limiting factors will improve the viability of the existing populations, MPGs, and ESU/DPS.*

  Multiple threats across the life cycle contribute to the current status of the species. To improve population and ESU/DPS viability, our strategy focuses on a wide range of habitat, hydropower, harvest, and hatchery- related actions. Together, the actions address the many threats that currently impact Snake River spring/summer Chinook salmon and steelhead viability. The strategy also recognizes there are unknowns regarding our understanding of the specific issues that affect the fish now, or might influence their recovery in the future. As a result, it includes actions to gain key information about the factors that affect the fish, or may affect the fish given global climate change. Continuing effective research, monitoring, and evaluation is critical to our success.

- *The Plan is based on technically sound ecological principles and an effective adaptive management approach that will allow us to meet the needs of the species.*

  Our recovery strategy recognizes that efforts to address habitat, hydropower, fisheries, and hatchery-related issues affecting Snake River spring/summer Chinook salmon and steelhead need to be planned and implemented with a clear understanding of ecological processes ─ including biological and habitat processes ─ and how past and current activities affect these processes.

- *Long-term persistence of the species requires development of partnerships that integrate recovery needs with the needs of other stakeholders.*

  For this recovery plan to be effective, we need to develop and implement a common framework that will help us frame recovery efforts so they are strategic, comprehensive and proactive. This requires a multi-faceted effort with coordination between federal, state, and local agencies, tribes, and the private sector, that links efforts at the watershed, population, MPG, and ESU/DPS levels. To this end, we will implement the recovery plan through effective communication, education, coordination, and governance.

- *An effective adaptive management approach will allow us to gain an understanding of each limiting factor and the specific actions that can modify the species' environment and result in a biological response (through improvements in productivity, abundance, spatial structure, and diversity).*

  The recovery strategy and subsequent actions reflect our current understanding of limiting factors and threats to Snake River spring/summer Chinook salmon and steelhead.

> However, we understand that actions may not yield desired results, gaps in data may emerge, and recovery efforts will need to be broadened and adapted. Acknowledging these limitations and integrating adaptive management into the recovery plan is an essential part of the recovery strategy. Through an adaptive management process, we will be able to recognize limitations and account for them in our approach, allowing recovery efforts to adjust to the uncertainty of the future. We will work with our partners to reevaluate and update the recovery strategies, actions, and activities as new information becomes available.

6.2 Recovery Strategy and Adaptive Management Framework

Our strategic vision for recovery of Snake River spring/summer Chinook salmon and steelhead is to establish viable self-sustaining, naturally spawning populations in the wild that are sufficiently abundant, productive, and diverse and no longer need Endangered Species Act protection. As the species continues to recover over time, broader goals that go beyond achieving species recovery may also be met to provide multiple ecological, cultural, social, and economic benefits.

As we look forward, we know that future actions, in addition to those in this Plan, will need to be identified and implemented to recover the species. Consequently, our approach to recovery is multifaceted. A critical piece of our recovery plan is to continue to research uncertainties and use the information we gain to focus future efforts. Section 7.4.1, Research on Key Information Needs, identifies future actions that address critical uncertainties and data gaps regarding the limiting factors and threats affecting these two species. Investigating these uncertainties will result in new information to identify, prioritize, and implement additional recovery actions. At the same time, our recovery plan identifies actions we can take right now. There are ongoing actions that need to be implemented, including actions in the 2008 FCRPS biological opinion and its 2010 and 2014 supplements (NMFS 2008a, 2010, 2014c), and we expect to continue this implementation. There are also new actions identified in this Plan, and associated Northeast Oregon, Southeast Washington, and Idaho management unit plans, modules, and other documents. Our goal is to complete these new actions; some of the actions will take time and we need to get started right away to implement them.

We expect that together the implementation of ongoing actions and new actions identified in this Plan, including research, will narrow viability gaps and improve Snake River spring/summer Chinook salmon and steelhead status. However, due to remaining critical uncertainties and data gaps, all the actions needed to achieve salmon and steelhead recovery cannot be enumerated at this time. This highlights the fact that additional actions beyond those identified in this Plan, such as potential future actions discussed in Section 6.4 and Table 6-8, will be needed before the species are self-sustaining in the wild and can be delisted under the ESA.

Adaptive Management Process and Framework

Our approach is centered on the adaptive nature of the recovery strategy. We recognize the importance of learning as we go, and adjusting our efforts accordingly. Thus, the recovery strategy depends on implementation of an adaptive management framework that targets site-specific actions based on best available science, monitors to improve the science, and updates actions based on new knowledge. We need to identify critical uncertainties and address them through RM&E. We need to conduct modeling to weigh the effects of different factors, individually and combined, across the life cycle. We also need to monitor and evaluate the site-specific actions over time to determine progress in addressing the viability gaps. At the same time, we need to identify the next round of future actions, implement them, and then monitor their effects and influence on our progress toward recovery (see Figure 6-1).

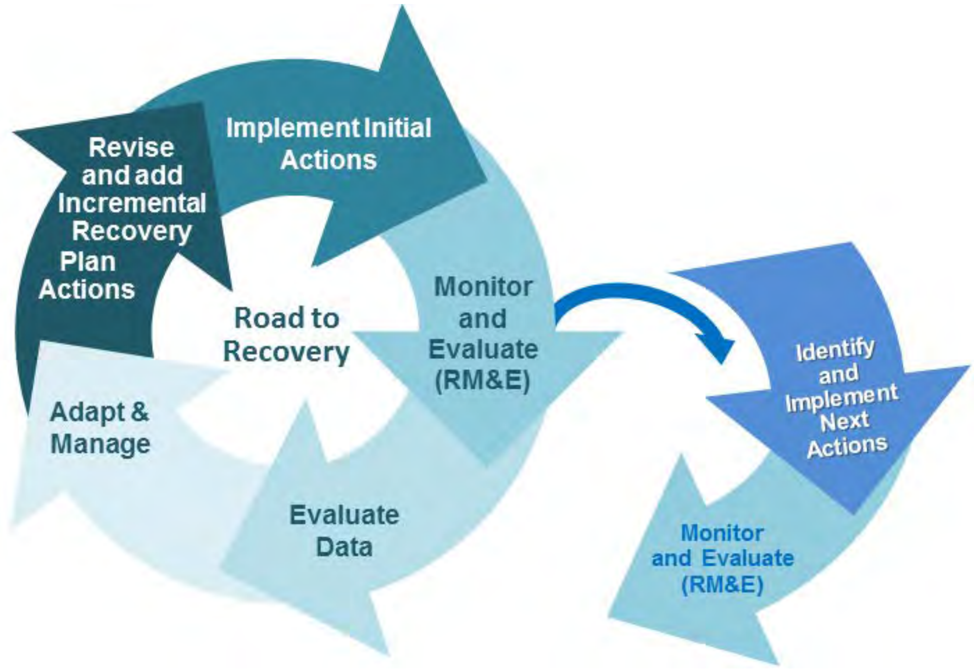

Figure 6-1. Adaptive Management Process Framework

Several key questions will guide the adaptive management process:

- Are efforts working according to expectations?
- For RM&E implementation:
    - Are the actions being implemented?
    - Are our background assumptions still valid (i.e., climate)?
    - Are the actions having the expected effects (changes in habitat, response by fish populations)?
- What is the suite of potential future actions?
- What questions need to be answered to implement additional actions?

A life cycle context is essential to this adaptive approach. It will allow us to determine the best opportunities for closing the gap between the species' current status and achieving the proposed status. The use of multi-stage life cycle models and other tools will improve our understanding of the combined and relative effects of limiting factors and recovery actions across the life cycle. Section 6.5 and Chapter 7 describe the life cycle modeling approach and other research, monitoring, and evaluation actions.

The adaptive management framework will provide structure for decision making so we can alter our course strategically as we gain new information.

1. Establish recovery goals and viability and threats criteria for delisting (Chapter 3).
2. Determine species current status and the gaps between the current status and the viability criteria (Chapter 4).
3. Assess the limiting factors and threats across the life cycle (and in the context of variable ocean conditions and climate change) that are contributing to the gaps between current status and viability criteria (Chapter 5 and management unit plans).
4. Identify, prioritize, and implement recovery strategies and management actions (Chapter 6, management unit plans and modules) that target the limiting factors and threats.
5. Prioritize and implement research, monitoring, and evaluation actions to evaluate the status of the species, the status and trends of limiting factors and threats, and the effectiveness of ongoing and potential actions (Chapter 7).
6. Address key information needs. There are key information needs concerning the role of ocean and climate change, the potential effects of density dependence on growth and survival, and the best opportunities for further improving survival to meet the viability criteria. These uncertainties are described and prioritized in the research, monitoring, and evaluation chapter (Chapter 7).
7. Establish contingency processes. The actions recommended in this Plan and the supporting management unit plans will improve viability toward achieving recovery. Still, we need to be prepared if the status of one or both species does not continue to improve in a timely manner and also if there are significant declines in status. Section 6.8 discusses the need to develop contingency processes.
8. Regularly review implementation progress, species response, monitoring and modeling results, and new available information (Chapter 9).
9. Adjust actions through an implementation structure that recognizes the interests of different stakeholders and the best opportunities to improve viability (Chapter 9).
10. Repeat the adaptive management cycle. Adaptive management should be a continuous loop of action including implementation, monitoring, and evaluation, assessment of new information, and updated actions.

Each management unit plan describes an adaptive management framework that defines an approach tailored for the specific populations and major population groups it addresses.

6.3 Recovery Strategies and Actions at the ESU/DPS Level

Our overall recovery strategy aims to establish self-sustaining, naturally spawning populations of Snake River spring/summer Chinook salmon and steelhead that are sufficiently abundant, productive, and diverse, and no longer need ESA protection. Achieving species recovery will require coordinated and collaborative management and implementation of actions at local, watershed, and regional levels.

This section describes recovery strategies and actions to address limiting factors and threats at the regional level (tributaries, mainstem, estuary, plume, and ocean). The associated management unit plans identify site-specific actions to address local-level and tributary-level limiting actions and threats. The actions are summarized at the MPG level in Section 6.6.

6.3.1 Strategies and Actions for Tributary Habitat

Protecting existing high quality and good quality tributary habitat, and restoring impaired habitats will specifically benefit spring/summer Chinook salmon and steelhead in the spawning and juvenile rearing life stages. Investigations and habitat restoration actions are also needed to improve habitat conditions and to reduce mortalities during outmigration to the Snake River, especially in lower mainstem reaches and key production areas. Improved tributary spawning, rearing, and migration conditions means that more fish will reproduce, more juveniles will survive and migrate, and consequently more adults will return to the area.

Recognition of the importance of sequencing or prioritizing restoration and recovery efforts over time has been gaining increasing attention in the conservation literature. Examples include approaches to prioritizing among sites in biological reserve planning (McBride et al. 2010; Wilson et al. 2011), considerations for maximizing the preservation and enhancement of inherent genetic diversity among populations varying in size (Aitken et al. 2013; Willi et al. 2006), and population size vs. environmental variation in metapopulation frameworks (Drechsler and Wissel 1998). Several examples highlight the importance of explicitly considering how to maximize gains towards long-term objectives in light of starting conditions and inherent limitations on annual resources available for restoration activities in a given period of time (e.g., 1-5 years). Another important consideration is the time for restoration actions to achieve desired improvements in habitat conditions and the associated lags in benefits to fish. In many ways the basic principles for these multi-population level sequential planning strategies parallel advice regarding within population protection and restoration (Beechie et al. 2010).

This Plan describes a starting point (current status) and a desired end conditions (ESU/DPS viability) in terms of individual populations organized into major population groups. The recovery plan also catalogues key limiting factors and identifies corresponding potential actions for each population. Status evaluations and ESA recovery objectives for Interior Columbia ESUs and DPSs are organized around populations grouped into major population groups (MPGs). This basic framework for assessing ESUs/DPSs is adapted and employed by regional technical recovery teams in all west coast salmonid recovery domains (McElhany et al. 2000).

Evaluating ESU/DPSs in this context supports consideration of not only the collective individual status of each population, but also the particular contribution of each population. The ICTRT recommended MPG-level recovery criteria were explicitly designed to provide for resilience against year-to-year variations in environmental influences, opportunities for exchange with nearby populations in the event of short-term localized catastrophic impacts, the maintenance of major patterns of life-history diversity, and adaptability to changing environmental conditions (ICTRT 2007). At the MPG level, each set of population-specific plans collectively contain the basic information needed to identify populations for immediate focus to support progress from current status towards long-term viability goals. Each management unit plan adopts a MPG recovery scenario that identifies target levels for component populations (e.g., viable or maintained). For each population, the management unit plans also outline key opportunities for tributary habitat protection and restoration that would contribute to improving populations towards those objectives.

This Plan acknowledges that employing strategic approaches to implementing actions will enhance the potential for success in achieving and moving beyond long-term ESA recovery objectives. Opportunities to implement protection and restoration actions will vary across populations depending on the geomorphic setting, land ownership patterns, etc. In many cases restoration implementation will need to consider short-term limitations on available logistic or monetary resources. For some populations there may be important sequencing considerations – e.g., particular habitat improvement opportunities that, if adequately addressed, would increase the potential benefits of subsequent actions aimed at other factors. As recovery progresses, the emphasis would be expected to broaden or shift to include the additional populations required to improve in status to meet or exceed their assigned viability objectives.

Considering short-term priorities for immediate focus of restoration activities is especially important for ESUs/DPSs wherein all MPGs and their component populations are well below viability objectives ─ e.g., Snake River spring/summer Chinook salmon. Although almost all Snake River spring/summer Chinook salmon populations are rated at overall high risk, the gaps to reduced risk status vary. Some of those populations may be exhibiting levels of natural production that, while below long-term targets, retain a substantial component of ESU-specific genetic diversity relative to populations at much lower average levels. Combined with habitat size/complexity and current abundance, the spatial arraignment of populations within MPGs is also an important consideration in targeting near-term actions. In the near term, assigning higher priorities to restoration/protection activities in current or potential ‘source’ populations would benefit overall ESU/DPS recovery. Those populations could serve to bolster or even recolonize nearby populations in the case of prolonged downturns in survival, or chance localized catastrophic events before their own recovery actions have a chance to take effect. Another important consideration in sequencing application of restoration resources would be the relative vulnerability of populations to potential climate change impacts.

Management Strategies and Actions

Our habitat strategy recognizes that recovery demands the application of well-formulated, scientifically sound approaches. It is founded on the concepts presented in several salmonid habitat recovery planning documents and scientific studies (e.g., Beechie and Boulton 1999; Roni et al. 2002; Beechie et al. 2003; Roni et al. 2005; Stanley et al. 2005; Isaak et al. 2007; Roni et al. 2008; Beechie et al. 2010; Beechie et al. 2013; Roni and Beechie 2013). These studies show that restoration planning that carefully integrates watershed ecosystem processes is more likely to succeed in restoring depleted salmonid populations (Beechie et al. 2003). Beechie et al. (2010) outlined four principles that would ensure that river restoration is guided toward sustainable actions:

1. Address the root cause of degradation.
2. Be consistent with the physical and biological potential of the site.
3. Scale actions to be commensurate with the environmental problems.
4. Clearly articulate the expected outcomes.

The recovery strategies are consistent with these four principles. They also build on the many conservation efforts that are already helping to protect, conserve, and restore spawning and rearing habitats on public and private lands in Northeast Oregon, Southeast Washington, and Idaho. Recovery projects throughout the Snake River basin include: (1) protecting and conserving natural ecological processes and existing high quality habitat, (2) improving fish passage and stream flows to increase access to high quality habitat, (3) restoring floodplain connectivity and riparian vegetation, (4) improving water quality, (5) restoring instream habitat complexity, and (6) screening of irrigation diversions.

Many of these projects are being accomplished through coordination between water and land managers, private landowners, public interest groups, and others using a variety of funding sources.

- In Northeast Oregon, numerous habitat restoration projects have been completed for instream and floodplain restoration, including wood placement projects, riparian plantings, fencing, off-channel stock water development, and culvert replacement projects. These include a large stream and floodplain restoration project along Catherine Creek implemented by the Confederated Tribes of the Umatilla Indian Reservation and ODFW. Funds provided by BPA, the tribes, Grande Ronde Model Watershed, Freshwater Trust, and others have also been used to improve instream flows, such as in Catherine Creek and the Lostine River.
- In Southeast Washington, habitat restoration projects implemented by the Snake River Salmon Recovery Board, Washington Department of Fish and Wildlife, and other

partners include increasing channel complexity through the distribution of large wood over more than 13 miles of the Tucannon River from 2012 through 2015. Floodplain connectivity was also increased during this time period through levee removal, side channel restoration, and floodplain creation and reconnection. These recent activities build on many other watershed restoration activities that have occurred in the past decade.

- In the Clearwater River basin, habitat restoration projects have focused primarily on tributary watersheds important to steelhead, such as Lapwai Creek, Potlatch River, Big Canyon Creek, Newsome Creek, and Crooked River. A number of fish passage barriers have also been removed, including Dutch Flat Dam in the Potlatch River watershed, restoring fish passage to 35 miles of stream above the dam. In the Lapwai Creek drainage, significant increases in stream flow have occurred in Sweetwater Creek, Webb Creek, and the mainstem of Lapwai Creek below the confluence with Sweetwater Creek from changes in operation of water diversions. Efforts by the Lewiston Orchards Irrigation District and U.S. Bureau of Reclamation will further increase instream summer flow in Lapwai Creek by switching the water supply from the current surface water diversions to deep wells. A number of coordinated habitat restoration projects have also been funded and implemented through a participating agreement between the Nez Perce Tribe and Nez Perce-Clearwater National Forest in Idaho.
- In the Salmon River basin, recent habitat restoration actions have focused on reducing sediment delivery, restoring fish passage (including in the South Fork Salmon River, Loon Creek in the Middle Fork Salmon River drainage, and in the Lemhi, Pahsimeroi, and Yankee Fork drainages in the Upper Salmon River basin), and on improving hydrologic function and water quality through riparian and floodplain improvement projects. In addition, water transactions and on-farm irrigation improvement projects have increased summer stream flow in many locations across the Upper Salmon River basin. For example, 24 transactions, four easements, and irrigation changes in the Lemhi River basin generated about 85 cfs of flow improvement in key tributary and mainstem habitats (NMFS 2016).

Numerous opportunities for habitat restoration and protection remain throughout the Snake River basin, as described in the Northeast Oregon, Southeast Washington, and Idaho management unit plans. NMFS will coordinate with the various partners to refine, prioritize, and implement tributary habitat actions for recovery of the Snake River spring/summer Chinook salmon and steelhead populations. Table 6-1 shows the types of actions to be implemented to improve tributary habitat conditions. Adaptive management, RM&E, and life cycle modeling are important parts of the habitat implementation strategy. For example, life cycle models will provide a valuable tool for assessing the potential response of the species to alternative actions under different climate scenarios. This information and structure will be used to identify the most effective management strategies and direct the development of new projects that address priority limiting factors as they change over time.

In addition, several of the recovery strategies and actions identified to address other limiting factors are interconnected to the habitat actions because they may impact habitat conditions, or require habitat protection and/or restoration. For example, the types of actions described in Section 6.4.4 and Table 6-6 to address toxic pollutants are habitat-related actions.

In some cases, existing regulations also may need review to determine if benefits to riparian functions, water quality, and stream habitats could be achieved through rule revision. While protective measures have generally improved in recent years, there may be cases where the regulations or their implementation could be adjusted to better protect or restore habitat conditions. For example, it may be possible to adjust legal requirements under Section 404 of the Clean Water Act to make it easier for logging companies to place large woody debris in select stream reaches on private forest lands during forest practices. NMFS will work with the states and other stakeholders to evaluate and possibly revise such rules and regulations to assist recovery efforts.

Table 6-1. Regional approach to address tributary habitat-related factors limiting recovery of Snake River spring/summer Chinook salmon and steelhead populations.

Tributary Habitat	
Strategies	**Types of Actions**
Protect and conserve natural ecological processes that support population, MPG, and species viability	• Protect highest quality habitats through acquisition and conservation. • Maintain current wilderness protection. • Adopt and manage Cooperative Agreements. • Conserve rare and unique functioning habitats. • Consistently apply Best Management Practices and existing laws to protect and conserve natural ecological processes.
Restore passage and connectivity to habitats blocked or impaired by artificial barriers and maintain properly functioning passage and connectivity.	• Remove or replace barriers blocking passage, such as dams, road culverts, irrigation structures and hatchery weirs. • Provide screening at irrigation diversions. • Replace screens that do not meet criteria.
Maintain and restore floodplain connectivity and function.	• Reconnect side channels and off-channel habitats. • Restore wet meadows. • Reconnect floodplain to channel.
Restore stream complexity and structure and maintain properly functioning conditions.	• Place stable wood and other large debris in streambeds. • Stabilize stream banks. • Restore natural channel form.
Restore riparian condition and LWD recruitment and maintain properly functioning conditions.	• Restore natural riparian vegetative communities. • Develop grazing strategies that promote riparian recovery.
Restore natural hydrograph to provide sufficient flow during critical periods.	• Implement water conservation measures. • Improve irrigation conveyance and efficiency. • Lease or acquire water rights and convert to instream.

Tributary Habitat	
Strategies	**Types of Actions**
Improve degraded water quality and maintain unimpaired water quality.	• Reduce chemical pollution inputs. • Apply BMPs to animal feeding operations. • Restore natural functions and processes through remediation actions.
Restore degraded and maintain properly functioning upland processes to minimize unnatural rates of erosion and runoff.	• Upgrade or remove problem forest roads. • Restore native upland plant communities. • Employ BMPs to forest practices, livestock grazing, road management, and agricultural practices.

Types of RM&E Actions to Address Tributary Habitat Limiting Factors

Implementation of research and monitoring actions also continues. These efforts are providing needed information about the life stages that are currently hindered the most and need habitat restoration, and what habitat factors and ecosystem functions are currently limiting productivity. For example, RM&E will provide needed information regarding key habitats, such as cold-water refugia and overwintering habitat, which can be protected or improved to increase juvenile productivity and survival. It will also examine sources of mortality for juvenile migrants between tributary reaches and Lower Granite Dam, especially upstream from the Snake and Clearwater River confluence and in the mainstem Salmon River, where studies show substantial juvenile mortality occurs (Faulkner et al. 2016).

Monitoring also needs to be in place to determine the effectiveness of habitat improvements in increasing tributary habitat function and carrying capacity, and to evaluate how the fish respond to habitat restoration efforts, including the aggregate effects of multiple habitat actions at the watershed or population scale. In addition, evaluating several appropriate habitat metrics (e.g., flow and temperature) across a diversity of ecological regions and habitat types will help us assess and compare responses of the different populations to climate change. Chapter 7 and the management unit plans describe the research, monitoring, and evaluation framework that will be implemented to gain this needed information.

Research and monitoring will also examine potential density dependence limitations on spring/summer Chinook salmon and steelhead productivity in freshwater habitats. As discussed in Chapter 5, recent increases in spring/summer Chinook salmon spawning have not always resulted in additional smolt production. RM&E will examine potential factors that could be influencing spring/summer Chinook salmon productivity, including how various factors affect overwintering juvenile Chinook salmon in natal streams and downstream reservoir reaches, and how the factors influence adult returns.

Monitoring will also examine how food availability in freshwater habitat may be influencing abundance of juvenile Chinook salmon, as well as growth, smolt size, and survival. Targeted RM&E will improve our understanding of the natural potential of different stream systems, the use of various habitat areas at different life stages, the relationship of density dependence to environmental conditions, and the ability of existing habitats to support desired spawning, parr, and smolt production.

Information on spatial structure and diversity can also be improved by conducting studies to examine salmon and steelhead distribution, potential drivers of different life-history types (yearling vs sub-yearling spring/summer Chinook salmon; A-run vs B-run steelhead), and habitat preference. For instance, RM&E will examine the relationship between A-run and B-run steelhead life-history expressions, and the factors that are affecting the different run types and need to be addressed to maintain this life-history diversity. In addition, ongoing improvements in the monitoring, evaluation, and reporting of habitat metrics and fish population response will allow us to better identify biologically significant reaches for habitat restoration, and to assess the effectiveness of habitat restoration actions and progress toward the viability criteria for these ESUs and DPS.

6.3.2 Strategies and Actions for Estuary, Plume, and Ocean Habitat

Since spring/summer Chinook salmon and summer steelhead are stream-type fish and generally prefer deeper estuarine waters, the characteristics of these areas can be important to the growth and survival of these species. Actions that affect habitat in the estuary, decrease exposure to toxicants, and decrease predation should improve the abundance, productivity, and diversity of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS.

Management Strategies and Actions

The estuary habitat strategy is to continue ongoing actions and implement additional actions to maintain and improve spring/summer Chinook salmon and steelhead condition as fish migrate through the estuary. The strategy focuses on providing adequate off-channel and intertidal habitats; restoring habitat complexity in areas modified by agricultural or rural residential use; decreasing exposure to toxic contaminants; and lowering late summer and fall water temperatures. Over the long term the habitat improvement actions will help restore hydrologic, sediment, and riparian processes that structure habitat in the estuary. Table 6-2 shows the types of actions to be implemented to improve these habitat conditions in the Columbia River estuary. The Estuary Module (Appendix E) also identifies management actions that will improve the condition and survival of salmon and steelhead migrating through and rearing in the estuary and plume. These actions ─ many of which are already underway ─ address changes in floodplain connectivity, habitat quality and availability, water quality, and predation.

The recovery strategy for Snake River spring/summer Chinook salmon and steelhead in the ocean focuses on gaining additional information (see Key Information Needs) to better understand fish distribution, and the factors and threats that affect their growth, health and survival. This information will also help measure how the species respond to changes in climate.

Types of RM&E Actions to Address Estuary, Plume, and Ocean Habitat Limiting Factors

RM&E actions will continue and expand as needed to improve our understanding of the use of estuarine and plume habitats by juvenile Snake River spring/summer Chinook salmon and steelhead, and to identify potential bottlenecks that could be restricting productivity of natural-origin fish. This information will increase our understanding of the estuary's carrying capacity, and whether habitat improvements are sufficient to improve the survival and fitness of natural-origin juvenile fish as they prepare to enter the ocean phase of their life cycle.

Efforts will also continue to evaluate global-scale processes in the ocean and atmosphere, and their effects on productivity of marine, estuarine, and freshwater habitats of salmon and steelhead. Gaining a better understanding of these processes will improve our understanding of natural variability and help managers correctly interpret the response of salmon and steelhead to management actions. For example, assessing needed survival improvements based on spawner returns during periods of below average climatic and other background conditions has the effect of projecting these poor conditions into the future. If more of the years included in life cycle analysis represent more favorable ocean conditions, the estimated required survival increases to reach recovery would decrease. Additional research is needed to help managers understand the mechanisms by which ocean conditions and climate affect survival for different life-history types, and to improve forecasting and related fisheries management capabilities so that Snake River spring/summer Chinook salmon and steelhead populations persist over the full range of environmental conditions they are likely to encounter.

RM&E is also needed to improve our understanding of the physical and biological relationships between habitat conditions in freshwater, the estuary, the plume, and the nearshore ocean. In particular, we need more information on how ocean growth and survival, especially during the time that salmon and steelhead spend in the Northern California Current, are influenced by characteristics of the fish (size, timing, condition) during their time in the estuary and plume. This includes the potential effects of density dependence on growth and survival, especially as they relate to the effects of hatchery fish on wild fish. Gaining a better understanding of these relationships through RM&E, including the inputs to life cycle modeling, will help us evaluate how recovery actions are working and identify needed changes. Chapter 7 and the Estuary Module identify research, monitoring, and evaluation actions to obtain this needed information.

Table 6-2. Regional approach to address estuarine habitat/plume/nearshore ocean related factors limiting recovery of Snake River spring/summer Chinook salmon and steelhead populations.

Estuarine Habitat	
Strategies	**Types of Actions**
Restore degraded estuarine and plume habitats and associated ecological processes.	• Protect/restore riparian areas. • Remove pile dikes. • Protect remaining high-quality off-channel habitat. • Breach or lower dikes and levees. • Identify and reduce sources of pollutants. • Monitor and restore contaminated sites. • Adjust the timing, magnitude, and frequency of flows.
Plume and Nearshore Ocean	
Strategies	**Types of Actions**
Continue to monitor and evaluate ocean conditions that the species experience.	• Study physical conditions in the ocean, especially bottlenecks or critical periods in survival. • Examine physical and biological relationships between estuarine, plume, and ocean habitats, and impacts on species' ocean growth and survival.

6.3.3 Strategies and Actions for Mainstem Snake and Columbia River ─ Hydropower System and Fish Passage

Management Strategies and Actions

The recovery strategy continues current efforts and proposes additional actions to improve Snake River spring/summer Chinook salmon and steelhead viability by addressing the mainstem effects of Columbia and Snake River hydropower operations. The hydropower strategy contains three components: (1) improve passage survival at mainstem Columbia and Snake River dams, (2) address impacts in tributaries by implementing actions prescribed in Federal Energy Regulatory Commission agreements regarding operation of individual tributary dams, and (3) implement mainstem flow management operations to benefit fish migrating to and from the Snake River. The actions are designed to increase juvenile and adult fish passage and survival, reduce predation, and improve flows and temperatures that affect the fish.

The management strategy builds on ongoing efforts to address hydropower-related limiting factors. Many of these actions are being implemented under the 2008 FCRPS biological opinion. Specific actions include structural improvements, changes in configuration and operations, development and implementation of fish passage plans, and storage and release of water to enhance migratory conditions for juvenile and adult migrants (e.g. flow, temperature, etc.). NMFS expects that the changes in flow management operations to increase spring flows have benefits downstream, improving survival in the estuary and, potentially, the plume.

Actions implemented since 2006 include:

- Provision of voluntary spill at all mainstem dams, 24 hours a day during juvenile migration season.
- Installation of surface passage routes (spillway weirs) and other modifications to provide a safer and more effective passage route for migrating smolts at Little Goose, Lower Monumental, McNary, John Day, Bonneville, The Dalles, and Ice Harbor Dams. The changes reduce migration delay (time spent in the forebay of the dams) and increase the proportion of smolts passing the dams via the spillway rather than via the turbines or juvenile bypass systems (spill passage efficiency). Decreased forebay delay and shortened travel times also potentially reduced exposure to predators, as well as to elevated water temperatures that may occur during the migration period. They likely also benefit steelhead kelts and volitional adult Chinook salmon fallbacks at the dams.
- Relocation of juvenile bypass system outfalls to avoid areas where predators collect.
- Flow management from storage reservoirs; this includes releases of cool water from Dworshak Dam on the North Fork Clearwater River to reduce summer water temperatures for migrating adult and juvenile salmon and steelhead in the Snake River migration corridor.
- Installation of avian wires to reduce juvenile losses to avian predators.
- Initiation of measures to reduce losses from piscivorous fish and pinniped predators.
- Changes to reduce dissolved gas concentrations that might otherwise limit spill operations.
- Installation of adult PIT-tag detectors at all adult fishways (with exception of John Day Dam) to better assess adult losses in the Snake and Columbia Rivers.
- The temporary alteration of operations at Lower Granite and Little Goose Dams in 2014 and 2015 to improve passage conditions and temperatures for Snake River summer Chinook and sockeye salmon and steelhead.
- Flow releases from the Hells Canyon Complex and other dams in the upper Snake River basin to enhance conditions for summer migrants in the lower Snake River.

The recent operational improvements and passage route configuration changes at mainstem dams have already reduced juvenile mortality and injury rates, especially for Snake River steelhead. Survival studies show that with few exceptions, fish passage measures, including the use of surface passage structures and spill, are performing as expected and are very close to achieving, or have already achieved, the juvenile dam passage survival objective of 96 percent for yearling Chinook salmon and steelhead migrants defined in the 2008 FCRPS biological opinion (in NMFS 2014c). The improvements, particularly surface passage routes and 24-hour spill at the three Snake River collector projects, have resulted in substantially reduced juvenile Chinook salmon and steelhead transportation rates. Nevertheless, more information is being collected to evaluate the effects of juvenile in-river vs. transport strategies on overall survival rates, including reach survival estimates (including the effects of reservoir passage) and smolt-to-adult return rates (NMFS 2014c). Collectively, these measures, because they reduce travel times of migrating smolts to the ocean and stressors associated with dam passage routes, are expected to reduce several of the hypothesized causes of latent mortality of juvenile migrants in the estuary and ocean. However, many years of adult returns will be necessary to assess the efficacy of these actions given the inherent ecological variation in the Columbia River basin and ocean environment.

The installation of spill weirs and other surface passage routes at each of the mainstem FCRPS dams to improve juvenile passage also benefited steelhead kelts. Colotelo et al. (2013, 2014) estimated that tagged steelhead kelts released at or above Lower Granite Dam survived to river kilometer 156 (downstream of Bonneville Dam) at rates of 40 percent in 2012 and 27.3 percent in 2013; compared to estimated survival rates of about 4 to 16 percent in 2001 and 2002.

The recovery strategy builds on recent improvements by continuing to implement the 2008 FCRPS biological opinion and its 2010 and 2014 supplements, which address the configuration and operation of the hydropower system (NMFS 2008a, 2010, 2014c). The Reasonable and Prudent Alternative (RPA) for the FCRPS takes a comprehensive approach to ESA protection that includes hydropower, habitat, hatchery, and predation measures to address the biological needs of salmon and steelhead in every life stage within human control. NMFS developed the RPA after collaborating with the three agencies that operate the FCRPS: Bonneville Power Administration, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation and the regional, state, and tribal sovereigns to identify priority hydropower, habitat, and hatchery actions, as ordered by the U.S. District Court.

Additional actions to improve survival may arise through the Columbia River Systems Operation (CRSO) Environmental Impact Statement (EIS) process, which is now underway as ordered by the U.S. District Court. As directed by the court (and discussed in Section 1.7.1) the federal Action Agencies (Corps, BPA, and USBR) are preparing this new EIS under the National Environmental Policy Act (NEPA) to address the operation, maintenance, and configuration of 14 federal dam and reservoir projects that are operated as a coordinated water management system.[26] The EIS is referred to as the Columbia River System Operations EIS. As part of this process, BPA, the Corps, and the USBR (i.e., the “co-lead agencies” for the EIS) will evaluate a range of alternatives, including a no-action alternative (current system operations and configuration). Other alternatives will also be developed, and will likely include an array of alternatives for different system operations and additional structural modifications to existing projects to improve fish passage, including breaching one or more dams. Alternatives will include those within the EIS co-lead agencies’ current authorities, as well as certain actions that are not within the co-lead agencies’ authorities, based on the court’s observations about alternatives that could be considered, and on comments received during the scoping process. In

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[26] These 14 projects are: Bonneville, The Dalles, John Day, McNary, Chief Joseph, Albeni Falls, Libby, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak Dams (operated and maintained by the Corps), and the Hungry Horse Project and Columbia Basin Project, which includes Grand Coulee (operated by the USBR). Also see Section 1.7.1.

addition, the EIS will evaluate alternatives to insure that the prospective management of the Columbia River system is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of designated critical habitat, including evaluating mitigation measures to address impacts to listed species. The EIS will allow federal agencies and the region to evaluate the costs, benefits, and tradeoffs of various alternatives as part of reviewing and updating the management of the Columbia River system.

The Corps has previously evaluated breaching the four lower Snake River dams, in the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (USACE 2002). In 2010, the Corps prepared the Lower Snake River Fish Passage Improvement Study: Dam Breaching Update Plan of Study (Corps 2010), which describes the process for initiating an evaluation of dam breaching in the event salmon populations significantly declined. Since breaching of a dam at the scale of the lower Snake River dams has not yet occurred, many of the effects considered are estimates or preliminary assessments. Further, the previous assessments do not take into account the most current information.

As discussed in these prior analyses, if lower Snake River dams are breached, some effects are fairly certain to occur for yearling juvenile migrants for both species. Juvenile travel time through the lower Snake River would be faster; juvenile fish transportation would no longer be available at projects that collect fish for transport which were breached, and changes in total dissolved gas caused by releasing water through spillways would be eliminated at projects that were breached.

The previous analyses indicated there is greater uncertainty about the sediment loads and river conditions fish might experience during drawdown and breaching. Turbidity would increase dramatically for the first several years with much of the sediment transport occurring in the spring months. Juveniles migrating in the spring would experience highly turbid conditions. A similar impact from turbidity is anticipated for spring migrating adults because they migrate upstream during the high flow period when sediment transport will be greatest. Predictions of the effect of increased sediment on the survival of migrating salmon and steelhead would be highly subjective and would depend on flows during the post-dam breaching period.

Temperature effects would vary by species. Large reservoirs, because of their thermal inertia, generally alter water temperatures (compared to an unimpounded river) by reducing summer maximum temperatures, increasing winter minimum temperatures, and delaying warming in the spring and cooling in the fall. Breaching the lower Snake River dams would diminish these effects and likely cause an increase in peak maximum summer temperatures. The magnitude of the peak temperatures could be ameliorated by releasing cool water from Dworshak Dam in the North Fork of the Clearwater River, but the extent to which these cool water releases would mix with the warmer waters of the mainstem Snake River with breached dams has not been thoroughly evaluated. As discussed in the prior analyses, little effect is anticipated for juvenile spring Chinook salmon and steelhead because temperatures during their spring out migration are not expected to change substantially due to breaching. Early migrating adult spring-run Chinook salmon also would likely show little effect. Summer Chinook salmon and steelhead would benefit if the temperature was cooler after breaching, but would be negatively affected if temperatures increased. Temperature models are being developed that should give some insights into these effects.

The effect of avian predators on juvenile salmonids during and after dam breach is unknown, but effects of birds in the estuary would probably not change. Caspian terns and cormorants at inland roosting and nesting sites are effective predators in free-flowing river systems and would likely continue to have an effect on juvenile salmonids. However, gulls are opportunistic feeders that would likely have a reduced impact in a free-flowing river.

The response of predatory fish (native pikeminnow as well as non-native smallmouth bass, channel catfish, and walleye) was even less certain. It is likely that the return to a more riverine system in this portion of the Snake River could reduce salmon predation losses to native and non-native invasive fishes that have taken advantage of the reservoir habitat, such as northern pikeminnow and walleye. Migrating smolts would be less exposed due to decreased travel times through the lower Snake River, but, at least initially, the large existing population of predators would be concentrated into smaller volume of the unimpounded river, potentially increasing predation rates.

The changes in conditions during the dam breaching period could have the greatest negative effects on fish passage. The breaching action could span a number of years, depending on how many dams are breached and the methods used to breach them. These could include deteriorated conditions in the adult ladder entrances and exits due to changes in depth and water supply, reduced spillway passage efficiency, and reduced juvenile bypass passage efficiency. Life-cycle modeling that incorporates expected effects of the altered river environment will help inform the questions of how juvenile and adult migrants might respond to breaching of the lower Snake River dams, although uncertainties regarding the combined effects on each species' populations will remain.

Following completion of the NEPA process, NMFS will work with the Action Agencies to identify actions to implement the preferred alternative and ensure the long-term survival and productivity of Snake River spring/summer Chinook salmon and steelhead, as well as other affected ESA-listed species. Future actions may include the potential additional actions identified below in Table 6-8. In the meantime, the Action Agencies will continue to implement measures required by the 2008 biological opinion and supplements, which will contribute toward improvement in species' viability and abundance.

Other potential ways to gain survival improvements or increase travel times in reaches of the hydropower system will also be explored through the Plan's adaptive management framework. For example, survival improvements for summer-migrating Chinook salmon have been gained through the use of Dworshak Dam cool water releases and are being maintained. The recent installation of a new intake structure at Lower Granite Dam in 2016, which draws a greater volume of water from a 60-foot depth in the forebay to cool the water flowing into the exit section of the adult ladder, should further improve survival of summer Chinook salmon and other summer-migrating salmonids. Regional co-managers will continue to evaluate passage information from adult migrations and identify additional actions that could benefit adult migrants during high temperature periods. Other efforts will explore opportunities to reduce predation on juvenile migrants in reservoir reaches.

In April 2017, the United States District Court for the District of Oregon, ordered the litigation parties to confer on a process to develop a spill implementation plan for increased spring spill for juvenile fish passage at the Corps' lower Snake River and lower Columbia River projects for the 2018 migration season. The parties were directed to consider an appropriate protocol and methodology for spill at each dam, incorporating the most beneficial spill patterns. The Regional Implementation Oversight Group (RIOG) is the forum where parties are collaborating on the development of recommendations for a 2018 spill implementation plan. Through the collaboration process, the federal agencies, state, and tribal representatives formed working groups. One working group is conducting a project-by-project review to identify potential constraints associated with increased spring spill. This review will help identify information that may reveal harmful effects where spilling to the "gas cap" levels could result in erosion, blocking or delay of adult passage, or increased predation of juveniles, among other unintended consequences. A second working group is conducting spill pattern development on physical models at the Corps' Engineer Research and Development Center in Vicksburg, Mississippi. The physical models will allow the teams to conduct trial and error simulations with spill gate combinations in concert with powerhouse turbine unit priorities to mitigate or eliminate harmful effects from increased spill. The RIOG forum will also consider potential unintended consequences of increasing spring spill for fish passage on biological monitoring (e.g. PIT tag detections) and power system reliability. Periodic status conferences with the Court are scheduled to ensure that the parties are making sufficient progress toward a spring spill implementation plan for the 2018 migration season.

Table 6-3 summarizes the strategies and actions being implemented to improve juvenile and adult salmon and steelhead survival through the Columbia and lower Snake River hydropower system. Table 6-8 identifies other potential actions that could further improve survival and support recovery efforts.

State of Oregon Position regarding Hydropower Operations

It is the state of Oregon's position that additional and/or alternative actions to the FCRPS biological opinion should be taken in mainstem operations of the FCRPS to improve passage, survival, and habitat quality in the mainstem Columbia and Snake Rivers for ESA-listed salmon and steelhead. Some additional or alternative actions recommended by Oregon, while considered, were not included in NMFS' FCRPS biological opinion. At this time, Oregon is a plaintiff in litigation against the FCRPS agencies and NMFS, challenging the adequacy of the measures contained in the current (2008 as supplemented in 2010 and 2014) FCRPS biological opinions.

Types of RM&E Actions to Address Mainstem Hydropower and Fish Passage Limiting Factors

This section summarizes the types of RM&E needed to address mainstem Snake and Columbia River hydropower and fish passage limiting factors. Chapter 7 of this Plan, the Hydro Module (Appendix G), and the 2014 Supplemental FCRPS Biological Opinion (NMFS 2014c) provide more information on these information needs.

Columbia and Lower Snake Rivers Hydropower System

Ongoing studies will continue to research and monitor juvenile survival rates at each dam, survival through long migratory reaches, seasonal trends in smolt-to-adult returns, adult survival rates for different stocks, and other factors. This monitoring provides a better understanding of smolt migration timing and mortality rates through the lower Snake and Columbia Rivers, including the effects of spring and summer spill operations on juvenile and adult migrants. Future research will also examine the drivers for expression of the life-history diversity in Snake River spring/summer Chinook salmon and steelhead. This includes examining differences in strategies of movement and holding between downstream migrating yearling and sub-yearling Chinook salmon in both free-flowing and reservoir mainstem reaches. Monitoring will also continue to examine juvenile survival in the migration corridor between John Day Dam and the Columbia River estuary. Additional investigations will provide needed information on factors that could contribute to latent mortality of fish passing through the hydropower system.

Monitoring of adult migrants will also continue. For example, RM&E will continue to examine where and how adults are being lost between Bonneville and Lower Granite Dams, as well as why Tucannon River Chinook salmon and steelhead are passing their natal river system and Lower Granite Dam. Maintaining or enhancing existing adult PIT-tag detection systems in the mainstem migration corridor and adjacent rivers would aid managers in determining the causes of these losses (e.g., adult fallback at spillways, unauthorized harvest, injuries from pinniped attacks, etc.) and developing potential remedies.

Further, passage conditions existing at mainstem projects at the time of migration will also be monitored. For example, water temperatures will be monitored and reported at all mainstem adult fish ladders to better identify temperature differentials that contribute to adult passage issues, such as those that occurred in 2015.

Finally, modeling is needed to better understand the differential survival between populations of Snake River spring/summer Chinook salmon and steelhead migrating through the FCRPS, and the relative effects of fish losses in different portions of the life cycle on population abundance and productivity so we can target actions effectively to address key limiting factors. Multi-stage life cycle evaluations also need to be conducted using latest information on survival through mainstem corridor, estuary, and plume.

Research on Reintroduction for Broad Sense Recovery

While reintroduction of the species above the Hells Canyon Complex is not needed to achieve ESU and DPS delisting, it remains an important broad sense goal for the state of Oregon, the four Upper Snake River Tribes (Burns Paiute Tribe, Fort McDermitt Paiute-Shoshone Tribe, Shoshone-Bannock Tribes of the Fort Hall Reservation, and Shoshone-Paiute Tribes of the Duck Valley Reservation), and the Nez Perce Tribe. Research is ongoing through the Hells Canyon Complex relicensing process to examine the risks and feasibility of providing passage, improving habitat conditions, and reintroducing naturally producing Chinook salmon and steelhead into historical habitats in blocked areas above Hells Canyon Dam. The information will be used to determine the potential benefits of reintroductions to Pine Creek, Indian Creek, the Wildhorse River, and other areas; identify considerations under which reintroductions would be suitable; and develop potential alternative reintroduction strategies and techniques through an adaptive management process.

Table 6-3. Regional approach to address hydropower system constraints to recovery of Snake River spring/summer Chinook salmon and steelhead populations.

Hydropower System	
Strategies	**Types of Actions**
Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects; and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future. Implement spill and juvenile transportation improvements at Columbia and Snake River dams. Operate and maintain juvenile and adult fish passage facilities at Corps mainstem projects to improve in-river survival. Develop and implement a kelt management plan.	• Draft storage reservoirs (Libby, Hungry Horse, Grand Coulee, and Dworshak) to improve mainstem conditions (flows and temperatures) in the lower Snake and Columbia Rivers (June, July, and August). • Pursue negotiations with Canada to provide 1 million acre feet of storage to augment summer flows. • Implement measures to improve flows during the lowest 20th percentile years. • Continue releases of cool water from Dworshak Dam during late summer to reduce mainstem Snake River temperatures and maintain adequate migration conditions (for adults and juveniles) in the lower Snake River. • Continue flow augmentation from upper Snake River basin projects to enhance flows in lower Snake River from April through June. • Provide spring spill at mainstem lower Snake River and Columbia River dams to maintain adequate passage conditions for actively migrating smolts. • Operate and maintain juvenile and adult fish passage facilities at Corps mainstem projects to maintain biological performance. • Federal Action Agencies will complete a NEPA process (see discussion in Section 6.3.3) that evaluates a range of alternatives for increasing survival of salmon and steelhead in the Columbia River basin that pass through the FCRPS. The result of this effort should result in feasible and effective actions, which, once implemented, will improve survival and productivity of Snake River spring/summer Chinook salmon and Snake River Basin steelhead, as well as other salmonid species in the basin. • Implement actions to reduce juvenile losses to predacious fish and birds. • Implement actions to reduce adult spring Chinook salmon and steelhead losses to marine mammal predators. • Continue to implement a steelhead kelt management plan to both improve the survival of post-spawning adults through the mainstem corridor and to recondition adults from B-run populations to increase repeat spawning. • Continue efforts to improve adult passage at the ladder at Lower Granite Dam, building on current releases of cool water from Dworshak Dam during summer to reduce mainstem Snake River temperatures.

6.3.4 Strategies and Actions for Fisheries Management

Management Strategies and Actions

The harvest strategy aims to protect Snake River spring/summer Chinook salmon and steelhead in the mainstem Columbia River, ocean, and tributaries by maintaining low impact fisheries. This section summarizes overall harvest strategies and actions for the two species. The management unit plans provide more detailed discussions.

The mainstem Columbia River fisheries that affect Snake River spring and summer Chinook salmon and steelhead are under the jurisdiction of *U.S. v. Oregon* and have been managed to reduce impacts on ESA-listed species since adoption of the May 2008 *U.S. v. Oregon* Management Agreement. The *U.S. v. Oregon* Management Agreement for 2008-2017 provides a framework for managing the mainstem fisheries. Harvest limits defined in the management agreement are thought to be sufficiently protective to allow for the recovery of ESA-listed species. The management agreement calls for the implementation of an abundance-based management framework for Columbia River fisheries, such that allowable ESA mortality rates may increase or decrease in proportion to the abundance of natural-origin fish forecast to return each year. The mainstem Columbia River fisheries are then under constant monitoring to assess the relative impacts of the fisheries on survival and recovery of ESA-protected species.

Available harvest information indicates that since 2011, harvest rates have remained relatively constant in the aggregate of fisheries for Snake River spring/summer Chinook salmon, 10.3 percent annually, and Snake River A-run steelhead, 1.3 percent in recreational fisheries (TAC 2011-14). Harvest impacts since 2011 have been trending downwards for Snake River B-run steelhead, from 17.3 percent in fall treaty fisheries and 1.4 percent in recreational fisheries to less than 13.8 percent and 1.0 percent, respectively (TAC 2011-14; NMFS 2016).

The regional strategy calls for managers to continue to implement the abundance-based management framework for managing mainstem and tributary fisheries to limit ESA impacts on natural-origin Snake River spring/summer Chinook salmon and steelhead populations. Fishery opportunities will continue to be responsive to annual population abundance and recovery criteria, while remaining consistent with tribal trust responsibilities and formal agreements. Fisheries in the Columbia River mainstem will continue to comply with criteria developed through negotiation in *U.S. v. Oregon* to limit impacts on ESA-listed species. Tributary fisheries for Snake River spring/summer Chinook salmon will continue to be managed according to management frameworks that include abundance-based sliding-scales to determine year-specific allowable harvest rates to support natural production and not reduce the likelihood of juvenile and adult survival and recovery of the ESU. A similar approach is being considered in developing a harvest framework for Snake River steelhead.

Types of RM&E Actions to Address Harvest Limiting Factors

The harvest strategy also calls to refine monitoring and research efforts. Genetic tools are available to monitor and manage population-specific impacts on natural-origin spring/summer

Chinook salmon and steelhead. Table 6-4 shows the types of actions to be implemented to reduce potential risks from fisheries in the Columbia and Snake Rivers and tributaries.

Fisheries data gained through PIT-tag detection and other studies will help managers better understand the sources of losses and improve harvest management, including the setting of abundance-based sliding-scale harvest rates. Information will also be collected to better estimate harvest impacts from catch and release fisheries. In addition, information collected through population monitoring programs and to identify density dependent relationships will be used to focus fisheries to harvest surplus hatchery fish, and help achieve spawning escapement goals for natural-origin populations.

Table 6-4. Regional approach to address fishery-related factors limiting recovery of Snake River spring/summer Chinook salmon and steelhead populations.

Fishery Management	
Strategies	**Types of Actions**
Continue to manage to maintain current low impact fisheries and reduce harvest related adverse effects in those fisheries that have significant impacts.	• Continue implementing fisheries in the mainstem Columbia that comply with management agreements developed under the jurisdiction of *U.S. v. Oregon* and associated biological opinions. • Coordinate harvest among all co-managers to ensure that the collective impacts to each population are consistent with recovery goals, and associated management plans and biological opinions. • Work with co-managers to assure that future Fishery Management and Evaluation Plans (FMEPs) and Hatchery and Genetic Management Plans (HGMPs) are aligned with recovery goals and strategies identified in this Plan. • Continue to manage tributary harvest and reduce adverse effects by implementing state and tribal fishery plans that have been reviewed and authorized under the ESA by NMFS. • Develop population-specific sliding scales for harvest management based on natural-origin returns and designed to minimize impacts to natural-origin fish.
Continue to refine monitoring and research efforts to gain more and improved data needed to reduce impacts on natural-origin returning fish.	• Implement and improve creel surveys and other fishery monitoring to assess and manage impacts on natural-origin returns. • Continue marking hatchery-origin juveniles (e.g., fin clip, genetic marking, and coded-wire and internal tags). • Use parental-based tagging and genetic stock identification when available and appropriate, and/ or PIT-tag studies to determine population-specific impacts from mainstem Columbia, Snake, and tributary fisheries.

6.3.5 Strategies and Actions for Hatchery Management

The central challenge of recovery planning with respect to hatchery programs is finding a balance between the risks and benefits of hatchery production in working to achieve recovery goals. The path to determining the appropriate role of hatchery programs in recovery is complicated by the requirements of the Endangered Species Act, legal agreements regarding production levels, agreements regarding mitigation levels, harvest agreements, tribal trust responsibilities, and scientific uncertainty.

Management Strategies and Actions

A key part of the hatchery strategy is to continue ongoing actions and implement additional actions to improve species' viability by reducing impacts of hatchery-origin fish on the productivity or genetic characteristics of natural-origin populations and the habitats that support them. Hatchery programs exist for many of the Snake River spring/summer Chinook salmon and steelhead populations, with the dual purpose of providing fish for fisheries and supplemental spawners to help rebuild depressed natural populations. Recovery plan actions need to be integrated with hatchery management to maintain the genetic diversity of natural-origin populations and habitats that support their resilience, while supporting the conservation and utilization benefits of the programs.

Hatchery programs for Snake River spring/summer Chinook salmon and steelhead continue to evolve as the status of the natural-origin populations changes. For example, many captive programs initiated during the 1990s to conserve Snake River spring/summer Chinook salmon genetic resources were terminated after the status of these fish improved. Also, a new small-scale reintroduction program is being implemented using broodstock that are included in the ESU to add to the spatial structure of the existing ESU. Another recent change has been the reduction of hatchery steelhead releases into mainstem areas where they are difficult to monitor and manage (NMFS 2016). This recovery plan identifies actions that support the recovery of viable natural-origin, self-sustaining populations of Snake River spring/summer Chinook salmon and steelhead in the wild. Recovery plan actions will help ensure that hatchery programs minimize demographic risks to the genetic and productive character of the natural-origin populations. The approach to recovery incorporates uncertainty with respect to population response and proceeds as a series of staged actions, many that are contingent on achieving measurable progress benchmarks.

The hatchery programs are authorized under the Lower Snake River Compensation Plan and other mitigation programs. Production goals, release sizes, release locations, release priorities, life stage, and marking of released fish for Snake River spring/summer Chinook salmon and steelhead hatchery programs are established through the *U.S. v. Oregon* management process.

Currently, Hatchery and Genetic Management Plans (HGMPs) are being reviewed under the ESA for each hatchery program in the Snake River basin. The plans provide detail on the components, facilities, and other aspects of these hatchery programs. HGMPs are developed by the operating entities to minimize hatchery impacts on ESA-listed species. The most recent plans are available on the NMFS website: http://www.westcoast.fisheries.noaa.gov/hatcheries/salmon_and_steelhead_hatcheries.html.

NMFS uses the HGMPs as a basis for providing ESA coverage of hatchery operations through section 7 consultations, section 10 permits, and/or 4(d) rule limits. The HGMP development process is also used to identify where additional research is needed to examine potential issues that hinder efforts to achieve recovery goals. Hatchery effects on the Chinook salmon and steelhead populations and potential actions contributing to recovery are also discussed in NMFS' Appendices C and D of the Supplemental Comprehensive Analysis of the FCRPS (NMFS 2008c). Table 6-5 identifies the types of actions to be implemented to reduce risks associated with hatchery management and releases.

Types of RM&E Actions to Address Hatchery Limiting Factors

RM&E will continue to examine the impacts of hatchery releases on natural-origin Snake River spring/summer Chinook salmon and steelhead population abundance, productivity, and genetic integrity. Importantly, it will investigate the reproductive success of hatchery-origin fish spawning in the wild, and the benefits and risks to the natural-origin populations. It will also evaluate ecological interactions that occur between hatchery and natural-origin ESA-listed fish in the tributary, mainstem, estuary, and ocean environments. Managers will use information gained from this additional research to assess demographic risk versus conservation benefit of hatchery supplementation, and the implications of hatchery programs.

Collecting population-specific estimates of annual abundance and obtaining information on the relative distribution of hatchery-origin fish in natural spawning areas near major release sites within individual populations remain high RM&E priorities for the Snake River Basin steelhead DPS (NWFSC 2015).

At a larger scale, information is to be collected to determine the factors contributing to lower or greater reproductive success rates for hatchery fish, and the effects of total hatchery production on the listed salmon and steelhead populations.

Table 6-5. Regional approach to address hatchery-related factors limiting recovery of Snake River spring/summer Chinook salmon and steelhead populations.

Hatchery Management	
Strategies	**Types of Actions**
Manage hatchery fish to support recovery of viable natural-origin, self-sustaining populations by minimizing influences on the productivity or genetic characteristics of natural-origin populations and the habitats that support their resilience.	• Use local-origin natural-origin broodstock-based hatchery supplementation programs to reduce genetic adaptation risks. • Manage returning hatchery-origin fish to reduce or eliminate hatchery contribution in the wild and reduce genetic adaptation risks. • Evaluate ecological interactions and develop alternative release strategies if necessary to reduce demographic risk. • Work with co-managers to assure that future HGMPs are consistent with the Plan's recovery goals and strategies. Address potential risks through HGMP development and consultation process. • Implement HGMPs.
Reduce uncertainty in abundance and proportion of hatchery strays spawning naturally with the natural-origin populations.	• Increase monitoring to include estimates of adults returning to each population and to reduce uncertainty regarding hatchery strays and associated genetic risk.
Evaluate ecological interactions and develop alternative release strategies if necessary.	• Release strategies (life stage released, timing, etc.) • Release numbers • Release locations
Reduce uncertainty regarding out-of-basin hatchery strays and associated genetic risks.	• Increase monitoring efforts to restrict naturally spawning hatchery-origin fish in some natural-origin population areas.
Manage efforts to restore natural production into historically utilized habitat to protect the viability of ESA-listed populations.	• Evaluate feasibility of reestablishing naturally reproducing Chinook salmon and populations into historical habitats in blocked areas.

6.3.6 Strategies and Actions for Predation, Competition, Disease, and Exposure to Toxic Pollutants

Management Strategies and Actions

The overall strategy is to continue ongoing efforts and implement additional actions to reduce predation, competition, disease, and exposure to toxic pollutants that affect Snake River spring/summer Chinook salmon and steelhead. Strategies and actions to address limiting factors presented by predation, competition, disease, and toxic pollutants are discussed in the management unit plans, Estuary Module, Hydro Module, and this recovery plan. The documents also direct additional research, monitoring, and evaluation activities to quantify the impacts of predation, competition, disease, and toxic pollutants on Snake River spring/summer Chinook salmon and steelhead recovery efforts.

Actions are ongoing to reduce predation and increase survival of Snake River spring/summer Chinook salmon and steelhead. For the Columbia River estuary and mainstem and the lower Snake River, the Estuary Module and Hydro Module call for programs to reduce bird, fish, and marine mammal predation on listed salmon and steelhead through relocation, hazing, and bounties, guided by an ongoing research program. For Snake River steelhead, such actions include reducing avian predation by moving two Caspian tern colonies and reducing the number of double-crested cormorants.

Since multiple factors cause disease in salmonids, it cannot be directly addressed by recovery actions except in specific instances of known causal factors. It is more likely that nearly all of the recommended recovery actions to increase habitat health and the survival, abundance, and productivity of naturally produced salmon and steelhead will decrease the incidence of disease. Improving fish and habitat health will also reduce future potential disease-related risks for the populations due to rising water temperatures associated with climate change.

Strategies to address toxic pollutant contamination center on gaining additional information on the exposure and uptake of contaminants by juvenile spring/summer Chinook salmon and steelhead, and developing actions to reduce their effects on the fish. More monitoring of toxic pollutants is needed in the lower and middle mainstem Columbia River, Snake River, and tributaries that support the species. The strategy supports actions identified in the Estuary Module and by the Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, and Washington Department of Ecology to improve water quality.

Types of RM&E Actions to Address Predation, Competition, Disease, and Toxic Pollutant Limiting Factors

Predation, Competition, and Disease

RM&E will continue to evaluate the impact of predation on juvenile and adult Snake River spring/summer Chinook salmon and steelhead in the Columbia River estuary, mainstem migration corridor, and tributary reaches. Other native species (competitors and predators), invasive species (competitors, predators, and pathogens) and/or other populations (tradeoff among species) target salmon and steelhead populations and affect their viability. Threats are not restricted to direct predation. Instead, non-indigenous species and other native species can compete directly and indirectly with Snake River spring/summer Chinook salmon and steelhead for resources, significantly altering food webs and trophic structure, and potentially altering evolutionary trajectories (NMFS 2011c).

Several particular information needs regarding predation impacts stand out. More information is needed to understand the impact of sea lion predation on spring/summer Chinook salmon and steelhead, both directly through predation and indirectly via injuries from attacks that can lead to increased prespawning mortalities and decreased fitness. Information is also needed to evaluate impacts on life cycle recruitment of targeted natural-origin populations, as well as on ESU viability. Continued monitoring and evaluation also needs to occur to determine the level and impact of avian predation, especially for juvenile steelhead migrants in the Columbia River estuary, and from non-salmonids, such as predation by smallmouth bass in the reservoirs, and the efficacy of responsive management actions.

Information is also needed regarding whether competition has increased in certain areas because habitat capacity is limited and unable to support salmonids competing for key resources at the same time ─ whether on the spawning grounds, in natal rivers and downstream migratory reaches, in the estuary, or in the ocean (ISAB 2015). Information on how density dependence limits population growth and habitat carrying capacity is critical for setting appropriate biological goals and targeting actions effectively to reach recovery.

Exposure to Toxic Pollutants

Chemical contaminants are increasingly being recognized as a factor that has contributed to the decline of listed species (NMFS 2010). Recent scientific studies document the presence of elevated concentrations of bioaccumulative contaminants including PCBs, DDTs, PAHs, and PBDEs in bodies or prey of juvenile salmon in the lower Columbia River (Johnson et al. 2007; LCREP 2007; Sloan et al. 2010; as cited in NMFS 2010).

Our understanding of the effects of many contaminants on aquatic life, alone or in combination with other chemicals (potential for synergistic effects), is incomplete. Scientific information indicates that if chemical contaminates are affecting the survival and productivity of individual fish, the intrinsic productivity of affected populations also could be reduced. The toxic effects of various chemicals and pesticides could also indirectly affect viability by reducing non-target insect species that are important food for juvenile salmonids. More information is needed to determine if these chemical contaminants are limiting salmon and steelhead population viability. Table 6-6 describes the regional strategy to monitor and address limiting factors related to predation, competition, disease, and toxic pollutants.

Table 6-6. Regional approach to monitor and address limiting factors related to predation, competition, disease, and toxic pollutants that could affect recovery of Snake River spring/summer Chinook salmon and steelhead populations.

Strategies	Types of Actions
Predation	
Reduce predation and competition in the Columbia River mainstem, estuary, and plume.	• Reduce predation by pinnipeds. • Redistribute Caspian terns. • Reduce and redistribute cormorants. • Reduce impacts from predatory bird colonies that could establish on dredge spoil islands and other areas in the interior Columbia and estuary and prey on juvenile spring/summer Chinook salmon and steelhead. • Implement the Section 120 of Marine Mammal Protection Act program by Oregon, Washington, and Idaho to manage sea lions determined to have a significant negative impact. • Continue pikeminnow bounty program.
Competition	
Evaluate ecological interactions, and density dependence limitations. Restore habitat to increase population carrying capacity and productivity. Develop alternative hatchery release strategies if necessary.	• Release strategies (life stage released, timing, etc.). • Restore habitat to increase carrying capacity. • Release numbers. • Release locations. • Utilize fisheries.
Disease	
Reduce transmission and effects of disease.	• Release fish that have history of good health and are free of disease. • Monitor for disease or pathogen presence in hatchery and naturally produced fish. • Implement TMDLs for temperature and other water quality parameters that can reduce pathways of disease transmission.
Toxic Pollutants	
Identify and reduce sources of pollutants.	• Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of toxic contaminants. • Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants. • Restore or mitigate contaminated sites. • Implement storm water best management practices in cities and towns. • Implement National Pollution Discharge Elimination System permit program to address point source pollution.

6.3.7 Strategies and Actions for Climate Change

Management Strategies and Actions

Likely changes in temperatures, precipitation, streamflow, landscape-scale terrestrial habitats, drought risk, ocean conditions, wind patterns, and sea-level height due to climate change have profound implications for survival of Snake River spring/summer Chinook salmon and steelhead (see Section 5.2.7). All other threats and conditions remaining equal, future alteration of water quality, water quantity, and/or physical habitat due to climate change can be expected to cause a reduction in the number of naturally produced adult spring/summer Chinook salmon and steelhead returning to populations across the ESU and DPS. For example, reduced size of returning adults and fecundity of females resulting from ocean acidification and warming can lead to decreased egg survival. It is also possible that increased late summer and early fall water temperatures could cause migrating adult summer Chinook salmon and steelhead to delay passage (through reservoirs or adult fish ladders), or suffer higher losses through the mainstem migration corridor or in the lower reaches of natal tributaries. This could lead to shifts in migration timing, increased mortality or reduced spawning success, and increased susceptibility to predators, parasites, disease, and pathogens (Isaak et al. 2017). Sub-lethal temperatures are just as important as lethal temperatures in determining population response to climate change. For example, exposure of adults to sub-lethal temperatures during migration may impair egg viability.

It is also possible that, as has been shown in recent years, responses of other species, such as California and Steller sea lions, to changes in ocean temperatures and food supplies could affect survival. Such possibilities reinforce the importance of implementing research, monitoring, and evaluation to track indicators and adapt actions to respond to climate change (Beechie et al. 2013; Crozier and McClure 2015). It also reinforces the importance of maintaining habitat diversity and achieving survival improvements throughout the entire life cycle, and across different populations since neighboring populations with differences in habitat may show different responses to climate changes (Crozier et al. 2008; Justice et al. 2017; Morelli et al. 2016).

The ISAB (2007) developed strategies and recommendations to incorporate climate change considerations into restoration and recovery planning. This Plan adopts the ISAB’s general strategy and recommendations, together with new strategies based on best available science, current research, and modeling analyses. The ISAB strategy is three-pronged, addressing risks posed by climate change in freshwater habitats, the mainstem Snake/Columbia River corridor, and the ocean.

- For freshwater tributary habitat, the strategy is to: (1) minimize increases in summer temperatures in affected streams by implementing measures to retain shade along stream channels and augment summer flow; (2) help alleviate both elevated temperatures and low stream flow in affected streams during summer and autumn by managing water withdrawals to maintain as high a summer flow as possible; and (3) provide mitigation for declining summer flows by protecting and restoring wetlands, floodplains, and other landscape features that store water. Beechie et al. (2013) recommends that increasing floodplain connectivity, restoring stream flow regimes, and restoring incised channels to provide stream complexity (including through beaver reintroduction) are the actions most likely to ameliorate stream flow and temperature changes and increase habitat diversity and population resilience (Table 6-7).

- For the mainstem Snake and Columbia migration corridor, the strategy includes releasing cool water from reservoirs during critical periods, improving juvenile passage through warm dam forebays, improving temperatures in adult fish passage structures, and reducing warm-water predators. For the estuary, removing dikes to open backwater, slough, and other off-channel habitats can increase flow through these areas and encourage hyporheic flow.
- For the ocean, the climate change strategy is primarily to review mechanisms for timing arrival of smolts to avoid a mismatch with marine predators and prey, and to review harvest practices to ensure that harvest quotas are adjusted to reflect changing conditions.

Strategies and actions identified in this Plan, including the research, monitoring, and evaluation plan, define steps to preserve biodiversity, restore hydrologic functions and processes, adjust management actions to improve survival throughout the life cycle, and implement RM&E to track, analyze, and identify new actions through adaptive management to address the effects of climate change. Improvements in floodplain connectivity and hydraulic processes will provide the best opportunities to be proactive in the face of climate change. This is especially true in the migration corridor and in high elevation areas where cold-water refugia habitat may become critical to the survival of populations stressed by warming water temperatures, and in areas where off-channel and shallow floodplain refugia could allow juvenile salmonids to escape winter flooding conditions (Isaak et al. 2017). Managing climate change refugia across the landscape is also an important consideration when evaluating restoration and recovery actions (Morelli et al. 2016). There is great uncertainty regarding the impacts of climate change on different populations. Urban (2016) emphasizes the need to consider multiple recovery scenarios, include scientists in recovery planning, and consider conservation principles, along with the mechanistic understanding of how species and populations respond to climate impacts over time.

The ICTRT generally recommended a staged adaptive approach to restoration for ESUs/DPSs, with the highest priority initially being given to implementing actions targeting extant populations organized by MPGs (ICTRT 2007). The habitat strategies for extant population tributaries within the Snake River Spring-Summer ESU identify opportunities to protect or restore resiliency to projected trends in temperature and precipitation. The ICTRT also recommended that options to re-establish naturally adapted production in extirpated populations may, in the future, contribute to achieving ESU recovery. For example the historical Snake River Spring-Summer Chinook salmon ESU likely included several populations in the Clearwater River basin that were extirpated following the completion of Lewiston Dam in 1918. Current production in the Clearwater River is the result of continued outplants of non-local stocks and is not part of the Snake River Spring-summer Chinook salmon ESU (57 FR 14658). The Clearwater River basin includes habitats that are generally colder and wetter than extant population tributaries within the ESU. Depending upon future trends in climate changes across the basin and responses of extant ESU populations to restoration efforts, future adaptations of ESU recovery strategies may include re-establishing naturally adapted ESU production in the Clearwater River. In the meantime, monitoring the performance of current out-of-ESU production in the Clearwater River basin could give valuable insights into alternative reintroduction strategies and the local adaptation process.

Accurate datasets for ecological and climatological parameters across the landscape in the Snake River basin are increasingly available. Such datasets will aid researchers in downscaling future watershed-scale climate scenarios and potential impacts to fish populations (Isaak et al. 2017). An example is the NorWeST stream temperature scenario maps developed by the U.S. Forest Service Rocky Mountain Research Station, which cover all of the Pacific Northwest (Isaak et al. 2016). These stream temperature scenario maps were developed at a 1-kilometer resolution using spatial statistical stream network models and a crowd-sourced stream temperature database. Figure 6-2 shows a prediction of August stream temperatures in the Clearwater River basin in the 2040s, with colder streams suggesting the potential location of cold-water refugia in future decades. Combining these temperature models with high-resolution climate models of streamflow and other variables will increasingly allow researchers to predict population-specific responses to climate change for Snake River spring/summer Chinook salmon and steelhead.

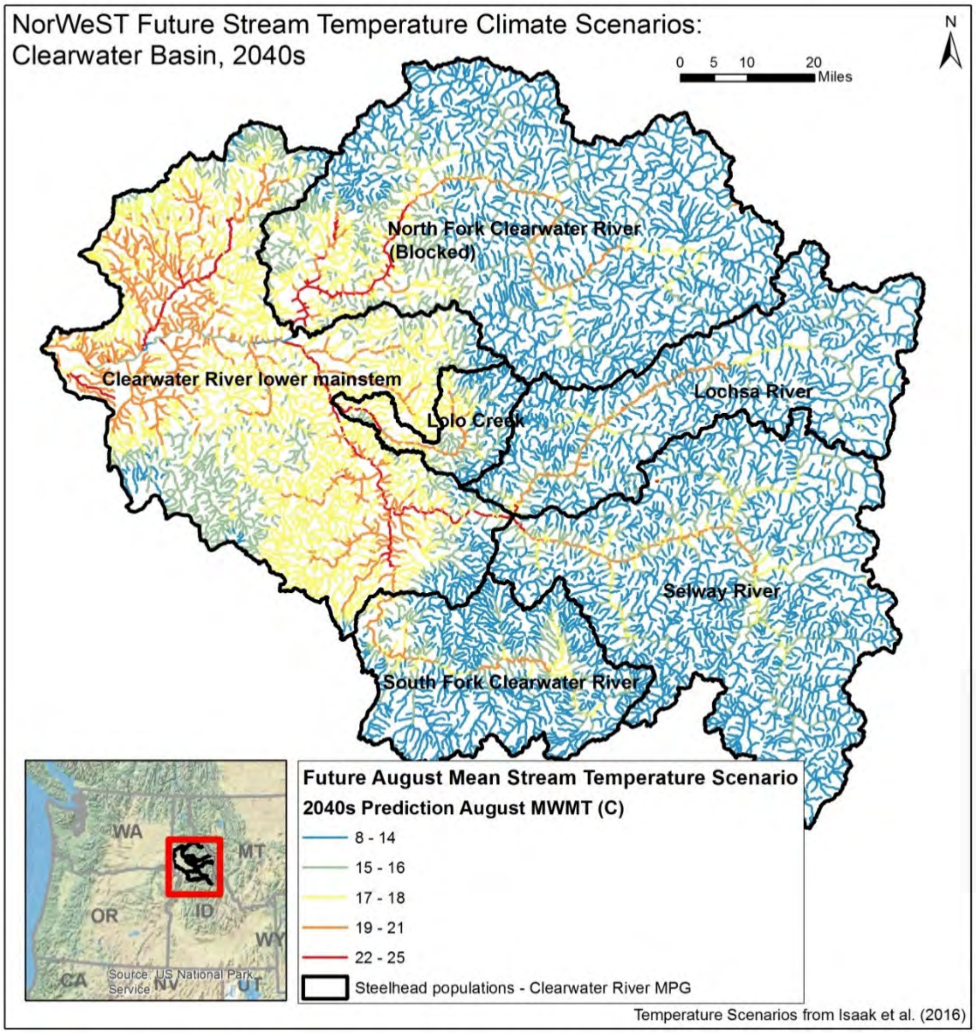


Figure 6-2. NorWeST future stream temperature climate scenario for the Clearwater Basin in the 2040s (AIB warming trajectory) (Isaak et al. 2016).

NMFS proposes to convene a future workshop with local stakeholders and researchers to: (1) share information; (2) identify how new climate change information and modeling can help prioritize recovery actions at the MPG and population scale; and (3) identify what we still need to learn about vulnerable geographic locations and populations, and the adaptive capacity of the species. As part of the workshop, NMFS may share information from research currently in development by the Northwest Fisheries Science Center to predict population-specific responses to climate change for Snake River spring/summer Chinook salmon populations. Understanding which populations within each MPG appear most resilient to climate change could help prioritize recovery actions across the MPG.

Strategies and actions identified in the Estuary and Hydro Modules, FCRPS biological opinions, and the three management unit plans also identify actions across all management sectors to protect and improve habitats that could be affected by climate change. In addition, Table 6-8 identifies potential future actions to address climate change. This climate change strategy necessitates a strong monitoring and evaluation program, along the lines of that included in the FCRPS Adaptive Management Strategy, as well as ongoing scientific studies and modeling projections. These program will help detect physical and biological changes associated with climate change, develop analytic tools and management scenarios to respond to climate-induced habitat changes, and determine the efficacy of responsive measures.

Types of RM&E Actions to Address Climate-Related Limiting Factors

Current research is providing insights to potential future climate change impacts for the Pacific Northwest region. Additional RM&E needs to be implemented to track indicators related to climate change. These include assessing the effects of climate change for different Snake River spring/summer Chinook salmon and steelhead populations and different life-history types, as well as the cumulative effects of climate change across the life cycle. Data needs to be collected throughout the salmonid life cycle to identify effects on survival from changes in freshwater conditions (snow pack, flows, and water temperatures), mainstem conditions (flow and temperature), and ocean conditions (temperature, acidity). Data needs also include changes in predation and competition threats throughout the life cycle. Finally, life cycle modeling needs to be conducted to assess habitat metrics (e.g., flow and temperature) across a diversity of ecological regimes and habitat types, and the cumulative effects of climate change across the life cycle. The life cycle modeling will allow us to evaluate responses to climate change and target actions accordingly.

Table 6-7. Summary of habitat restoration types and their ability to ameliorate climate change effects on peak flows, low flows, stream temperature, or to increase salmonid population resiliency (Beechie et al. 2013).

Category	Common techniques	Ameliorates temperature increase	Ameliorates base flow decrease	Ameliorates peak flow increase	Increases salmon resilience
Longitudinal connectivity (barrier removal)					
	Removal or breaching of dam	●	●	○	●
	Barrier or culvert replacement/removal	○	○	○	●
Lateral connectivity (floodplain reconnection)					
	Levee removal	●	○	●	●
	Reconnection of floodplain features (e.g. channels, ponds)	●	○	●	●
	Creation of new floodplain habitats	●	○	●	●
Vertical connectivity (incised channel restoration)					
	Reintroduce beaver (dams increase sediment storage)	●	●	●	●
	Remove cattle (restored vegetation stores sediment)	●	●	●	○
	Install grade controls	●	●	●	○
Stream flow regimes					
	Restoration of natural flood regime	●	●	○	◒
	Reduce water withdrawals, restore summer baseflow	●	●	○	○
	Reduce upland grazing	○	◒	◒	○
	Disconnect road drainage from streams	○	○	●	○
	Natural drainage systems, retention ponds, other urban stormwater techniques	○	◒	●	○
Erosion and sediment delivery					
	Road resurfacing	○	○	○	○
	Landslide hazard reduction (sidecast removal, fill removal)	○	○	○	○
	Reduced cropland erosion (e.g. no-till seeding)	○	○	○	○
	Reduced grazing (e.g. fencing livestock away from streams)	◒	○	○	○
Riparian functions					
	Grazing removal, fencing, controlled grazing	●	○	○	○
	Planting (trees, other vegetation)	●	○	○	○
	Thinning or removal of understory	○	○	○	○
	Remove non-native plants	◒	◒	○	○
Instream rehabilitation					
	Re-meandering of straightened stream, channel realignment	◒	○	○	◒
	Addition of log structures, log jams	◒	○	○	○
	Boulder weirs and boulders	◒			
	Brush bundles, cover structures	○	○	○	○
	Gravel addition	○	○	○	○
Nutrient enrichment					
	Addition of organic and inorganic nutrients	○	○	○	○

Actions are grouped by major processes or functions they attempt to restore: connectivity (longitudinal, lateral and vertical), watershed-scale processes (stream flow and erosion regimes), riparian processes, instream rehabilitation, and nutrient enrichment. Filled circles indicate positive effect, empty circles indicate no effect, and partially filled circles indicate context-dependent effects. See text for supporting citations.

6.4 Potential Future Actions

As discussed previously, this recovery plan depends on an adaptive management framework that implements site-specific management actions based on best available science, monitoring to improve the science, and updates to management actions based on new knowledge. We believe that the site-specific recovery actions recommended in this Plan, combined with actions already completed, will result in progress toward recovering the species. However, these actions alone are unlikely to achieve recovery. It is imperative to continue the adaptive management process and develop additional actions to achieve recovery.

A life cycle context should be used to determine the best opportunities for closing the gap between the species' status and achieving recovery goals. Candidate actions should be considered for all sectors, both public and private. For example, candidate recovery actions for habitat and hydropower would require consultation with federal agencies and/or other appropriate land and water managers. Careful management of harvest and hatchery actions in the Columbia and Snake Rivers will require discussion through the settlement agreements with the *United States v. Oregon* and Pacific Salmon Treaty parties to assure harvest and hatchery impacts on natural-origin fish are compatible with recovery goals.

All sectors should be prepared to do more as a result of ongoing research, life cycle modeling, and adaptive management. Table 6-8 identifies potential future actions to achieve ESU/DPS viability for each sector that may be considered during recovery planning.

Table 6-8. Potential future actions to achieve ESU/DPS viability.

Management Action Category	Potential Future Actions
Evaluate and improve viability across the life cycle.	• Develop multi-stage life cycle model that incorporates estimates of survival through various stages and achieving viability objectives. • Use life cycle modeling to assess the ESU and DPS as a whole, and interactions between the different spawning areas. • Conduct multi-stage life cycle modeling to assess potential response of Snake River spring/summer Chinook and steelhead to alternative management strategies and actions under alternative climate scenarios, and to determine the best opportunities for closing the gap between the species' status and achieving viability objectives. • Continue to conduct relevant actions under the life cycle initiative being carried out through the FCRPS Adaptive Management Implementation Plan. • Identify and prioritize locations where installation of additional PIT-tag detectors in tributary spawning grounds could substantially improve understanding of adult behavior and survival during seasonal high temperature events.
Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival,	• Upon completion of transportation studies, modify transportation program to enhance adult returns of migrating juvenile Snake River spring/summer Chinook salmon and steelhead, include consideration of terminating/modifying transport at one or more collector projects.

Management Action Category	Potential Future Actions
(2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects; and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.	• Install, if feasible, a passive integrated transponder (PIT) tag detector in the removable spillway weir at Lower Granite Dam to enhance understanding of the relationship between smolt-to-adult returns and environmental and operational factors. • Identify and prioritize locations (mainstem ladders, river mouths above Bonneville Dam) where installation of additional PIT-tag detectors could substantially improve understanding of adult behavior and survival during seasonal high temperature events, and cooperate in development and installation of these systems, if practicable. • Evaluate and implement structures or operations at Lower Granite Dam (or other affected projects) to more reliably address adult passage blockages (for summer Chinook and steelhead) caused by warm surface waters entering the fish ladders. • Continue to implement cool water releases from Dworshak Dam to help maintain adequate migration conditions (flow and temperature) for migrating adult summer Chinook salmon and steelhead in the lower Snake River. • Improve monitoring and reporting of water temperatures at all mainstem adult fish ladders and identify ladders with substantial temperature differentials (>1.0 °C). • Investigate, and install if feasible, methods to reduce maximum temperatures and differentials in mainstem adult fish ladders identified as having temperature differential problems. • Work with co-managers and federal project operators to develop methods to better predict when summer water temperatures are likely to exceed critical thresholds. • Implement actions to improve the quality of water discharged from the Hells Canyon Complex (dissolved oxygen, total dissolved gas) - as called for in NMFS recommendations for the Hells Canyon Federal Energy Regulatory Commission (FERC) Relicensing. • Federal agencies will complete a NEPA process that will consider a range of alternatives for increasing the survival of salmon and steelhead in the Columbia Basin that pass through the FCRPS. Based on the result of this effort, identify and implement feasible and effective actions to improve the survival and productivity of Snake River spring/summer Chinook and Snake River steelhead, as well as other salmon and steelhead species in the basin. • Operate the FCRPS hydropower system with increased spill levels in 2018 to improve passage survival and increase smolt-to-adult returns.
Protect and improve habitat conditions.	• Continue to identify and prioritize limiting factors affecting abundance and productivity of Snake River spring/summer Chinook and steelhead and develop projects to mitigate habitat effects in natal and migratory habitat. • Identify locations of nearshore habitat and cold-water refugia in mainstem reaches and identify and implement actions to protect and restore these areas to improve fish survival. • Continue to protect, conserve, and restore tributary habitats, including cold-water refugia, to reduce summer water temperatures during spawning, rearing, and migration.

Management Action Category	Potential Future Actions
	• Continue to improve floodplain connectivity and function, especially in areas where habitat conditions may become critical to the survival of populations stressed by warming water temperatures, and in areas where off-channel and shallow floodplain habitat is needed for juvenile salmonids to escape winter floods. • Continue to develop and implement Clean Water Act Total Maximum Daily Loads (TMDLs) to improve water quality in tributary and mainstem reaches. • Continue to develop and maintain instream PIT-tag detection systems for use in tributaries in order to identify sources of juvenile mortality between natal tributaries and Lower Granite Dam reservoir.
Protect and improve estuary habitat conditions.	• Continue to breach, lower, or relocate dikes and levees to reconnect the historical floodplain, to re-establish or improve access to off-channel habitats, and to ensure the flux of insect prey and detrital carbon to the mainstem migration channel. • Continue to protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for properly functioning rearing habitat. • Continue to restore or mitigate contaminated sites. • Continue to identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollution.
Address harvest effects.	• Develop harvest management frameworks and complete ESA regulatory reviews for Snake Basin fisheries that directly or incidentally take Snake River spring/summer Chinook and steelhead. • Update harvest management frameworks, as appropriate, to respond to potential changes in hatchery release strategies in 2018 and beyond. • Ensure that potential downriver fisheries do not result in harvest of natural-origin Snake River spring/summer Chinook and steelhead that is inconsistent with recovery objectives. • Improve estimates of catch-and-release harvest impacts, especially during warm summer conditions for summer Chinook and steelhead. • Evaluate the utility of using either PIT-tag or genetic-based information to improve estimates of harvest-related mortality. • Consistent with results of the evaluation described in RM&E, update harvest management plans through negotiations with appropriate fishery management forums.
Address predation, prey base, competition, and other ecological interactions.	• Continue research, monitoring, and identify actions to address source(s) of adult spring Chinook salmon loss between Columbia River mouth and Bonneville Dam, including improved understanding of pinniped predation on specific salmonid populations. • Expand monitoring efforts in the Columbia River to assess predator-prey interactions between pinnipeds and listed species. • Improve states of Oregon, Washington, and Idaho fishery management of native and non-native fish predator populations including pike minnow, smallmouth bass, channel catfish, and walleye.

Management Action Category	Potential Future Actions
	• Evaluate plume/nearshore ocean conditions that influence predator fish populations and predation rates during the early ocean life stage. • Evaluate impacts of competition and density dependence on natural-origin Snake River spring/summer Chinook and steelhead. • Take actions to prevent the expanding ranges of zebra mussel, quagga mussel, New Zealand mudsnail, Siberian prawns, and other invasive species from extending into Snake River spring/summer Chinook and steelhead habitat and depleting available nutrients in the rivers. • Periodically evaluate food web interactions in key habitats to better understand the ecological implications of invasive species on survival of Snake River salmon and steelhead. • Reduce impacts of reservoir and river channel maintenance dredging and disposal: impacts from predatory bird colonies that could establish on dredge spoil islands, and impacts of winter dredging and in-water disposal.
Address hatchery risks and improve hatchery effectiveness.	• Work through the *U.S. v. Oregon* co-managers forum to identify and assess management options that would achieve delisting, especially those that would satisfy both mitigation and ESA requirements. • Work with the *U.S. v. Oregon* co-managers to develop a shared understanding of hatchery risks and benefits. • Develop RM&E to address areas of uncertainty such as long-term risk. • Strengthen growing partnership between NMFS and USFWS to increase efficiency of the ESA section 7 consultation process. • Continue to refine fish culture strategies to improve survival and homing. • Evaluate the ecological or genetic impacts of releasing non-local hatchery-origin B-run steelhead into areas where they were not historically present, and how the hatchery fish interact with native listed steelhead. • Critically evaluate and refine HSRG and other modelling frameworks for managing hatcheries. • Explore potential for hatcheries to help mitigate impacts on natural-origin fish from climate change, disease outbreaks, and other risks.
Address toxic pollutants,	• Develop actions to reduce toxic contaminants at the sources. • Revise water and sediment quality criteria as needed to ensure they are protective of listed salmonids. • Implement National Pollution Discharge Elimination System permit programs to address point source pollution.
Address climate change.	• Continue ongoing actions and implement potential additional actions in all land and water management sectors including habitat related actions that will conserve Snake River spring/summer Chinook and steelhead. • Maintain surface passage routes that reduce travel time through forebays. • Consider ways to reduce abundance of warm-water predators in reservoirs.

Management Action Category	Potential Future Actions
	• Monitor temperatures and flows to assess trends that may be related to climate change. • Conduct periodic evaluation of hydropower system dam operations to reflect changing climatic conditions and passage timing.

6.5 Potential Effectiveness of Management Actions and Need for RM&E and Life-Cycle Evaluations

The effectiveness of most of the ongoing management actions have been evaluated and continue to be evaluated through their associated RM&E as part of individual ESA section 7 consultations. These RM&E actions are described in Chapter 7 of this Plan and in the management unit recovery plans for the Northeast Oregon management unit (Chapter 11), Southeast Washington management unit (Chapter 6), and Idaho management unit (Chapter 9). The management actions operate across the life cycle through different threat categories, i.e., hydropower and mainstem habitat, tributary habitat, harvest, hatcheries, estuary habitat, and so on. However, the combined effects, and the relative effects of actions in different threat categories across the life cycle, are not well understood.

Multi-stage life cycle models that are under development for Snake River spring/summer Chinook and steelhead should improve our understanding of the combined and relative effects of actions across the life cycle. These models incorporate empirical information and working hypotheses on survival and capacity relationships at different life stages. The models will provide a valuable framework for systematically assessing the potential response of Snake River spring/summer Chinook and steelhead to alternative management strategies and actions to address threats at different life stages and under alternative climate scenarios (Figure 6-3). In addition to informing decisions about near-term management strategies, the Snake River spring/summer Chinook and steelhead life cycle modeling will be used to assess the status of the ESA and DPS as a whole, and examine interactions between the fish in different populations and spawning areas. It will also be used to identify key RM&E priorities to improve future decision making. Accordingly, our ability to evaluate the combined and relative effects of actions across the life cycle will continue to improve.

- Evaluate findings from past and current evaluations.
    - Evaluate life cycle modeling results to highlight improvements expected with actions.
    - Identify gaps regarding past actions and the results from those actions to affect viability.
    - Summarize findings from EDT analysis for Northeast Oregon populations.
- Identify and conduct further evaluations and life cycle modeling.
    - Life-cycle monitoring is critical to evaluating density dependence and other impacts on populations, and at specific life-stages and populations and under different climate

scenarios, to ensure that we are focusing/targeting restoration efforts at the appropriate geography and life-stage.

- Incorporate findings into adaptive management process and use them to set priorities and identify additional actions.

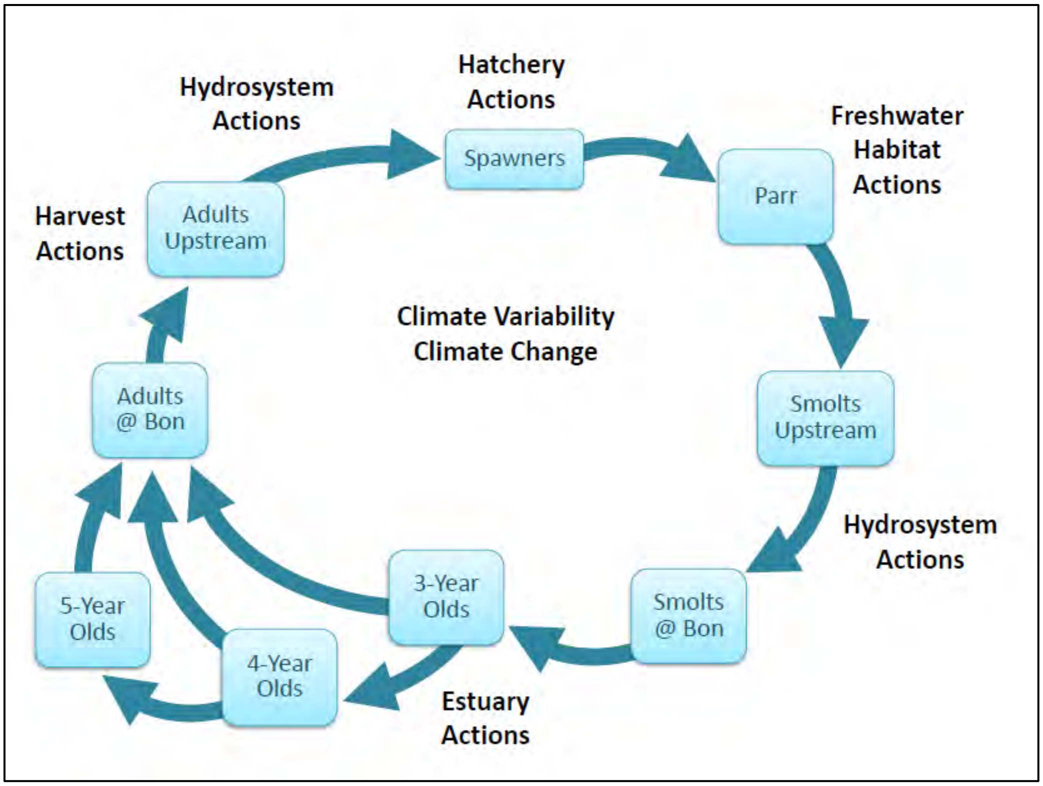


Figure 6-3. Life-cycle modeling across life stages.

6.6 MPG-Level Recovery Strategies and Actions

This section describes the recovery strategies designed to achieve viability for major population groups (MPGs) of Snake River spring/summer Chinook salmon and steelhead. As discussed in Chapter 3, each MPG must meet the biological viability criteria of being viable (at less than 5 percent risk of extinction) for the ESU/DPS to be removed from the ESA's threatened and endangered species list. The MPG-level strategies described here — in combination with the regional-level strategies described in this chapter — aim to achieve this recovery goal. They also aim to meet the listing factor/ threats criteria for Snake River spring/summer Chinook salmon and Snake River Basin steelhead, discussed in Section 3.4.2.

The section summarizes recovery direction for major population groups in the Snake River spring/summer Chinook salmon ESU (Section 6.6.1) and steelhead DPS (Section 6.6.2). It does not identify site-specific actions for the MPGs, which are defined in the management unit plans for Northeast Oregon, Southeast Washington, and Idaho. Direction provided in the section builds on information presented in previous chapters. Chapter 3 describes the recovery goals, delisting criteria, and potential recovery scenarios for the ESU and DPS and MPGs. Chapter 4 discusses the current status of the ESU/DPS and MPGs, and the gap that must be bridged to achieve recovery. Chapter 5 summarizes the recovery issues, limiting factors and threats, and recovery strategies that apply at a regional level and generally affect both species.

Material presented in this section draws from the three management unit recovery plans for the Northeast Oregon, Southeast Washington, and Idaho management units; several NMFS publications: the Supplemental Comprehensive Analysis of the 2008 biological opinion and supplemental biological opinions (NMFS 2008b, 2010, 2014c), the ICTRT's 2010 Status Assessments of Snake River species; the Northwest Fisheries Science Center's 2015 5-year status review update (NWFSC 2015); the ICTRT's 2007 Viability Criteria document and 2007 "Gap" report; NMFS' *5-Year Review: Summary and Evaluation of Snake River Sockeye Salmon, Snake River Spring-summer Chinook, Snake River Fall-run Chinook and Snake River Basin Steelhead* (NMFS 2016); and the four Snake River recovery planning modules. As discussed earlier, the recovery direction provided here for the MPGs will continue to be updated in the future based on results from ongoing research, life cycle modeling, and adaptive management.

6.6.1 MPG-Level Recovery Strategies for Snake River Spring/Summer Chinook Salmon

Consistent with the biological viability criteria discussed in Chapter 3, all MPGs in the Snake River spring/summer Chinook salmon ESU need to be viable (at less than 5 percent risk of extinction) for the ESU to be removed from the ESA's threatened and endangered species list. This section provides specific direction for recovery of the Snake River spring/summer Chinook salmon ESU. The strategies aim to restore the different MPGs to viable levels and support ESU delisting.

In addition to the strategies identified in this section, additional future actions ─ including the actions discussed in Section 6.4 and identified in Table 6-8 ─ may also be implemented to achieve MPG viability. Future potential actions will be developed during the recovery planning process based on ongoing research, life cycle modeling and adaptive management.

The Northeast Oregon, Southeast Washington, and Idaho management unit plans provide detailed discussions of the strategies summarized in this section and the recovery actions that will be implemented in specific population areas to achieve them.

6.6.1.1 Grande Ronde/Imnaha Rivers Spring/Summer Chinook Salmon MPG

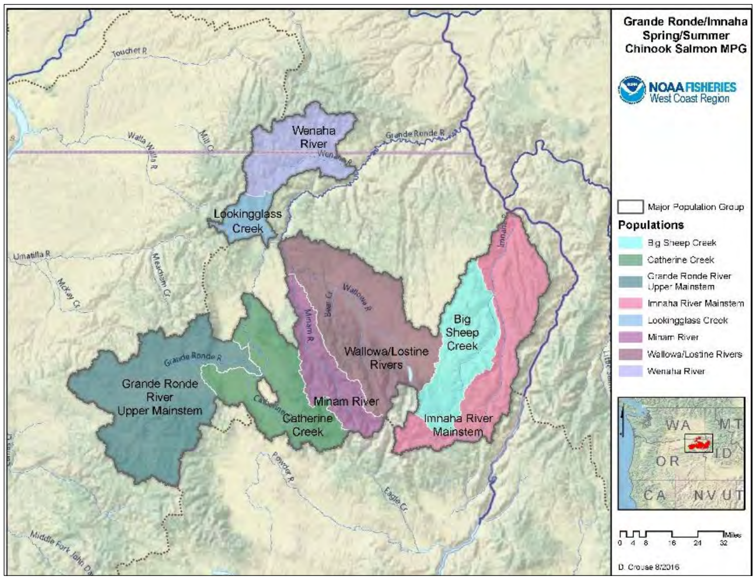
Current MPG Status

- The six extant populations in MPG are at high risk of extinction and non-viable in their current state.
- Two populations, Big Sheep and Lookingglass Creeks, are functionally extirpated.

Proposed MPG Recovery Scenario

- Achieve viable status (low risk) for the Imnaha, Lostine/Wallowa, Minam, and Wenaha Rivers and Catherine Creek populations, with at least one highly viable (very low risk).
- Achieve at least "maintained" status (moderate risk) for Upper Grande Ronde River population.
- Support reintroduction programs for Big Sheep and Lookingglass Creeks populations.

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Reduce mortalities during the outmigration from overwintering habitats to the Snake River, especially in the lower Grande Ronde River mainstem and key tributary production areas.
- Maintain current wilderness protection and protect pristine tributary habitat.
- Improve quantity and quality of winter rearing habitats, especially key overwintering areas in the Grande Ronde Valley, lower mainstem Grand Ronde River, and in tributary production areas.
- Protect/enhance spawning and summer rearing habitats in currently used areas of the Grande Ronde River and key tributary production areas, and improve potential summer rearing habitat quantity/ quality.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries according to an abundance-based schedule.
- Implement hatchery programs so they will reduce short-term extinction risk and promote recovery.
- Monitor/evaluate effects of Lookingglass and Imnaha hatchery programs on extant populations. Manage returning hatchery fish to minimize effects of hatchery fish on natural-origin spawners in affected populations.
- Restrict naturally spawning hatchery fish in all population areas where hatchery operations are not required for recovery.
- Utilize terminal fisheries to minimize the escapement of hatchery-origin fish in natural production areas.

6.6.1.2 Lower Snake River Spring/Summer Chinook Salmon MPG

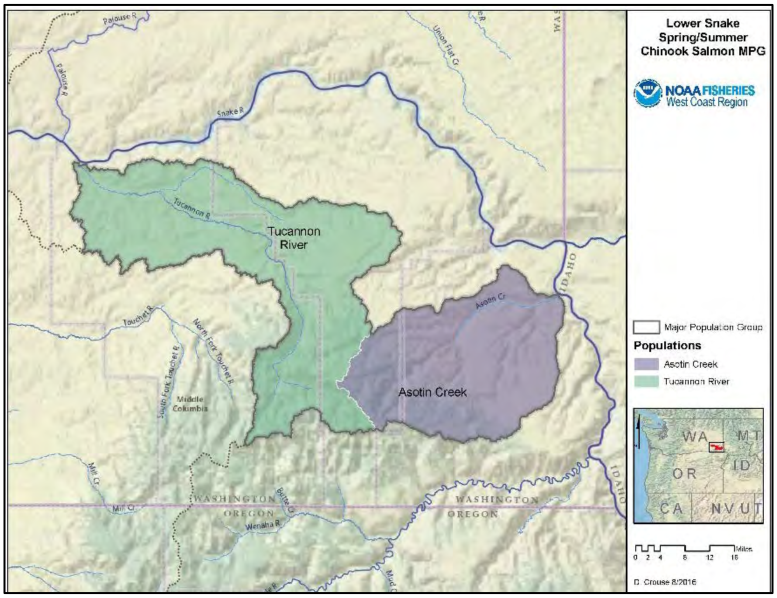
Current MPG Status

- The lone extant population, Tucannon River, remains at moderate to high risk of extinction and non-viable.
- The Asotin Creek population is functionally extirpated.

Proposed MPG Recovery Scenario

- Achieve highly viable status (very low risk) for the Tucannon River population.
- Focus initial recovery efforts on improving status of Tucannon River population, but support reintroduction program for Asotin Creek population.

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Protect, improve and increase summer rearing and overwintering habitat, especially in high potential reaches of the Tucannon River, Pataha Creek, and other tributaries by restoring riparian areas, reducing temperatures and embeddedness, and increasing recruitment of large wood.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries according to an abundance-based schedule.
- Conduct research to determine the cause of straying of Tucannon natural- and hatchery-origin fish that continue upstream of Lower Granite Dam instead of migrating into the Tucannon River, and take actions to reduce straying.
- Consider using hatchery fish from Tucannon Hatchery program for possible reintroduction in Asotin Creek to reduce extinction risk and support recovery.
- Continue hatchery management practices that minimize impacts from hatchery releases on naturally produced fish.
- Utilize terminal fisheries to reduce exotic predatory fish in natural production areas.

6.6.1.3 South Fork Salmon River Spring/Summer Chinook Salmon MPG

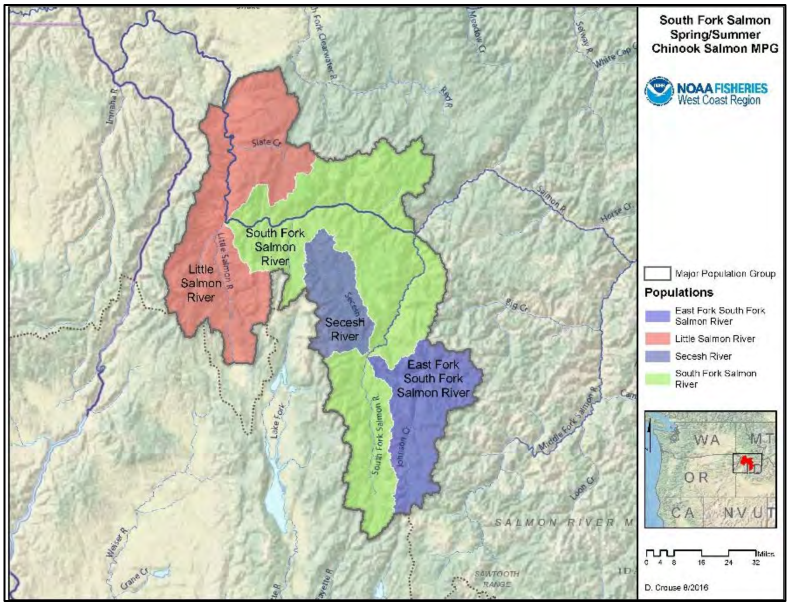
Current MPG Status

- All four populations in MPG remain at high risk of extinction and non-viable in their current state.

Proposed MPG Recovery Scenario

- Achieve highly viable status (very low risk) for the Secesh River population.
- Achieve at least viable status (low risk) for South Fork Salmon population.
- Achieve at least "maintained" status (moderate risk) for East Fork South Fork Salmon River, and Little Salmon River populations.

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Reduce juvenile mortality during outmigration from rearing habitats through the mainstem Salmon River, Little Salmon River, and key tributary production areas.
- Maintain current wilderness protection and protect pristine tributary habitat.
- Provide/improve passage to and from areas with high intrinsic potential through barrier removal, screening, and other projects.
- Reduce and prevent sediment delivery to streams by improving road systems and riparian communities, and rehabilitating abandoned mine sites.
- Improve riparian and floodplain health and function by encouraging beaver activity and enhancing riparian communities.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries according to an abundance-based schedule.
- Manage MPG for natural production in Secesh River and other areas where appropriate (e.g., upstream of weir on the Rapid River).
- Monitor straying of retuning hatchery-origin fish to spawning grounds. Manage returning hatchery fish to minimize straying and effects of hatchery fish on natural-origin spawners in affected populations.
- Manage brook trout to reduce predation and competition with spring/summer Chinook salmon.

6.6.1.4 Middle Fork Salmon River Spring/Summer Chinook Salmon MPG

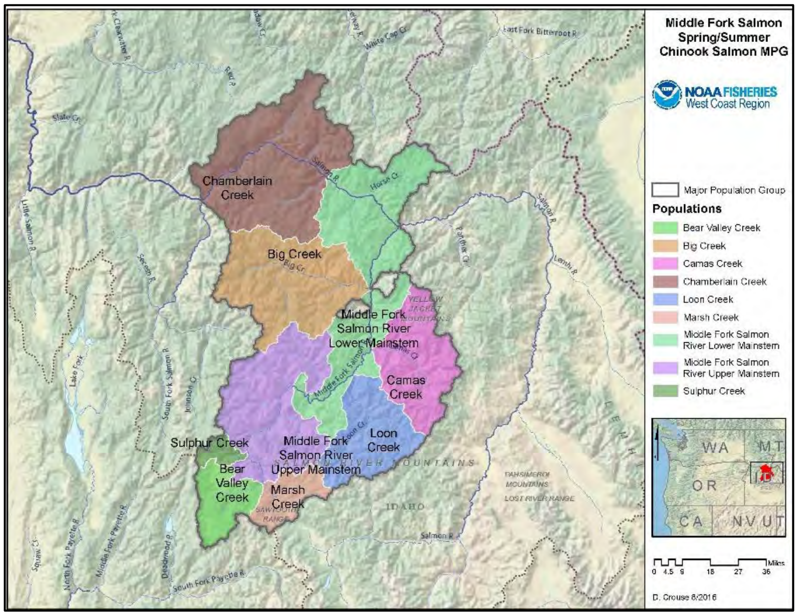
Current MPG Status

- All nine populations in MPG are extant but eight remain at high risk of extinction. One population (Chamberlain Creek) is at moderate risk. All populations are non-viable in their current state.

Proposed MPG Recovery Scenario

- Achieve highly viable status (very low risk) for the Big Creek population.
- Achieve at least viable status (low risk) for Loon Creek, Bear Valley Creek, Marsh Creek, and Chamberlain Creek populations.
- Achieve at least "maintained" status (moderate risk) for Lower Middle Fork Salmon River, Camas Creek, Upper Middle Fork Salmon River, and Sulphur Creek populations.

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Reduce juvenile mortality during outmigration from rearing habitats through the mainstem Salmon River.
- Maintain current wilderness protection and protect pristine tributary habitat.
- Investigate feasibility of increasing nutrients in areas where lack of nutrients may be limiting productivity.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries according to an abundance-based schedule.
- Manage MPG for natural production. Monitor for straying hatchery-origin fish to minimize effects of hatchery fish on natural-origin spawners.
- Manage brook trout to reduce predation and competition with spring/summer Chinook salmon.
- Address small, localized areas of degraded habitat: provide/improve passage to and from areas with high intrinsic potential through barrier removal, screening, and other projects; reduce and prevent sediment delivery to streams by rehabilitating abandoned mine sites and roads; improve riparian and floodplain health and function by encouraging beaver activity and enhancing riparian communities; and protect and improve instream flows during summer base flow periods.

6.6.1.5 Upper Salmon River Spring/Summer Chinook Salmon MPG

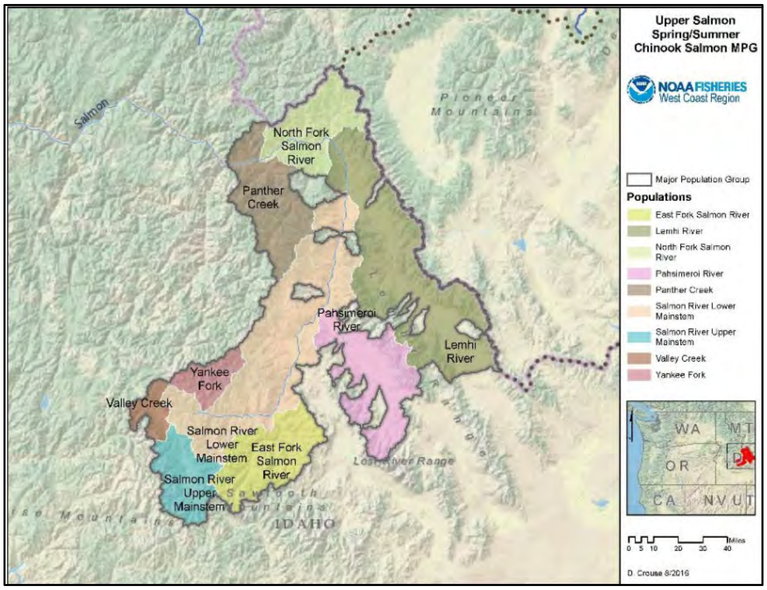
Current MPG Status

- Eight of MPG's nine populations are extant but remain at high risk of extinction and non-viable in their current state.
- The Panther Creek population is functionally extirpated

Proposed MPG Recovery Scenario

- Achieve highly viable status (very low risk) for the Upper Salmon River Upper Mainstem (above Redfish Lake Creek) population.
- Achieve at least viable status (low risk) for Lemhi, Pahsimeroi, East Fork Salmon Rivers, and Valley Creek populations.
- Achieve at least "maintained" status (moderate risk) for North Fork Salmon River, Salmon River Lower Mainstem (below Redfish Lake Creek), and Yankee Fork populations.
- Support reintroduction program for Panther Creek population; maintain/ enhance current levels of natural spawning.

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Reduce juvenile mortality during outmigration through the mainstem Salmon River.
- Maintain current wilderness protection and protect pristine tributary habitat.
- Protect and improve flows to support all spring/summer Chinook salmon life stages.
- Provide/improve passage to and from areas with high intrinsic potential through barrier removal, screening, and other projects.
- Reduce sediment delivery to streams from roads, recreation sites and livestock grazing.
- Improve riparian conditions and floodplain function in select areas.
- Improve water quality in areas of high intrinsic potential by implementing TMDLs.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries according to an abundance-based schedule.
- Manage populations in the North Fork Salmon, Salmon River Lower Mainstem, and East Fork Salmon Rivers, and Valley Creek for natural production. Monitor for straying hatchery-origin fish.
- Consider Yankee Fork and Dollar Creek hatchery programs for inclusion in the ESU.
- In all populations where hatchery production is used, minimize associated ecological and genetic risks.
- Manage brook trout to reduce predation and competition with spring/summer Chinook salmon.

6.6.2 MPG-Level Recovery Strategies for Snake River Basin Steelhead

Consistent with the biological viability criteria discussed in Chapter 3, all MPGs in the Snake River Basin steelhead DPS need to be viable (at < 5 percent risk of extinction) for the DPS to be removed from the ESA's threatened and endangered species list. This section summarizes the MPG-level recovery strategies for the DPS. It also identifies the key information needs specific to the DPS and its MPGs. This section builds on information presented in previous chapters. The management unit plans for the Northeast Oregon, Southeast Washington, and Idaho management units provide more detail on these strategies and specific actions for population-level recovery.

Research, monitoring, and evaluation play an important role in the recovery of the Snake River Basin steelhead DPS. Currently, there is a high degree of uncertainty regarding the current status of most of the steelhead populations, as well as how much improvement will be needed to achieve viability targets for the populations. Research and monitoring will provide needed information about the populations and their responses to various recovery efforts.

Based on ongoing research, life cycle modeling and adaptive management, additional future actions ─ including the actions discussed in Section 6.4 and identified in Table 6-8 ─ may be considered along with the strategies identified in this section to achieve MPG viability. Future potential actions will be developed during the implementation process.

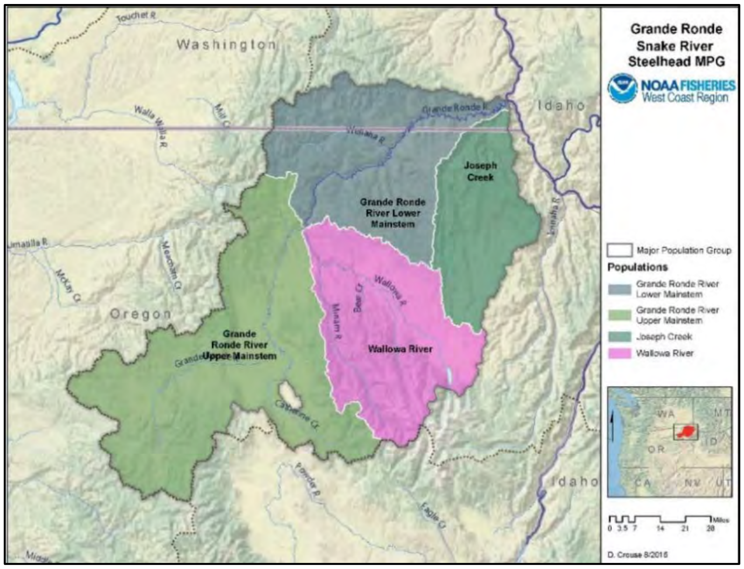
6.6.2.1 Grande Ronde River Steelhead MPG

Current MPG Status

- One population, Joseph Creek, is at very low risk of extinction and considered highly viable.
- The Upper Grande Ronde River population is at low risk, tentatively rated as viable based on existing data.
- The Lower Grande Ronde River and Wallowa River populations are at moderate risk of extinction and tentatively rated at maintained in their current state based on existing data.

Proposed MPG Recovery Scenario

- Achieve at least viable status (low risk) for at least two steelhead populations in the MPG, with at least one population at highly viable status (very low risk).
- Achieve at least maintained status (moderate risk) for the remaining populations.



MPG-Level Recovery Strategies

- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Reduce mortalities during outmigration from overwintering habitats to mainstem Snake River.
- Maintain current wilderness protection and protect and conserve pristine tributary habitat.
- Increase streamflows in the mainstem Grande Ronde River to improve habitat for summer parr.
- Reduce mortalities during the outmigration from overwintering habitats to the mainstem Snake River – with special emphasis on the Grande Ronde River mainstem.
- Improve winter rearing habitats in the lower Grande Ronde River and tributary production areas.
- Improve summer rearing habitats in the mainstem Grande Ronde River and tributary production areas.
- Enhance spawning and eggs and alevin survival by reducing sediment in spawning gravels in tributaries.
- Manage risks from Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans, and according to an abundance-based schedule.
- Maintain an integrated-type hatchery program. Manage releases of hatchery smolts so returning hatchery adults home to localized areas and do not interact to a substantial degree with the natural-origin population.
- Collect and analyze population-specific data to accurately determine viability status for the Lower Grande Ronde and Wallowa River populations.

6.6.2.2 Imnaha River Steelhead MPG

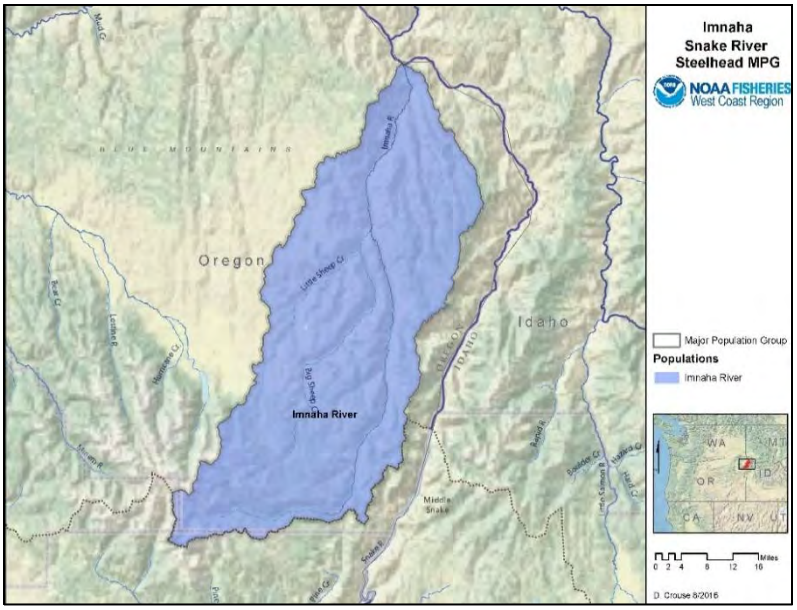
Current MPG Status

- The Imnaha River steelhead population is the only population located in this MPG.
- The population is rated at moderate risk of extinction and is tentatively rated as maintained in its current state based on existing data.

Proposed MPG Recovery Scenario

- The Imnaha River population must attain High Viability status (very low risk) for the MPG to achieve viable status and support delisting of the Snake River Basin steelhead DPS.

MPG-Level Recovery Strategy



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Collect and analyze population-specific data to accurately determine population status.
- Reduce mortalities during the outmigration from overwintering habitats to the mainstem Snake River.
- Maintain current wilderness protection.
- Protect and conserve pristine tributary habitat.
- Restore tributary habitat conditions, especially for steelhead spawners and juvenile rearing.
- Manage the Little Sheep Creek hatchery program to minimize genetic and ecological impacts on natural-origin spawning fish.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans, and according to an abundance-based schedule.

6.6.2.3 Lower Snake River Steelhead MPG

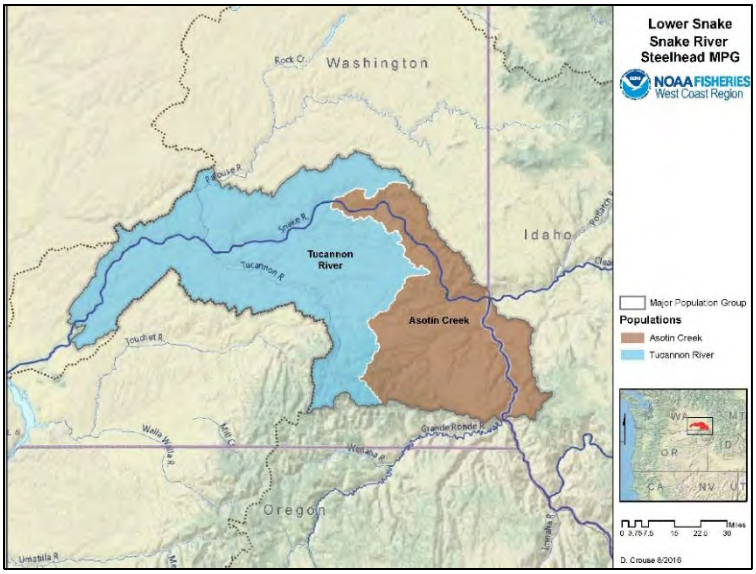
Current MPG Status

- The Tucannon River population remains at moderate or high risk of extinction and the Asotin Creek population has an uncertain rating of moderate risk based on existing data. Neither population is viable in its current state.

Proposed MPG Recovery Scenario

- Achieve at least viable status (low risk) for both the Tucannon River and Asotin Creek populations, with one of the populations at highly viable (very low risk).

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Continue to manage Asotin Creek steelhead population for natural production only.
- Collect and analyze population-specific data to accurately determine population status.
- Protect, improve and increase freshwater habitat to support summer rearing and overwintering in high potential reaches, especially by restoring riparian, channel and floodplain functions, reducing temperatures, and increasing instream habitat.
- Improve adult and juvenile passage at artificial barriers and diversions.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans, and according to an abundance-based schedule.
- Conduct research to determine the cause of straying of Tucannon natural- and hatchery-origin fish that continue upstream of Lower Granite Dam instead of migrating into the Tucannon River, and take actions to reduce straying.
- Continue hatchery management practices that minimize impacts from hatchery releases on naturally produced fish.
- Utilize terminal fisheries to minimize the escapement of hatchery-origin fish and exotic predatory fish to natural production areas.

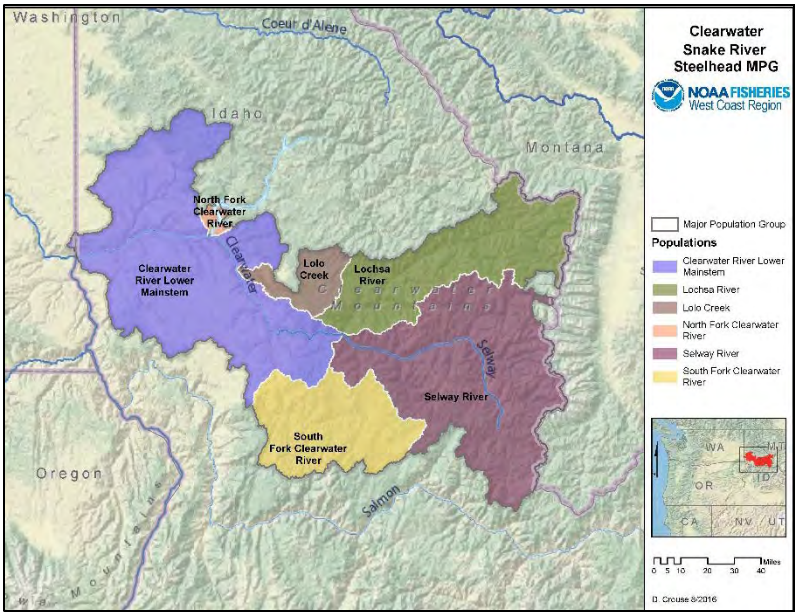
6.6.2.4 Clearwater River Steelhead MPG

Current MPG Status

- All extant populations in the MPG (Lower Mainstem, South Fork Clearwater, Lolo, Selway, and Lochsa Rivers) remain at moderate risk. All of the populations are considered non-viable.
- The North Fork Clearwater River population is extirpated.

Proposed MPG Recovery Scenario

- Achieve at least viable status (low risk) for the Lower Mainstem Clearwater, Selway, and Lochsa Rivers populations, with one of the populations (target Lochsa) at high viability (very low risk).
- Achieve at least maintained status (moderate risk) for SF Clearwater and Lolo Rivers populations.



MPG-Level Recovery Strategies

- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Collect and analyze population-specific data to accurately determine population status.
- Maintain current wilderness protection and protect pristine tributary habitat.
- Preserve, restore, or rehabilitate natural habitat-forming processes in areas with high suitability for steelhead by reestablishing riparian areas and reconnecting floodplains, and reducing surface runoff.
- Provide or improve access to and from historical habitat by removing/replacing culverts and other barriers and screening diversions.
- Reduce and prevent sediment delivery to streams by improving road systems and rehabilitating mining sites.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans, and according to an abundance-based schedule.
- Manage Selway River and Lochsa River population areas for natural production.
- Review hatchery programs in Lower Mainstem Clearwater, Lolo, and South Fork Clearwater population areas, and consider strategies to reduce or eliminate releases of non-localized fish, and transition to locally adapted broodstock.
- Monitor straying of retuning hatchery-origin fish to spawning grounds. Manage returning hatchery fish to minimize straying and effects of hatchery fish on natural-origin spawners in affected populations.

6.6.2.5 Salmon River Steelhead MPG

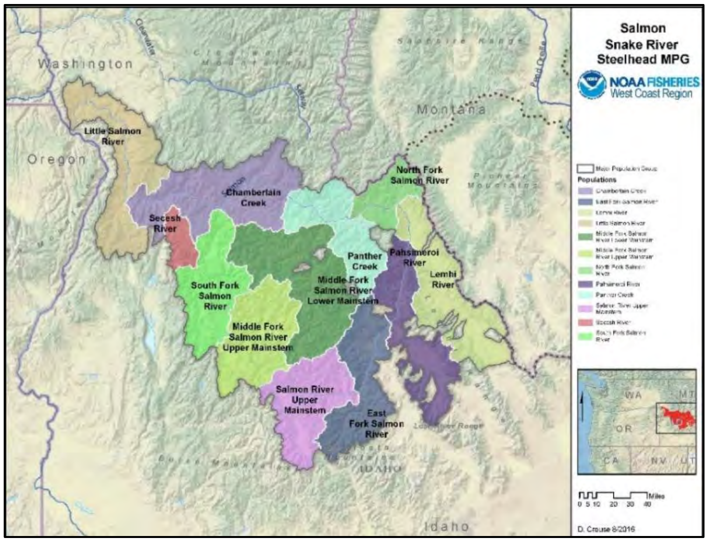
Current MPG Status

- Eleven populations in MPG remain at moderate risk (South Fork Salmon, Secesh, Chamberlain, Lower Middle Fork Salmon, Upper Middle Fork Salmon, Little Salmon, North Fork Salmon, Lemhi, Pahsimeroi, East Fork Salmon, and Upper Mainstem Salmon). One population (Panther Creek) is at high risk. All populations are considered non-viable.

Proposed MPG Recovery Scenario

- Achieve at least viable status (low risk) for the SF Salmon, Lower MF Salmon, Upper MF Salmon, and Lemhi Rivers and Chamberlain and Panther Creeks populations, with at least one population (target: Lower MF Salmon) at highly viable (very low risk).
- Achieve at least maintained status (moderate risk) for Secesh, Pahsimeroi, EF Salmon, Little Salmon, Upper Mainstem Salmon, and NF Salmon Rivers populations.

MPG-Level Recovery Strategies



- Operate the hydropower system to (1) improve juvenile and adult spring/summer Chinook and steelhead survival, (2) improve connectivity between extant populations, (3) maintain or improve rearing and migration habitat through mainstem Columbia and Snake River hydropower projects, and (4) continue identifying, evaluating, and implementing actions to further improve survival in the future.
- Collect and analyze population-specific data to accurately determine population status.
- Maintain wilderness protection and protect pristine tributary habitat.
- Preserve, restore, or rehabilitate natural habitat-forming processes in areas with high intrinsic potential by reestablishing riparian areas and reconnecting floodplains.
- Upgrade irrigation diversions to provide instream flow and fish passage.
- Eliminate passage barriers and improve connectivity to historical habitat.
- Acquire irrigation flow by lease or purchase to improve instream flow in Lemhi River.
- Reduce and prevent sediment delivery to streams by rehabilitating roads and mining sites.
- Manage risks from mainstem Columbia River fisheries through *U.S. v. Oregon*.
- Manage risks from tributary fisheries through updated Fisheries Management Evaluation Plans and Tribal Resource Management Plans, and according to an abundance-based schedule.
- Manage Rapid River, SF Salmon, Secesh, Upper MF Salmon, Lower MF Salmon, Chamberlain, Panther, and NF Salmon populations for natural production; consider managing Lemhi population for natural production.
- Review hatchery programs in Lemhi, Pahsimeroi, EF Salmon, and Upper Salmon populations; consider strategies to reduce/eliminate releases of non-localized fish, and transition to locally adapted broodstock.
- Monitor straying of retuning hatchery-origin fish to spawning grounds. Manage returning hatchery fish to minimize straying and effects of hatchery fish on natural-origin spawners in affected populations.

6.7 Site-Specific Recovery Actions

The three supporting management unit plans describe the site-specific actions defined to recover Snake River spring/summer Chinook salmon and Snake River Basin steelhead populations in each of the associated major population groups. The actions identified in these plans reflect the local knowledge and judgement of scientists, and public and private stakeholders in each management unit.

- The *Recovery Plan for Oregon Populations of Snake River Spring and Summer Chinook Salmon and Steelhead* identifies site-specific recovery actions for spring/summer Chinook salmon in the Grande Ronde/Imnaha Rivers MPG and steelhead populations in the Grande Ronde River MPG and Imnaha River MPG (Appendix A, Chapters 7 and 8). http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/snake_river_sp-su_chinook_steelhead.html
- The *Snake River Salmon Recovery Plan for Southeast Washington* discusses site-specific recovery actions for spring/summer Chinook salmon populations in the Lower Snake River MPG and Washington portions of the Grande Ronde/ Imnaha Rivers MPG, and steelhead populations in the Lower Snake River MPG and Washington portions of the Grande Ronde River steelhead MPG (Appendix B, Chapter 6). http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/snake_river_sp-su_chinook_steelhead.html
- The *Recovery Plan for Idaho Populations of Snake River Spring and Summer Chinook Salmon and Steelhead* describes specific recovery actions for spring/summer Chinook salmon in the South Fork Salmon River MPG, Middle Fork Salmon River MPG and Upper Salmon River MPG (Appendix C, Chapter 5); and steelhead populations in the Salmon River MPG and Clearwater River MPG (Appendix C, Chapter 6). http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/snake_river_sp-su_chinook_steelhead.html

6.8 Contingency Processes

As discussed in Section 6.2, we recognize the importance of learning as we go, and adjusting our efforts accordingly as we strive to rebuild the ESU and DPS to levels where they can be self-sustaining in the wild over the long term and delisted under the ESA. Thus, the recovery strategy depends on implementation of an adaptive management process that targets site-specific actions based on best available science, monitors to improve the science, and updates actions accordingly. We believe this adaptive management process will provide strategic guidance as we move toward achieving the recovery goals. Similarly, we recognize that we need to have contingency processes in place in case one or both of the species does not continue to move toward recovery in a timely manner and/or if there are significant declines in the species' status.

During implementation of this recovery plan, NMFS will work with co-managers and other appropriate entities, through the implementation framework described in Chapter 9, to consider and adopt appropriate contingency processes. These contingency processes might be modeled, to some extent, on the FCRPS Adaptive Management Implementation Plan (AMIP). NMFS worked with the Action Agencies to develop the AMIP as part of the 2010 FCRPS Supplemental biological opinion and incorporated it into the RPA for the 2008 FCRPS biological opinion (NMFS 2008b, 2009, 2010). The AMIP incorporates early warning indicators and significant decline triggers. If a trigger is tripped, then processes within existing management frameworks will be used to identify and implement response actions, most of which would be short-term in duration, in the hydro, predation, harvest, and hatchery sectors. Similarly, in implementation of this recovery plan, triggers could be identified, and in the event of a significant decline or other trigger, NMFS would work with the appropriate management forums to review and select the specific response actions most suitable for Snake River spring/summer Chinook salmon and/or steelhead, while considering the implications of those actions for other ESUs/DPSs and other relevant factors. As part of this effort, intermediate goals and time frames for meeting them might also be established as needed to indicate whether the species is making meaningful progress toward ESA recovery.

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7. Research, Monitoring, and Evaluation for Adaptive Management

This chapter describes the research, monitoring, and evaluation (RM&E) plan for Snake River spring/summer Chinook salmon and Snake River Basin steelhead, and discusses the role that RM&E plays in the recovery plan's adaptive management framework. The chapter summarizes the RM&E recommended for assessing the status and trends in population viability, addressing critical uncertainties, evaluating the success of management actions, and for identifying and prioritizing future actions to effectively address threats and support recovery.

Importantly, this ESU- and DPS-level Plan incorporates the detailed RM&E and adaptive management approaches described in the three management unit recovery plans for the Northeast Oregon management unit (Chapter 11 and Appendix A), Southeast Washington management unit (Chapter 6 and Appendix C) and Idaho management unit (Chapter 9 and Appendix C). The management unit plans provide specific RM&E actions for their areas, based on regional guidance for adaptive management and RM&E, the best available science for the listed populations and MPGs in each management unit, and the expectations and standards described in this document. The management unit RM&E plans and their respective implementation plans should be used to guide RM&E to evaluate status and trends in population viability, examine action effectiveness, research critical uncertainties, and guide future prioritization, funding and implementation of recovery actions in their respective regions.

The RM&E efforts expand on related regional efforts. Many different state, tribal, federal, local, and private entities currently conduct programs and actions designed to improve survival across all "H's" for Snake River spring/summer Chinook salmon and Snake River Basin steelhead as they travel from natal tributaries to the ocean and back. These entities also conduct various kinds of monitoring. Coordination of these diverse local and regional monitoring actions will be essential for future NMFS status reviews of this ESU and DPS, and for understanding the effects of recovery actions to improve ESU and DPS viability and promote recovery.

7.1 Role of Research, Monitoring, and Evaluation in Adaptive Management

RM&E plays a critical role in the recovery planning adaptive management framework. The long-term success of recovery efforts will depend on the effectiveness of incremental steps taken to move the remaining extant Snake River spring/summer Chinook salmon and steelhead populations from their current status to viable levels. Adjustments will be needed if actions do not achieve desired goals, and to take advantage of new information and changing opportunities. RM&E provides the information and adaptive management provides the mechanism to facilitate these adjustments.

Research, monitoring, and evaluation associated with recovery plans need to gather the information that will be most useful in tracking and evaluating implementation and action effectiveness, and assessing the status of listed species. Planners and managers then need to evaluate the combined and relative effects of actions across the life cycle using life cycle modeling and other tools, and employ the information to guide and refine recovery strategies and actions. This process is crucial for salmon and steelhead recovery because of the complexity of the species' life cycle, the range of factors affecting survival, and the limits to our understanding of how specific actions affect species' characteristics and survival.

Adaptive management works by coupling decision making with data collection and evaluation through RM&E, life cycle modeling, and use of other tools. It provides an explicit process through which alternative approaches and actions can be proposed, prioritized, implemented, and evaluated. Overall implementation plans for recovery actions incorporate monitoring and evaluation, and then link the RM&E results explicitly to feedback on the design, revision, and implementation of actions. Figure 7-1 illustrates the role of RM&E in the adaptive management process.

Figure 7-1. The role of RM&E in the adaptive management cycle.

7.2 Research, Monitoring, and Evaluation

This section provides an overview of the RM&E needed to support adaptive management for recovery of Snake River spring/summer Chinook salmon and steelhead. The three management unit plans each contain a detailed RM&E plan for their respective populations and MPGs. Each plan describes the RM&E actions recommended for assessing the status and trends in population viability and for evaluating the success of actions implemented to recover the ESU and DPS. In addition, the management unit plans identify current efforts and additional RM&E needs. Although logistical and monetary limitations exist, these plans will focus on the common goal of assessing success in population and ESU and DPS recovery.

Research, Monitoring, and Evaluation to Support NMFS' Listing Status Decision Framework

The RM&E plans for the Northeast Oregon, Southeast Washington, and Idaho management unit plans identify the level of monitoring and evaluation needed to determine the effectiveness of recommended actions and whether they are leading to species recovery. The plans are based in part on principles and concepts laid out in the NMFS documents *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed under the Federal Endangered Species Act* (Crawford and Rumsey 2011) and *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (NMFS 2007). These guidance documents provide a listing status decision framework, which is a series of decision questions that address the status and change in status of a salmonid ESU/DPS, and the risks posed by threats to the ESU/DPS (Figure 7-2). The documents also provide guidance to set data precision for monitoring before the RM&E plan or monitoring actions are implemented.

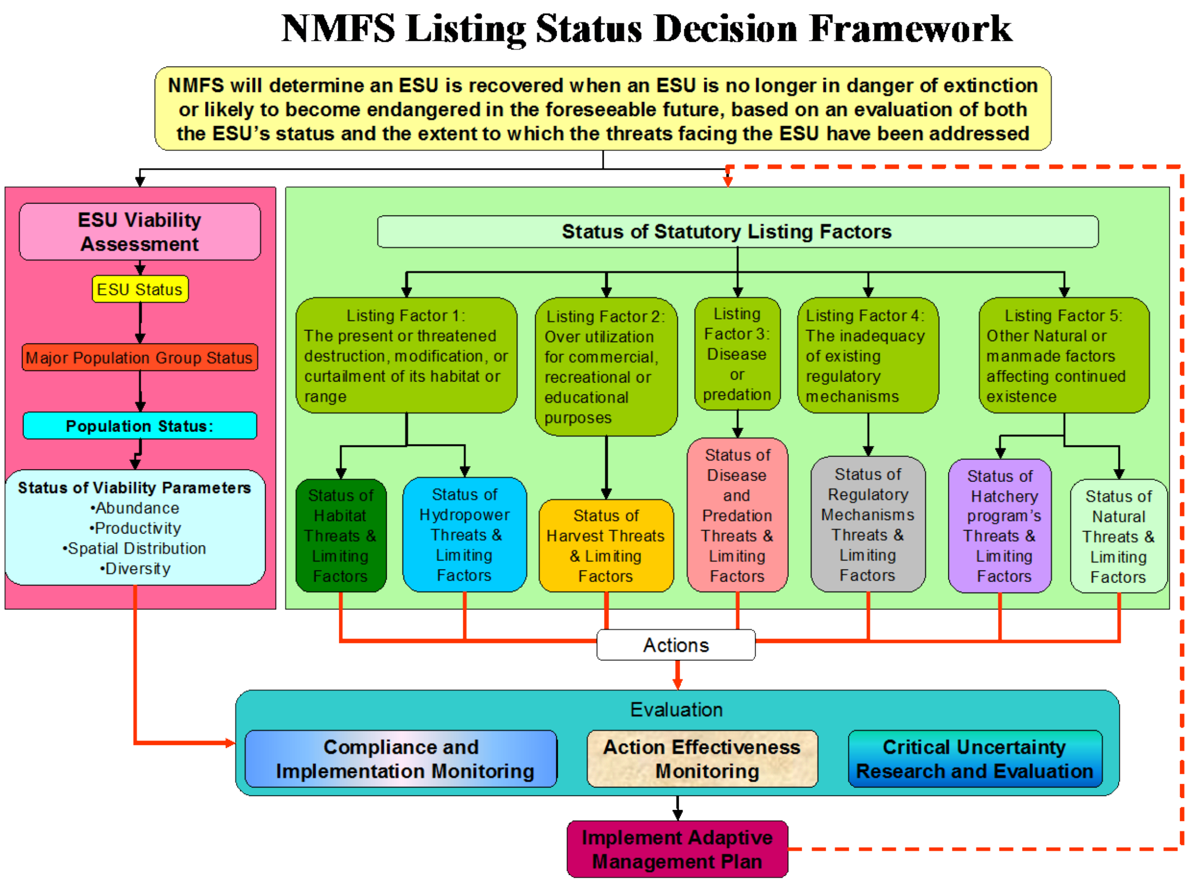

Figure 7-2. Flow diagram outlining the decision framework used by NMFS to assess the status of biological viability criteria and limiting factors criteria.

The RM&E plans also draw from guidance provided by other documents that fill in the specifics for RM&E to support recovery planning at every level, from watersheds and salmonid populations to ESU/DPS and Columbia Basin-wide perspectives. This guidance includes information from the *Columbia Basin Anadromous Salmonid Monitoring Strategy* (CBFWA 2010), which provides a monitoring strategy for the Snake River recovery domain. The Snake River strategy focuses mainly on implementing viability monitoring, but also addresses habitat action effectiveness and hatchery effectiveness for steelhead, spring/summer Chinook salmon, fall Chinook salmon, and sockeye salmon. The plans also rely on guidance from documents developed as part of the FCRPS biological opinion, including the *Recommendations for Implementing Research, Monitoring, and Evaluation for the 2008 NOAA Fisheries FCRPS Biological Opinion* (AA/NOAA/NPCC RM&E Workgroups, June 2009 and May 2010), and the *FCRPS Adaptive Management Implementation Plan* (AMIP) (NMFS 2009). In addition, RM&E efforts will be coordinated with the Integrated Status and Effectiveness Monitoring Program (ISEMP), created in 2003 and funded by BPA as an ongoing collaborative effort led by scientists at NOAA's Northwest Fisheries Science Center.

7.2.1 Types of Monitoring

Several types of monitoring will be used in each management unit to support adaptive management and allow managers to make sound decisions:

- *Status and trends monitoring:* Status monitoring describes the current state or condition of a population and its limiting factors at any given time. It is used to characterize existing or undisturbed conditions and to establish a baseline for future comparisons. For monitoring of salmon and steelhead status, the parameters of interest are abundance, productivity, diversity, and spatial structure. Trend monitoring tracks these conditions to provide a measure of the increasing, decreasing, or steady state of a status measure through time. Trend monitoring involves measurements taken at regular time or space intervals to assess the long-term or large-scale trend in a particular parameter. Together, status and trend monitoring includes the collection of standardized information used to describe broad-scale trends over time. This information is the basis for evaluating the cumulative effects of actions on fish and their habitats.
- *Action effectiveness monitoring:* Effectiveness monitoring evaluates the cause-and-effects of management actions. It is designed to determine whether a given action or suite of actions achieved the desired effect or goal. This type of monitoring is research oriented and, thus, requires elements of experimental design (e.g., controls and reference conditions) that are not critical to other types of monitoring. Consequently, action effectiveness monitoring is usually designed on a case-by-case basis. It can be implemented to provide funding entities with information on benefit/cost ratios, and resource managers with information on what actions or types of actions improved environmental and biological conditions.
- *Implementation and compliance monitoring:* Implementation and compliance monitoring determines whether activities were carried out as planned and meet established benchmarks. This type of monitoring is generally carried out as an administrative review or site visit and does not require any parameter measurements. Information recorded under this type of monitoring includes the types of actions implemented, how many were implemented, where they were implemented, and how much area or stream length was affected by the action. Implementation monitoring sets the stage for action effectiveness monitoring by demonstrating that the restoration actions were implemented correctly and followed the proposed design.
- *Research of key information needs to address critical uncertainties:* This research includes scientific investigations of critical assumptions and unknowns that constrain effective recovery plan implementation. Uncertainties include unavailable pieces of information required for informed decision making, as well as studies to establish or verify cause-and-effect and identification and analysis of limiting factors. Evaluation of uncertainties can also include life cycle modeling to assess relative effects across life stages, or under projected climate change scenarios.

7.2.2 Life-Cycle Modeling

Life-cycle modeling, similar to RM&E, will be conducted to support adaptive management and allow managers to make sound decisions. The development of multi-stage life cycle models will improve our understanding of the combined and relative effects of limiting factors and threats across the life cycle, as well as the effectiveness of specific and collective recovery actions. These models incorporate empirical information and working hypotheses on survival and capacity relationships at different life stages, and under alternative climate scenarios. They can then translate changes in demographic rates (survival, capacity, or fecundity) in specific life stages into measures of population viability metrics (e.g., long-term abundance, productivity, or probability of extinction), which are more relevant for population management. The results of life cycle modeling will be used to evaluate density dependence and other impacts on populations, and at what specific life stages and populations, to ensure that we are focusing/ targeting restoration efforts at the appropriate geography and life stages. They will also be used to identify key RM&E priorities to improve future decision making. They will provide insight by assessing “what if” scenarios that can identify potential changes in natural productivity from changes in habitat, ocean conditions, harvest, and hatchery operations.

7.3 Research, Monitoring, and Evaluation Plans for Management Units

Within the framework of the guidance described above, local recovery planners for Northeast Oregon, Southeast Washington, and Idaho have developed RM&E programs for their management unit recovery plans. These plans will provide conceptual-level guidance to RM&E implementation efforts at the local and regional scale. The data obtained through implementation of these RM&E plans will be used to assess, and if necessary make corrections to, current restoration strategies. Implementation of these RM&E plans will also be influenced by the regional coordination efforts.

7.3.1 Monitoring Frameworks for RM&E in the Management Units

The management unit plans for Northeast Oregon, Southeast Washington, and Idaho each provide a monitoring framework to measure progress toward achieving the desired outcome of long-term viability of naturally produced spring/summer Chinook salmon and steelhead distributed in the wild across their native range. To determine if the desired outcome has been achieved, the management unit plans frame RM&E to answer two general questions:

- Is the status of the population and MPG trending toward recovery?
- Are the effects of the factors limiting the status of the population and MPG increasing, decreasing, or remaining stable?[27]

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[27] NMFS determines if a population/ESU/DPS is no longer in danger of extinction by evaluating both the status of the population/ESU/DPS and the extent to which the threats facing the population/ESU/DPS have been addressed. The RM&E plans do not attempt to monitor “threats.” Rather, they measure the “limiting factors” that directly or indirectly affect the status of a population.

These two general questions provide the basis for the management unit-level RM&E plans. The three management unit plans identify specific questions under the two general questions. They also define specific monitoring objectives to address each question and guide monitoring activities for each population and MPG. For each monitoring objective, the RM&E plans summarize information to determine whether the viable salmonid parameters and population threats are being addressed as needed to reach recovery. They identify the types of monitoring efforts needed, monitoring questions, performance metrics, general approach (monitoring methods), and analysis. The need for this certainty and data precision is discussed in NMFS' document *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead listed under the Federal Endangered Species Act* (Crawford and Rumsey 2011). The RM&E plans for each management unit also recognize the need to prioritize monitoring objectives for each MPG.

The monitoring frameworks for RM&E in each management unit are consistent with direction in the adaptive management guidance document. The management unit monitoring and evaluation programs for Snake River spring/summer Chinook salmon and steelhead provide (1) a clear statement of the metrics and indicators by which progress toward achieving goals can be assessed, (2) a plan for tracking such metrics and indicators, and (3) a decision framework through which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the Plan's goals.

Because funds and resources limit the level of monitoring that can be implemented in the Snake River basin, NMFS will work with the implementation teams for each management unit to establish priorities before the RM&E plans or monitoring actions are implemented. In addition, before monitoring activities begins, monitoring objectives for each MPG will be prioritized using information in NMFS's document, *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead* (Crawford and Rumsey 2011), and other relevant guidance. NMFS anticipates working with implementation teams for each management unit to coordinate prioritization of monitoring actions and set timelines for RM&E tasks to ensure that they are consistent with relevant guidance, and that the information is developed and made available for consideration during future 5-year reviews.

The different management unit RM&E plans reflect the expertise and judgement of the different entities and agencies who will likely implement RM&E activities within the management unit. The RM&E plans direct studies to evaluate the status and trends of each population in terms of abundance, productivity, and spatial structure. They focus studies to determine the influence of current hatchery programs on natural-origin population abundance, productivity, spatial structure, and diversity. They also direct studies to examine effects on viability from hydropower operations and operational improvements, harvest, predation, disease, and other factors such as ocean conditions, climate change, and contamination from toxic pollutants. The management unit RM&E plans are provided in the associated management unit recovery plans in Appendix A (Northeast Oregon), Appendix B (Southeast Washington), and Appendix C (Idaho).

7.4 Tracking Progress through Adaptive Management and RM&E

NMFS developed two documents, *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed under the Federal Endangered Species Act* (Crawford and Rumsey 2011) and *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (NMFS 2007) to provide direction for tracking progress made toward delisting. Our approach for tracking progress toward recovery is based on this direction.

7.4.1 Research on Key Information Needs

This section summarizes the key information needs that are essential, timely, and of high priority for determining the status of Snake River spring/summer Chinook salmon and steelhead, and for focusing recovery actions effectively. Key information needs include scientific investigations of critical assumptions and unknowns that constrain effective recovery plan implementation. They also include information required for informed decision making, proper allocation of funds and resources, or to improve the outcome of recovery actions.

As discussed in Chapters 5 and 6, many important factors have reduced, and continue to affect, the abundance, productivity, spatial structure, and diversity of Snake River spring/summer Chinook salmon and steelhead. Actions need to be implemented to address these factors throughout the salmonid life cycle; however, many questions remain that can affect the success of these actions.

Recovery planners have identified key information needs that will help focus RM&E efforts. Gaining this information to resolve uncertainties will greatly improve chances of attaining recovery goals outline in this Plan. The key information needs for both species are summarized below. The management unit plans for Northeast Oregon, Southeast Washington, and Idaho provide more detail on these key information needs at the major population group and population levels.

The following key information needs were identified by Oregon, Washington, and Idaho recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff as areas where more information is particularly needed to guide our recovery efforts. During recovery plan implementation, NMFS will work with management unit recovery planners and the implementation teams to refine and prioritize the initial research and monitoring efforts for Snake River spring/summer Chinook salmon and steelhead, and to ensure that results are incorporated into future 5-year reviews. The research and monitoring priorities will then be revised as needed over time through the adaptive management process and based on results from life cycle modeling to ensure that we continue to focus our efforts effectively. The key information needs and critical uncertainties identified in the management unit plans and in this recovery plan will provide the basis for continuing discussion of how to prioritize funds and activities for monitoring and research in the Snake River basin.

The information needs highlight the importance of maintaining long-term tagging and monitoring programs, such as the one in the Grande Ronde River basin. Ongoing improvements in the monitoring, evaluation, and reporting of habitat metrics and fish population response will allow us to assess the effectiveness of habitat restoration actions and progress toward the viability criteria for the ESU and DPS.

Population, Major Population Group, and Species Viability

Much uncertainty remains about the viability status of many populations, particularly for Snake River Basin steelhead populations. Better information is needed to understand the status of the populations and the presence of similar genetic traits among the populations, including similarities and differences in their responses to variability in freshwater and marine productivity.

Information on population abundance and productivity can be improved by conducting population-specific abundance estimates using probabilistic sampling protocol for either redd counts or tagging studies (ICTRT 2007). Uncertainty remains regarding the relative distribution of hatchery spawners at the population level, and potential impacts of hatchery-origin fish on the growth and survival of natural-origin fish.

Information is needed to better understand existing ecological conditions, the effects of impaired conditions and natural habitat-forming processes on the fish populations, and the biological and physical relationships between use of habitats in freshwater areas, the estuary, plume, and ocean. For example, RM&E is needed to:

- Examine how and where potential density dependence limitations are affecting spring/summer Chinook salmon productivity in freshwater habitats, including what is happening in the overwintering life stage.
- Continue to evaluate the impacts of food web ecology on species' growth and use of estuarine habitats, and how this might then affect survival in ocean environments.
- Evaluate the effects of different habitat restoration actions by comparing long-term trends of actions with natural abundance and productivity of Snake River spring/summer Chinook salmon and steelhead populations.
- Improve our understanding of spatial structure and diversity by conducting studies to examine salmon and steelhead distribution, and habitat preference. For example, continue investigations to identify key tributary habitats that provide the highest survival for juveniles and adults, such as cold-water refugia in summer.
- For the Upper Salmon, Clearwater, Lostine/Wallowa River basins, identify whether there is a need to implement a process similar to the "Atlas" exercise carried out by BPA in the Catherine Creek and Upper Grande Ronde River basins.

Life-History Patterns

Investigations are needed to understand the factors contributing to the expressions of life-history diversity, such as yearling vs. subyearling life-history strategies for spring/summer Chinook salmon, or the relationship between A-run and B-run steelhead. We need to examine factors influencing the adoption of alternative life-history patterns, and how such changes might contribute to the abundance and productivity of affected populations.

- Continue to evaluate the relationship between A-run and B-run steelhead, and the relative impacts of threats to those runs. A better understanding of the impacts and threats to these runs is needed to maintain life-history diversity.
- Investigate factors that contribute to the sub-yearling life-history pattern of spring/summer Chinook salmon and the limiting factors that determine adult returns. Understand where this is happening in the over-wintering life stage.
- Understand the drivers for the expression of the life-history diversity in Snake River salmon and steelhead, contributions to viability, causes and distribution of juvenile loss between natal streams and the hydropower system, the effects of reservoir habitat conditions, and appropriate actions to address the sources of this loss.
    - Downstream spring/summer Chinook salmon migrants that overwinter before outmigration;
    - Expression of “true” sub-yearling spring/summer Chinook salmon life history;
    - Relationship between A-run and B-run steelhead forms; and
    - Duration and intervals of movement and holding, presumable for resting and feeding, of downstream yearling and sub-yearling Chinook salmon in both free-flowing and reservoir mainstem reaches. The common view of these fish as being flushed nearly continuously to the ocean from tributary rearing areas may be insufficient for effective management (ISG 2000).

Hydropower System

Continued research and monitoring is needed to gain a better understanding of smolt migration timing and mortality rates through the lower Snake and Columbia Rivers, including before juveniles reach Lower Granite Dam, and to determine the effects of spring and summer spills.

- Investigate why, where, and to what extent juvenile losses are occurring during outmigration between natal rearing habitat and hydropower system. PIT-tag studies have been used to estimate survival rates for Snake River spring/summer Chinook salmon from upstream hatcheries and smolt traps to Lower Granite Dam. The studies for yearling spring/summer Chinook salmon from Snake River hatcheries showed a significant negative linear relationship between migration distance and survival during 1993-2015 (R2 = 0.850, P = 0.003). Survival rates varied from a 22-year mean of 0.778 for smolts released from Dworshak Hatchery (116 km to Lower Granite Dam) to 0.455 for those released from the Salmon River Sawtooth Hatchery (747 km to Lower Granite Dam)

(Faulkner et al. 2016). The survival probabilities of wild Chinook smolts during 2015 were also inversely related to the distance of the trap from Lower Granite Dam. Sources of mortality during the outmigration could be investigated by identifying sub-reaches where active (e.g., radio or acoustic) tags disappeared and then looking for contributing factors.

- Identify habitat restoration actions to address sources of juvenile losses in mainstem habitat after they leave tributaries and before reaching the mainstem hydropower system.
- Research the factors contributing to "overshoot" of Tucannon River steelhead and Chinook salmon, and Middle Columbia River steelhead, above Lower Granite Dam, and investigate actions to improve volitional passage of adults back downstream. Determine the effects of “overshooting” Middle Columbia River steelhead on Snake River Basin steelhead populations.
- Investigate factors that could contribute to latent mortality of fish passing through the mainstem hydropower system.
- For adults, research and monitoring is needed to understand why returning adults are being lost between Bonneville and Lower Granite Dams, as well as temperature-related effects, especially on summer Chinook salmon that migrate through the lower Snake River in late summer.

Ocean Productivity and Natural Variation

Global-scale processes in the ocean and atmosphere can regulate the productivity of marine, estuarine, and freshwater habitats of salmon and steelhead. A better understanding of natural variability, and how this variation affects marine survival for different life-history types, is needed to correctly interpret the response of salmon and steelhead to management actions over the full range of environmental conditions they are likely to encounter.

Climate Change

Scientists predict that expected changes in climate and resulting changes in temperature, precipitation, wind patterns, ocean acidification, and sea-level height could have significant implications for survival of Snake River spring/summer Chinook salmon and steelhead in their freshwater, estuarine, and marine habitats. It will be important to monitor key environmental variables to document climatic effects on freshwater, estuary, and ocean productivity, and adjust recovery actions accordingly through adaptive management.

- Continue research on local climate change impacts on Snake River basin salmon and steelhead habitat and populations, and refine restoration strategies and priorities to improve resiliency to climate change.
- Continue to investigate ocean indicators of marine survival for Snake River salmonids and life-history types, and projections of climate change impacts on these relationships.

Hatchery Effectiveness

Information is needed regarding the potential for both benefits and harm of hatchery-produced fish on natural-origin salmon and steelhead populations. This includes information on the impacts of hatchery releases on natural-origin population abundance, productivity, and genetic integrity, as well as a determination of contributing factors for lower or greater reproductive success rates for hatchery fish. Managers need to implement relevant reproductive success studies and evaluate spawner effectiveness of hatchery fish. They also need to evaluate the impacts of hatchery fish releases (both anadromous and resident) on Snake River spring/summer Chinook salmon and steelhead viability in the tributary, mainstem, estuary, and ocean environments. This includes examining the reproductive success of hatchery-origin fish spawning in the wild and the benefits and/ or risks to natural-origin populations. Additional research will also help managers assess the demographic risks versus conservation benefits of hatchery supplementation, sliding-scale hatchery management, and the overall implications of hatchery programs. Further, the impacts of associated RM&E efforts remain uncertain, including impacts from RM&E handling (electrofishing, weirs, catch and release, tagging, marking, trapping, and sorting).

Harvest Management

While harvest management has improved greatly in recent years, additional benefits may be gained with better information. Conducting PIT-tag detection for all harvested fish could improve harvest management by providing a better understanding of the sources of losses in conversion rates. Information collected on the fish populations can be used to identify density dependent relationships, and can help focus fisheries to harvest surplus hatchery fish and to achieve spawning escapement goals for natural-origin populations. Estimates of catch and release impacts also need to be improved.

Predation, Competition, Disease

Non-indigenous species and other native species can compete directly and indirectly with Snake River spring/summer Chinook salmon and steelhead for resources, significantly altering food webs and trophic structure, and potentially altering evolutionary trajectories. More information is needed to evaluate the effects of these threats on population and ESU/DPS viability. Specifically, information is needed to assess causes of mortality on juvenile spring/summer Chinook salmon and steelhead as they migrate from natal tributaries, and then through the Snake and Columbia River migration corridor, and to determine the impact on spring/summer Chinook salmon viability from sea lion predation in the estuary.

- Continue research on the source(s) of adult spring Chinook salmon loss between the Columbia River mouth and Bonneville Dam, including improved understanding of pinniped predation on specific salmonid populations.
- Continue research to identify sources and locations of losses/mortality of juvenile spring/summer Chinook salmon and steelhead from predation as they migrate from natal tributary areas to Lower Granite Dam, and through the mainstem lower Snake and

Columbia River migration corridor. Expand monitoring efforts in the Columbia River and Willamette River to assess predator-prey interactions between pinnipeds and listed species.

- Complete life cycle/extinction risk modeling to quantify predation rates by predatory pinnipeds on listed salmon and steelhead stocks in the Columbia River.
- Expand research efforts in the Columbia River estuary on survival and run timing for adult salmonids migrating through the lower Columbia River to Bonneville Dam.

Exposure to Toxic Pollutants

Chemical contaminants are increasingly being recognized as a factor contributing to the decline of listed species. Information is needed to better understand the effects of contaminants on aquatic life, alone or in combination with other chemicals (potential for synergistic effects). The toxic effects of various chemicals and pesticides could also indirectly affect viability by reducing non-target insect species that are important food for juvenile salmonids. More information is needed to determine the role of these chemical contaminants in limiting salmon and steelhead population viability.

Reintroduction Research

Reintroducing spring/summer Chinook salmon and steelhead to historical habitats upstream of Hells Canyon Dam would address state of Oregon and tribal broad sense goals. While not needed to achieve species' recovery, it could also potentially reduce extinction risks by increasing geographic distribution and abundance, and by buffering risks associated with catastrophic events. However, as a first step we need to gain a better understanding of related benefits and risks. Information is needed to determine the potential benefits of reintroductions of naturally producing Chinook salmon and steelhead into historical habitats in blocked areas upstream of Hells Canyon Dam, to examine considerations under which reintroductions would be suitable, and to develop potential alternative reintroduction strategies and techniques. Discussions related to providing fish passage to historical habitats above the Hells Canyon Complex and improving habitat conditions are continuing as part of the relicensing of the Hells Canyon Complex by FERC, pursuant to the Federal Power Act.

Regional RM&E Programs

A review of related regional-level RM&E programs is needed.

- Review regional RM&E programs and identify the programs that should be maintained.
- Bring together researchers and local technical experts to review the best science on fish use and habitat relationships, and habitat conditions with a focus on how to best influence life-stage survival. As part of this process, identify how to effectively sequence restoration actions, using principles from conservation biology.
- Continue implementation of RM&E actions identified in NMFS' 2008/2010/2014 FCRPS biological opinions.
    - Develop a long-term framework for implementation of RM&E under FCRPS biological opinions with specific strategies through 2028.
    - Continue to affirm and enhance our understanding of fish-habitat relationships, the effectiveness of habitat treatments, and projecting fish/habitat benefits of restoration actions.
    - Continue systematic mapping of current fish habitat conditions relative to potential to inform prioritization and sequencing of conservation actions.
- Continue regional monitoring programs that evaluate *representative* population-specific smolt migration, timing, and mortality rates through the lower Snake and Columbia Rivers.

8. Time and Cost Estimates

ESA section 4(f)(1) requires that recovery plans, to the maximum extent practicable, include "estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal" (16 U.S.C. 1533-1544, as amended). Information presented in this chapter and the management unit plans is intended to meet this ESA requirement.

8.1 Time Estimates

NMFS estimates that recovery of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS, similar to recovery for most of the ESA-listed Pacific Northwest salmon and steelhead, could take 50 to 100 years. This recovery plan contains an extensive list of actions to move the ESU and DPS toward viable status; however, the actions will not get us to recovery. There will still be gaps, and our recovery efforts will need to be broadened and adapted as we progress toward the time when the species are self-sustaining in the wild and can be delisted under the ESA.

Much work remains, both at a regional level and at the local levels, before Snake River spring/ summer Chinook salmon and steelhead will be self-sustaining in the wild and no longer need ESA protection. Recovering the fish will require large improvements to address the multiple limiting factors and threats that currently affect the fish throughout the life cycle ─ in tributary habitats, the Snake and Columbia River migration corridor, and in the estuary and plume. Most importantly, it will require the diligent and successful partnering of many different entities and individuals to ensure that the large range of recovery strategies and actions are implemented effectively.

Estimating the time required for salmon and steelhead recovery remains challenging because of the complex relationship of the fish to their environment and to human activities in the water and on land. The many uncertainties that preclude a precise estimate of recovery time include biological and ecosystem responses to recovery actions and the unknown impacts of future economic, demographic, and social developments.

Many factors will influence the time required to recover the two species; it will depend on whether existing protective actions remain in place, and on whether implementation of ongoing actions continues. It will depend on the timeliness of effective additional actions that close the gap between the species' present status and viability, on the adequacy of RM&E activities to monitor changes in fish status, identify windows for improvement, and evaluate management action effectiveness. Further, it will depend on how the fish respond to both ongoing and additional actions, as well as to changes in ocean conditions, climate, and the impacts of other ecological factors. Given the many challenges to recovery, the timing will also depend on the implementation of a functioning and funded adaptive management framework as described in Chapter 6. Finally, the time to recovery includes the need to have effective regulatory mechanisms in place, including binding agreements. This will allow NMFS to have a high level of confidence that once the species are delisted, they would continue to be conserved and the threats would remain ameliorated. This is to ensure that the species would not be likely to need to be listed again in the foreseeable future.

Thus, while continued programmatic actions in the management of habitat, hatcheries, hydropower, and harvest will warrant additional expenditures beyond the first ten years, NMFS believes it is impracticable to estimate all projected actions and costs over 50 to 100 years given the large number of economic, biological, and social variables involved. Instead, NMFS believes it is most appropriate to focus on the first 10 years of action implementation with the understanding that before the implementation of each 5-year implementation period, actions and costs will be estimated for subsequent years.

The Plan's adaptive management framework and process are central to this approach. Rather than speculate on conditions that may or may not exist 25, 50, or 100 years into the future, the Plan relies on the adaptive management framework's structured process to conduct monitoring to improve the science and on periodic plan reviews, to evaluate the status of the species and add, eliminate, or modify actions based on new knowledge. The adaptive management process will continue to frame decision making to gain needed information and use it to alter our course of action strategically until such time as the protection under the ESA is no longer required.

8.2 Cost Estimates

This section provides 10-year and 25-year cost estimates as called for under ESA section 4(f)(1)(B) and Recovery Planning Guidance (NMFS and USFWS 2010). Based on the limiting factors and threats identified in the three Snake River management unit plans, staff from NMFS' West Coast Region and the Northwest Fisheries Science Center, in coordination with tribal, state, and other federal agency staff, identified ongoing and potential additional actions to recover ESA-listed Snake River spring/summer Chinook salmon and steelhead. These recovery strategies and actions were developed using the most up-to-date assessment information for the species without consideration of cost or potential funding. This section summarizes the potential costs for project implementation in the three management units based on available information.

Snake River management unit plan leads worked with the state, tribal, and federal staff familiar with the current and proposed recovery actions to prepare cost estimates for actions where information was sufficient to allow reasonable estimates to be made. To estimate the total cost of each project, they used the scale described for each action, where available, together with unit costs for each project type. For some actions, no scale estimate was available at the time, in which case no cost estimate was provided in the management unit plan.

All yearly costs identified in the management unit plans are presented in present-year dollars (that is, without adjusting for inflation). Costs are estimates for the Fiscal Year (FY) in millions of dollars ($M). The total costs are the sum of the yearly costs without applying a discount rate. Unless otherwise noted, the costs are direct, incremental costs, meaning that they are (1) out-of-pocket costs that a public or private interest would pay to initiate and complete a management action, and (2) costs that are in addition to the baseline costs for existing programs and activities. This approach is consistent with NMFS West Coast Region guidance on cost estimates for ESA recovery plans.

The costs identified in the management unit plans are primarily a reflection of what is being spent now for recovery actions, and these costs have been carried forward to estimate the costs associated with implementation of tributary habitat actions during the first 10 years of Plan implementation. The Management Unit Plans identify that more recovery actions and funding are needed in the future to recover these species. Therefore, NMFS anticipates that cost estimates will increase over time as more projects are identified and implemented. These actions range widely from fish passage projects to habitat protection and enhancement. Actions also vary considerably in length of time over which they will take place. In some cases, a length of time and true financial costs for their implementation have yet to be determined. NMFS will work with regional experts during the Plan implementation to identify costs for actions that require more information. The information will be updated in the management unit plans as new or improved information is developed ahead of publishing this final Plan.

8.2.1 Recovery Actions and Corresponding Cost Estimates

Four different categories of actions were used for purposes of developing cost estimates:

- *Baseline actions*: Actions categorized as part of ongoing, existing programs that will be carried out regardless of this Plan. No cost estimates are provided for these actions because they do not represent new costs that are a result of this Plan.
- *Cost Estimate Exists:* Actions for which an estimate and scale are available.
- *To Be Determined*: Actions for which additional information is needed to develop a cost estimate, including unit costs and/or project-scale estimates with sufficient detail to support a cost estimate. These costs will be developed during the implementation phase and the recovery costs will be updated accordingly.
- *Not Applicable:* Actions that are generally policy actions requiring staff time and do not have separate costs associated with them.

The total cost estimates reflect costs for both species combined, because many of the recovery actions benefit both species, and there is no practicable way to allocate the costs between the species at this time. A rough estimate would be to divide the total costs equally between the two species. In the implementation phase, NMFS will work with regional experts and local implementers to identify costs for actions that require more information. The cost estimates in the Plan and associated management unit plans will be updated as new cost information becomes available.

8.2.2 Total Cost of Recovery

The total estimated cost of tributary habitat recovery actions for the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS is expected to be approximately $139 million over the initial 10-year period (Table 8-1), given available cost estimates as provided in the management unit plans for Northeast Oregon, Southeast Washington, and Idaho (see Section 8.2.3). The total estimated cost of recovery actions for ESA-listed Snake River spring/summer Chinook salmon and steelhead over the next 25 years is projected to be approximately $347 million. This cost estimate may change in the future as additional actions are identified and implemented to achieve recovery. Costs for those actions will be identified at that time.

Table 8-1. Summary of approximate cost estimates for tributary habitat projects for Snake River spring/summer Chinook salmon and steelhead.

Management Unit Plan	First 10 years ($M)
Northeast Oregon	$20
Southeast Washington	$79
Idaho	$40
Total	$139

The cost estimates do not include costs directly associated with implementation of other programs being implemented to meet other mandates or requirements. As noted previously in this document, many salmon and steelhead recovery actions are already ongoing, or will be implemented in the future, as baseline actions; they will be carried out regardless of this Plan. We have not included cost estimates for such actions, because they do not represent new costs that are a result of this Plan.

Costs associated with implementing actions and RM&E for the following baseline programs are considered baseline costs:

- Federal Columbia River Power System (FCRPS) operations, structural improvements, transport, research, and other actions to maintain and enhance spawning, incubation, rearing, and migration conditions for Snake River spring summer Chinook and steelhead, as specified in the FCRPS biological opinion (NMFS 2014c).
- Hatchery programs that support Snake River spring summer Chinook and steelhead recovery as described in this Plan and adopted Hatchery and Genetic Management Plans (HGMPs) for these species.
- Idaho Power Company activities related to maintaining or improving rearing and migratory conditions for these two species.

- Activities conducted by multiple harvest-management jurisdictions to reduce harvest on Snake River spring/summer Chinook and steelhead in ocean and in-river fisheries, as described in the Harvest Module (Appendix F) and in NMFS' ESA biological opinion on the fishing regimes (NMFS 2008c). FCRPS and other actions improve Snake River spring/summer Chinook and steelhead survival and productivity in the Columbia River estuary and plume, including those to increase habitat access, food availability, water quality, and flow conditions. These actions are described in the Estuary Module (Appendix E) and the FCRPS biological opinion (NMFS 2014c).
- Habitat actions for recovery of Snake River Fall Chinook (NMFS 2017) or Snake River Sockeye Salmon (NMFS 2015).

8.2.3 Management Unit Cost Estimates

Cost estimates for recovery actions described in the three management unit plans for Snake River spring/summer Chinook salmon and steelhead are provided below. There are several cautions that must be highlighted regarding these costs, because many cost estimates may be incomplete in scope, scale, or magnitude until actions are better defined. Specifically, costs for potentially expensive projects such as land and water acquisition, water leasing, and RM&E have not yet been estimated for the ESU/DPS. For other projects, unit cost estimates or determination of project scale may also still need to be calculated. The management unit plans present summary costs for recovery actions identified that will help promote recovery (delisting) of the ESU and DPS. Cost estimates may be adjusted up or down, as unit cost estimates, scale of projects, total number of actions, and currently unforeseen costs for actions are determined.

Further, while the management unit plans provide some preliminary cost estimates for RM&E, these costs are incomplete pending completion of research and monitoring plans and further development of each project. The implementation teams for each management unit will work with NMFS to develop study designs that define specific RM&E needs to support adaptive management, and allow managers to make sound decisions. Coordination and funding will also be needed to provide a comprehensive monitoring program for the Snake River recovery domain that includes the full range of monitoring needed for this recovery plan (e.g., monitoring of population-level spatial structure and diversity, monitoring of habitat status and trends at various scales, and action effectiveness monitoring).

Northeast Oregon Management Unit

Because of the large effort needed to recover the populations and the amount of time that recovery will likely take, planners for the Northeast Oregon management unit did not attempt to quantify the amount or extent of the tributary habitat actions. Instead, they worked with natural resource specialists to develop a list of potential projects and associated costs for recovery of the populations with the intent that the list would be used for guidance and planning purposes. This list ─ developed by a team including staff from NMFS, other federal and state agencies, tribes, and stakeholder groups ─ addresses limiting factors and threats for the populations within the management unit. Overall, the planners estimated the total cost for implementation of all identified potential tributary habitat actions for recovery of Oregon spring/summer Chinook salmon and steelhead populations, where costs are available for all populations, at approximately $214.2 million. They estimated that, given the estimated costs of project implementation, accomplishing all of the identified restoration actions at the current rate of spending would take roughly 80 to 100 years; or 35 to 40 years at twice the current rate of spending for implementation. Based on this estimate of total recovery costs for 100 years to recovery, it will cost approximately $2 million per year to implement these projects. The overall total cost estimated for all actions during this 10-year period, where costs are available, is approximately $20 million.

The recovery plan for the Northeast Oregon management unit recognizes that many ongoing recovery efforts and pre-existing laws or regulations will benefit the species and their environments, including ongoing resource management and habitat restoration activities of the U.S. Forest Service, ODFW, Grande Ronde Model Watershed, tribes, and soil and water conservation districts. It also recognizes that actions and priorities for habitat restoration in the Northeast Oregon management unit will change as new information becomes available. For example, studies such as the Catherine Creek Tributaries Assessment (USBR 2011) have provided new scientific information on how channel and floodplain processes are affecting salmonid habitat. The implementation process in the management unit plan allows results from such studies to be used to promote and implement alternative actions to those in the plan to achieve recovery goals. The management unit plan also recognizes that actions to achieve a specific recovery strategy may vary due to logistics, project opportunities, willingness of landowners to participate, funding constraints, or an organization’s authorities and administrative processes. The management unit plan does not constrain or inhibit entities or individuals from implementing actions as opportunities or funding become available.

Given the uncertainties in developing project cost estimates, the management unit plan directs that the NE Oregon Snake River Chinook and Steelhead Recovery Team will work with NMFS to develop an implementation schedule with specific project costs and directions on how recovery plan implementation will be coordinated. Recovery costs will be revised as specific project budgets are completed.

Southeast Washington Management Unit

The Southeast Washington management unit plan for Snake River spring/summer Chinook salmon and steelhead describes actions to move the listed populations toward recovery, but recognizes that the populations will not likely meet the biological and threats criteria for delisting for many years. Because of the possible lengthy recovery period, the management unit plan stops short of predicting the time and cost of meeting the criteria for those populations, but instead provides the intermediate steps toward that goal as represented by the 10-year actions and costs. The actions specified in the management unit plan are intended to make incremental improvements needed to move Southeast Washington populations from their current status to healthy and harvestable levels.

The management unit plan includes near-term site-specific actions and costs, and a 10-year list of actions and costs at a broader geographic scale within the management unit. Table 8-2 estimates the costs for implementing proposed projects in the Southeast Washington management unit.

Table 8-2. Estimated 10-year implementation costs for recovery of Snake River spring/summer Chinook salmon and steelhead in the Southeast Washington Management Unit.

Projects and Expenditures	Snake River DPS and ESU
Capital Project	**Estimated Cost ($M)**
Habitat Restoration	$24
Land and Easement Acquisition	$19
Passage Barrier Retrofits	$2
Instream Flow Enhancement	$3
Water Quality Improvements	$10
Subtotal for Capital Expenditures	*$58*
Non-Capital Expenditures	
Program Operations	$4
Monitoring, Studies and Assessments*	$15
Outreach and Education	$1
Development and Regulation	$1
Subtotal for non-capital Expenditures	*$21*
Total**	**$79**

*Many of the specific RM&E tasks have costs that are yet to be determined so the values in this table represent the minimum expense for the overall category at this time.

**The costs shown for program operations, outreach/education and development of regulations are half the estimated costs for the total MU, which includes steelhead in the Mid-Columbia DPS.

The management unit plan recognizes that adjustments in effort or direction will be made if actions do not achieve their desired goals, and to take advantage of new information, more specific objectives and changing opportunities. It proposes that the adaptive management process provide the mechanism to facilitate these adjustments and updated cost estimates based on new information/data, objectives, and opportunities.

The management unit plan notes that actions will be implemented through a variety of funding sources. Currently, a mix of sources fund capital activities in the management unit, including the Salmon Recovery Funding Board (Pacific coastal salmon recovery and state funding), BPA, U.S. Department of Agriculture, Department of Energy, land trusts, regional fisheries enhancement groups, non-governmental organizations, landowners, and other state and federal sources. Funding for non-capital activities is currently provided by the Salmon Recovery Funding Board, BPA, Department of Energy, U.S. Forest Service, Conservation Commission, and regional fisheries enhancement groups. As of 2011, approximately $6 million in funding was provided for capital expenses while about $2 million went for non-capital expenses. At this rate of funding, planners estimate that funds will be sufficient to support only about one-third of the costs proposed in the plan. The largest gap in funding for capital projects is habitat restoration followed by instream flow enhancement, passage barrier retrofit, land and easement acquisition, and water quality improvements. The vast majority of the gap in funding for non-capital activities is monitoring.

Idaho Management Unit

Recovery strategies to address limiting factors for Idaho Snake River spring/summer Chinook salmon and steelhead populations include short-term and long-term actions. The short-term actions are projects scheduled to be implemented within the next five years by a resource management agency or local stakeholder group. The Idaho management unit plan provides baseline cost estimates for specific projects scheduled for FY 15. These baseline costs are included in the Idaho management unit plan to show the scope and scale of baseline actions that are being implemented. However, the actions and costs for the projects are generally associated with implementation of the FCRPS biological opinion and are not included in the estimated costs associated with the recovery plan. Instead, to estimate costs for tributary habitat recovery actions in Idaho, NMFS used its annual allocation of NOAA's Pacific Coast Salmon Recovery Fund (PCSRF) dollars to the State of Idaho Governor's Office of Species Conservation to calculate annual and 5-year costs for recovery. Overall, NMFS estimated the total cost for implementation of all potential tributary habitat actions for the next 5-year period, where costs are available, at approximately $20 million for recovery of Idaho spring/summer Chinook salmon and steelhead populations.

The Idaho management unit plan also identifies long-term actions to increase population abundance, productivity, spatial structure, and diversity. Long-term actions are categories of actions that could increase productivity for the population, but for which a specific project has not yet been proposed by a resource management agency or other stakeholder. These more general long-term actions include reducing sediment loading through road decommissioning and riparian enhancement, restoring riparian function by improving riparian vegetative communities, and eliminating fish passage barriers. The management unit plan does not estimate the potential costs associated with these long-term actions because specific projects have not yet been proposed.

Similar to planners for the Northeast Oregon and Southeast Washington management unit plans, recovery planners for the Idaho management unit plan recognize that there is a high degree of uncertainty in estimating the amount of improvement necessary to achieve the viability target for the different Snake River spring/summer Chinook salmon and steelhead populations. Due to this uncertainty, the management unit plan proposes an adaptive management strategy that will be used, in conjunction with the ESA's 5-year status reviews and information gained from RM&E, to further identify and prioritize actions to achieve desired improvements.

9. Implementation

Ultimately, the recovery of Snake River spring/summer Chinook salmon and steelhead rests on the commitment and dedication of the many entities, tribes, agencies, and individuals who share responsibility for shaping the species' future. Together we face a common challenge. We need to bring both species to levels where we are confident that they are viable and naturally self-sustaining. We also need to ensure that the threats to the species have been adequately addressed and that regulatory and other programs are in place to conserve the species once they are delisted.

This chapter proposes a framework for achieving coordinated implementation of this Plan. The framework aims to build on and enhance existing partnerships. It proposes processes for achieving coordinated evaluation, reporting, prioritizing, and implementation of future recovery actions. It also describes processes for revisiting and updating the Plan and its strategies and actions as implementation occurs over time. This framework will add value to the suite of different management programs and actions. It will provide a comprehensive, life cycle context for prioritizing additional site-specific and RM&E actions, evaluating the collective and relative effectiveness of management actions, examining uncertainties regarding the fish and their habitats, and determining the additional actions that will most benefit the fish and lead to ESA recovery.

While efforts to improve the status of the ESU and DPS began prior to ESA listing in 1992 and 1997, additional and accelerated actions since the listing have contributed to significant improvements in the species' status, as well as to enhanced coordination among those responsible for managing the species. NMFS acknowledges the leadership, hard work, and dedication of the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Shoshone-Bannock Tribes, states of Washington, Idaho, and Oregon, the FCRPS action agencies, the U.S. Fish and Wildlife Service, Burns Paiute Tribe, other federal agencies, and stakeholders that have worked for many years on Snake River spring/summer Chinook salmon and Snake River Basin steelhead research, monitoring, and conservation programs. Accordingly, this Plan builds upon the successes of these partnerships and agreements.

During implementation of the recovery plan, NMFS will rely, to a great extent, on the continued implementation of ongoing programs and management actions, as identified in Chapter 6 and the management unit plans. The Plan also acknowledges that additional actions are needed, and that determining the best path forward will require close coordination and communication among co-managers. As discussed in Chapters 4, 6 and 8, both species have a long way to go before delisting, and will require coordinated implementation of new management actions and RM&E. The various fish and habitat managers will need to work together to prioritize and implement RM&E efforts, identified in Chapter 7, evaluate results, and then use the information to identify and implement the additional management actions most likely to bring the species to a point where we are confident that it can be self-sustaining in the wild for the long term. This chapter describes a process that will provide this structure for recovery plan implementation.

This chapter presents NMFS' vision for recovery plan implementation, defines implementation responsibilities for NMFS and the management units, and describes how implementation of this recovery plan may be structured and coordinated.

9.1 Implementation Framework

The recovery plan implementation framework presented below is intended to begin discussion about the best way to implement this Plan and engage with and coordinate among interested parties. The framework relies heavily on existing forums and seeks to facilitate coordination among those forums. It anticipates close working relationships with existing groups, tribes, and agencies to build on the conservation work already underway, and seeks continued collaboration.

In general, NMFS' vision for recovery implementation is that recovery plan actions are carried out in a cooperative and collaborative manner so that recovery and delisting occur. NMFS' strategic goals to achieve that vision are as follows:

- Sustain local support and momentum for recovery implementation.
- Implement recovery plan actions within the time periods specified in each plan.
- Encourage others to use their authorities to implement recovery plan actions.
- Ensure that the implemented actions contribute to recovery.
- Provide accurate assessments of species status and trends, limiting factors, and threats.

NMFS' strategic approach to achieving these goals is as follows:

- Support existing management forums and local efforts, and provide needed coordination among those existing efforts, to encourage recovery plan implementation.
- Use recovery plans to guide regulatory decision making.
- Provide leadership in regional forums to develop RM&E processes that track recovery action effectiveness and status and trends at the population and ESU/DPS levels.
- Provide periodic reports on species status and trends, limiting factors, threats, and plan implementation status.
- To the extent practicable, staff and support the Snake River Coordination Group and support management unit plan implementers as needed.

NMFS will carry out its vision, goals, and strategic approach to recovery for the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS by working in partnership with the Snake River Coordination Group, management unit recovery planners, tribes, states, and others with authority to implement recovery efforts.

9.2 Implementation Roles and Responsibilities

Effective implementation of recovery actions for Snake River spring/summer Chinook salmon and steelhead will require coordinating the actions of diverse private, local, state, tribal, and federal entities and management forums spread across three states. Multiple existing forums are responsible for managing the species and its habitat throughout different phases of both species life cycle. These include forums established for *U.S. v. Oregon*, the FCRPS biological opinion, the Lower Snake River Compensation Plan, the Pacific Salmon Treaty, and other harvest management forums. Also involved are other entities that coordinate, oversee, and implement fish and habitat restoration efforts at the watershed level (e.g., the Northwest Power and Conservation Council, ODFW, IDFG, WDFW, Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, Shoshone-Bannock Tribes, Burns Paiute Tribe, Grande Ronde Model Watershed, Oregon Watershed Enhancement Board, U.S. Forest Service, Bureau of Reclamation, Snake River Salmon Recovery Board, Clearwater Technical Group, Upper Salmon Basin Watershed Program, Idaho Governor's Office of Species Conservation, NMFS, Columbia River Estuary Partnership, soil and water conservation districts, private landowners, and many others.) We need to ensure that adequate coordination exists so these diverse forums can individually and collectively consider the best management opportunities to protect and improve the species' status across the life cycle and take actions accordingly.

This chapter proposes additions to existing management structures with the objective of facilitating the sharing of RM&E information and coordinating decisions regarding implementation of recovery actions among existing forums and throughout the species life cycle.

This implementation framework links efforts for scientific review, policy review, and overall coordination of efforts by the many players with management responsibilities across the species' life cycle. The components of this implementation framework include the following teams (Figure 9-1):

- NE Oregon Snake River Chinook and Steelhead Recovery Team;
- SE Washington Snake River Recovery Board;
- Idaho Implementation Team; and
- Snake River Coordination Group.

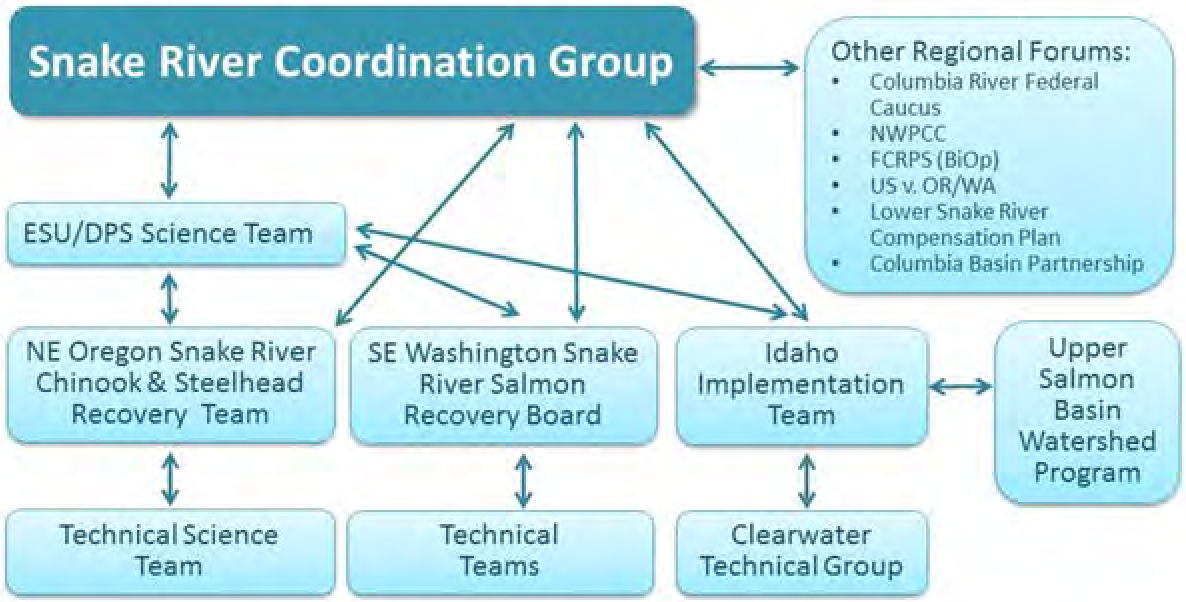

Figure 9-1. Snake River Spring/Summer Chinook and Snake River Basin Steelhead Recovery Plan Implementation Framework.

This framework builds on existing recovery coordination efforts. Potential roles for these teams are described below. The existing Snake River Coordination Group, convened by NMFS, covers all Snake River ESA-listed salmon and steelhead species and addresses basinwide communication and issues related to multiple species. All of these groups are information sharing and coordination groups. Decision-making authority is retained by the state, tribal, and federal co-managers and within existing management processes.

9.2.1 Management Unit Leads and Roles in Implementation

The proposed organizational structure for plan implementation within Oregon, Washington, and Idaho relies heavily on the agencies, organizations, entities, tribes, and individuals that have been involved in the development of the respective management unit plans, and who have often worked for many years on Snake River salmon and steelhead recovery programs. One of the teams in the implementation framework, the Northeast Oregon Snake River Chinook and Steelhead Recovery Team, is new and will focus coordination of the recovery efforts in Northeast Oregon. Implementation teams for the other two management units, the Southeast Washington Snake River Salmon Recovery Board and Idaho Implementation Team, already exist.

The following three recovery organizational units have responsibilities for implementing the tributary-based plans. Performance of these responsibilities will be influenced by management unit lead capacity, authority, and management unit priorities, and will likely require other support structures or processes to fully accomplish these responsibilities. Not all of these duties can be accomplished initially with the current financial resources available. We understand that groups will need resources to fully participate in these recovery implementation activities. Recognizing these resource limitations, we will strive to coordinate meetings at times and locations in conjunction with other relevant meetings to conserve staff resources, save travel time, and reduce expenses whenever possible.

Northeast Oregon Snake River Chinook and Steelhead Recovery Team

An Implementation Coordinator, provided by ODFW, will be responsible for coordinating implementation activities for the Northeast Oregon management unit. The Implementation Coordinator will also represent the management unit on the Snake River Coordination Group.

The Implementation Coordinator will receive advice and guidance from the Northeast Oregon Snake River Chinook and Steelhead Recovery Team. This team will include the Implementation Coordinator; action implementation representatives from various state, federal, tribal, and non-governmental organizations (e.g., ODFW, NMFS, Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, Oregon Watershed Enhancement Board, U.S. Forest Service, U.S. Bureau of Reclamation, Grande Ronde Model Watershed, soil and water conservation districts, The Nature Conservancy, Trout Unlimited, The Freshwater Trust, and other entities as identified); and representatives from a technical workgroup (e.g., technical science team/ RM&E team). The Northeast Oregon Snake River Chinook and Steelhead Recovery Team will be responsible for overall policy, leadership, coordination, direction, and agenda-setting for implementation of the management unit plan. It will coordinate at relevant federal, state and regional levels, and identify and seek funding for action implementation. It will also develop a 5-year implementation schedule, identify action priorities, and report annual progress on implementation and monitoring actions to ODFW and NMFS. The Northeast Oregon management unit plan (Appendix A) provides more detail on the different teams that make up Oregon’s implementation framework.

Southeast Washington Snake River Salmon Recovery Board

Coordination of actions and information sharing for the Southeast Washington management unit will continue to occur through the Snake River Salmon Recovery Board (SRSRB) and associated subcommittees and technical teams. The SRSRB is a cooperative group comprised of representative from each of the five counties in Southeast Washington, the Confederated Tribes of the Umatilla Indian Reservation, various state and federal agencies, landowners, and private citizens. Other processes, including those implemented through the Lower Snake River Compensation Plan, also assist in regional coordination.

The SRSRB operates through several committees including the Lead Entity Project Review and Ranking Committee. This committee is responsible for developing a ranked habitat project list for the SRSRB to use in requesting funding from the state-level Salmon Recovery Funding Board. The SRSRB has also appointed a Regional Technical Team to review and provide input to the recovery effort from the technical and scientific standpoints. The Executive Committee is responsible for developing broad policy recommendations, guidance, and budgets. These recommendations are referred to the full SRSRB for consideration.

The SRSRB will make decisions for recovery plan implementation using a consensus-driven process. The Board is committed to implementing a recovery plan that is supported by science and the community. The plan proposes that the adaptive management process be used to facilitate adjustments in effort or direction to achieve desired goals and to take advantage of new information, more specific objectives, and changing opportunities. The Southeast Washington management unit plan (Appendix B) provides more detail on the different teams that make up Washington's implementation framework.

Idaho Implementation Team

The Idaho Snake River Implementation Team (Implementation Team) will provide overall leadership, coordination, direction, agenda setting, and communication for implementation of the Idaho management unit recovery plan. The Implementation Team will coordinate with entities at relevant federal, state and regional levels, and will represent Idaho Snake River spring/summer Chinook salmon and steelhead recovery plan implementation in Snake River Coordination Group meetings. The team is made up of representatives from IDFG, Nez Perce Tribe, Shoshone-Bannock Tribes, U.S. Forest Service, Clearwater Technical Group, Upper Salmon Basin Watershed Program, soil and water conservation districts, Idaho Department of Water Resources, BPA, NMFS, and other entities and stakeholders as identified. It develops a 3-year implementation schedule, identifies action priorities, and reports annual progress on implementation and monitoring actions to the public.

Several existing groups in Idaho currently implement actions to improve salmon and steelhead habitat conditions. These groups reflect strong representations by the private, state, federal, and tribal entities that manage land and other resources within Idaho Snake River drainages. The entities include the IDFG, Idaho Governor's Office of Species Conservation, Clearwater Technical Group, Upper Salmon Basin Watershed Program, the Nez Perce Tribe, the Shoshone-Bannock Tribes, U.S. Forest Service, BLM, NMFS, Idaho Department of Water Resources, the Natural Resource Conservation Service, Idaho Soil Conservation Commission, irrigation districts, different county soil and water conservation districts, The Nature Conservancy, Trout Unlimited, private landowners, and many other groups necessary to accomplish habitat restoration goals. These different entities have created effective processes for working together, providing technical reviews of proposed projects and working with interested parties to accomplish conservation on the ground. They are all partners with NMFS in some capacity in recovering listed salmon and steelhead. The Idaho management unit plan (Appendix C) provides more detail on the different teams that make up Idaho's implementation framework.

9.2.2 Snake River Coordination Group's Role in Coordination

The Snake River Coordination Group, convened by NMFS, will be responsible for coordination across the Snake River recovery domain. While there is no established membership for participation in the Coordination Group, it brings together representatives from the tribes, states, other federal agencies, local recovery planning, and other implementing entities to coordinate policy and technical issues across the four listed Snake River salmon and steelhead ESUs and DPS. The group provides organizational structure for communication and coordination on a tri-state and multi-tribal level across the Snake River recovery domain.

Specific functions include the following tasks:

- Facilitate coordination and communication between federal agencies, the Northwest Power and Conservation Council, states, tribes, management unit leads, and local recovery boards.
- Advocate for the recovery of Snake River spring/summer Chinook salmon and steelhead.
- Promote the application of adaptive management.
- Provide recommendations for resource prioritization.
- Network with other multi-jurisdictional Columbia recovery planning groups (e.g., Mid-Columbia, Lower Columbia, and Upper Columbia) and Northwest Power and Conservation Council subbasin planning efforts.
- Coordinate and synthesize RM&E efforts and activities as appropriate within the Snake River basin.
- Coordinate and communicate to help ensure that 5-year status reviews by NMFS are informed and efficient.

The Snake River Coordination Group will coordinate with broader efforts to develop common indicators for measuring trends. It may also identify legislative, congressional, and other funding opportunities for management actions and RM&E within the ESU and DPS. Policy issues will be resolved within respective local, state, federal, and tribal authorities and agencies.

9.2.3 NMFS’ Role in Recovery Plan Implementation and Coordination

NMFS’ role in implementation of this recovery plan is threefold: (1) to ensure that the agency’s statutory responsibilities for recovery under the ESA are met; (2) to ensure coordination of recovery planning efforts with other related efforts in the Columbia River basin; and (3) to serve as the convening partner for the Snake River Coordination Group and, as practicable, for the recovery entities described above.

NMFS' ESA Statutory Responsibilities

NMFS recovery planning responsibilities include the following tasks:

- Ensure that the recovery plan meets ESA statutory requirements, tribal trust and treaty obligations, and agency policy guidelines.
- Conduct ESA 5-year status reviews (see Section 9.3.2).
- Make determinations regarding listing, changes in ESA listing status, and delisting determinations.
- Coordinate with other federal agencies to ensure compliance under the ESA.
- Implement actions in this recovery plans for which NMFS has the authority and funding to do so.
- Report on the implementation of the management and RM&E actions in this Plan, and prepare updated findings during 5-year status reviews, or sooner if information warrants.

NMFS' Coordination Role

NMFS will work with the Snake River Coordination Group and management unit leads to ensure that Snake River recovery efforts are closely coordinated with related regional efforts.

NMFS' Convening Role

As convening partner for the Snake River Coordination Group, NMFS will:

- Coordinate with state, tribal, and federal partners to implement this ESA recovery plan and work with partners to produce 5-year Implementation Schedules.
- Convene Snake River Coordination Group meetings on a regular basis (once or twice a year) and convene additional meetings as needed.
- Provide meeting facilitation services and manage the meeting process.
- Provide Coordination Group meeting venues.
- Prepare and distribute meeting notes and follow up on tasks agreed to by the Coordination Group.
- Serve as central clearinghouse for information, to include: ESU/DPS-wide stock status, relevant federal scientific research, and ESU/DPS-wide gaps in recovery efforts.
- Coordinate with state, tribal, and federal partners to assure that NMFS' ESA 5-year reviews are based on the best available scientific information.
- As requested by the Coordination Group, establish and facilitate state, federal, and tribal meetings necessary for the coordination of recovery activities.

9.3 Implementation Schedules and Status Reviews

9.3.1 Implementation Schedules

NMFS and the recovery planners for the Northeast Oregon, Southeast Washington, and Idaho management units estimate that recovery of the Snake River spring/summer Chinook salmon and steelhead MPGs could take over 50 years. Given the large number of economic, biological, and social uncertainties involved, NMFS and the management unit leads will focus recovery actions to improve conditions in the first 10 years of implementation, with the provision that before the end of each 5-year implementation period, specific actions and costs will be estimated for subsequent years. The implementation schedules developed for these 5-year periods will identify and prioritize site-specific actions and RM&E needs, determine costs and time frames, and identify responsible parties for action implementation, based on the strategies and actions in this recovery plan. Over the longer term, the recovery plan relies on ongoing monitoring and periodic Plan review regimes to add, eliminate, modify, and prioritize the recovery strategies and actions through the adaptive management process as information becomes available, and until such time as the protection of the Endangered Species Act is no longer required.

9.3.2 ESA 5-Year Status Reviews

Under the ESA, NMFS is required to review the status of listed species at least every five years. The 5-year status review is used to determine whether an ESA-listed species should (1) be removed from the list, (2) be changed in status from an endangered species to a threatened species, or (3) be changed in status from a threatened species to an endangered species.

Accordingly, at 5-year intervals, NMFS will conduct status reviews of the Snake River spring/summer Chinook salmon ESU and Snake River Basin steelhead DPS. These reviews will consider information that has become available through RM&E since the most recent status review and that informs assessment of the biological status of the ESU/DPS and/or of the limiting factors and threats that affect the species. The reviews will make recommendations regarding whether a change in listing status is appropriate. Any status reviews will be based on the NMFS Listing Status Decision Framework (see Figure 7-2) and will be informed by the information obtained through implementation of the monitoring, research, and evaluation programs in each management unit plan and the recovery modules.

Similarly, new information considered during 5-year status reviews may also compel more in-depth assessments of implementation and effectiveness monitoring and associated research to inform adaptive management decisions to guide Snake River spring/summer Chinook salmon and steelhead recovery efforts.

Modifying or Updating the Recovery Plan

Joint NMFS and U.S. Fish and Wildlife Service guidance for conducting 5-year status reviews suggests that following a 5-year status review, an approved recovery plan should be reviewed in conjunction with implementation monitoring to determine whether the plan needs to be updated (USFWS and NMFS 2006).

Recovery planning guidance provides for three types of plan modifications: (1) an update, (2) a revision, or (3) an addendum (NMFS and USFWS 2010). An update involves relatively minor changes. An update may identify specific actions that have been initiated since the plan was completed, as well as changes in species status or background information that do not alter the overall direction of the recovery effort. An update does not suffice if substantive changes are being made in the delisting criteria or if any changes in the recovery strategy, criteria, or actions indicate a shift in the overall direction of recovery; in this case, a revision would be required. Updates can be made by NMFS' West Coast Region, which will seek input from co-managers and implementing partners prior to making any update. An update would not require a public review and comment period.

A revision is a substantial rewrite and is usually required if major changes are needed in the recovery strategy, objectives, criteria, or actions. A revision may also be required if new threats to the species are identified, when research identifies new life-history traits or threats that have significant recovery ramifications, or when the current plan is not achieving its objectives. Revisions represent a major change to the recovery plan and must include a public review and comment period.

An addendum can be added to a recovery plan after the plan has been approved and can accommodate minor information updates or relatively simple additions such as implementation strategies, or participation plans, by approval of the NMFS West Coast Region. More significant addenda (for example, adding a species to a recovery plan) should undergo public review and comment before being attached to a recovery plan. Addenda are approved on a case-by-case basis because of the wide range of significance of different types of addenda. NMFS will seek input from stakeholders on minor addenda to this Plan.

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Appendix A: Northeast Oregon Management Unit Plan

This appendix can be found at:
http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/snake_river_sp-su_chinook_steelhead.html

Appendix B: Southeast Washington Management Unit Plan

This appendix can be found at:
http://snakeriverboard.org/wpi/wp-content/uploads/2013/01/Full-Version-SE-WA-recovery-plan-121211.pdf

Appendix C: Idaho Management Unit Plan

This appendix can be found at:
http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/snake_river_sp-su_chinook_steelhead.html

Appendix D: Module for Ocean Environment

This appendix can be found at:
http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/ocean_module.pdf

Appendix E: Estuary Module

This appendix can be found at:
http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/estuary-mod.pdf

Appendix F: Snake River Harvest Module

This appendix can be found at:
http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/harvest_module_062514.pdf

Appendix G: 2017 Supplemental Recovery Plan Module for Snake River Salmon and Steelhead Mainstem Columbia River Hydropower System

This appendix can be found at: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/2017_hydro_supplemental_recovery_plan_module.pdf.

Appendix H: Snake River Basin Steelhead DPS: Updated Viability Curves and Population Abundance/Productivity Status

This appendix can be found at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/snake_river_sp-su_chinook_steelhead.html

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Short communication

QUAL2Kw – A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration

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Abstract

QUAL2Kw is a framework for the simulation of water quality in streams and rivers. Dynamic diel heat budget and water quality kinetics are calculated for one-dimensional steady-flow systems. The framework includes a genetic algorithm to facilitate the calibration of the model in application to particular waterbodies. The genetic algorithm is used to find the combination of kinetic rate parameters and constants that results in a best fit for a model application compared with observed data. The user has the flexibility to select any combination of parameters for the optimization and specify any appropriate function for goodness-of-fit.

Keywords: Genetic algorithm; Calibration; Water quality modeling; Streams and rivers; Conventional pollutants

Software availability

Name of software: QUAL2Kw
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Tel.: +1 360 407 6485
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Email: gpel461@ecy.wa.gov
Software requirements: Microsoft Windows and Excel
Program language: Microsoft Excel VBA, Fortran 95
Availability: Free download of Excel/VBA source code and Fortran executable at http://www.ecy.wa.gov/programs/eap/models/

1. Introduction

Computer models are used extensively for water-quality management of rivers and streams (see Thomann and Mueller, 1987; Chapra, 1997 for reviews). These models must typically be calibrated by adjusting a large number of parameters to attain optimal agreement between model output and field measurements. Such calibration is often performed by the time-consuming process of manual trial-and-error. The present paper describes a new river model that includes automatic calibration.

The advantages of global optimization algorithms for calibration of water quality models have been noted by many authors (e.g. Zou and Lung, 2004; Mulligan and Brown, 1998). Several alternative tools are available for automatic calibration of models (e.g. UCODE by Poeter and Hill, 1998, or PEST by Scientific Software Group). However, the present model is not compatible with the requirements of tools such as UCODE and PEST, and a customized function optimization algorithm was required.

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Genetic algorithms (hereafter GAs) are a class of search techniques analogous to the process of natural selection during evolution (see Goldberg, 1989 for reviews). GAs have been used in many types of models (e.g. Gupta et al., 1999; Wang, 1997). The GA used in QUAL2Kw is the PIKAIA algorithm (Charbonneau and Knapp, 1995). PIKAIA has been applied successfully in other modeling applications (Metcalfe, 2001).

2. Overview of the water quality model in QUAL2Kw

QUAL2Kw is a modeling framework that is intended to represent a modernized version of the U.S. Environmental Protection Agency's standard river water-quality model: QUAL2E (Brown and Barnwell, 1987). In addition to incorporating more current science, the framework also includes several new features that allow it to be applied to shallow, upland streams.

As with QUAL2E, QUAL2Kw simulates the transport and fate of conventional (i.e., non-toxic) pollutants. The framework represents the river as a one-dimensional channel with non-uniform, steady flow, and simulates the impact of both point and non-point pollutant loadings. The model simulates changes within the daily cycle with a user-selected time step of less than 1 h.

The model simulates the transport and fate of a number of constituents such as temperature, carbonaceous biochemical oxygen demand, dissolved oxygen, phytoplankton and several forms of the nutrients phosphorus and nitrogen (Table 1). It also simulates several other constituents that are not typically included in generally-available software. In particular, the model simulates pH, alkalinity, inorganic suspended solids, pathogenic bacteria, and bottom algae. The inclusion of bottom algae is essential for simulating shallow streams. These algae have the novel feature of variable stoichiometry of the nutrients nitrogen and phosphorus.

Table 1
State variables in QUAL2Kw

Variable	Units[a]
Temperature	°C
Conductivity	μmhos
Inorganic suspended solids	mg D/L
Dissolved oxygen	mg O_2/L
Slowly reacting CBOD	mg O_2/L
Fast reacting CBOD	mg O_2/L
Organic nitrogen	μg N/L
Ammonia nitrogen	μg N/L
Nitrate nitrogen	μg N/L
Organic phosphorus	μg P/L
Inorganic phosphorus	μg P/L
Phytoplankton	μg A/L
Detritus	mg D/L
Pathogen	cfu/100 mL
Alkalinity	mg $CaCO_3$/L
Total inorganic carbon	mole/L
Bottom algae biomass	g D/m^2
Bottom algae nitrogen	mg N/m^2
Bottom algae phosphorus	mg P/m^2

[a] mg/L ≡ g/m^3, D = dry weight, A = chlorophyll *a*.

The model has two other features that distinguish it from other frameworks. First, sediment–water fluxes of dissolved oxygen and nutrients are simulated internally rather than being prescribed. That is, oxygen and nutrient fluxes are computed as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters. Second, the hyporheic zone is modeled. This is the area below the streambed where water percolates through spaces between the rocks and cobbles. This is another feature that is necessary in order to simulate shallow streams.

QUAL2Kw is implemented within Microsoft Excel. It is programmed in Visual Basic for Applications (VBA). Excel is used as the graphical user interface for input, running the model, and viewing of output. The numerical integration during a model run is performed by a compiled Fortran 95 program that is run by the Excel VBA program.

A general mass balance for a constituent concentration (c_i) in the water column of a reach (excluding hyporheic exchange) is written as (Fig. 1):

$$\frac{\mathrm{d}c_i}{\mathrm{d}t}=\frac{Q_{i-1}}{V_i}c_{i-1}-\frac{Q_i}{V_i}c_i-\frac{Q_{\mathrm{ab},i}}{V_i}c_i+\frac{E'_{i-1}}{V_i}(c_{i-1}-c_i)+\frac{E'_i}{V_i}(c_{i+1}-c_i)+\frac{W_i}{V_i}+S_i \tag{1}$$

where Q_i = flow [m^3/d, ab = abstraction], V_i = volume (m^3), E'_i = the bulk dispersion coefficient between reaches i and $i+1$ [m^3/d], W_i = the external loading of the constituent to reach i [g/d or mg/d], and S_i = sources and sinks of the constituent due to reactions and mass transfer mechanisms [g/m^3/d or mg/m^3/d]. For bottom algae in the water column the transport and loading terms are omitted from the mass balance differential equations.

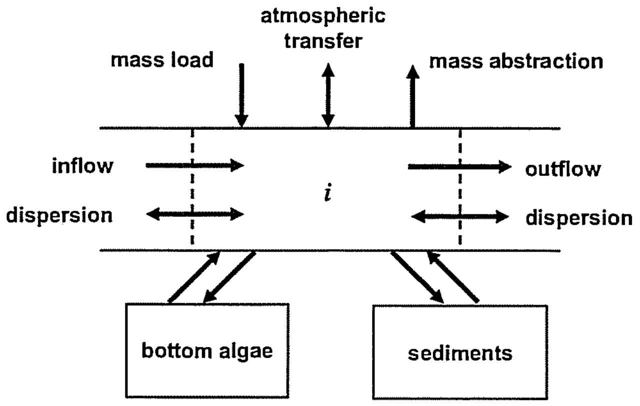

Fig. 1. Mass balance for constituents in a reach segment "*i*".

The source/sink term (S_i in Eq. (1)) requires specification of a large number of parameters for each state variable (e.g. maximum growth rate of bottom algae). The user may select which parameters are held at constant values and which are to be optimized by the GA.

A detailed description of the model is provided elsewhere (http://www.ecy.wa.gov/programs/eap/models/).

3. The genetic algorithm for the calibration of QUAL2Kw

A flowchart of the PIKAIA GA used in QUAL2Kw is shown in Fig. 2. The GA maximizes the goodness-of-fit of the model results compared with measured data. The GA carries out its maximization task on a user-selected number of model runs to define a population. The population size remains constant throughout the evolutionary process. Rather than evolving the population until some preset tolerance criterion is satisfied, the GA carries the evolution forward over a user-specified number of generations.

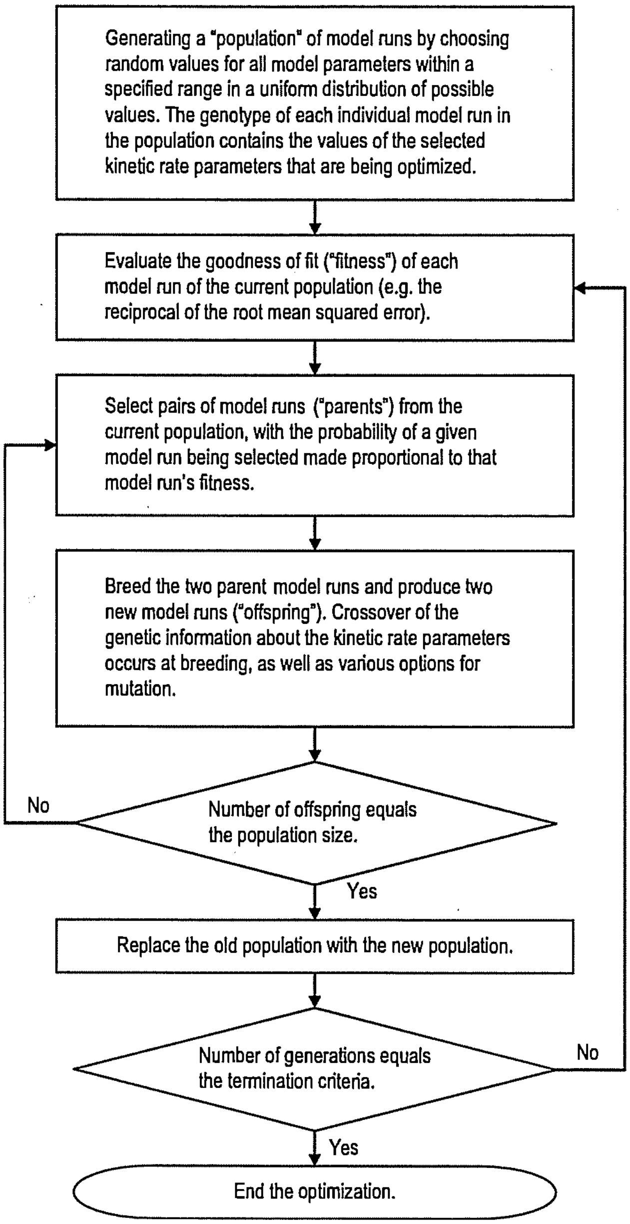

Fig. 2. Flowchart for the genetic algorithm.

Charbonneau and Knapp (1995) provide a tutorial for GA concepts and comprehensive documentation of the PIKAIA GA. The PIKAIA GA is adaptable for use in a wide variety of modeling applications. The original Fortran 77 code for PIKAIA was translated to Excel VBA for use in QUAL2Kw.

The VBA code accounts for only a small fraction of the computational time when the GA is run. Most of the computational time is spent by the compiled Fortran program that is driven by the GA to perform the numerical integration of the water quality model each time the fitness function is evaluated.

The user may select any combination of kinetic rate parameters to include in the optimization. The user also specifies the minimum and maximum values for any kinetic rate parameters that are being optimized.

The GA maximizes the function $f(x)$ in a bounded n-dimensional space, for

$$x \equiv (x_1, x_2, \ldots, x_n) \quad x_k \in [0.0, 1.0] \tag{2}$$

where n is the number of parameters that are being optimized. The parameters (x) are bounded in the range of 0.0 to 1.0 in the GA. The kinetic rate parameters for the model are scaled from the values of x according to a linear interpolation between the specified minimum and maximum value of each kinetic rate parameter that is being optimized.

The value of the function $f(x)$ corresponds to the fitness of a particular model that is run with the set of kinetic rate parameters that are scaled from x. For example, the fitness may be determined as the reciprocal of the root mean squared error (RMSE) of the difference between the model predictions and the observed data for water quality constituents. The reciprocal of the RMSE is a better indicator of fitness than the RMSE because the GA maximizes the function $f(x)$. Specification of the fitness function and inclusion of appropriate variables and data are crucial for the successful performance of the GA.

A robust fitness function should represent all of the state variables of the model (Table 1). An example of a possible fitness function for multiple state variables is the reciprocal of a weighted average of the normalized RMSE, which can be estimated as follows,

$$f(x)=\left[\sum_{i=1}^{q} w_i\right]\left[\sum_{i=1}^{q}\frac{1}{w_i}\left[\frac{\dfrac{\sum_{j=1}^{m} O_{i,j}}{m}}{\left[\dfrac{\sum_{j=1}^{m}\left(P_{i,j}-O_{i,j}\right)^2}{m}\right]^{1/2}}\right]\right] \tag{3}$$

where $O_{i,j}$ = observed value, $P_{i,j}$ = predicted value, m = number of pairs of predicted and observed values, w_i = weighting factor, and q = number of different state variables (e.g. dissolved oxygen, pH, nutrient concentrations, etc.) included in the reciprocal of the weighted normalized RMSE. The Excel framework provides flexibility to construct any fitness function with any combination and weighting of water quality constituents to control the calibration results.

At the beginning of an evolutionary run, the initial values for x for each individual model run in the population are selected from a uniform random distribution between 0 and 1. Most of the individual model runs in the initial population have very poor fitness values. However, some individuals have better fitness than others, and the natural selection process during the evolution favors those individuals.

A "roulette wheel" algorithm is used to select both parents during the reproductive cycle. The relative fitness based on rank is used as a measure of the selection probability. The user specifies the fitness differential that is used to translate the rank into the relative fitness.

A "chromosome" is created for each parent from the n parameters in x. The GA encodes the values in x with 1-digit base 10 integers (0–9). Each digit represents a "gene" in the "chromosome". The user specifies the number of digits for the encoding. For example, if $n = 2$, $x_1 = 0.25034275$, $x_2 = 0.6718247$, and 5 digits are used for encoding, then the encoded chromosome would have a value of 2503467182. The GA also incorporates a mutation operator that may vary dynamically over the course of the evolution to potentially alter the values of each "gene".

Optional crossover modes are provided: one-point, two-point, uniform, and arithmetic. The crossover operator acts on a pair of parent chromosomes to produce a pair of offspring chromosomes. For one-point and two-point crossover, the break points are randomly selected along the length of the chromosome. For example, if the two parents have the encoded chromosome values 2503467182 and 4276986439, and one-point crossover occurs at the 4th digit, then the offspring chromosomes are 2503986439 and 4276467182. Crossover occurs if a user-specified number is exceeded by a uniform random number between 0 and 1, otherwise the offspring are exact copies of the parents.

Two-point crossover is similar to one-point except that the chromosome is randomly split into three segments and the middle segment is crossed. Uniform crossover randomly crosses each gene. Arithmetic crossover decodes the parent chromosomes, randomly interpolates the real values in vector x between the parents, and then encodes the interpolated vectors to create the offspring chromosomes. Hybrid modes are also available for combinations of one-point, two-point, uniform, and arithmetic crossover.

The offspring chromosomes are decoded back to real values of x between 0.0 and 1.0, scaled between the

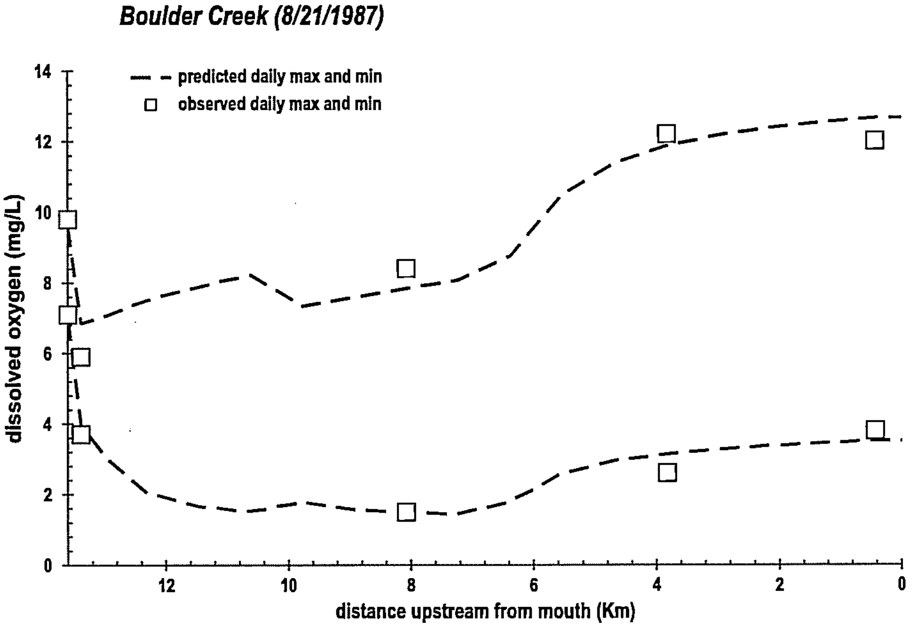

Fig. 3. An example calibration for dissolved oxygen in a small stream.

specified minimum and maximum values for the kinetic rate parameters, and the model is run with the new decoded and scaled kinetic rate parameters. The fitness value of these new offspring model runs is then determined and this process is repeated until the number of offspring equals the number of model runs in the population.

Several optional reproduction plans are available to control how the algorithm incorporates the offspring into the population during the evolution. These include (1) full generational replacement, (2) steady-state-delete-random, and (3) steady-state-delete-worst. Under the first plan the entire population is replaced by the offspring as soon as the number of offspring equals the size of the population. Under the second and third, the offspring are incorporated into the population as they are produced. The second and third plans differ in terms of which members of the population are deleted from the population when the offspring are incorporated.

The GA incorporates an optional strategy of elitism which allows the user to specify whether the fittest individual in a population will be guaranteed to be passed on to the next generation.

4. Example application

Application of a model generally includes calibration and confirmation (e.g. Chapra, 2003). QUAL2Kw

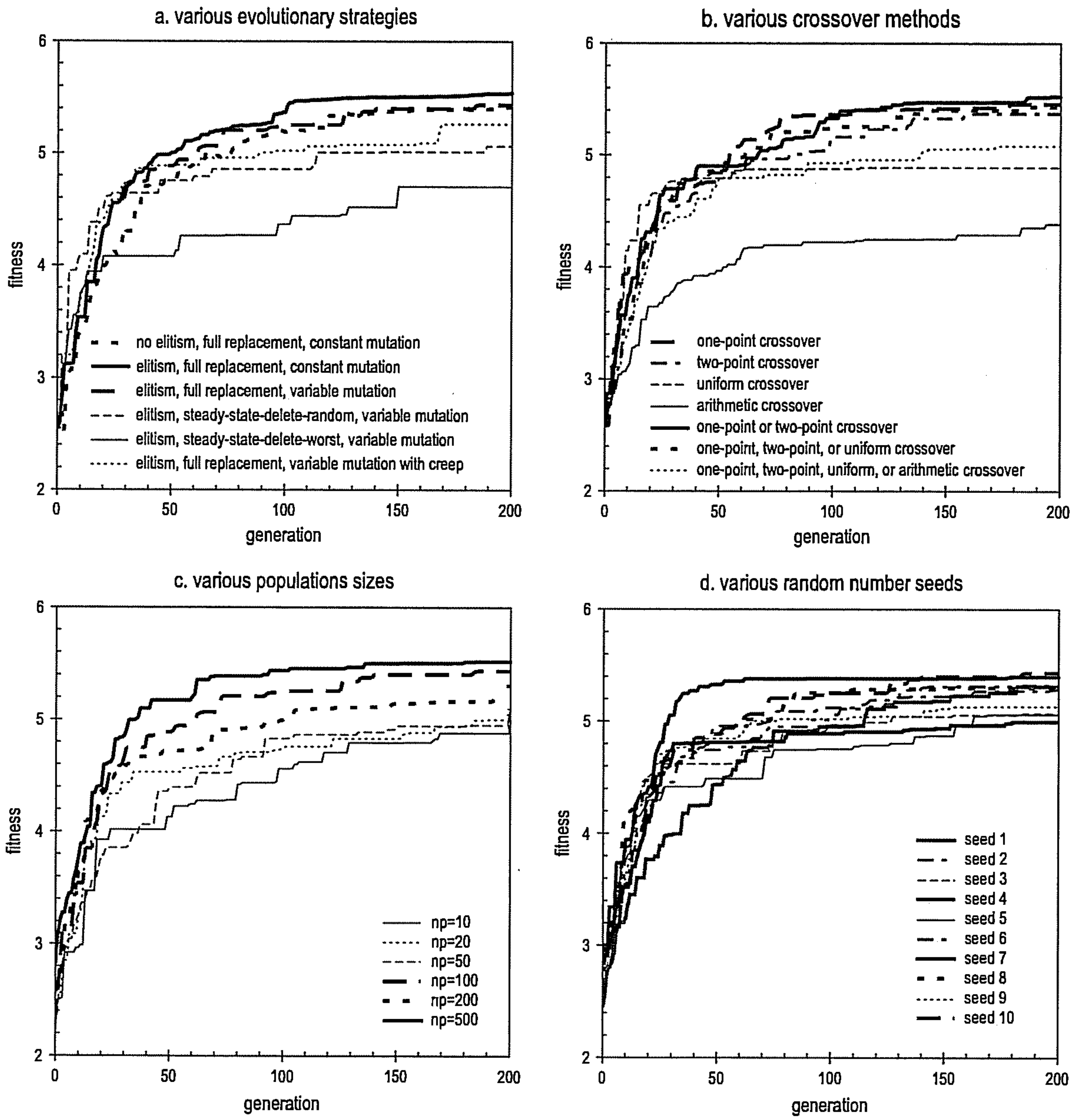

Fig. 4. Results of various evolutionary strategies and options. A population size of 100 was used for a, b, and d. The same random number seed was used for a, b, and c.

Table 2
Variability of selected optimal parameters for bottom algae kinetics from 10 GA simulation runs (at final fitness shown in Fig. 4d)

Parameter	Units[a]	Mean	Standard deviation	Range of GA constraints
Maximum unlimited growth rate	mg A/m^2/d	472	23	(0–500)
Respiration	day^{-1} at 20 °C	0.39	0.04	(0–0.5)
Excretion of N and P	day^{-1} at 20 °C	0.39	0.07	(0–0.5)
Death	day^{-1} at 20 °C	0.29	0.08	(0–0.5)
External N half saturation	μg N/L	158	66	(0–300)
External P half saturation	μg P/L	46	38	(0–100)
Subsistence quota for N	mg N/mg A	0.30	0.24	(0.0072–7.2)
Subsistence quota for P	mg P/mg A	0.031	0.029	(0.001–1)
Maximum uptake rate for N	mg N/mg A/d	94	78	(1–500)
Maximum uptake rate for P	mg P/mg A/d	17	12.3	(1–500)

[a] A = chlorophyll *a*, assumed chlorophyll stoichiometry of 1% of dry weight.

allows for separate calibration and confirmation evaluations, or simultaneous calibration of up to three data sets. The following example of calibration would generally be followed by confirmation with independent data.

An example showing the results of an application of the GA for calibration of a water quality model for dissolved oxygen in a small effluent-dominated stream is presented in Fig. 3. The GA was able to accurately calibrate the model over a very wide diel range for dissolved oxygen (Fig. 3). Fitness in this example was defined as the reciprocal of a weighted average of the normalized root mean squared errors of the differences between observed and predicted concentrations of various water quality constituents (Eq. (3)). Since the fitness function included most of the state variables, the same calibration run also resulted in accurate simultaneous calibration of the other water quality constituents, including pH and nutrient concentrations. Model run time for a population of 100 with 100 generations was approximately 6 h using a 3.2 GHz Pentium 4 processor.

Fig. 4 shows the improvement in fitness over the course of the evolution for various (a) evolutionary strategies, (b) crossover methods, (c) populations sizes, and (d) random number seeds. Performance was diminished by using steady state reproduction (Fig. 4a) and arithmetic crossover (Fig. 4b). The best strategy appears to include a combination of elitism and full generational replacement (Fig. 4a). Adjustable mutation and constant mutation performed similarly in this example, although adjustable mutation could be better in case convergence occurs quickly. The best crossover method appears to be a hybrid with equal probability of one-point or two-point, possibly also including the uniform method (Fig. 4b). A population size of 100 performs better than smaller numbers and nearly as well as a population of 500 (Fig. 4c).

The random number seed determines the sequence of random numbers that are generated during the optimization to create the initial population and control the genetic operators. Each of the 10 GA optimizations in Fig. 4d uses a different random number seed but are otherwise identical, using a strategy of elitism, full generational replacement, adjustable mutation, and equal probability of crossover with one-point, two-point, or uniform operators. Each of the 10 GA optimizations in Fig. 4d could be acceptable for calibration even though each has a different set of optimum values for the kinetic rates and constants. Results of the GA allow exploration of the variability of the optimum kinetic rate parameters (Table 2).

5. Conclusions and recommendations

The Excel framework performs well and allows a great deal of flexibility with reasonable computational speed. A hybrid method using one-point, two-point, and uniform crossover combined with a full generational replacement strategy with adjustable mutation and elitism is recommended. Future enhancements could include additional GA methods for selection, crossover, and mutation. Reasonable ranges for parameters and strategies for selecting which parameters to include in the optimization should also be explored. Additional research is also suggested for methods of calculating goodness-of-fit and for the interpretation of the variability of the optimum parameter set.

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Changes in Salmon Spawning and Rearing Habitat from Increased Delivery of Fine Sediment to the South Fork Salmon River, Idaho

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Abstract.—Levels of surface and subsurface fine sediment (<4.75 mm in diameter) were measured annually from 1965 to 1985 in spawning and rearing areas for chinook salmon *Oncorhynchus tschawytscha* and steelhead *O. mykiss* (formerly *Salmo gairdneri*) in the South Fork Salmon River, Idaho. Between 1950 and 1965, logging and road construction, in combination with large storm events of 1964 and 1965, resulted in the delivery of increased amounts of fine sediments to the South Fork Salmon River. Surface and subsurface fine sediment levels peaked at 46% of the surface area in 1966 and 48% of the volume in 1969, respectively. A logging moratorium initiated in 1965, coupled with natural recovery and watershed rehabilitation, led to significant decreases in the amounts of fine sediments delivered to and stored in the South Fork Salmon River; this reduction led to a limited resumption of logging operations within the watershed in 1978. By 1985, surface and subsurface sediment levels in chinook salmon spawning areas averaged 19.7% of the surface area and 25.4% of the volume, respectively. However, additional recovery to prelogging fine sediment levels is probably contingent on both further watershed recovery and the occurrence of flood flows capable of transporting material downstream. An equilibrium between incoming sediment from the watershed and outgoing sediment from the river appears to have been reached under flow regimes that have occurred since 1975.

Large increases in sediment loads delivered to streams can create changes in channel morphology and substrate composition causing detrimental conditions for fish. Salmonids are particularly susceptible to reductions in streambed particle size in spawning and rearing habitats (Cordone and Kelly 1961; Platts and Megahan 1975; Hausle and Coble 1976). Increased amounts of fine sediments (defined as particles less than 4.75 mm in diameter) can cover or infiltrate larger channel materials and cause considerable mortality to salmonid embryos and young within the substrate (McNeil and Ahnell 1964; Koski 1966; Hall and Lantz 1969; Phillips et al. 1975).

Substantial evidence indicates that logging and road construction can affect the volume, rate, and timing of sediment movement into and through a stream (Burns 1972; Platts and Megahan 1975; Cederholm et al. 1981; Lisle 1982; Coats et al. 1985; Heifetz et al. 1986). However, little has been reported about the temporal and spatial trends of stream-bottom substrate in response to accelerated erosion. This study describes the effect of accelerated amounts of fine sediment delivered into the South Fork Salmon River, Idaho, on spawning and rearing habitat of anadromous fish over a 20-year period, from 1965 to 1985.

Study Area

A major tributary of the Salmon River, the South Fork Salmon River (45°50′N, 116°45′W) drains a 3,290-km² watershed representative of the forest-

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ed, mountainous terrain in central Idaho. Historically, the South Fork supported Idaho's largest run of summer chinook salmon *Oncorhynchus tshawytscha,* estimated at approximately 10,000 returning adults (Richards 1963). Prelogging runs of returning steelhead *O. mykiss* (formerly *Salmo gairdneri*) have been estimated at 3,000 adults (R. Thurow, Idaho Department of Fish and Game, personal communication). The South Fork drainage is part of the 41,440-km^2 Idaho Batholith, a landform characterized by steep slopes, heavily dissected topography, and highly erodible soils. Elevations range from 640 to 2,740 m above sea level, and annual precipitation ranges from 76 to 152 cm. The South Fork is about 160 km long from its headwaters to its confluence with the Salmon River. It averages 22.8 m wide and 0.91 m deep at the Poverty Flat spawning area during summer base flows. Before the period of accelerated erosion within the watershed, the particle size distribution within spawning areas was dominated by gravels (4.75–76.0 mm in diameter), whereas rubble (76.1–304 mm) and boulders ($\geq$305 mm) predominated in the higher gradient rearing areas.

Road construction and timber harvest began in the South Fork drainage soon after World War II, and timber production peaked in 1961 (Seyedbagheri et al. 1987). By 1965, logging activities within the drainage had removed about 15% of the timber in the watershed above the study area. These activities required the construction of 1,000 km of logging roads, 69% of which were constructed on steep (>45% grade), dissected, fluvial land types (Platts 1970). Soil disturbances from logging and particularly from road construction within the South Fork watershed have the potential for greatly accelerating soil erosion (Megahan and Kidd 1972; Megahan et al. 1980). Accelerated soil erosion as a result of logging, road construction, and large storm events occurred in the South Fork drainage from 1950 to 1966 (Figure 1); soil erosion rates increased by 350% over prelogging levels (Arnold and Lundeen 1968). Surface erosion between 1958 and 1964 loaded small-order tributaries with sediments. Large storm events in 1964 and 1965 transported part of this sediment into the South Fork. High sediment loads in stream channels were exacerbated further by road washouts during large storms (Platts 1970). Arnold and Lundeen (1968) determined that during 1964 and 1965, total sediment production averaged about 72,000 m^3 annually of which about 17,000 m^3 (24%) were from natural sources. Their estimates placed the total amount of increased sediment delivered to the river channel to date at about 2 × 10^6 m^3. Much of this increased sediment was attributed to accelerated slope failure as a direct result of road construction. In 1965, a logging and road construction moratorium was initiated within the South Fork watershed. Stocks of anadromous fish were depressed severely as a result of both habitat degradation and downstream hydroelectric development. In 1985, numbers of returning chinook salmon and steelhead were estimated at approximately 1,200 and 800 adults, respectively.

In the South Fork, chinook salmon spawn mainly in the upper 50 km of the river. This study centered on five major spawning areas: Upper and Lower Stolle Meadows, Poverty Flat, Krassel, and Glory Hole. These are low-channel gradient areas (<2%) that account for about 75% of all chinook salmon spawning areas in the river. Spawning areas, because of their low gradient, can also function as areas of aggradation.

Methods

Channel surface materials.—We established 10 transects at each of the five spawning area study sites. For the Glory Hole, Krassel, and Poverty Flat sites, the first transect was selected randomly, and the remaining nine transects were located systematically at 91.2-m intervals. At both the Upper and Lower Stolle Meadows spawning areas, 10 cross sections were established in the channel at 305-m intervals. Surface substrate characteristics of the spawning areas were measured along each transect annually from 1966 to 1981 (except 1969) and biennially from 1981 to 1985. Measurements were made according to a visual technique (Platts et al. 1983). Spawning areas of chinook salmon are characterized by stream gradients of less than 2%, velocities between 30 and 110 cm/s, and gravel–rubble substrates (Reiser and Bjornn 1979).

We evaluated channel substrate characteristics in rearing areas of chinook salmon by establishing five transects at 15-m intervals at each of 47 sample stations. Sample stations were located randomly at 1.6-km intervals from headwaters to the mouth of the river, so there were 235 permanent transects. Transect lines ran from bank to bank and were perpendicular to the main flow of the stream; we determined substrate size-classes along the transect from waterline to waterline. Each transect was divided into 0.31-m intervals, and the dominant streambed material in each increment was determined visually. Streambed particles were assigned to size-classes according to the

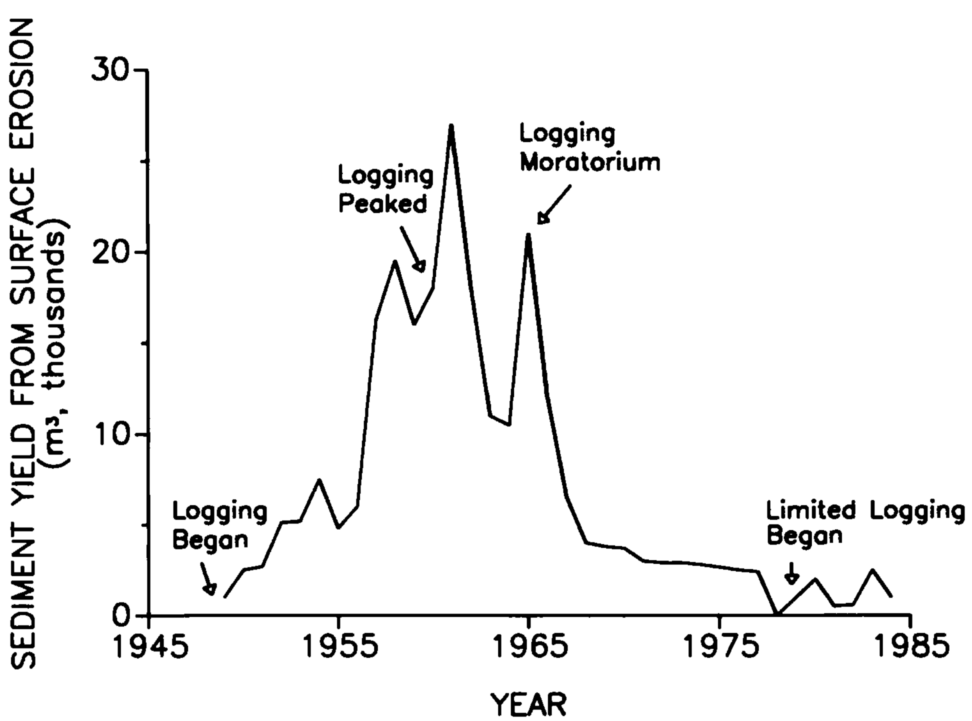

FIGURE 1.—Estimated annual sediment production from surface erosion of temporary logging roads in the watershed of the South Fork Salmon River, Idaho (Megahan et al. 1980).

criteria of Platts et al. (1983): boulder (≥305 mm in diameter), rubble (76.1–304 mm), gravel (4.75–76.0 mm), and fine sediment (<4.75 mm).

Data were collected in rearing areas in 1967, 1971–1974, and 1978. Rearing areas were those habitats that young chinook salmon used during their freshwater growth period. Rearing areas vary seasonally and according to the size of fish but are generally characterized by steeper gradients, greater water velocities, and larger substrate sizes than spawning areas (Reiser and Bjornn 1979).

For each transect, the relative abundance of each substrate particle type was represented by the proportion of 0.31-m intervals in which that particle size was dominant. We used the average abundance of each particle size for all transects to describe temporal changes in substrate composition in each rearing area. Measurements were taken in the spawning and rearing areas during base-flow conditions, as recommended by Chapman and McLeod (1987). Our sampling period coincided with shallow water depths, good water clarity, and minimum movement of channel sediment.

Channel subsurface materials.—Subsurface substrate of channels was sampled within spawning areas of chinook salmon from 1966 through 1985 to a channel depth of 153–254 mm; a modified 305-mm-diameter McNeil streambed core sampler was used (McNeil 1964). From 1966 to 1972, core samples of channel sediment were analyzed by the Materials Testing Laboratory, U.S. Forest Service, Salt Lake City, Utah. The samples were heat-dried and screened, and a weight was obtained for each particle size-class. Core samples were not collected in 1973 and 1974.

From 1975 to 1985, core samples were collected and analyzed by passing the collected sediments with water through standard sorting screens (76.2-, 32.0-, 25.4-, 12.7-, 9.5-, 6.3-, 4.75-, 2.0-, 0.85-, and 0.20-mm-diameter meshes) for sediment separation. Sediments in each size-class were measured by water displacement and expressed as volumetric proportions of the whole substrate sample (Platts et al. 1983). Water retained in the sediment was accounted for with a conversion factor used to convert wet volume to dry volume (Shirazi and Seim 1979). No substrate core samples were collected in rearing areas of the South Fork.

Statistical analysis.—Temporal changes in sediment size composition were examined for both rearing and spawning areas. Regression models were developed to describe temporal trends. During our sampling period, we typically observed a rapid initial decline in the percentage of surface fines, and this rate decreased considerably with time. The model selected for analysis consisted of the simple inverse transformation of the form

$$Y = a + b/X \tag{1}$$

Y is percent fines; X is time in years; and a and b are regression coefficients. The transformation regression was used previously to express sediment time trends in the South Fork (Platts and Megahan 1975; Megahan et al. 1980), and it consistently explained significant sources of variation in observed time trends. This model also conformed to the observed sediment time trend in the river: surface fines initially decreased rapidly then decreased more slowly as an equilibrium state was approached.

The curve of the inverse transformation model descends rapidly from an initial maximum and asymptotically approaches the X-axis. Coefficient a in equation (1) is a conservative estimate of the percentage of fines in the absence of logging. However, the baseline level obtained with this method will probably result in an overestimate of the percentage of surface fines, particularly because limited logging was permitted near the end of the observation period and surface fines increased slightly. Events such as logging, road building, storm events, and landslides may cause a temporary increase in fines, but if such inputs are reduced, we may expect the level of fines to revert to equilibrium.

Autocorrelation is frequently a problem in time-trend analysis. One of the principal assumptions of regression analysis is that the variables are independent (i.e., an observation does not affect the outcome of any other observation). This assumption, however, is not always true for time-series data. As a result, commonly employed least-squares estimates of the variances of the regression coefficients are likely to be seriously low, and any test of hypotheses may be invalid. After the model was developed, we examined the residuals for the presence of autocorrelation by the Durbin–Watson D-statistic (Durbin and Watson 1951). When autocorrelation occurred, the model was discarded as inadequate, and other more appropriate models were used.

Results

Channel Surface Materials

From 1966 to 1985, there was a significant ($P < 0.01$) decrease in the percentage of surface fine sediment in 42 of the 50 (84%) transect locations in spawning areas (Figure 2). The magnitude of decrease was more pronounced in downriver locations, where stream gradients and water power were higher. Generally, each of the spawning area sites exhibited similar temporal changes in substrate sediment (Figure 2). Surface fine sediment decreased by 16.7, 62.3, 68.5, 71.5, and 76.5% between 1966 and 1985 for the Upper Stolle, Lower Stolle, Poverty Flat, Krassel, and Glory Hole sites, respectively. Significant relationships ($P < 0.05$) were found between time and gravel and percentages of fine sediment at spawning sites (Table 1). Initially, in 1966, all spawning areas had between 38 and 51% surface fines. By 1974, major decreases in areas covered by surface fines were evident in all spawning areas, and the areas were equivalent to 62% of those measured in 1966. From 1974 to 1981, the rate of decrease slowed, and surface fine sediments were further reduced by 18% in the five spawning areas. Since 1981, we have measured increases in surface fine sediment of 32.9% (Upper Stolle), 85.1% (Lower Stolle), 5.5% (Poverty Flat), 83.8% (Krassel), and 22.2% (Glory Hole).

The percentage of the spawning area surface occupied by fine sediment and gravel varied temporally (1966–1985); fine sediment decreased (Figure 3), and gravel generally increased. From 1966 to 1985, there was a significant increase in the percentage of surface gravel ($P < 0.01$) in 37 of 50 spawning area transects. The magnitude of increase was similar to that observed for the decrease of surface fines, and downstream areas exhibited a stronger response over time. Between 1967 and 1985, gravel increased by 28.0, 33.0, 140.2, 33.7, and 113.1% in the Upper Stolle, Lower Stolle, Poverty Flat, Krassel, and Glory Hole sites, respectively.

We measured the lowest percentage of gravel in spawning areas during 1967 because there was an increased delivery of fine sediment to the channel in the South Fork that covered spawning areas with sand; the percent spawning surface covered by gravels averaged 39% for the five spawning areas. From 1967 to 1974, the gravel component increased by an average of 30% (Figure 3) because fine sediments were transported out of the system, and thus existing gravel beds were exposed. From 1975 to 1985, the percent gravel increased by only 5% overall, although significant increases were observed at the Upper Stolle site (30%). The curve of the time-trend model for percent gravel (Table 1) was similar to that for percent fines; a negative coefficient b resulted from increased gravel composition relative to the other substrate types.

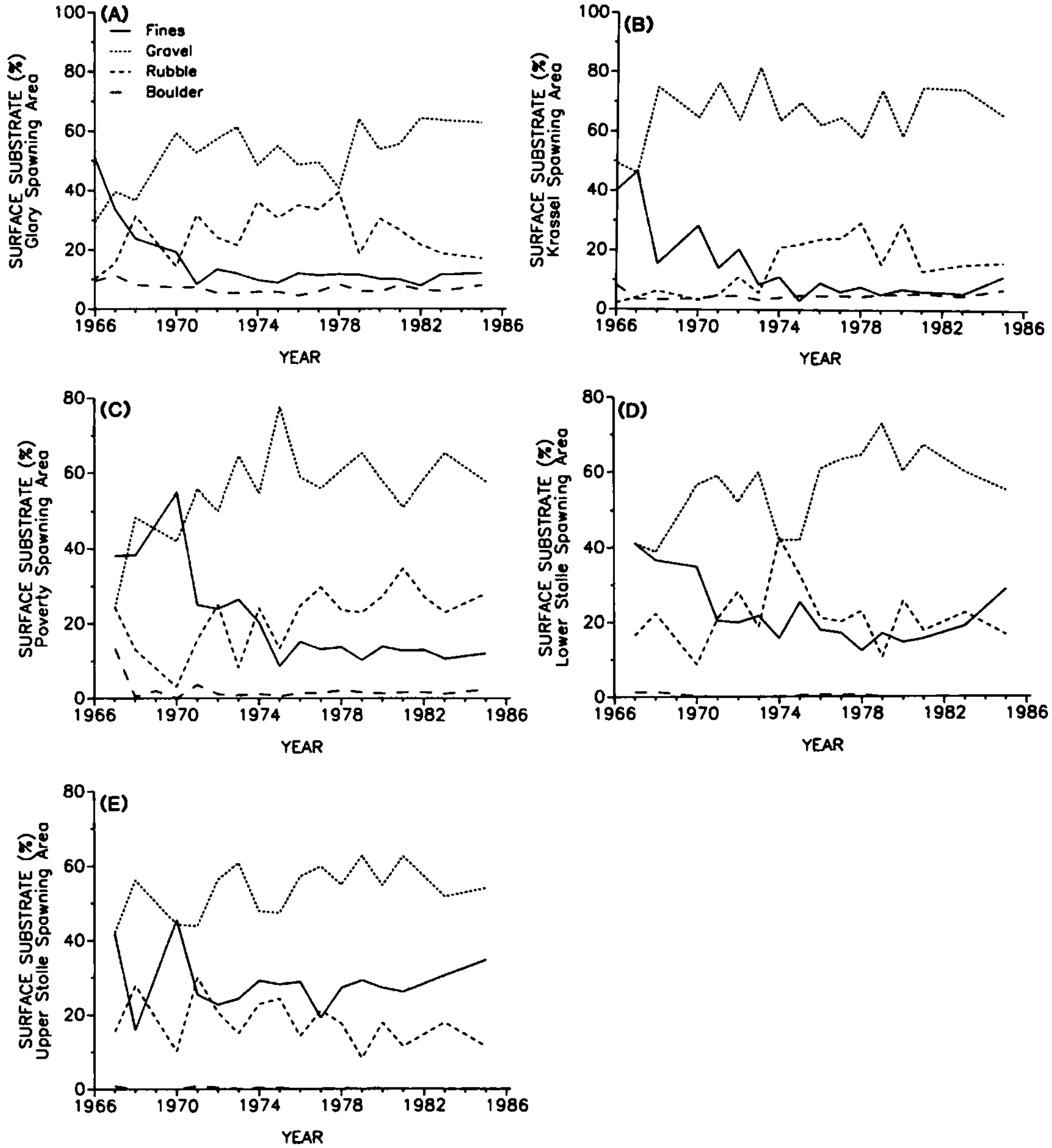

FIGURE 2.—Temporal trends in the size composition of surface sediments in spawning areas of the South Fork Salmon River, Idaho, during 1966–1985: (A) Glory Hole and (B) Krassel; and during 1967–1985: (C) Poverty Flat, (D) Lower Stolle, and (E) Upper Stolle. Note that the scale on the vertical axis differs among panels.

However, this model is not quite a mirror image of the model for surface fines because there was greater deviation of actual values from the fitted model. Coefficient *a* in the gravel model can be interpreted as an estimate of percent gravel on the channel surface at equilbrium.

The percentage of area occupied by rubble in spawning areas increased by 11.6%, whereas the percentage of boulders, which occupy less than 1% of the surface in South Fork spawning areas, showed no significant trends over time. When fine sediments were removed from the spawning riffles, the predominant underlayer was gravel and, to a lesser degree, rubble. Boulders are not an important component of chinook salmon spawning habitat, whereas rubble is critical for formation and stability of the egg pocket during high water or ice flows. In the egg pockets that we examined

TABLE 1.—Coefficients of the fitted models $Y = a + b/X$ for surface and subsurface fine sediment (<4.75 mm) and surface gravel (4.75–76.0 mm) in spawning areas of chinook salmon in the South Fork Salmon River, Idaho. Y = percent fines; X = time in years.

Site	Fines model			Gravel model		
	a	*b*	R^2	*a*	*b*	R^2
			Surface			
Upper Stolle	26.25	15.85	0.07	57.39	−27.91	0.25
Lower Stolle	14.06	59.06	0.67	63.15	−52.16	0.39
Poverty Flat	9.86	79.23	0.54	65.95	−75.76	0.61
Krassel	6.23	43.34	0.67	70.41	−22.81	0.32
Glory Hole	7.07	45.65	0.95	58.22	−32.26	0.54
Combined	13.75	37.41	0.76	61.16	−26.81	0.66
			Subsurface			
Upper Stolle	17.41	19.56	0.38			
Glory Hole	28.90	3.45	0.09			
Poverty Flat	28.23	13.20	0.16			
Combined	26.51	14.36	0.20			

visually in 1972–1973, chinook salmon primarily chose rubble to form the base of the egg pocket.

In contrast to the spawning areas, which predominantly had gravel and rubble surfaces, rearing areas were composed primarily of rubble (35%) and boulders (25%). Juvenile chinook salmon rear throughout the South Fork from the upstream Stolle Meadows sites down to the river's mouth. Overall, the percentage of fines on the surface of rearing areas of the South Fork decreased by 73.5% from 1967 to 1974 (Figure 4). It appears that rearing areas, like spawning areas, experienced minor decreases in fine sediments after 1974. Only 6 years of data were available for rearing areas, so a complete interpretation of substrate composition trends was not possible. However, the data suggest that, unlike the spawning areas, when the amount of fines in rearing areas was reduced, mainly rubble and boulders were exposed. Rearing areas of the South Fork Salmon River did not exhibit the dramatic increases of fines on the channel surface that accompanied the accelerated watershed erosion, as occurred in the lower gradient spawning areas. Initial fine sediment levels in 1967 for the 235 transects averaged 32% of the channel surface area. Our data indicate that most of the fine sediment from accelerated erosion was transported through the higher-gradient rearing areas and deposited in spawning areas and pools.

Channel Subsurface Materials

Streambed core data from the Upper Stolle, Poverty Flat, and Glory Hole spawning areas were used to evaluate time trends. (Data sets from the

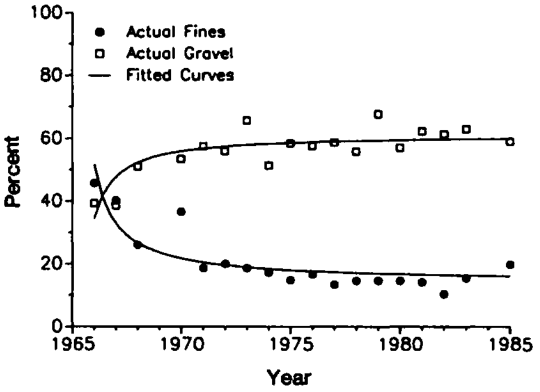

FIGURE 3.—Temporal trends in mean percentages of surface fine sediment (<4.75 mm in diameter) and gravel (4.75–76.0 mm) for five spawning areas of chinook salmon in the South Fork Salmon River, Idaho, 1966–1985.

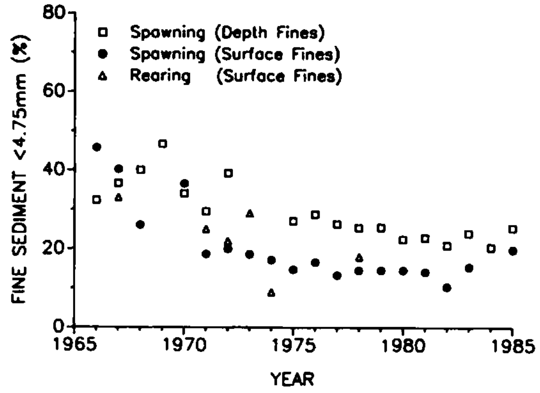

FIGURE 4.—Temporal trends in mean percentages of fines (<4.75 mm in diameter) in surface and subsurface (depth) sediments in spawning areas and surface sediments in rearing areas for chinook salmon in the South Fork Salmon River, Idaho, 1967–1985.

TABLE 2.—Percent volume of fine sediment (<4.75 mm) in subsurface in spawning areas of chinook salmon in the South Fork Salmon River, Idaho, 1966–1985.

	Site				
Year	Upper Stolle	Glory Hole	Poverty Flat	Krassel	Mean of all sites
1966	28	32	32	37	32
1967	43	28	40	35	36
1968			40		40
1969			46		46
1970			34		34
1971	26		33		29
1972	33	32	43	49	39
1975	16	33	31		27
1976	21	33	32		29
1977	18	31	29		26
1978	18	30	29		26
1979	19	29	29		26
1980	16	26	25		22
1981	18	27	24		23
1982	14	27	21		21
1983	19	31	21		24
1984	16	25	19		20
1985	19	31	26		25

Krassel and Lower Stolle sites were incomplete.) Overall, each site exhibited a significant ($P < 0.05$) decrease in the percentage of fines over the 20-year period (Table 1). The downward trend appeared to stabilize and approach a condition of equilibrium. This was similar to the trend observed for surface fines (Table 2). Between 1966 and 1975, subsurface fine sediments decreased by 16.1% for the three spawning areas. A further 15.8% reduction in subsurface fines was observed between 1975 and 1981. This trend reversed between 1981 and 1985 when we measured a 10.9% increase in subsurface fine sediment in South Fork spawning areas.

From 1966 to 1985, the proportion of subsurface fine sediment generally followed the same downward trend as that for surface sediments. Therefore, we suspected a possible relationship between surface and subsurface fine sediment levels. We used least-squares linear regression and found a significant but weak relationship between surface and subsurface fines for the Upper Stolle Meadow and Poverty Flat sites (Table 3).

Discussion

The data collected over a 20-year period demonstrated that both surface and subsurface channel substrates of the South Fork Salmon River responded dramatically to changes in watershed condition. There have been several studies of trends in channel morphology in response to extreme changes in sediment transport, but there has been little documentation of the response of salmonid habitat to such events. Cederholm and Salo (1979) stated that fine sediment levels in the Clearwater River, Washington, were directly correlated to the density of logging roads. Lisle (1982) reported that floods in 1964 caused streams in northern California to have a reduced pool–riffle frequency, to widen by as much as 100%, and to aggrade by up to 4 m. Beschta (1983, 1984) found that in the Upper Kowai basin, New Zealand, a 150-year storm in 1951 delivered sediments to the channel that remained 30 years later.

TABLE 3.—Coefficients for least-squares linear regression[a] of surface and subsurface fine sediments against time for spawning areas of chinook salmon in the South Fork Salmon River, Idaho, 1966–1985.

Site	a	b	R^2
Upper Stolle	3.84	0.64	0.21
Glory Hole	29.70	0.02	0.01
Poverty Flat	23.87	0.32	0.42
Combined	20.82	0.37	0.44

[a] $Y = a + b/X$; Y = percent fines; X = time in years.

As the sediment delivered to the South Fork increased to a peak of 72,000 m^3 in 1964–1965, aggradation occurred in low-gradient spawning areas and pools and, to a lesser degree, in rearing habitats. Initially, there was insufficient hydraulic energy to transport the increased sediment load downstream, and the sediment transport capability of the South Fork was quickly overwhelmed. Arnold and Lundeen (1968) estimated that the river is able to transport 27,000 m^3 of sediment annually; as much as 45,000 m^3 accumulated in the river during the 1964–1966 period. As the sediment delivered to the river declined after 1965 because of a logging moratorium and watershed rehabilitation, the hydraulic energy was adequate to export fine sediment from the system (Megahan et al. 1980). Even though river flows from 1966 to 1970 were not particularly high (mean monthly maximum, 89 m^3/s), there was considerable reduction of fine sediment. High river flows in 1971, 1972, and 1974 (mean monthly maximum, 152 m^3/s) continued to flush sediment from the channel system. From 1975 to 1983, during both extreme low and high flows, the South Fork reached an equilibrium with respect to sediment transport; both surface and subsurface sediment levels decreased by only 4.0 and 11.4%, respectively.

Increases of fine sediments in spawning areas of 24% (surface) and 28% (subsurface) were observed in 1985. This trend has several explanations. Rice

Creek, a tributary 2.4 km upstream from the Stolle Meadows spawning areas, was affected by a mud flow from a summer storm in 1984 that deposited 1,000–7,000 m^3 of sediment in the river. This event may explain the observed increase of 13.7% in surface fine sediment between 1983 and 1985 at the Stolle Meadows spawning sites.

Another explanation for the observed increases involves the existing road system. Although the sediment supply to the South Fork from road surface erosion was drastically reduced after the 1965 logging moratorium (Figure 1), significant amounts of sediment still enter the river. The main log-hauling road was built adjacent to, and in many places constricts, the river. It is estimated that the main road contributes 1,268 tonnes (roughly 880 m^3) of sediment per year to the river; this figure represents about 30% of the management-induced sediment delivery to the upper South Fork, and provides the single greatest opportunity for improvement (R. Edwards, Payette National Forest, personal communication). Sediment from this and similar sources may explain the lack of further recovery of salmonid habitat.

A third explanation of the increases is that elimination of the remaining fine sediments in the channel was not possible under the extant hydrologic regimes during the study period. From 1950 to 1966, the period of accelerated sediment delivery, the extreme sediment loads could have decreased channel roughness, increased channel surface uniformity (i.e., filled in pools) and thereby increased water velocity, which in turn increased the capacity of a unit of water to transport bedload materials. Lisle (1982) found that in streams in northern California affected by the same 1964 flood, bed load became smaller in size, pools became shallower with higher velocity, and moderate discharges transported sediment more effectively. Water laden with sediment has a more erosive effect on the channel and is capable of carrying higher amounts of bed-load sediment per unit volume than clear water (Jackson and Beschta 1984). After this increased transport capacity has reduced the levels of excess sediment, there may be a corresponding decrease in transport efficiency.

If the South Fork indeed has equilibrated with present hydrologic and watershed conditions, further reductions in the levels of surface and subsurface fine sediment will be contingent on further watershed rehabilitation. The river may be reacting to a watershed that still delivers fine sediments to the channel at a rate above prelogging levels. Sediment stored in tributaries and on existing road fills, cuts, and prisms will continue to be transported and will cause a large recovery lag. Therefore, if the South Fork is to recover, land managers must continually implement those practices that minimize both existing and potential increases in sedimentation. Grant et al. (1984) stated that onsite effects of timber management are clearly linked in space and time with specific activities. Our data, based on 20 years of time-trend data in spawning areas, indicate that under present management (little timber harvest) surface sediment in spawning areas may actually increase by 5% by the year 2016.

Our data show that, initially, the South Fork Salmon River was unable to export the increased amounts of fine sediment delivered to the channel. However, when deposits were reduced, excess surface sediments were removed more quickly than subsurface sediments. Subsurface fine sediment (percent volume) remained 10–20% higher (by area) than surface fine sediment through the period of rapid recovery (1970–1975). During the last 10 years, both sediment levels have reached an equilibrium of approximately 15% for surface and 30% for subsurface. Such a relationship may be expected for a river incapable of transporting high amounts of sediment because less energy is required to remove sand from the bed surface than to remove sand mixed with gravel, rubble, and boulders within the bed. Beschta and Jackson (1979) found that flushing of fines will not occur in the interstices of the substrate unless the armor layer moves.

Channel surface fines decreased by 31% between 1966 and 1985, but there was a 21% decrease in subsurface fine sediments. The weak relationship between temporal changes in surface and subsurface sediment composition may be related to an annual hydrograph that results in infrequent movement of the bed load. In a coastal Alaskan stream receiving 167 cm of rainfall annually, scouring of coarse material was triggered only by high flows with a periodicity greater than 5 years (Sidle 1988). Similarly, the magnitude of storm flow determined the transport rate of bed load in an Alaskan stream (Estep and Beschta 1985). Schumm (1971) found a strong interdependency between flow conditions, sediment transport, and associated streambed composition. Subsurface sediment in the South Fork may not be greatly changed unless there is a flow event of great enough magnitude to scour the streambed and disrupt armor layers.

Trends in sediment composition indicate that habitat conditions for chinook salmon in the South Fork Salmon River have improved over the last 20 years. However, further watershed rehabilitation must take place before the river can return to prelogging conditions. Our results also indicate that rivers react dramatically to changes in watershed conditions. Rivers are capable of returning to prelogging conditions if watershed stress is relieved or of remaining degraded if land uses continue to generate high levels of sediment for an extended time.

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Abstract

Research, monitoring and evaluation of the Nez Perce Tribe's Johnson Creek Artificial Propagation Enhancement project was completed for juvenile (2015-2016) and adult (2016) summer Chinook Salmon (*Oncorhynchus tshawytscha*). This marked the eighteenth year of operation for the program. Operation of a picket style weir and intensive multiple-pass spawning ground surveys were used to monitor and evaluate adults, while operation of rotary screw traps on Johnson Creek and on the lower Secesh River were used to trap, mark, and monitor migrating juveniles. The 2016 adult return to Johnson Creek consisted of an estimated 731 Chinook, which was slightly higher than that of the Secesh River reference population (547). Natural origin spawner abundance for the East Fork population was 569 compared to 475 for the Secesh population. Most Chinook returned as age-four (2-salt). The estimated total migration of brood year 2014 natural origin juvenile Chinook salmon, as calculated from daily trapping at the Johnson Creek rotary screw trap, was 310,461. The natural origin population estimate at the lower Secesh was 559,428. Most juveniles migrated at the fry-parr life history stage. An estimated 115,662 BY14 supplementation smolt were released into Johnson Creek over a three-day period in March, 2016. Survival of natural origin Johnson Creek juveniles to Lower Granite Dam ranged between 12% and 23% (parr and presmolt, respectively), while the range of survival of natural origin Secesh juveniles to Lower Granite Dam was between 11% and 55% (parr and smolt, respectively). Survival for BY14 Johnson Creek supplementation smolt to Lower Granite was estimated to be 53%. Key recommendations include collection of tissue from all Chinook that are outplanted into the East Fork South Fork Salmon River.

Introduction

The Johnson Creek Artificial Propagation and Enhancement (JCAPE) program is a small-scale supplementation initiative that was initiated in 1998. The primary goal of the program was to prevent the extirpation of a weak but recoverable spawning aggregate of ESA-listed summer Chinook salmon (*Oncorhynchus tshawytscha*) in Johnson Creek, ID, USA, and jump start its recovery through artificial propagation. Objectives specific to monitoring and evaluation efforts are provided in Vogel et al. (2005), as are the underlying assumptions and associated hypothesis. The program consists of a monitoring and evaluation (M&E) component and an operations and maintenance (O&M) component, both of which are scheduled to run for at least five generations.

The O&M component utilizes portable, temporary, low capital facilities to trap returning adult salmon. All supplementation-origin adults are allowed to spawn naturally while a portion of the natural-origin return are removed for brood stock (all others are allowed to spawn naturally). Egg incubation and juvenile rearing occurs in existing McCall Fish Hatchery facilities. Juveniles are reared to the smolt life stage, after which they are direct released back into Johnson Creek.

The M&E component quantifies 38 regionally standardized performance measures (e.g., Beasley et al. 2008) to evaluate the status and trends of natural- and hatchery-origin Johnson Creek spring/summer Chinook. Data collection occurs almost year-round and covers both adult and juvenile life stages. Monitoring includes multiple pass extensive area spawning ground surveys in Johnson Creek, the East Fork South Fork Salmon River, and the Secesh River, weir operation in Johnson Creek, mark-recapture abundance estimates, juvenile abundance estimates, and monitoring of juvenile emigration timing and survival.

The primary study area (Figure 1) consists of Johnson Creek, the portion of the East Fork South Fork Salmon River upstream of Yellow Pine, ID, and the Secesh River (and its tributaries). It is located in west-central Idaho, USA within the South Fork Salmon River (SFSR) subbasin. Johnson Creek is the primary spawning aggregate and production area for the East Fork South Fork Salmon River Chinook salmon population (South Fork Salmon River MPG in the Snake River ESU), and represents the component of the population for which the majority of status and trend monitoring occurs. The Secesh River, an unsupplemented population within the MPG, is located to the northwest of Johnson Creek and shares similar hydrographical features. The Secesh is used as a reference stream to aid in program performance evaluation.

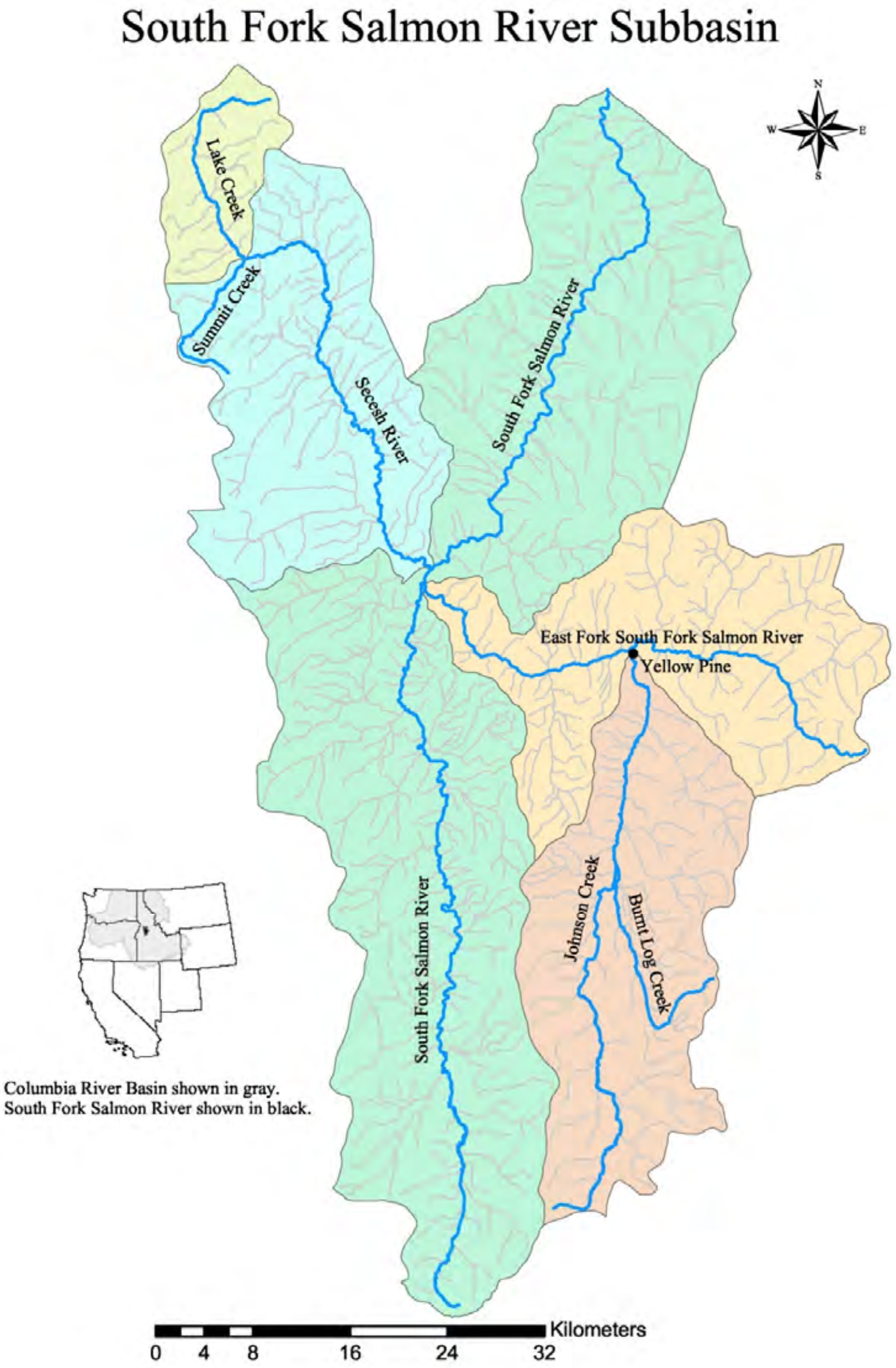

Figure 1. South Fork Salmon River subbasin including the South Fork Salmon River mainstem, Secesh River, East Fork South Fork Salmon River, and Johnson Creek.

Anadromous species in the study area consist of summer Chinook salmon, summer steelhead *O. mykiss*, and the recently reintroduced Pacific Lamprey *Entosphenus tridentatus*. Resident rainbow trout *O. mykiss*, cutthroat trout *O. clarki,* bull trout *Salvelinus confluentus*, brook trout *S. fontinalis*, mountain whitefish *Prosopium williamsoni*, longnose dace *Rhinichthys cataractae*, and sculpin *Cottus* spp. are among the numerous non-anadromous species occurring in the study area. The majority of Chinook salmon spawning habitat in Johnson Creek is located between Deadhorse Rapids (RKM 9.75) and the confluence of Moose Creek (RKM 15.2). The quantity and quality of Chinook spawning habitat in the East Fork South Fork Salmon River is lower than that found in Johnson Creek, which is attributed in part to historic mining in headwater reaches.

This report presents status and trend M&E results for adult and juvenile Chinook salmon from the East Fork South Fork Salmon River spring/summer Chinook population (SFEFS), and from the Secesh River population (SFSEC). The period of interest for juveniles is brood year (BY) 2014, which includes emigrants sampled in 2015-2016. Results from 2016 spawning ground surveys in the SFEFS, and the SFSEC provides the basis for within- and between-population comparisons. Trend data for the SFEFS, which has been collected since the inception of the project (1998), provides a temporal context.

Methods

Methodology used relative to data collection and data analysis are described in the M&E Plan (Vogel et al. 2005), in Kinzer et al. (2015), and in the appendices sections contained within this report. Sections are organized by *Field Operations* and by *Performance Measures*.

Field Operations

The JCAPE project used several one-ton 4x4 trucks equipped with 500-gallon aerated tanks to transport juvenile hatchery-supplementation Chinook smolt from their rearing location at the McCall Fish Hatchery to their release location at river kilometer (RKM) 13.8 in Johnson Creek. All juvenile hatchery fish received tags (coded-wire tags (CWT) and passive integrated transponder (PIT) tags) prior to their release to enable origin-based differentiation and metric evaluation. The project relied upon a removable picket-style weir (located 8.2 kilometers upstream of the confluence of Johnson Creek and the East Fork South Fork Salmon River at N 44.901166° W 115.488842°) to collect live adults and associated data. We used five-foot rotary screw traps in Johnson Creek (located 6.2 kilometers above the confluence of Johnson Creek at N44.91764 º W115.48336 º) and the lower Secesh River (located 7.4 kilometers upstream of the confluence of the Secesh River with the South Fork Salmon River at N45.05952° W115.756908°) to collect juvenile data. Multiple-pass spawning ground surveys were conducted in Johnson Creek, the East Fork South Fork Salmon River, and the Secesh River (and tributaries) during the months of August and September, 2016. Detailed descriptions of field methods are in Vogel et al. (2005), previous annual reports (e.g., Rabe and Nelson 2016), or in Appendix 2.

Performance Measures

A suite of quantifiable 'Performance Measures', including those related to Abundance, Survival-Productivity, Distribution, Genetics, and Life History, are used to provide reliable indicators of status and change for the Johnson Creek Chinook salmon population. The core activities used to quantify performance measures include:

- Temporary weir operation,
- Redd counts (spawning ground surveys)
- Harvest monitoring (creel surveys)
- Juvenile emigration trapping using rotary screw trap
- Fish marking (natural and hatchery groups) with PIT, CWT, and/or VIE tags
- Genetic analysis

Abundance

Adult abundance was estimated in three ways: (1) to the tributary (a.k.a. *tributary escapement*) (2) as *spawner abundance* (separated by natural origin and hatchery origin) and (3) as an *index of spawner abundance* (a.k.a. redd surveys). Our Johnson Creek *tributary escapement* estimate incorporated two independent estimates; one above the Johnson Creek weir and one below the weir. We used the adjusted Petersen estimator (Chapman 1951; Seber 1982), a mark-recapture model (with variance), to estimate above-weir Chinook escapement. Methods described in Chasco et al. (2014) were used to estimate escapement below the weir, in the East Fork South Fork spawning aggregate, and in the Secesh (SFSEC). The SFEFS estimates were summed to provide a population-based *total escapement* estimate (refer to Appendix 2 for further discussion). Methods discussed in Kinzer et al. (2015) were used for Secesh computations.

The *spawner abundance* performance measure was estimated for natural and hatchery origin spawners on the spawning ground (e.g., Beasley et al. 2008). The *index of spawner abundance*, or redd counts, were a direct count with no expansion. Methods used in the collection of spawning ground data are provided in Vogel et al. (2005) and Appendix 2. Survey frequency in extended reaches was three passes while frequency in the Johnson Creek index area was five passes. Methods discussed in Kinzer et al. (2015) were used for Secesh computations.

Juvenile emigrant abundance was estimated in two ways; 1) as the abundance of juvenile emigrants (by life stage) leaving the tributary, and 2) as the abundance of smolt (*equivalents*) reaching Lower Granite Dam from the tributary. Methods used in calculations are described in section 1.d.1 in Vogel et al. (2005) and in Appendix 2. Methods used to calculate *hatchery production abundance* are in Appendix 2.

Survival/Productivity

Juvenile survival to Lower Granite Dam (LGD) was estimated using methods presented in Section 1.d.3 in Vogel et al. (2005) and is described in Appendix 2. Survival for BY13 juveniles was estimated by life stage (parr, presmolt, smolt) and as an overall 'smolt' value (a.k.a., *smolt equivalents*) at LGD.

The *smolt to adult return rate* (SAR) performance measure represents the total number of adult returns from a given brood year returning to a point (stream mouth, weir) divided by the number of smolts that left this point 5 years prior (e.g., Beasley et al. 2008). The measure was calculated using two sets of interrogation locations; tributary to tributary and Lower Granite Dam to tributary. The derivations were abundance-based. The tributary to tributary SAR was calculated by dividing the sum of the three cohorts of natural [and hatchery] origin adults (includes jacks) that returned to the tributary by the estimated number of natural-origin [and the known number of hatchery-origin] juveniles that left the tributary 5 years prior. The Lower Granite Dam to tributary ratio was calculated similarly, however the denominator was the estimated number of smolts at Lower Granite Dam (a.k.a. 'smolt equivalents' when referring to natural origin Chinook that emigrated at different life history stages; see also Appendix 2). Methods discussed in Kinzer et al. (2015) were used for Secesh computations.

Methods to calculate *juvenile recruits per spawner* were similar to those in Vogel et al. (2005) describing *smolts per redd* productivity estimations (1.d.5) and are discussed in greater detail in Appendix 2. As discussed in Beasley et al. (2008), *recruit per spawner* estimates, or juvenile abundance (can be various life stages or locations) per redd or female, is used to index population productivity, since it represents the quantity of juvenile fish resulting from a pair of spawners (juvenile abundance divided by spawner abundance) or female. Methods discussed in Kinzer et al. (2015) were used for Secesh computations.

The *progeny per parent ratio* (P:P) is analogous to the *juvenile recruits per spawner* ratio, in that it provides an index of productivity, but at the adult level. Methods used in the calculation of the P:P performance measure are provided in Vogel et al. (2005) and are discussed in greater detail in Appendix 2. Methods discussed in Kinzer et al. (2015) were used for Secesh computations.

Distribution

We used geo-referenced locations of redds to portray *adult spawner spatial distribution* in the SFEFS and SFSEC populations. We compared geo-referenced locations of hatchery and natural female carcasses to further evaluate differences in *spawner spatial distribution*, and specifically if hatchery spawners were aggregated at or near the juvenile release location in Johnson Creek (e.g., Vogel et al. 2005; 1c).

The *stray rate* in the population was calculated from 1) total known-origin carcasses, and 2) origin of fish released above weir. The measure represented an estimate of the percent (and number) of hatchery-origin Chinook on the spawning grounds (also referred to as percent hatchery origin on spawning grounds, or 'pHOS'). The estimate was adjusted for unmarked carcasses above and below the weir.

Genetics

An in-depth discussion of methodology associated with genetic analysis (e.g., *reproductive success*) is provided in Vogel et al. (2005), in Hess et al. (2012), and in Appendix 2. Genetic tissue was collected from all adults captured at the Johnson Creek weir (which includes all brood stock fish) and from all unmarked carcasses collected in 2014. The genetic tissue was stored dry on uniquely labeled sheets of Whatman paper and/or envelopes. Genetic sample analysis was completed by the Columbia River Inter-Tribal Fisheries Commission (CRITFC).

Tissue samples were assayed for variation at 12 microsatellite loci. The resulting genotypes were used to assign individuals to adults sampled in the previous generation. Assignments were conducted using both exclusionary criteria (Taggert 2007) and probabilistic approaches that explore the likelihood of each possible parentage assignment and establish statistical criteria for accepting the true parent (Marshall et al. 1998). These analyses were conducted to evaluate the relative reproductive success of hatchery-reared supplementation Chinook.

Life History Characteristics

The a*ge class structure, age at return, age at emigration, size at return, age, size, and condition at emigration, percent females (adults), adult run timing,* and *juvenile emigration timing* life history performance measures are used by the JCAPE M&E program to evaluate similarities and differences of natural and hatchery/supplementation Chinook traits which affect growth, reproduction, and survivorship. Where possible, we provide data from the Secesh spring/summer Chinook population (SFSEC) to provide comparisons and contrasts between a hatchery-influenced population and one that does not receive hatchery influence. References to methods used to collect, analyze, and report data are available in Vogel et al. (2005) and are discussed in Appendix 2. Methods discussed in Kinzer et al. (2015) were used for Secesh computations.

Results

Field Operations

The JCAPE brood year 2014 hatchery origin supplementation smolts were released by Nez Perce Tribe personnel on March 28-30, 2016. The release consisted of a total of 115,662 fish, at 22.3 fish per pound (5.12 inches (130 mm) fork length). Smolt were successfully transported to Johnson Creek and released near Wapiti Ranch with negligible mortality.

The Johnson Creek weir was made 'fish tight' on June 15, 2016 (installation). The first Chinook was captured on June 18, 2016 and the last on September 14, 2016. Weir removal initiated on September 15, 2016. Over the period of operation, a total of 701 Chinook salmon were trapped; 624 were released above the weir for natural spawning, 67 were removed for brood stock, and 10, which were adipose-clipped strays, were removed from the spawning aggregate (Table 1). All fish released above the weir for natural spawning received a punch in the left opercle plate. Over the course of the trapping season, the weir was estimated to be 100% efficient, as all carcasses collected above the weir possessed a left opercle punch (Figure 2; refer to Appendix 2 for methods).

Table 1. Disposition of natural (NAT), supplementation (SUP), and hatchery-origin stray (Stray) Chinook trapped at the Johnson Creek picket weir in 2016.

Location	NAT	SUP	Stray	Total
Captured at weir, released and remained upstream	442	182	0	624
Brood stock spawned	57	0	0	57
Brood stock culled	0	0	0	0
Brood stock mortalities	10	0	0	10
Euthanized at weir	0	0	10	10
Trucked to South Fork Salmon River	0	0	0	0
Weir mortalities	0	0	0	0
Total trapped at Johnson Creek weir	509	182	10	701

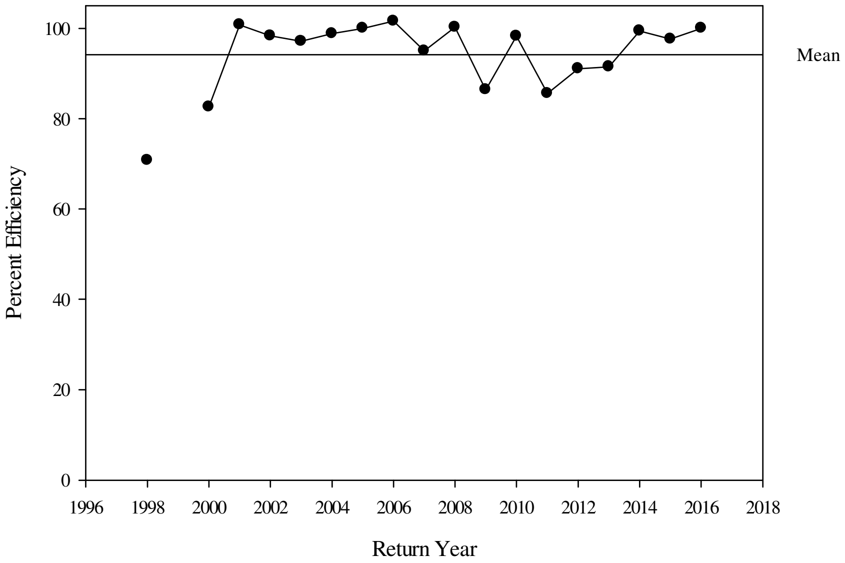

Figure 2. Johnson Creek adult picket weir efficiency estimates for spring/summer Chinook returning in 1998; 2000-2016.

The Johnson Creek rotary screw trap was made operational on February 27, 2015. It remained operational approximately 244 days in 2015 (14 days were defined as non-operational), and 122 days in 2016 (26 days were defined as non-operational) with the primary objective of capturing BY14 juvenile Chinook (fry/parr and presmolt life stages in 2015 and smolt stage in 2016). Average efficiency over the period of operation was estimated to be 28%. Efficiency was inversely related to discharge. The trap was expressly not fished during spring releases of hatchery fish and/or during periods of high water (runoff). Other events contributing to non-operational periods were freezing temperatures and heavy debris loads in the trap.

The lower Secesh rotary screw trap was made operational February 26, 2015. Primary objectives were to capture natural origin summer steelhead (*O. Mykiss*) and brood year 2014 spring/summer Chinook. The lower Secesh rotary screw trap remained operational for 263 days in 2015 (it was partially, or non-operational for 8 days in 2015). The lower Secesh trap was reinstalled on March 1, 2016 and made operational for BY14 for 122 days. During this 122 day period, the trap fully operated for 107 days. The partial periods of operation consisted of days when the fish technicians found the cone not spinning when they arrived at the trap site. The cone was not spinning due to icing/freezing conditions, debris jams and low water flows.

Nez Perce Tribe personnel also assisted IDFG personnel with the transport and outplant of adult Chinook Salmon from the South Fork Salmon River to the East Fork South Fork Salmon River. A total of 536 'segregated production[1]' Chinook (285 females and 251 males) were released into Meadow Creek (an East Fork South Fork Salmon tributary) on three separate days in 2016; August 29, 31, and September 6. In the future, we recommend that tissue be collected from all fish destined for release in the East Fork South Fork, so as to enable pedigree analysis.

Multiple-pass spawning ground surveys were completed in Johnson Creek (and tributaries), the East Fork South Fork Salmon River (and tributaries), and in the Secesh River (and tributaries) in August and September, 2016. Surveys initiated on August 1 and concluded September 15, 2016. A total of four surveyors completed surveys on 49 km in the Johnson Creek drainage (see Appendix Table 1 and Appendix Table 2), 22.1 km in the East Fork South Fork Salmon drainage (see Appendix Table 3), and 53 km in the Secesh River drainage. Survey frequency in the Johnson Creek index area consisted of four passes, while the frequency in all other extensive area (i.e., non-index) transects consisted of three passes (see Appendix Table 34 - Appendix Table 42 for a description of transects surveyed in 2016).

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[1] For the purposes of this document, 'segregated production' refers to Lower Snake River Compensation Program Chinook that are raised with the primary intent of being harvested (e.g., IDFG et al. 2016). Segregated production stock are adipose-clipped to allow anglers to visually separate harvestable Chinook from wild, or non-target Chinook.

All BY14 hatchery origin Johnson Creek supplementation Chinook received a coded wire tag in July, 2015. The retention of the CWT was estimated to be 99% (Appendix Table 11). In October, 2015, 2,097 of the 115,662 smolt release group also received a PIT tag.

Performance Measures

Abundance

The 2016 estimated ***tributary escapement*** in Johnson Creek was 731 Chinook (refer to Appendix Table 12 for specific breakdown in Johnson Creek). Escapement into the East Fork South Fork Salmon River was estimated to be 118 Chinook (CI±23; CV=0.10), resulting in a population-based ***total escapement*** estimate of 849 Chinook in 2016 (Figure 3). The 2016 escapement estimate for the SFSEC population was 547 (C. Watry, personal communication, 5/10/2017).

After accounting for pre-spawn mortality and reductions of natural origin fish collected for brood stock, an estimated 453 Chinook comprised the Johnson Creek ***natural origin spawner abundance*** (NOSA); an additional 116 natural origin spawners were estimated in the East Fork South Fork aggregate, bringing the total ***NOSA*** estimate for the population to 569 (Figure 4). The NOSA for the SFSEC population was 475 (C. Watry, personal communication, 5/10/2017).

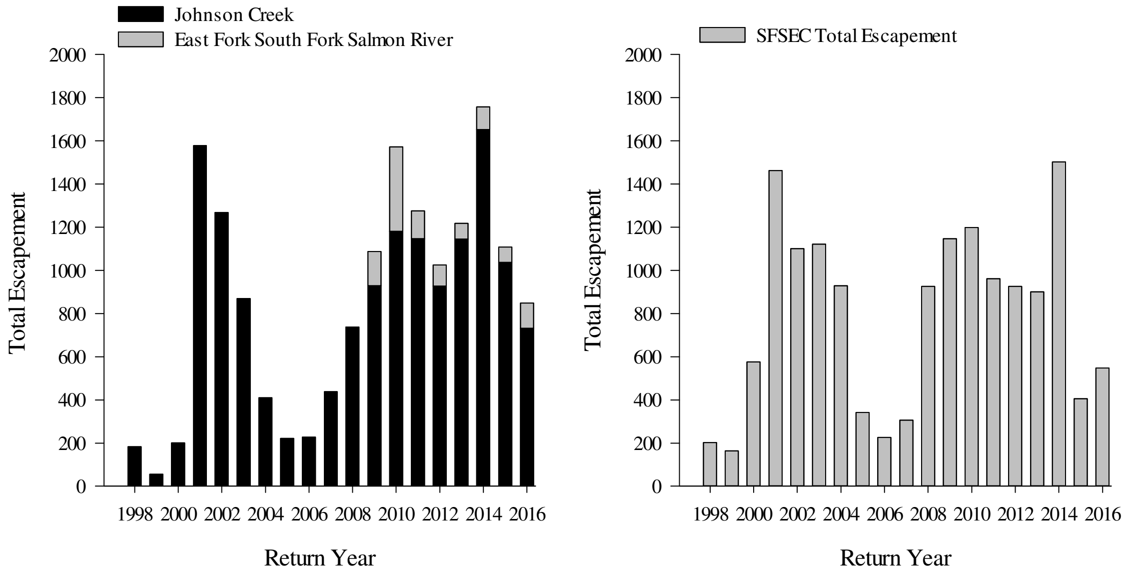


Figure 3. Estimated total escapement of spring/summer Chinook to the East Fork South Fork Salmon population (left) and Secesh (SFSEC) population (right; 1998-2016).

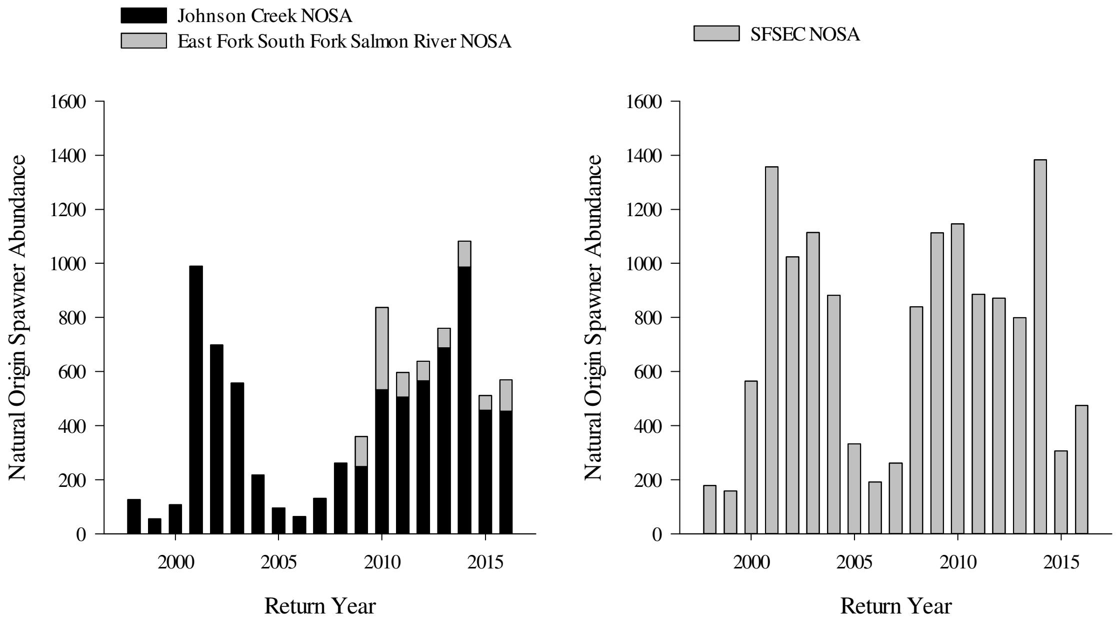


Figure 4. Estimated natural origin spawner abundance (NOSA) for spring/summer Chinook in the East Fork South Fork Salmon population (left) and Secesh (SFSEC) population (right; 1998-2016).

A total of 281 new redds were observed in the Johnson Creek drainage between August 4 and September 15 (refer to Appendix Table 1 and Appendix Table 2 for additional detail). There were 17 redds below the weir and 264 redds above the weir. There were 216 redds observed in the index area (comprising 77% of the total observed). Multiple-pass redd counts conducted on the East Fork South Fork Salmon River and associated tributaries yielded a total of 221 unique redds. Multiple-pass redd count surveys completed in the Secesh yielded a total of 283 redds.

The estimated abundance of brood year 2014 Johnson Creek natural origin juveniles at the tributary was 310,461 (Figure 5). An estimated 115,662 BY14 supplementation smolt were released into Johnson Creek over a three-day period in March, 2016. The 10-year geomean (brood years 2005-2014) for Johnson Creek was 117,168 natural juveniles (see Appendix Table 16 for additional information). There were an estimated 44,939 natural origin and 60,722 supplementation-origin 'smolt equivalents' at Lower Granite dam (refer also to Appendix Figure 1). There were an estimated 559,428 BY14 juvenile Chinook at the lower Secesh Trap (Table 2). Similar to Johnson Creek, the majority of juveniles were represented by the fry/parr life stage.

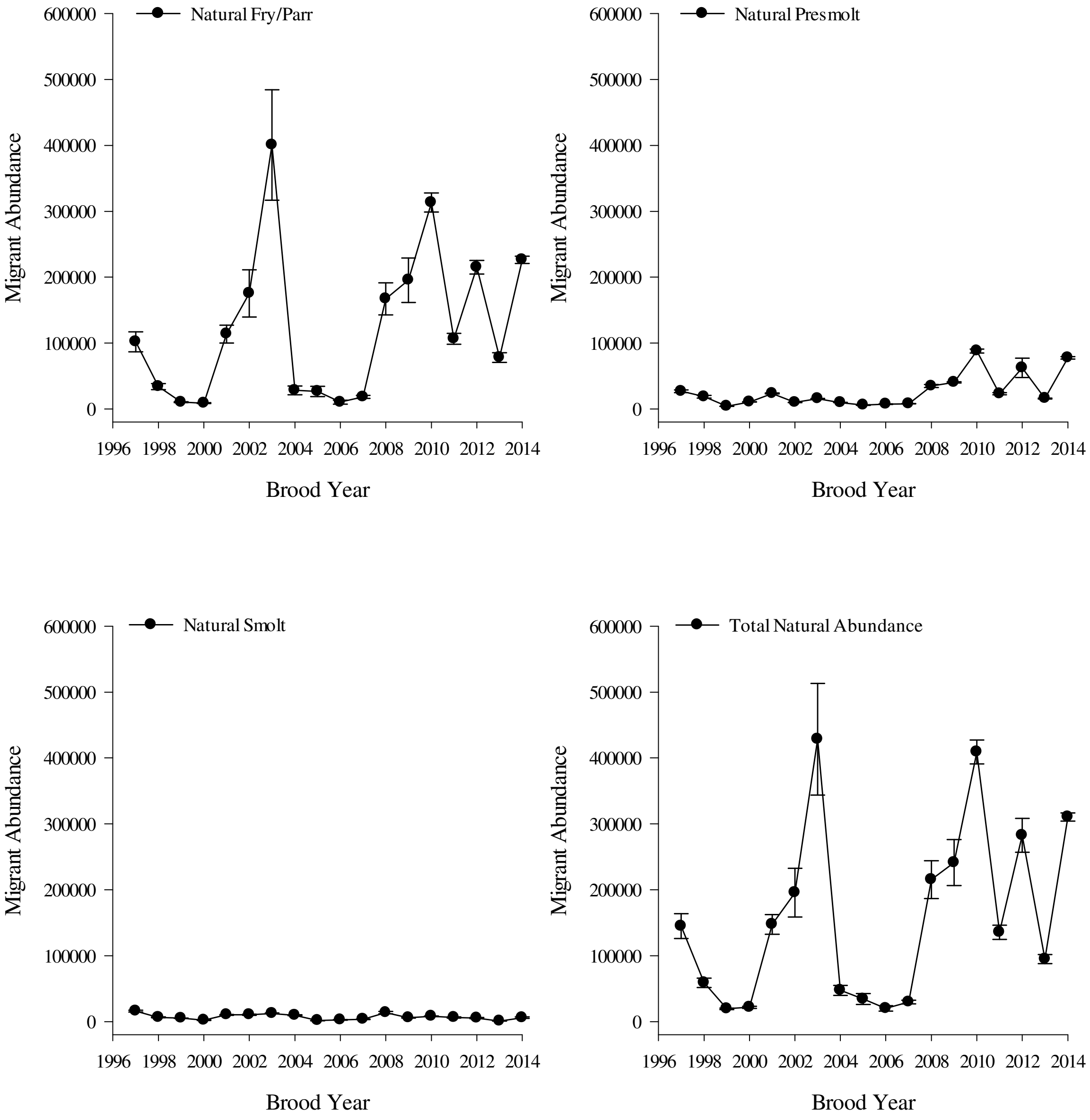


Figure 5. Natural origin juvenile abundance estimates and associated standard error for Johnson Creek fry/parr, presmolt, and smolt life history stages (Brood Years 1997-2014). Estimates were made from data collected at the Johnson Creek rotary screw trap.

Table 2. Lifestage-specific abundance estimates and associated standard errors (SE) for brood year 2014 natural-origin juvenile Chinook salmon captured at the lower Secesh rotary screw trap.

Brood Year	Parr	SE	Presmolt	SE	Smolt	SE	Total Natural	SE
2014	389,382	12,236	159,480	3,509	14,656	3,934	559,425	12,970

Survival/Productivity

Life stage-specific survival of natural and hatchery-origin Johnson Creek Chinook, from the tributary to Lower Granite Dam, is shown in Figure 6. Survival of brood year 2014 natural origin parr was 12% (SE<0.01), presmolt was 23% (SE=0.02), and smolt was 21% (SE=0.02). Hatchery origin supplementation smolt survival probability, from Johnson Creek to Lower Granite Dam, was 53% (SE=0.03; refer also to Appendix Table 17). See

Figure 7 for Lower Secesh survival estimates.

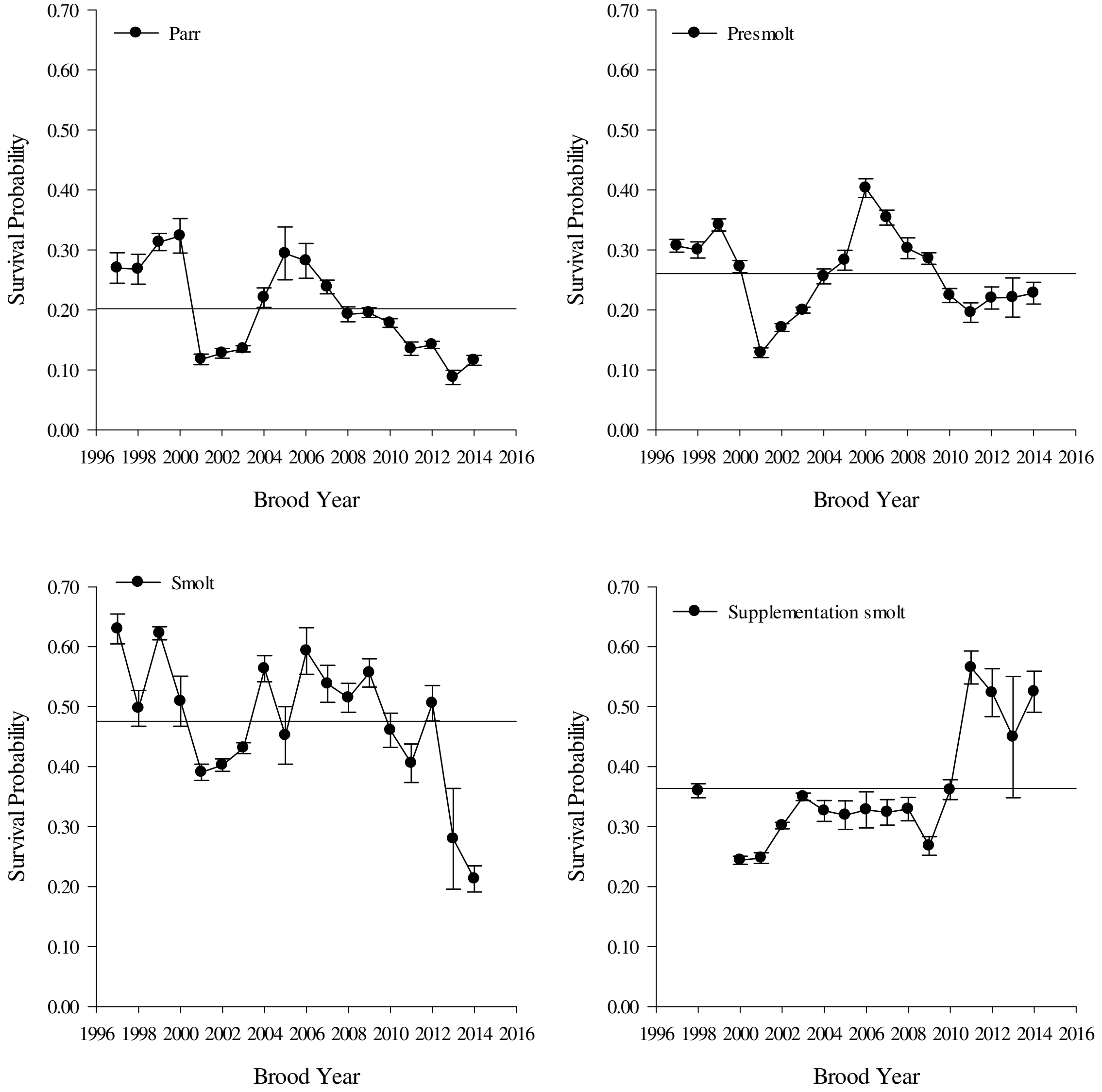


Figure 6. Life stage-specific survival (including standard error of the mean) of Johnson Creek juvenile summer Chinook from the tributary to Lower Granite Dam (Brood Years 1997-2014). The mean survival per life stage is represented by the horizontal line.

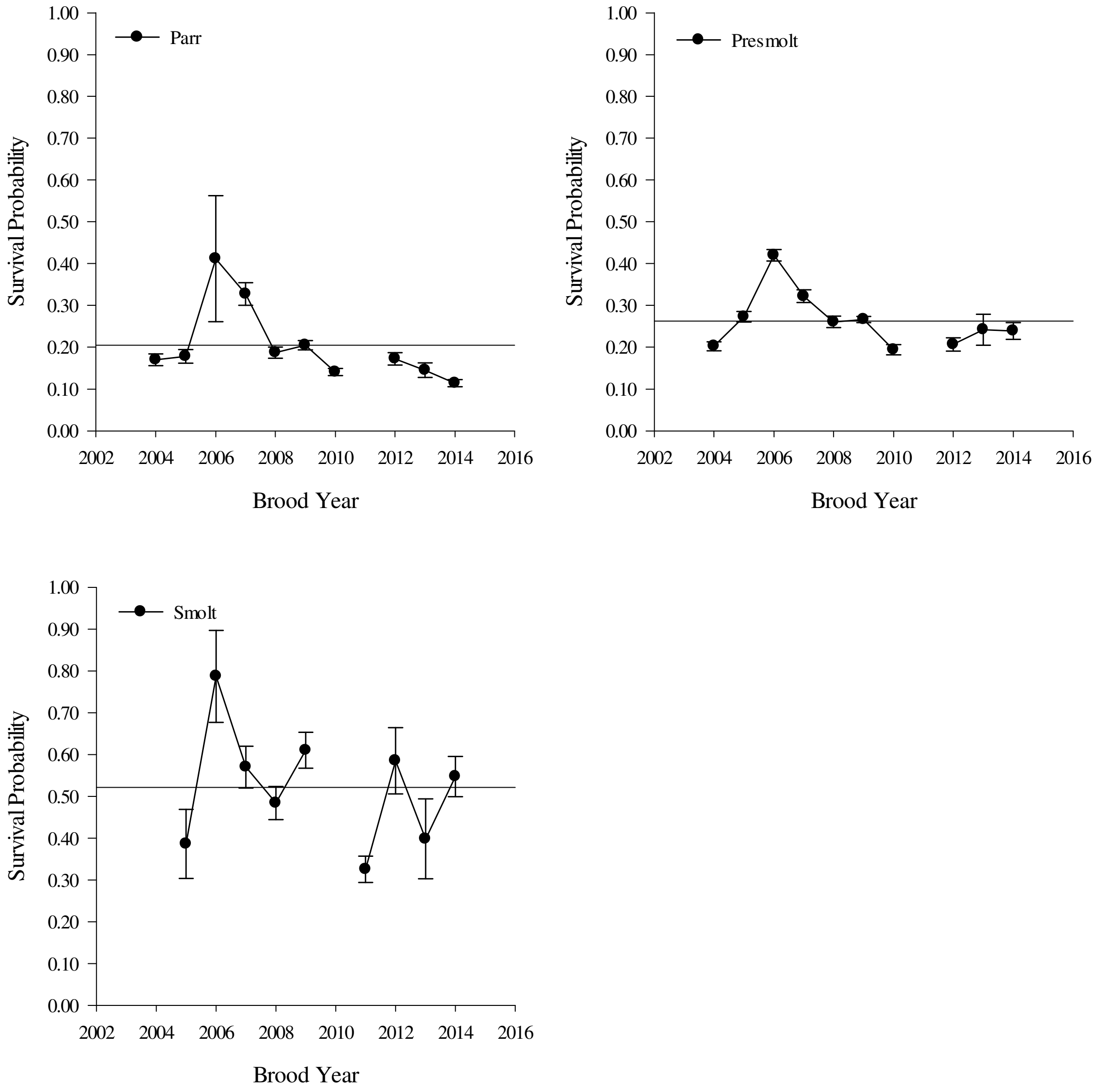
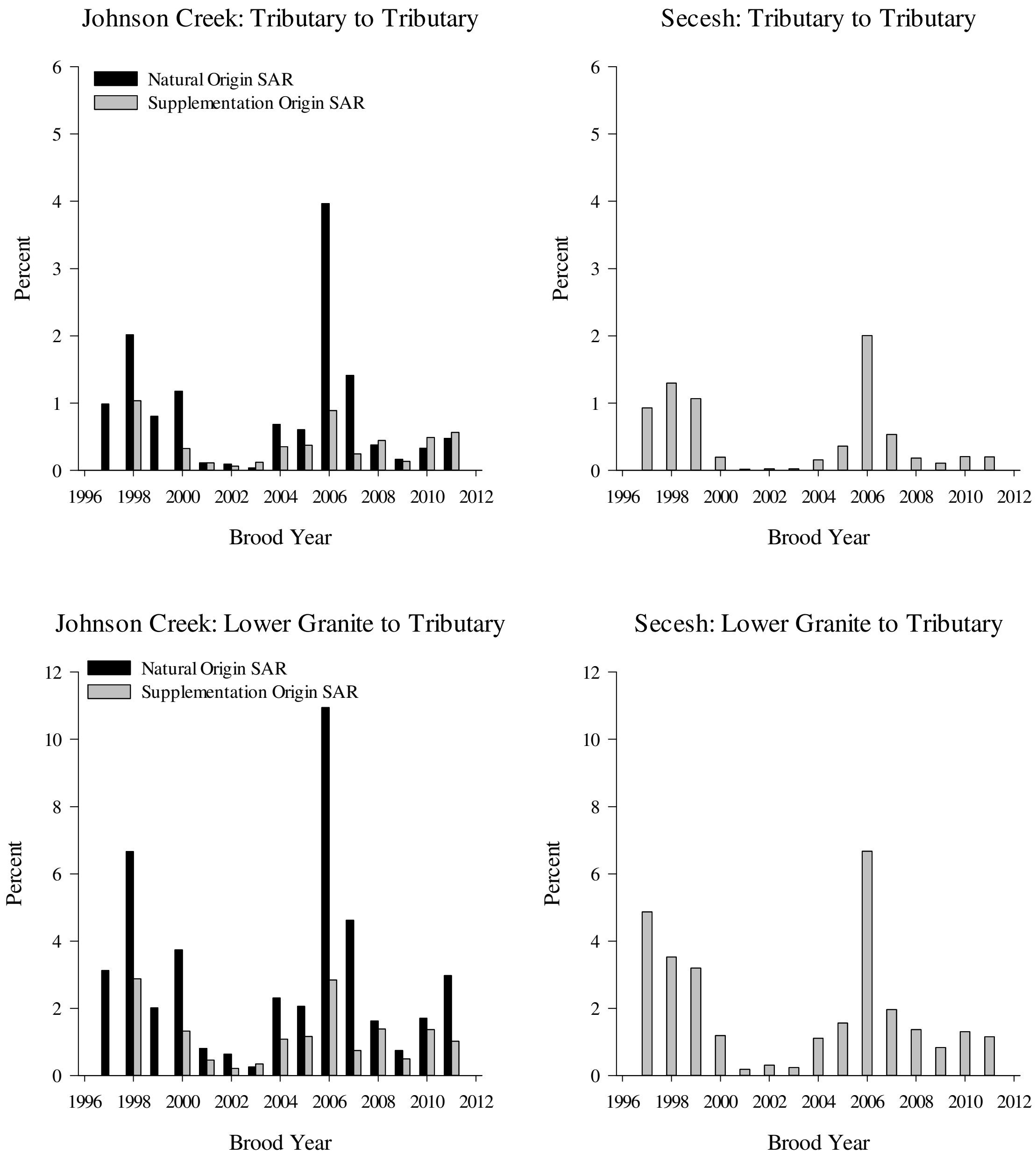


Figure 7. Life stage-specific survival (including standard error of the mean) of lower Secesh juvenile summer Chinook from the tributary to Lower Granite Dam (Brood Years 2004-2014). The mean survival per life stage is represented by the horizontal line.

The tributary-to-tributary smolt to adult return rate (SAR) for brood year 2011 Johnson Creek Chinook was <1.0% (Figure 8). The Lower Granite Dam-to-tributary SAR was 3.0% and 1.0% for natural and supplementation origin Chinook (respectively) and 1.2% for the SFSEC. Additional detail is available in Appendix Table 18.



Johnson Creek: Tributary to Tributary

Secesh: Tributary to Tributary

Johnson Creek: Lower Granite to Tributary

Secesh: Lower Granite to Tributary

Figure 8. Smolt to adult return rates (SAR) for Johnson Creek natural and supplementation-origin Chinook and Secesh Chinook from tributary to tributary (top plot) and from Lower Granite to tributary (bottom plot). Data are for brood years 1997-2011.

Juvenile recruits per spawner differed between, and within the population (Figure 9). At the tributary, we estimated there were 64 emigrants per Johnson Creek spawner compared to 398 emigrants per Secesh spawner. At lower Granite Dam, we estimated 30 smolt per Johnson Creek spawner versus 64 smolt per Secesh spawner. Recruits per spawner estimates for Johnson Creek supplementation smolt were higher at both the tributary and at Lower Granite.

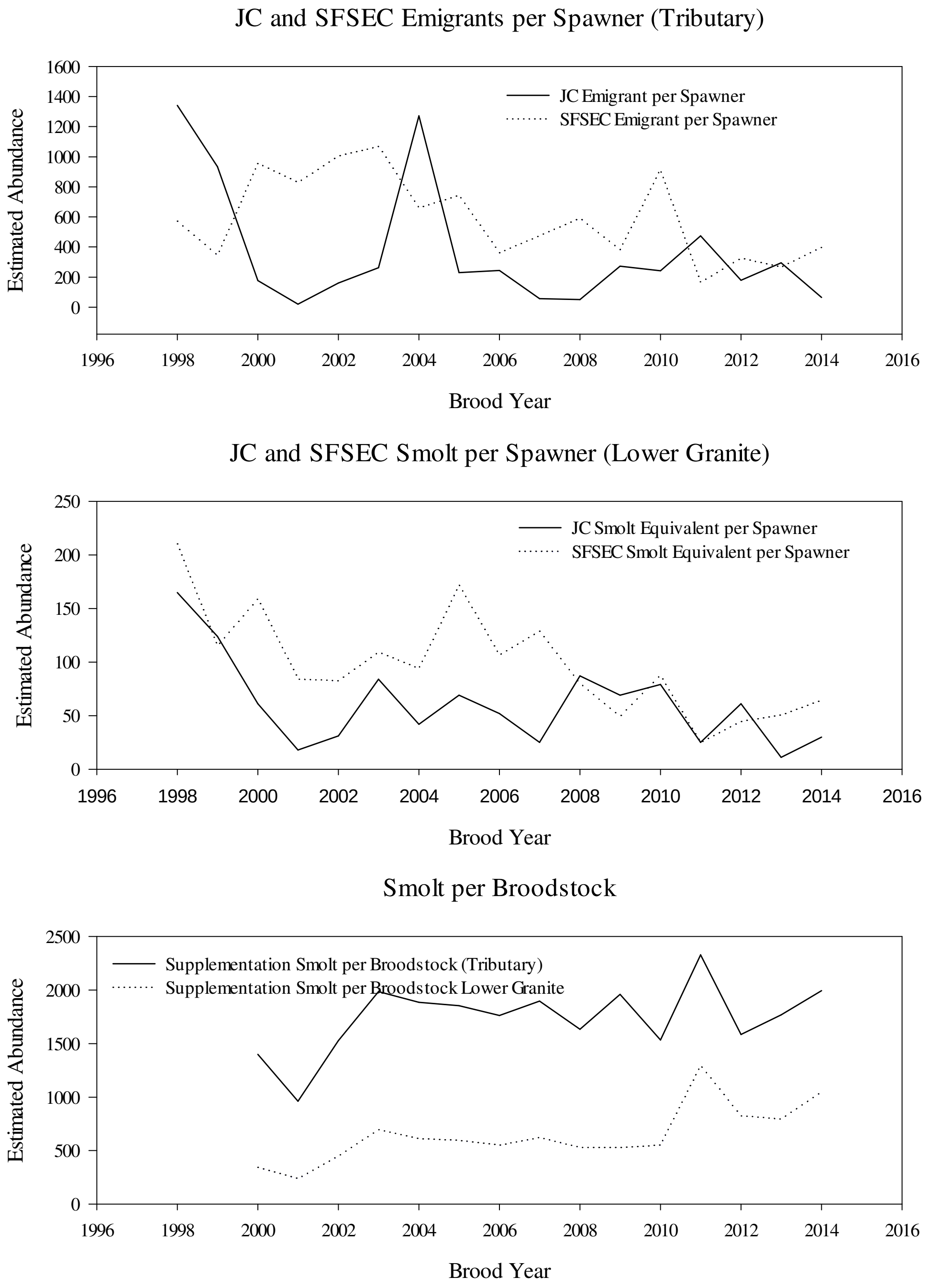


Figure 9. Johnson Creek and Secesh (SFSEC) natural origin juvenile recruits per spawner at the tributary (top plot) and at Lower Granite Dam (middle plot; brood years 1998-2014). Bottom plot shows Johnson Creek smolt per brood stock spawner.

The progeny per parent ratio for brood year 2011 natural origin Johnson Creek Chinook was 1.38, 13.21 for supplementation-origin Chinook, and 0.54 for natural origin SFSEC Chinook (Plot a, Figure 10). Productivity values in Johnson Creek, as measured by adult progeny per spawner, or female progeny per female spawner, remained at, or slightly above, replacement for natural origin Chinook and above replacement for hatchery-origin supplementation Chinook (Plots b and c, Figure 10; see also Appendix Table 21 through Appendix Table 23).

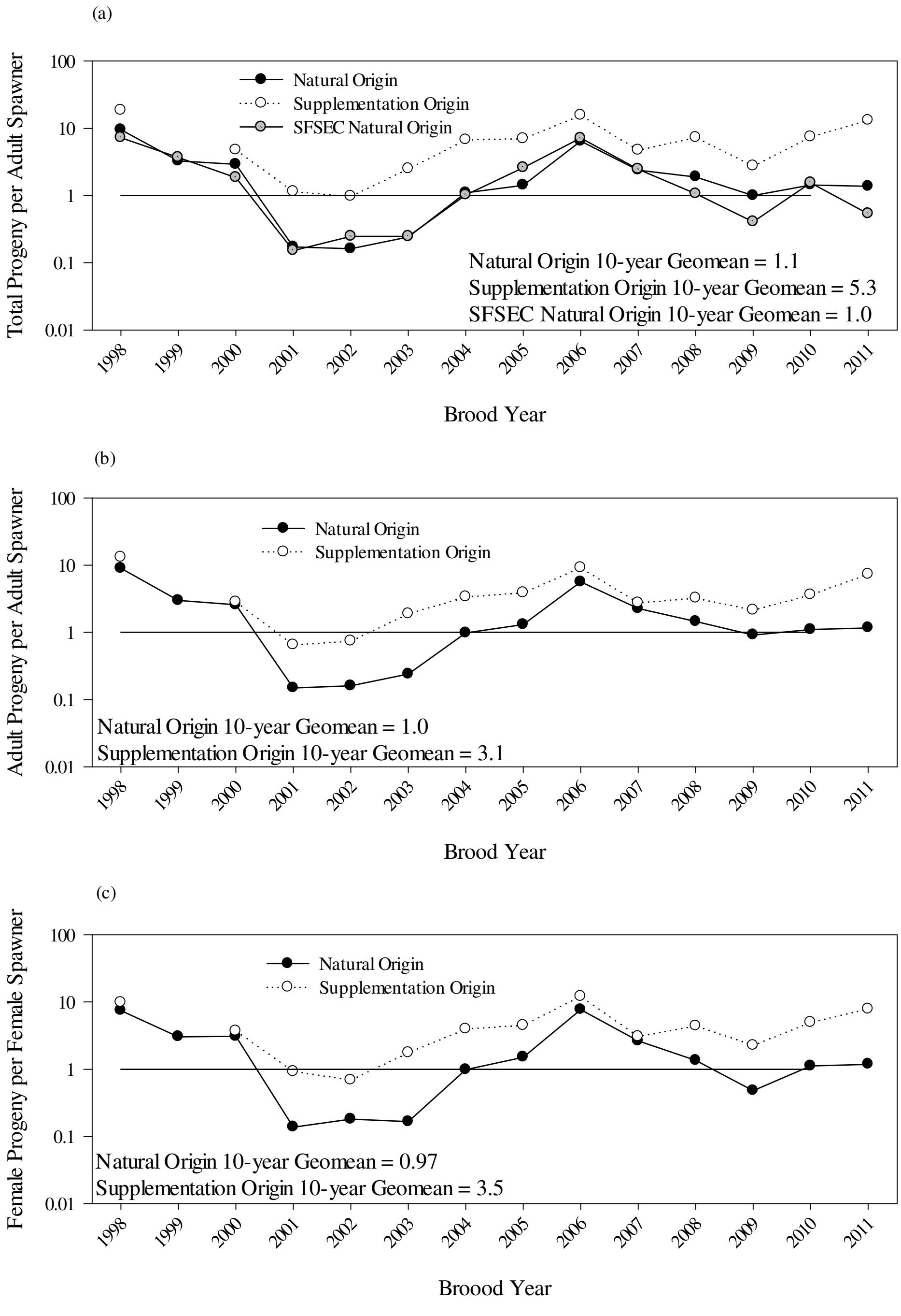


Figure 10. Progeny per parent ratios for natural and supplementation-origin Johnson Creek Chinook (brood years 1998-2011). Plot (a) represents total escapement, plot (b) represents adult escapement, and plot (c) female escapement.

Distribution

An estimated 77% of all spring/summer Chinook redds observed during 2016 surveys of Johnson Creek occurred within Section 4, also referred to as the 'index area' (Figure 11). The highest percentage of redds observed in the East Fork South Fork Salmon River (58%) occurred in Meadow Creek, a tributary to the East Fork within which surplus South Fork Salmon River Chinook were outplanted. Redds were most abundant in Section 3 of the mainstem Secesh and Section 1 of Lake Creek, a tributary of the Secesh (Figure 12; see also Appendix Table 24).

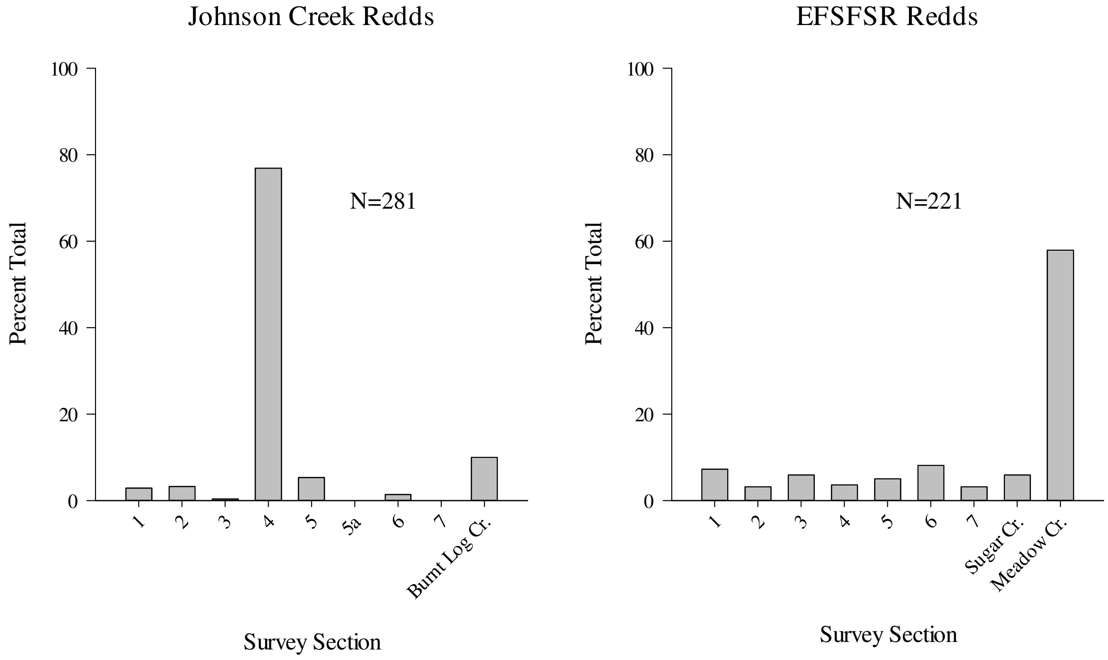


Figure 11. 2016 spring/summer Chinook redd distribution in Johnson Creek (left plot) and the East Fork South Fork Salmon River (right plot). Data are expressed as percent total by stream survey section. Section numbers progress from low to high elevation; tributaries are represented at the end of the x-axis and do not correspond to the same elevation gradient as section numbers.

Most female carcasses were collected in section 4 of Johnson Creek (Figure 13). Supplementation female carcasses were collected in similar proportions to natural females throughout the survey area. The proportion of hatchery-origin females that were collected as carcasses near the [juvenile] release location did not differ from natural origin females. The *percent hatchery origin spawner* or 'pHOS' in Johnson Creek and for the Secesh population is shown in Figure 14. The 2016 pHOS in Johnson Creek was 29%. The 2016 SFSEC pHOS was <2%, and averages less than 5% annually (Kinzer et al., 2015).

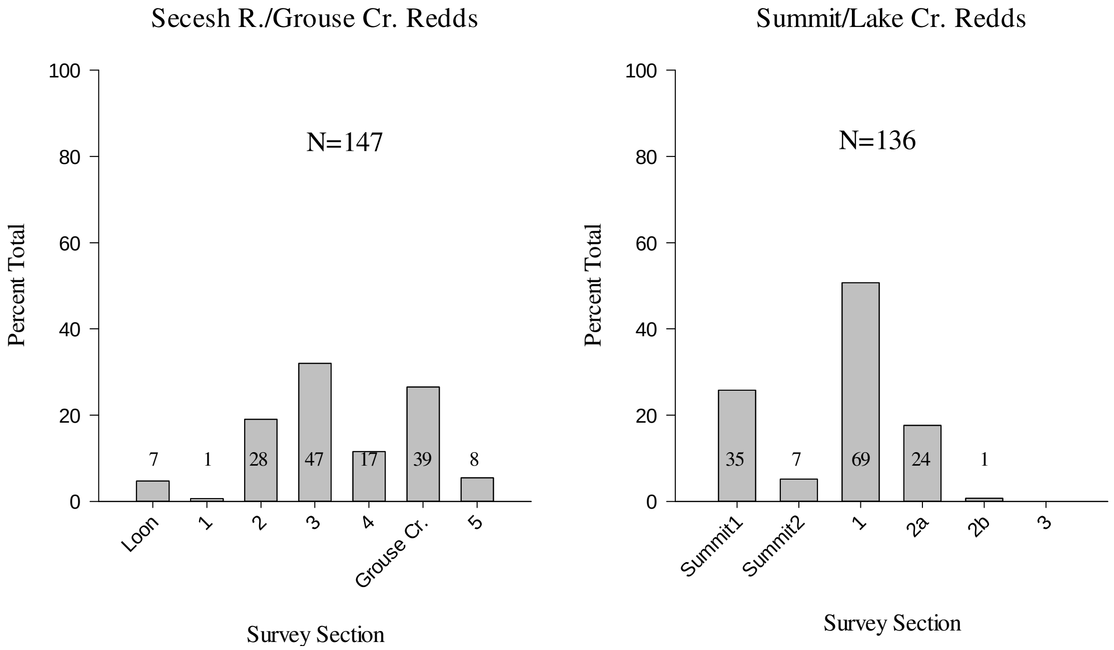


Figure 12. 2016 spring/summer Chinook redd distribution in the Secesh River and Grouse Creek (left plot) and in Summit/Lake Creek (right plot). Data are expressed as percent total by stream survey section. Section numbers/tributaries progress from low to high elevation.

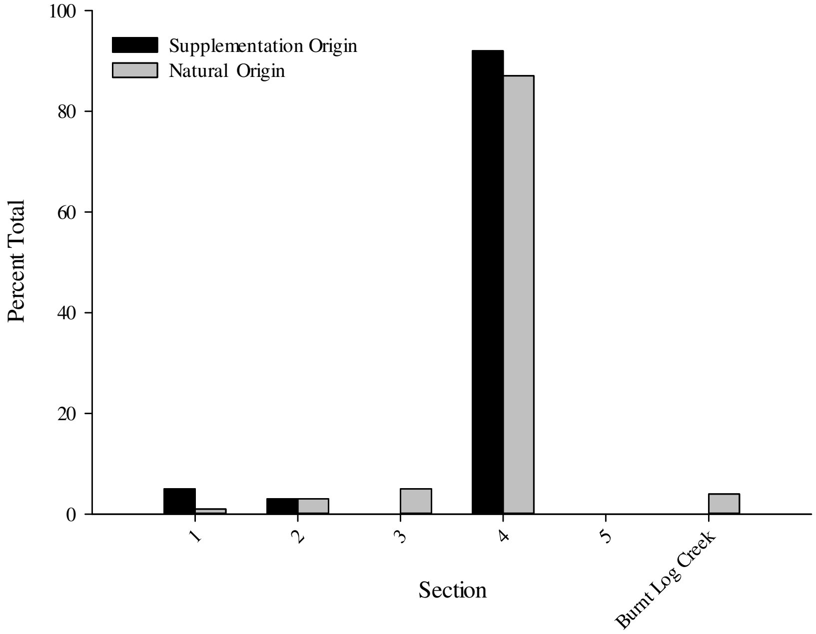


Figure 13. Percent total, by section, of Johnson Creek female spring/summer Chinook that were collected as carcasses in 2016. Section numbers progress from low to high elevation.

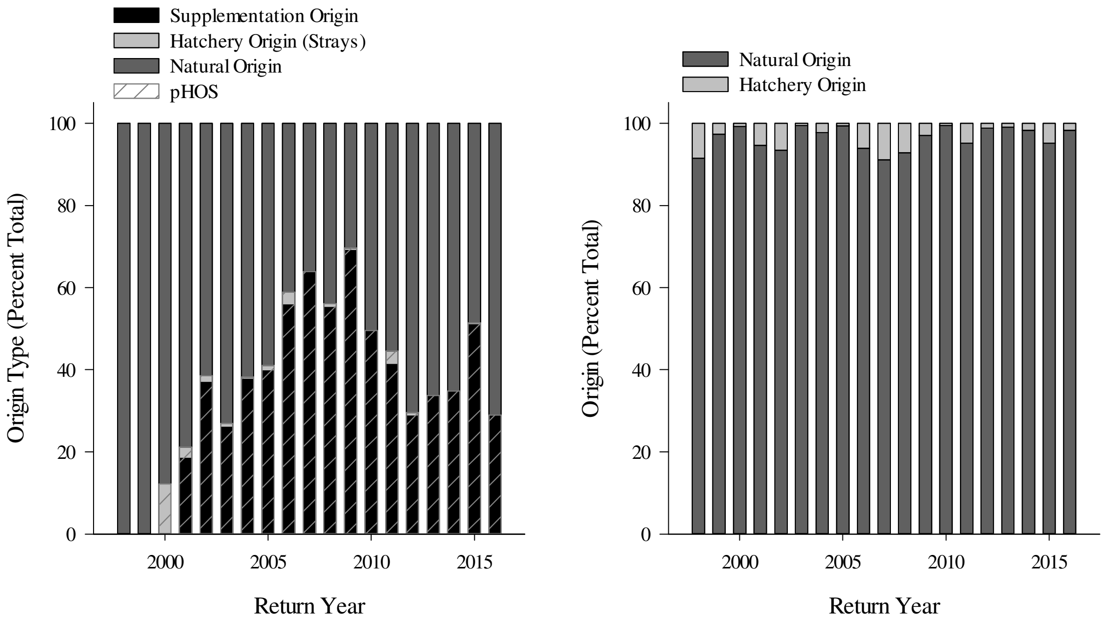


Figure 14. Percent total of Johnson Creek (left plot) and Secesh (right plot) spawners (1998-2016 return years). The proportion of hatchery origin spawners (pHOS) is represented in diagonal stippling and is comprised of hatchery origin supplementation and stray Chinook.

Genetics

The parentage-based genetic analyses completed in 2016 extends the results of a previous study by Hess et al. (2012) that presented genetic-based pedigrees for adults genotyped between 1998-2010. That study provided parentage analyses for hatchery-reared and natural-origin fish that spawned in nature during 2003-2005, with adult offspring returning during 2006-2010. The parentage-based genetic analyses completed in 2016 represents samples collected from 2011-2015 that provide parentage results for hatchery-reared and natural-origin fish that spawned in nature between 2006-2010 and their adult offspring that returned between 2009-2015 (Koch et al., *in press*). The additional brood years increased the sample size to 5 complete generations, encompassing 18 years of data.

The first objective of the parentage study was to determine if the supplementation program provided a demographic boost, not only in the first generation, but in succeeding generations. On average, a fish taken into the hatchery environment produced almost 4.5 times more adult offspring, and 2.7 times more adult grand-offspring than naturally reproducing fish (Table 3).

Table 3. Reproductive success comparisons of natural- and hatchery-origin supplementation Johnson Creek Chinook. Shown are progeny per parent values representing the adult offspring produced relative to natural-origin (a.k.a. F1 Chinook) and progeny per grandparent values representing adult grand-offspring produced relative to natural-origin (a.k.a. F2 Chinook).

Brood year	Adult offspring produced relative to natural-origin (F1)	Adult grand-offspring produced relative to natural-origin (F2)
1998	2.79	1.25
1999	N/A	N/A
2000	1.20	0.85
2001	5.22	3.93
2002	5.40	4.78
2003	7.94	10.02*
2004	5.25	TBD
2005	4.41	TBD
2006	3.40	TBD
2007	4.70	TBD
2008	5.69	TBD
2009	4.38	TBD
2010	6.26	TBD
Mean	4.72	2.70

*Does not yet include F2 offspring from 2013 return, and BY is not included in mean

The second objective was to examine differences in reproductive success between hatchery-reared and natural-origin fish spawning naturally. We did this in two ways: by including all potential parents (i.e., including fish that produced no detectable adult offspring; Figure 15), and by including only successful parents (i.e., only those parents that produced adult offspring; Figure 16). For the first group, while we found no detectable difference in fitness among females, hatchery-reared males in one year had significantly lower reproductive success compared to their natural-origin counterparts. For the second group (i.e., fish that contribute offspring to the next generation, and therefore have potential for direct genetic effects on fitness), we found relative reproductive success estimates to be similar across groups and not statistically significant between any group of hatchery and natural-origin fish (though some comparisons had low power due to small sample size, particularly for jacks).

Figure 15. Relative RS (RRS) of all BY 2002-2010 potential four and five-year-old female and male spawners. RRS estimates represent the average number of offspring per adult standardized to NOR adult RS (i.e. total number of offspring per HOR adult/total number of offspring per NOR adult). Asterisk represents results of ANOVA comparing the number of offspring produced by HOR vs. NOR adults ($p<0.05$). Error bars represent 1 SD from 95% confidence intervals (taken from Koch et al., *in press*).

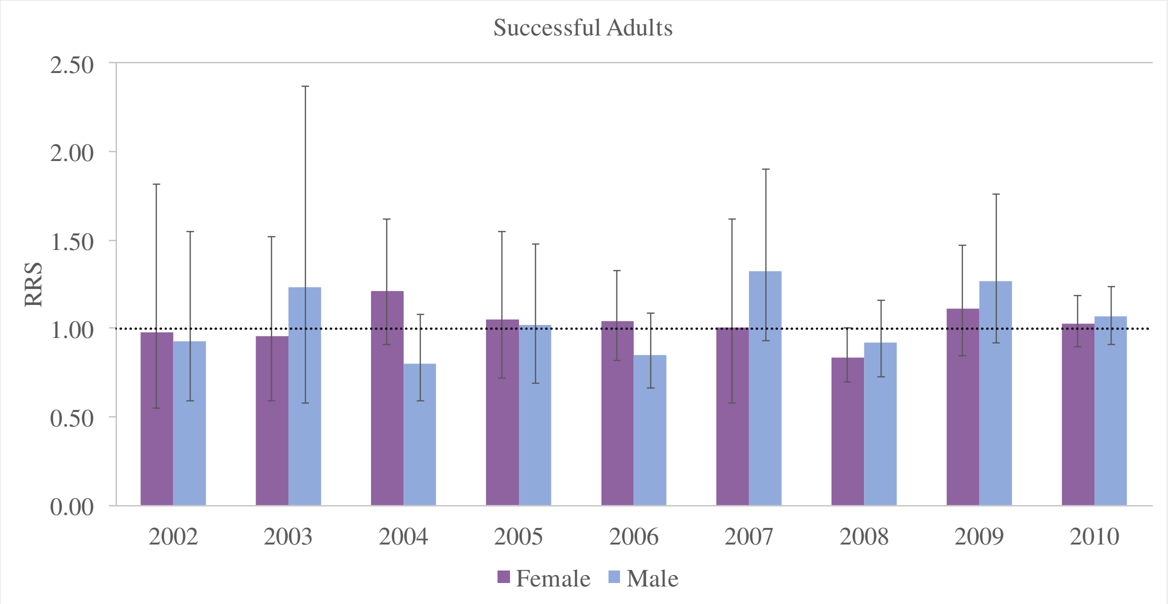


Figure 16. RRS of successfully reproducing BY 2002-2010 four and five-year-old female and male spawners. Error bars represent 1 SD from 95% confidence intervals. Note: There were no significant results ($p<0.05$) from an ANOVA comparing the number of offspring produced by HOR vs. NOR adults (taken from Koch et al., *in press*).

The third objective was to evaluate the effect of hatchery-reared fish on the fitness of natural-origin fish, or put another way, to determine if hatchery-reared fish have a negative genetic impact on natural-origin fish when they mate. To do this we compared the reproductive success among mating types in the wild for BY 2003 to 2010 (e.g., hatchery x natural (HxN), hatchery x hatchery (HxH), or natural x natural (WxN)). Combining 8 brood years of data, we found that the relative reproductive success (RRS) of hatchery-reared fish that mated in the wild with either hatchery or natural origin fish were generally equivalent to those of NxN pairings (Figure 17).

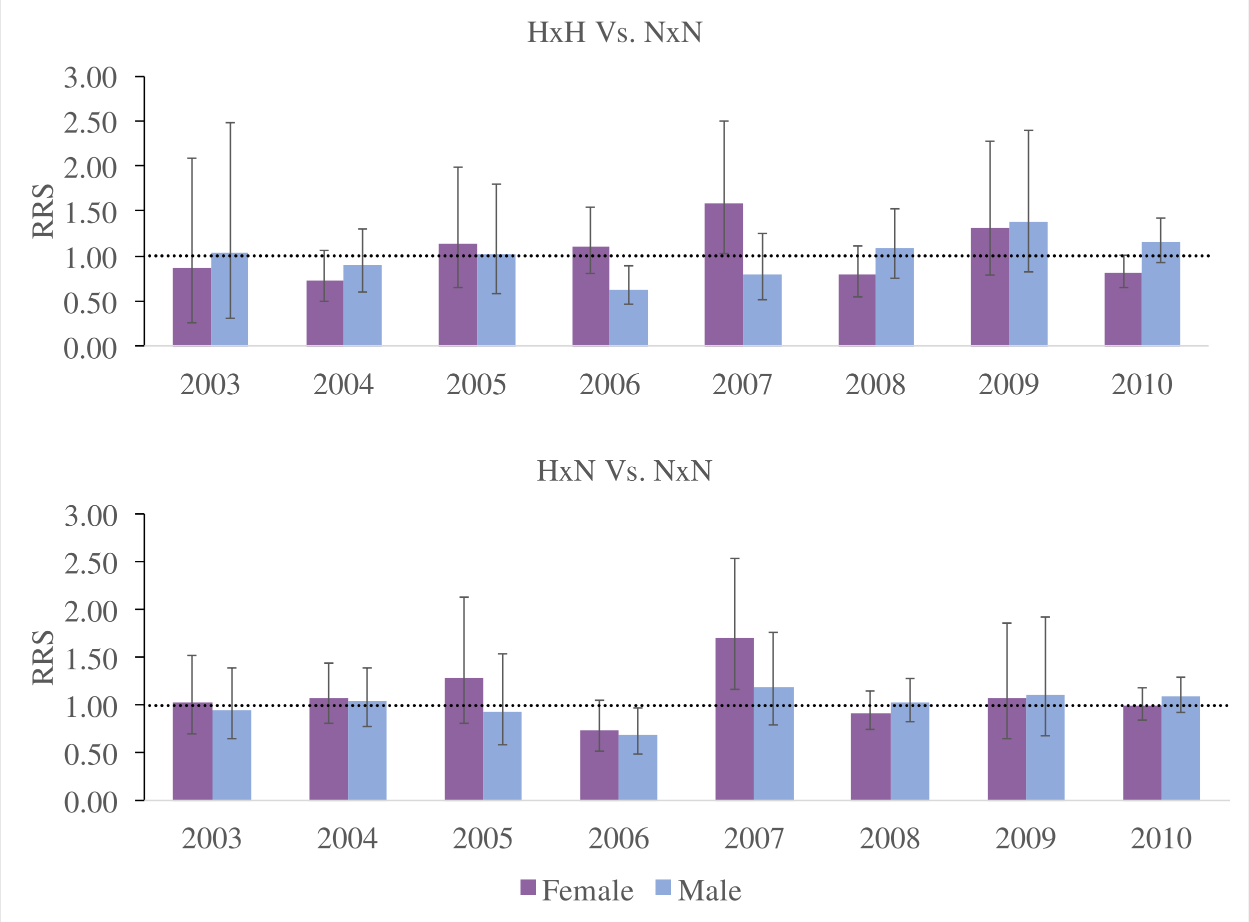


Figure 17. RRS of BY2002-2010 successful parental crosses containing at least one HOR parent (Hx -) compared to parental crosses involving two NOR parents (NxN); top graph: HOR by HOR(HxH) RS (RS)/NxN RS; bottom graph: HOR by NOR (HxN) RS/NxN RS. All RRS values are standardized to NxN crosses. Error bars represent 1 SD from 95% confidence intervals. Note: There were no significant results ($p<0.05$) from an ANOVA comparing the number of offspring produced by Hx - vs. NxN adults (taken from Koch et al., *in press*).

Life History Characteristics

Age Class Structure

The age class structure of adult (includes jacks) natural and hatchery origin Chinook that returned to Johnson Creek, to the East Fork South Fork Salmon River and to the SFSEC population in 2016, is shown in Table 4, Table 5, and Table 6 (respectively; additional data are available in Appendix Table 25 and Appendix Table 26).

Table 4. Age class structure of natural origin, hatchery origin supplemented, and hatchery origin stray spring/summer Chinook that returned to Johnson Creek in 2016. Values represent 'known age' carcasses (refer to the Appendix 2: List of Metrics and Indicators in the Appendix for a description on methods used to age fish).

Origin	**Age 3 (%)**	**Age 4 (%)**	**Age 5 (%)**	**Age 6 (%)**	**Total**
Natural	8 (0.03)	188 (0.65)	91 (0.32)	1 (0.00)	288
Hatchery Supplemented	1 (0.01)	51 (0.75)	16 (0.24)	0 (0.00)	68
Hatchery General Prod.	0 (0.0)	1 (1.00)	0 (0.00)	0 (0.00)	1
Total	9 (0.03)	240 (0.67)	107 (0.30)	1 (0.00)	357

Table 5. Age class structure of natural origin, and hatchery origin stray spring/summer Chinook that volitionally returned to the East Fork South Fork Salmon River in 2016. Values represent 'known age' carcasses (refer to the Appendix 2: List of Metrics and Indicators in the Appendix for a description on methods used to age fish).

Origin	**Age 3 (%)**	**Age 4 (%)**	**Age 5 (%)**	**Age 6 (%)**	**Total**
Natural	0 (0.00)	18 (0.39)	28 (0.61)	0 (0.00)	46
Hatchery General Prod.	0 (0.00)	0 (0.00)	1 (1.00)	0 (0.00)	1
Total	0 (0.00)	18 (0.38)	29 (0.62)	0 (0.00)	47

Table 6. Age class structure of spring/summer Chinook that returned to the Secesh population in 2016. Values represent 'known age' carcasses (refer to the Appendix 2: List of Metrics and Indicators in the Appendix for a description on methods used to age fish).

Origin	**Age 3 (%)**	**Age 4 (%)**	**Age 5 (%)**	**Age 6 (%)**	**Total**
Natural	6 (0.04)	129 (0.76)	35 (0.21)	0 (0.00)	170
Hatchery General Prod.	0 (0.00)	2 (0.67)	1 (0.33)	0 (0.00)	3
Total	6 (0.03)	131 (0.76)	36 (0.21)	0 (0.00)	173

Age at Return

The age at return of adult Chinook (includes jacks) to Johnson Creek and to the Secesh population (SFSEC) is depicted in Figure 18. Chinook returning from brood year 2011, which was comprised of age-three returns in 2014, age-four returns in 2015, and age-five returns in 2016, consisted primarily of age-four fish for Johnson Creek Chinook and the Secesh, while age-three fish dominated BY11 hatchery-origin supplementation returns. Tabular data are also available in Appendix Table 27.

Size at Return

The size at return for adult Johnson Creek and SFSEC Chinook in 2016 is shown in Figure 19. Size at return data for the Johnson Creek groups over the years 1998-2016 are provided in the same figure; tabular data is available in Appendix Table 28 and Appendix Table 29 (respectively).

Adult Spawner Sex Ratio (adults)

The percentage of female spawners in Johnson Creek and in the Secesh population in 2016 is provided in Table 7. In Johnson Creek in 2016, 54% were estimated to be female. Management actions (i.e., removal of natural origin females for brood stock and/or removal of stray females at the weir), combined with pre-spawn mortality acted to change the percentage of females in the spawner abundance. Additional data is available in Appendix Table 30 and Appendix Table 31.

Adult Run Timing

The first adult (includes jacks) Chinook observed at the Johnson Creek picket weir in 2016 occurred on June 18th (Figure 20); the last was trapped on September 14 (see also Appendix Figure 2).

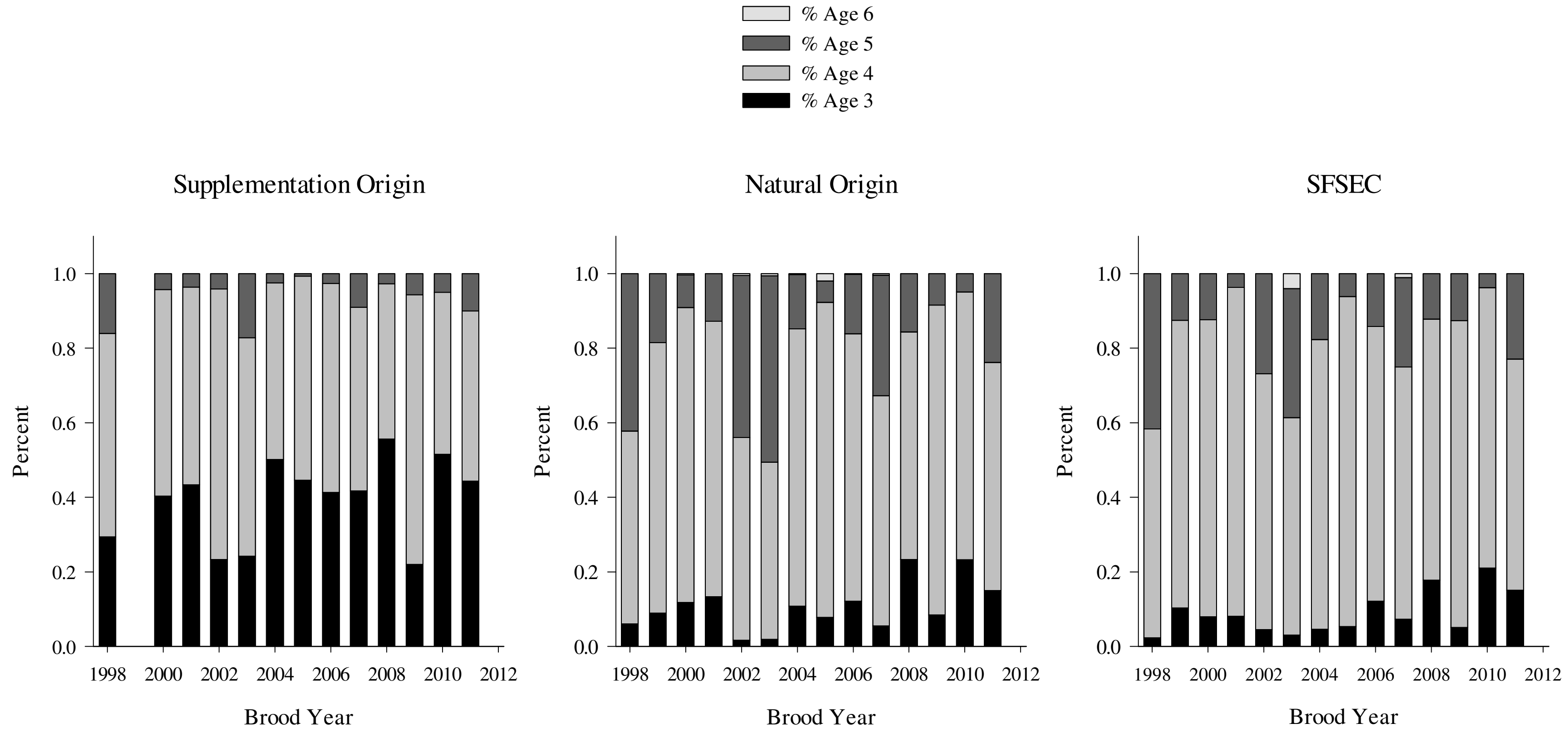


Figure 18. Age at return for adult (includes jacks) Chinook to Johnson Creek and to the Secesh population (SFSEC) for brood years 1998-2011 (does not include age at return to the East Fork South Fork Salmon).

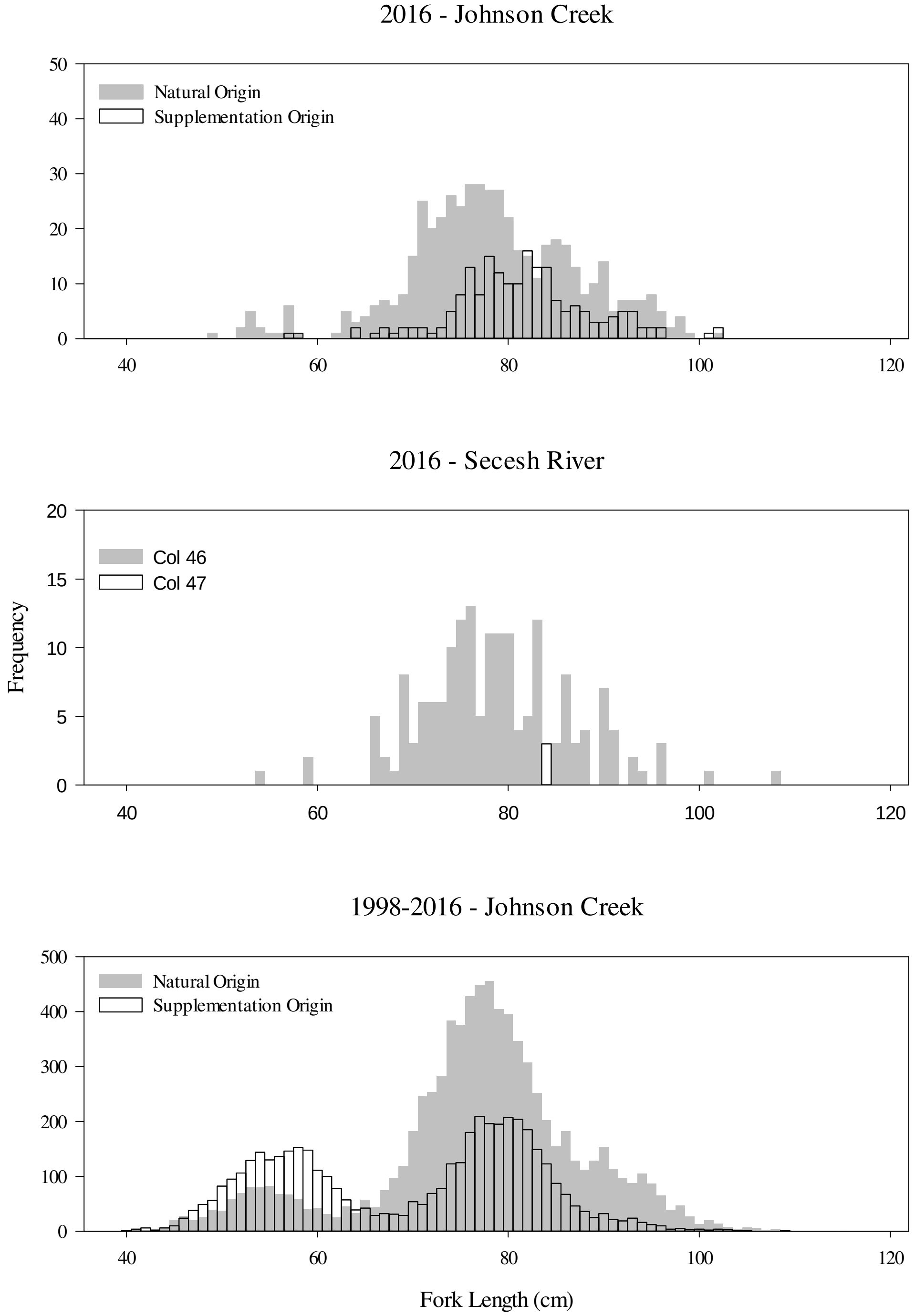


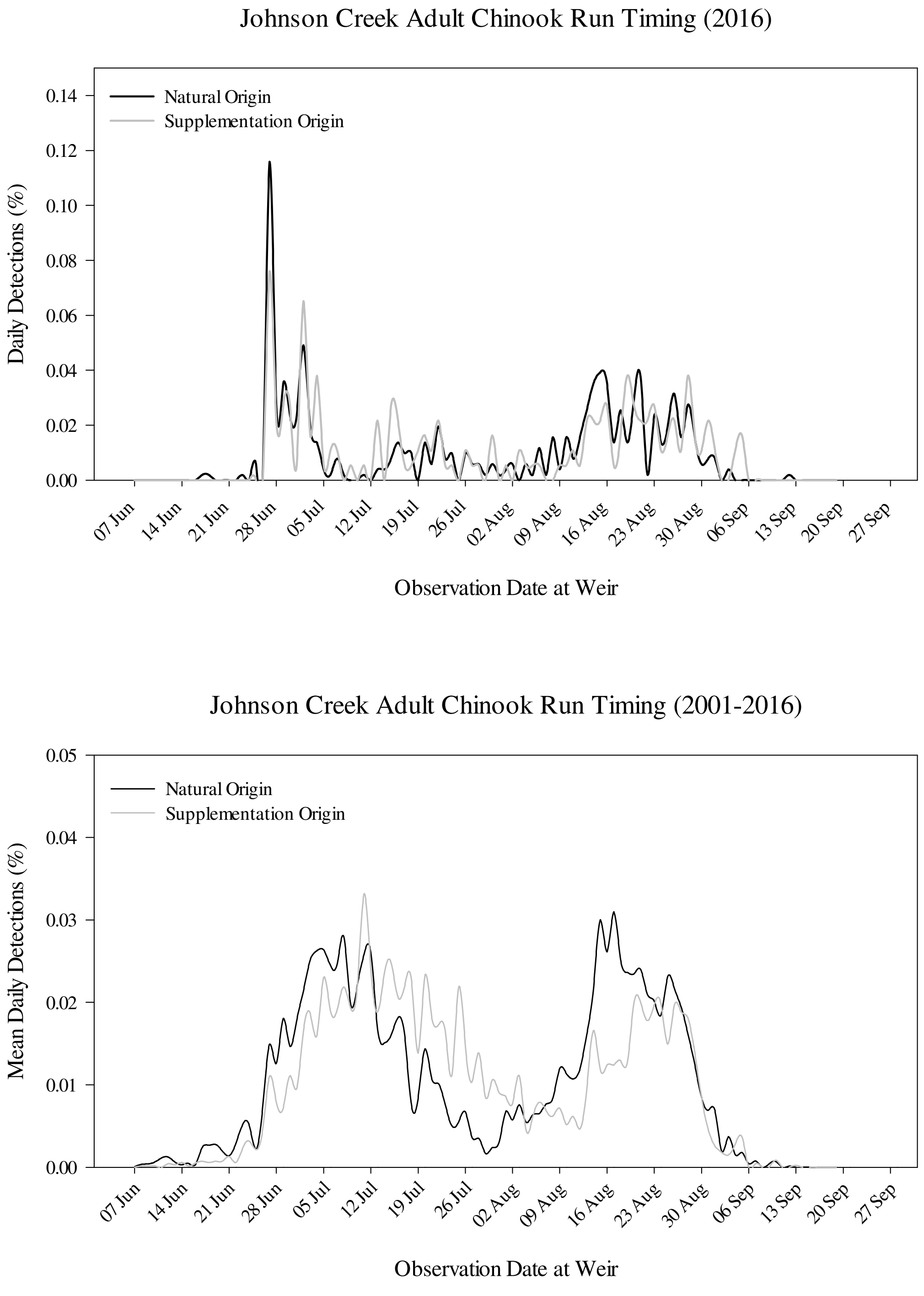
Figure 19. Size at return in 2016 for Johnson Creek (top plot), Secesh (middle plot), and for Johnson Creek during the period 1998-2016 (bottom plot). All Johnson Creek lengths were taken at the adult picket weir. Secesh lengths were taken during spawning ground/carcass surveys.

Table 7. Percent females (adults) that returned to the East Fork South Fork Salmon River (SFEFS) population and to the Secesh (SFSEC) population in 2016. Values were derived from known-sex carcasses collected during multiple-pass spawning ground surveys conducted by the Nez Perce Tribe.

Population	Stream	Female	Male		Percent Female
SFEFS	Burnt log Creek	5	0	5	63%
	Johnson Creek	152	87	239	
	East Fork South Fork Salmon River	48	34	82	
	Sugar Creek	1	1	2	
SFSEC	Secesh River	52	46	98	60%
	Grouse Creek	23	14	37	
	Summit Creek	10	3	13	
	Lake Creek	26	12	38	

Age, Size, and Condition at Emigration

The age, size (fork length), and condition factor of brood year 2014 natural origin juvenile Chinook trapped at the Johnson Creek rotary screw trap and at the lower Secesh River rotary screw trap is provided in Figure 21. As discussed in Appendix 2, the size and condition factor of supplementation origin juveniles was not provided due to measurement inconsistencies. Johnson Creek natural origin size-at-emigration for all brood years combined is provided in Appendix Figure 3.


Johnson Creek Adult Chinook Run Timing (2016)

Johnson Creek Adult Chinook Run Timing (2001-2016)

Figure 20. Adult (includes jacks) run timing for natural and supplementation origin Chinook to the Johnson Creek picket weir in 2016 (top) and over the period 2001-2016 (bottom). Run timing comparisons for the SFSEC population were not conducted due to computational inconsistencies.

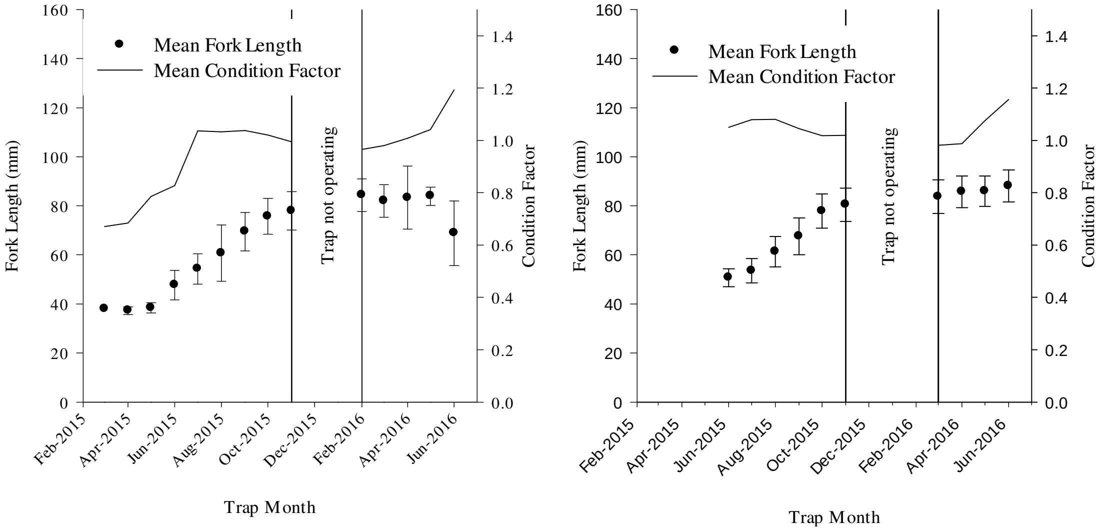
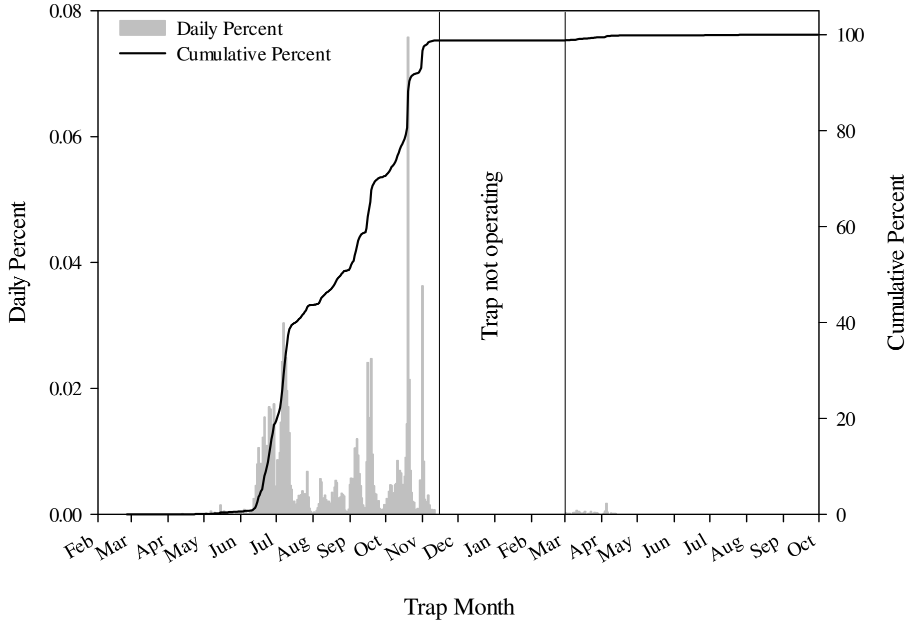


Figure 21. Size and condition at emigration of brood year 2014 natural origin juvenile Chinook interrogated at the Johnson Creek rotary screw trap (left plot) and at the lower Secesh River rotary screw trap (right plot). Error bars represent the standard deviation around monthly mean fork lengths.

Juvenile Emigration Timing

The majority of juveniles migrated from Johnson Creek during their first summer (age 0+) and specifically during the mid-June to mid-July time period (Figure 22). Notable spikes occurred October 20 (7%) and November 1 (4%). Juvenile arrival timing at Lower Granite dam is shown in Table 8. Additional juvenile migration timing data is available in Appendix Table 32.



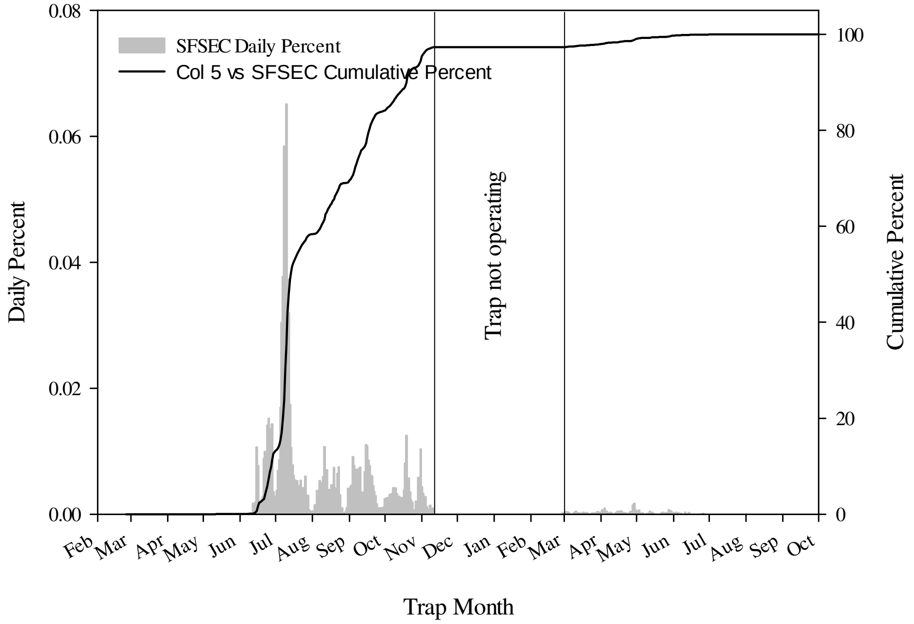


Figure 22. Run timing for brood year 2014 natural-origin juvenile Chinook salmon captured at the Johnson Creek (top plot) and lower Secesh (bottom plot) rotary screw traps.

Table 8. Cumulative percent of brood year (BY) 2014 passive integrated transponder (PIT)-tagged Johnson Creek and Secesh juvenile Chinook salmon detections at Lower Granite Dam (LGD).

Population	Life Stage	LGD Detections	Cumulative Percent Detection Date (2016)				
			0%	10%	50%	90%	100%
BY 2014 (Johnson Creek)	Natural Fry/Parr	115	4/5/2016	4/12/2016	4/22/2016	5/9/2016	6/12/2016
	Natural Presmolt	228	4/7/2016	4/13/2016	4/23/2016	5/9/2016	6/10/2016
	Natural Smolt	145	4/1/2016	4/16/2016	5/6/2016	5/22/2016	6/15/2016
	Hatchery Smolt	399	4/14/2016	4/25/2016	5/5/2016	5/10/2016	6/9/2016
	Total Natural	488	4/4/2016	4/13/2016	4/27/2016	5/13/2016	6/15/2016
	Overall Total	877	4/6/2016	4/15/2016	4/28/2016	5/12/2016	6/15/2016
BY 2014 (Secesh)	Natural Fry/Parr	201	3/24/2016	4/9/2016	4/13/2016	4/25/2016	5/9/2016
	Natural Presmolt	133	3/26/2016	4/9/2016	4/13/2016	4/22/2016	5/27/2016
	Natural Smolt	208	4/6/2016	4/14/2016	5/7/2016	5/15/2016	6/12/2016
	Total Natural	542	3/24/2016	4/10/2016	4/15/2016	5/10/2016	6/12/2016

Discussion/Conclusion

Field Operations

Fish Transport

The transport and release of brood year 2014 smolts went smoothly. As mentioned previously, the release occurred over a period of three days in March, 2016 (3/28-3/30). Fish health was presumed excellent during the journey from the hatchery to the Johnson Creek release site at river kilometer 13.8, as no mortalities were observed. Oxygen saturation fluctuation in the transport tanks was minimal, and often exceeded 175% total saturation. Similar to previous years, supplementation smolt initiated their downstream migration promptly, as very few hatchery fish were encountered in the rotary screw trap (RKM 6.3) which resumed operation on 4/2/2016.

Picket Weir Installation and Operation

The June 15 picket weir installation date occurred sufficiently early to capture all Chinook destined to spawn above that particular location in Johnson Creek; all carcasses interrogated during spawning ground surveys possessed a mark indicating a census count. The 100% efficiency in 2016 contributed to an overall mean of 94% (N=19 years; SE=0.02). The efficiency of the Johnson Creek weir sets it apart from other low cost or temporary vertical picket weirs, which typically have capture rates/efficiencies in the 25%-60% range (e.g., Schroeder 1996; Cousens et al. 1982). And since the majority of all production in the drainage occurs above the weir, we're able to place high level of confidence in our understanding of this particular spawning aggregate.

Rotary Screw Trap Operation

Rotary screw trap operations at the Johnson Creek and Secesh River locations were similar over the course of the brood year 2014 migration period. Operations in the early part of the summer of 2015 (subyearling period) were characterized by low flows, high stream temperatures, and high fish numbers (between the two traps, nearly 50,000 natural origin Chinook were captured over the period 7/5 – 7/14). This combination required trap tenders to complete their processing during early morning hours, often in the dark, so as to avoid endangering fish health due to thermal exposure. Not surprisingly, trap efficiencies during this low flow period were high (21% at JCT and 16% at SCT).

Trapping during fall months (presmolt life history stage) was characterized by isolated days of high emigration at both traps. At Johnson Creek, 5,015 natural origin Chinook were captured on October 20, representing 7% of the total abundance estimate. Twelve days later, on November 1, an additional 2,402 juvenile presmolt were captured (4% of the total abundance estimate). The number of juvenile Chinook captured at the Secesh was also high, with approximately 2,000 fish captured during the same two days. The spikes in emigrant abundance were related to the exceptional return in 2014 and to isolated storm events, which on both dates caused flows in Johnson Creek to exceed the 89-year median.

Spawning Ground Surveys

Redd and carcass surveys (a.k.a. 'spawning ground surveys') were initiated in August. Multiple-pass surveys were completed on all transects in Johnson Creek, the upper-East Fork South Fork

Salmon River drainages, and in the Secesh drainage. Single pass surveys occurred in select reaches, such as the headwater reaches of Johnson Creek. The three-pass frequency was deemed sufficient in scope and intensity to obtain accurate estimates of production and spawner composition.

Performance Measures

Abundance

The 2016 tributary escapement (also referred to as 'total abundance') of 731 Chinook in Johnson Creek ranked eighth lowest out of nineteen years while the escapement in the Secesh ranked 7th lowest out of nineteen years. The escapement of 157 Chinook to the East Fork South Fork was the second highest since surveys were formally initiated by the NPT in 2009. When considering natural origin spawners only (NOSA), we estimated that there were a total of 453 Chinook available to spawn in the East Fork South Fork Salmon River population. The *NOSA* 10-year geomean for this population is still well below the Interior Columbia Technical Recovery Team's 1,000-spawner minimum (N=423), however, continues to exhibit an upward trajectory (Figure 23) and is at its highest level since project inception.

Abundance estimation (e.g., total escapement and spawner abundance) for the East Fork South Fork Salmon River spawning aggregate was unique from most systems, in that the escapement estimate was lower than the spawner abundance estimate. In most cases, the number of spawners estimated to be available in a population is lower than the total escapement because of reductions or removals (i.e., brood stock, euthanized fish, mortalities, etc.). In this case, the number of spawners exceeded the number of natural returns through the additions from the outplanted fish (N=536).

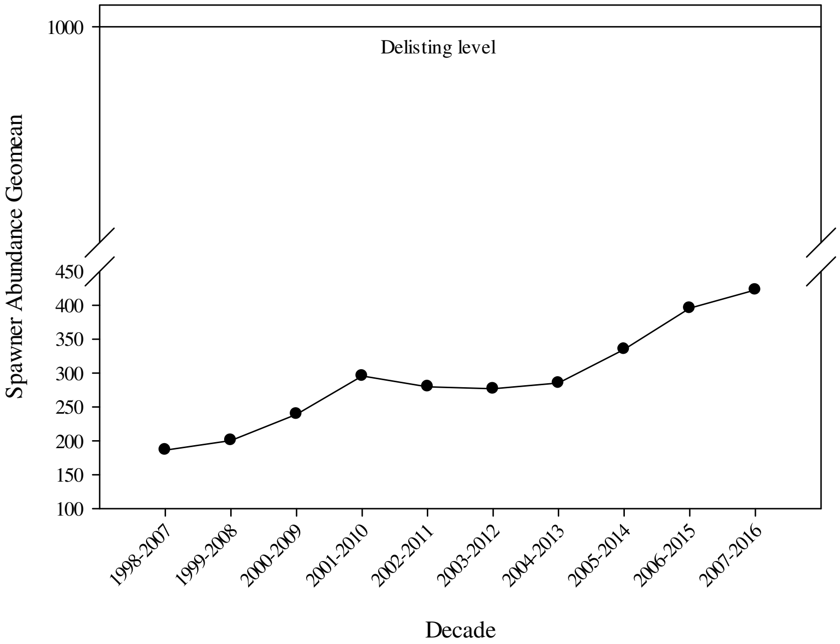


Figure 23. Ten-year moving geomean of natural origin spawner abundance (NOSA) for the East Fork South Fork Salmon River spring/summer Chinook population. Prior to 2009, values shown are calculated using only Johnson Creek escapement estimates; 2009 and beyond includes escapement estimates for both the Johnson Creek and East Fork South Fork spawning aggregates.

Survival/Productivity

Brood year 2014 juvenile survival ($\hat{s}$) from Johnson Creek to Lower Granite dam was below average ($\bar{s}$) for natural origin Chinook ($\hat{s}$ =27% vs. $\bar{s}$=32%), and above average for supplementation origin smolt ($\hat{s}$ =53% vs. $\bar{s}$=36%). An estimated 53% of brood year 2014 supplementation smolt survived from release in Johnson Creek to Lower Granite dam, which marked the fourth consecutive year in which survival of hatchery releases to Lower Granite Dam were well above the previous 12-year average survival ($\bar{s}$ = 31%). The continued above-average survival of hatchery-origin supplementation Chinook appears related to an adaptive management action which resulted in the modification of the time at release of supplementation smolt (refer to Rabe and Nelson 2013, 2014a; 2014b; Nelson 2015 Unpublished poster).

Evaluations of productivity, including smolt to adult return rates (SAR), recruit per spawner (R:S), and progeny per parent ratios (P:P), trended around mean values for both Johnson Creek and it's reference population, the Secesh River, however, similar to previous years, the Johnson Creek SARs were slightly higher than those for the Secesh River. The number of brood year 2011 natural origin Johnson Creek smolts estimated at Lower Granite Dam was 21,593, which was half as many as the Secesh population (43,115); an estimated 643 natural origin Johnson Creek adults (includes jacks) returned back to the tributary (in 2014-2016), resulting in a natural origin smolt to adult return rate (SAR) of 2.98% ($\overline{SAR_{NAT}} = 2.95\%$). This was compared to the Secesh, which had an estimated 500 adults return from the 43k smolt group, yielding a Granite to tributary SAR of 1.16%. The higher conversion of Johnson Creek smolt to adult than that for the reference population is common across years; on average, there are around 67,000 Secesh smolt at Lower Granite Dam annually, compared to around 29,000 Johnson Creek smolt. The 67,000 Secesh smolt to adult conversion rate is around 1.3% (or 880 adults). For Johnson Creek, the 29,000 smolt at Granite convert back to adults in the tributary at a rate of around 2% (or 566 adults). Also, the Johnson Creek estimates exclude returns to the East Fork South Fork, making them more conservative than the Secesh estimate.

The Northwest Power and Conservation Council (NPCC 2009) adopted a goal of achieving overall SARs (including jacks) in the 2%-6% range (minimum 2%; average 4%) for federal ESA-listed Snake River and upper Columbia River salmon and steelhead. Historic (1964-1969) SARs (geometric mean) for Snake River spring/summer Chinook (upper dam smolts-to-Columbia River returns, jacks included) were 4.3%, compared to 0.8% during 1994-1999 and 1.1% since 2000 (DeHart 2014). The tributary to tributary, abundance-based geometric mean SAR for Johnson Creek natural origin spring/summer Chinook for brood years 1998-2011 (0.005) is well below the minimum NPCC goal[2], and while the poor productivity may be blamed on a myriad of factors, the majority are thought to occur out-of-basin (e.g., Sontag 2013; Tiffan et al. 2009).

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[2] It is possible that the NPCC SAR calculations differ from those conducted by the JCAPE M&E project. Nevertheless, regardless of computational differences, we are confident that Johnson Creek SAR's continue to be well below the NPCC targets of 2% - 6%.

Genetics

The parentage-based genetic analyses completed in 2014 complemented prior analyses of brood years 1998, 1999, and 2000 (e.g., Hess et al. 2012), with analyses of brood years 2001, 2002, and 2003. The additional brood years increased the sample size from 2 to 5 complete generations which includes 18 years' worth of data. The lack of difference between mating types does not provide us any reason to believe that the presence of supplementation fish spawning in the wild leads to a reduction in the fitness of wild fish.

Life History Characteristics

The age class structure of natural- and supplementation-origin Chinook that returned to Johnson Creek in 2016 differed from that observed in previous years. Based on 'known' ages (e.g., Table 4), only 3% of natural- and 1% of supplementation-origin returns were age-three; age-three's typically comprise 9% of the natural-origin return, and around 40% of the supplementation origin return. When considering size at return (e.g., Figure 19), natural-origin Chinook measuring <63cm (a length used at the weir to distinguish between age three and age four fish) were represented, however supplementation Chinook weren't; only one age-three supplementation origin Chinook was observed (weir or spawning ground surveys) in the Johnson Creek drainage in 2016.

A likely reason for the poor showing of age-three Chinook in the 2016 Johnson Creek return is related to the prior years' migration conditions through the Snake and Columbia hydrosystem. An assumption made in Rabe et al. (2016) stated that "[poor migration conditions in 2015]… will have negative consequences to returns of jacks in 2016, and adults in 2017-2018." The assumption was that a combination of factors, including temperature, spill, extended travel times, and reduced barging contributed to reduced survival for yearling Johnson Creek Chinook throughout the hydrosystem (e.g., Smith unpublished 2016).

Adaptive Management & Lessons Learned

The results from the 2015-2016 implementation of the Johnson Creek Artificial Propagation Enhancement, Monitoring and Evaluation project can be used to inform future program strategies, including field operations, hatchery operations, and assessment of data.

Field Operations

As mentioned previously, it would be beneficial if tissue samples were collected off all fish destined for release [outplants] into the East Fork South Fork Salmon River. The tissue samples would provide opportunities for pedigree analysis, which may become increasingly important given possible changes in resource management actions within the spawning aggregate.

Performance Measures

There were no changes in calculations of performance measures in 2015-2016.

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Appendices

Appendix 1: Data sets or products

Field Operations

Spawning Ground Survey Data

Appendix Table 1. Multiple pass spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Johnson Creek in 2016.

Transect	Date	Number of new redds
1 (Mouth to Screw Trap) (6.28 km)	15-Aug	0
	29-Aug	5
	12-Sept	3
Subtotal		8
2 (Screw Trap to Adult Weir) (1.91 km)	15-Aug	0
	29-Aug	5
	12-Sept	4
Subtotal		9
3 (Adult Weir to Top of Deadhorse Rapids) (1.56 km)	15-Aug	0
	29-Aug	0
	12-Sept	1
Subtotal		1
4 (Top of Deadhorse rapids to Moose Cr. (Index Area) (5.45 km)	4-Aug	2
	18-Aug	55
	1-Sept	145
	15-Sept	14
Subtotal		216
5 (Moose Cr. to Burnt log Cr.) (6.36 km)	16-Aug	4
	30-Aug	10
	13-Sept	1
Subtotal		15
5a (Burnt log Cr. to Whitehorse rapids (2.04 km)	16-Aug	0
	30-Aug	0
	13-Sept	0
Subtotal		0

Transect	Date	Number of new redds
6 (Old Burnt Log Trail Crossing to Landmark Bridge) (6.5 km)	15-Sept	4
Subtotal		4
7 (Landmark Bridge to Swamp Cr.) (10.05 km)	15-Sept	0
Subtotal		0
TOTAL		253

Appendix Table 2. Multiple pass spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Burnt log Creek in 2016.

Transect	Date	Number of new redds
1 (Burnt Log Cr.Mouth to 2.5 km Upstream of Buck Creek) (2.8 km)	16-Aug	10
	30-Aug	11
	13-Sept	5
Subtotal		26
2 (2.5 km Upstream of Buck Cr. To East Fork of Burnt Log Cr.) (5.3 km)	16-Aug	1
	30-Aug	0
	13-Sept	1
Subtotal		2
3 (East Fork of Burnt Log Cr. to 1st tributary upstream) (0.7 km)	16-Aug	0
	30-Aug	0
	13-Sept	0
Subtotal		0
TOTAL		28

Appendix Table 3. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in East Fork South Fork Salmon River in 2016.

Transect	Date	Number of new redds
1 (Quartz Creek to Lower EFSFSR Bridge) (2.51 km)	17-Aug	5
	31- Aug	10
	14-Sept	1
Subtotal		16
2 (Lower EFSFSR Bridge to Profile Creek) (3.45 km)	17-Aug	3
	31- Aug	4
	14-Sept	0
Subtotal		7
3 (Profile Creek to Tamarack Creek) (4.06 km)	17-Aug	4
	31- Aug	8
	14-Sept	1
Subtotal		13
4 (Tamarack Creek to Salt Creek) (3.72 km)	17-Aug	5
	31- Aug	3
	14-Sept	0
Subtotal		8
5 (Salt Creek to Sugar Creek) (2.23 km)	17-Aug	6
	31- Aug	5
	14-Sept	0
Subtotal		11
6 (Sugar Creek to Glory Hole) (1.11 km)	17-Aug	5
	31- Aug	12
	14-Sept	1
Subtotal		18
7 (Fiddle Creek to Mouth of Meadow Creek) (2.3 km)	16-Sept	7
Subtotal		7
TOTAL		80

Appendix Table 4. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Sugar Creek in 2016.

Transect	Date	Number of new redds
1 (Sugar Cr. mouth to Cinnibar Cr. mouth) (4.99 km)	17-Aug	7
	31- Aug	6
	14-Sept	0
TOTAL		13

Appendix Table 5. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Meadow Creek in 2016.

Transect	Date	Number of new redds
1 (Bottom Rip-Rap/Tailings to Meadow Cr. Mouth) (2.1 km)	16-Sept	128
TOTAL		128

Appendix Table 6. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in the Secesh River in 2016.

Transect	Date	Number of new redds
'Loon' (Alex Cr. to Whangdoodle Cr.) (6.7 km)	8-Sept	7
Subtotal		7
1 (Didson Weir to Alex Cr.) (1.82 km)	12-Aug	1
	25- Aug	0
	9-Sept	0
Subtotal		1
2 (Didson Weir to Long Gulch Bridge) (2.98 km)	12-Aug	3
	25- Aug	15
	9-Sept	10
Subtotal		28
3 (Piah Cr. mouth to Long Gulch Bridge) (4.6 km)	12-Aug	7
	25- Aug	34
	9-Sept	6

Transect	Date	Number of new redds
Subtotal		47
4 (Grouse Junction Bridge to Piah Cr.) (2.5 km)	12-Aug	3
	25- Aug	10
	29-Aug	1
	9-Sept	3
Subtotal		17
5 (Lake Cr. Mouth to Grouse Junction Bridge) (5.0 km)	12-Aug	1
	25- Aug	5
	9-Sept	2
Subtotal		8
TOTAL		108

Appendix Table 7. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Grouse Creek in 2016.

Transect	Date	Number of new redds
2nd Culver to Mouth (3.0 km)	1-Aug	10
	15- Aug	20
	29-Aug	9
TOTAL		39

Appendix Table 8. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Summit Creek in 2016.

Transect	Date	Number of new redds
1 (Summit Cr. mouth to Lake Rock Bridge) (5.5 km)	8-Aug	16
	23-Aug	19
	7-Sept	0
Subtotal		35
2 (Lake Rock Bridge to sharp corner) (3.5 km)	8-Aug	7
	23-Aug	0
	7-Sept	0
Subtotal		7
TOTAL		42

Appendix Table 9. Spawning ground surveys conducted by Nez Perce Tribe (NPT) employees in Lake Creek in 2016.

Transect	Date	Number of new redds
1 (Lake Cr. mouth to Three-Mile Cr. mouth) (7.0 km)	10-Aug	8
	24- Aug	53
	8-Sept	8
Subtotal		69
2a (Three-Mile Cr. Mouth to Willow Cr. Mouth) (3.7 km)	10-Aug	15
	24- Aug	9
	8-Sept	0
Subtotal		24
2b (Willow Cr. Mouth to Corduroy Junction Bridge) (1.56 km)	12-Aug	0
	25- Aug	0
	9-Sept	0
Subtotal		0
3 (Corduroy Junction Bridge to 0.5 km upstream of Corduroy Cr.) (3.7 km)	10-Aug	1
	24- Aug	0
	8-Sept	0
Subtotal		1
TOTAL		94

Appendix Table 10. Johnson (JC) and Burnt Log Creek (BLC) redd numbers by section and year (1998-2016). Data was collected by Nez Perce Tribe DFRM employees. Refer to individual annual progress reports for specific section locations.

Stream	Section	‘98	‘99	‘00	‘01	‘02	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13	‘14	‘15	‘16
JC	1	5		2	4	8	8	6	5	4	1	6	10	19	13	17	18	10	5	8
JC	2	11		1	12	9	22	19	5	9	7	6	6	16	4	17	10	5	5	9
JC	3													1		1	1	1	1	1
JC	4	69	23	28	312	273	310	90	45	23	63	163	203	277	166	183	155	336	223	216
JC	5	2	1		28	9	11	1			1	14	15	29	9	14	14	19	21	15
JC	6	2				9	1					2						2	0	4
JC	7			1		8							1						0	0
JC	BLC. to Halfway											2								
JC	BLC to Whitehorse													3	2	2	3	3	2	0
BLC	Mouth to Buck	7			28	42	11	13		2	2									
BLC	Mouth to EF											30	16	52	41	63	34	36	17	26
BLC	Abv. EF																	5	3	2
Total		96	24	32	384	358	363	129	55	38	74	223	251	397	235	297	235	417	277	281

Hatchery Marking and Tagging Data

Appendix Table 11. Hatchery marking summary for Johnson Creek summer Chinook (Brood Years 1998-2014).

Brood Year	Number Smolt Released	PIT Tags Released	CWT Checked	CWT Detected	CWT Retention	Number Released w/CWT	VIE Checked	VIE Detected	VIE Retention	Number Released w/VIE	VIE Color	Comments
1998	78,950	8,043	2,597	2,545	0.9800	77,369	2,279	2,155	0.9456	74,654	RER	
1999	0	0	0	0	N/A	0	0	0	N/A	0	N/A	No brood stock were collected
2000	57,392	9,987	2,276	2,197	0.9653	55,400	2,519	2,471	0.9809	56,298	LEY	
2001	73,000	12,132	2,598	2,590	0.9969	72,775	2,999	2,964	0.9883	72,148	REO	
2002	112,870	12,186	2,890	2,836	0.9813	110,761	3,101	3,072	0.9906	111,814	REG	
2003	105,230	12,049	9,460	9,329	0.9862	103,773	9,460	9,409	0.9946	104,663	LER	
2004	90,450	12,058	12,095	11,959	0.9888	89,433	12,095	11,967	0.9894	89,493	LEY	
2005	120,415	12,060	12,158	11,981	0.9854	118,662	12,158	12,090	0.9944	119,742	LEO	
2006	88,085	11,957	12,073	11,989	0.9930	87,472	12,073	11,820	0.9790	86,239	REG	
2007	91,080	2,094	2,157	2,120	0.9828	89,518	2,157	2,120	0.9828	89,518	LER	
2008	99,618	4,412	4,465	4,450	0.9966	99,283	1,040	1,021	0.9817	48,615	LEY	
2009	105,757	4,169	4,200	4,159	0.9902	104,725	1,208	1,194	0.9884	52,454	REO	
2010	93,456	4,374	4,401	4,372	0.9934	92,840	1,200	1,174	0.9783	43,647	REG	
2011	130,284	2,092	2,102	2,096	0.9971	129,912	0	0	N/A	0	N/A	(1)
2012	94,968	2,098	2,100	2,064	0.9829	93,340	0	0	N/A	0	N/A	(1)
2013	105,990	1,936	2,100	2,043	0.9729	103,118	0	0	N/A	0	N/A	(1)
2014	115,662	2,090	2,097	2,095	0.9990	115,546	0	0	N/A	0	N/A	(1)

[1] Application of VIE was suspended indefinitely

Performance Measure Data

Adult Abundance

Appendix Table 12. Annual summary of total escapement (Total Esc.) and spawner abundance (SA) in Johnson Creek for the periods 1998; 2000-2016.

Year	Origin[a]	Esc. Abv. Weir[b]	SE	Esc. Bel. Weir[c]	Trib. Harvest	Brood Taken	Weir Morts[d]	Euthanized at Weir	Strays Trucked	Total Esc.[e]	Hatchery Fraction	SA[f]	% SUP
1998	NAT	107		22	0	53	0	0	0	182		126	
	AdClip	0		0	0	1	0	0	0	1		0	
Totals		107	7	22	0	54	0	0	0	**183**	0.01	**126**	0.00
2000	NAT	96		16	0	73	1	0	0	186		109	
	AdClip	14		1	0	0	0	0	0	15		15	
Totals		110	11	17	0	73	1	0	0	**201**	0.07	**124**	0.12
2001	NAT	1,099		49	0	141	5	0	0	1,294		1,130	
	SUP	228		4	0	8	0	0	0	240		232	
	AdClip	14		2	0	1	0	10	18	45		34	
Totals		1,341	2	55	0	150	5	10	18	**1,579**	0.18	**1,396**	0.19
2002	NAT	656		42	0	96	9	0	0	803		640	
	SUP	431		15	0	1	0	0	0	447		420	
	AdClip	18		0	0	0	0	1	0	19		13	
Totals		1,105	4	57	0	97	9	1	0	**1,269**	0.37	**1,073**	0.40
2003	NAT	514		53	0	77	1	0	0	645		553	
	SUP	194		9	0	2	0	1	0	206		188	
	AdClip	6		1	0	0	0	12	0	19		7	
Totals		714	3	63	0	79	1	13	0	**870**	0.26	**748**	0.26
2004	NAT	152		44	0	55	1	0	0	252		218	
	SUP	116		21	0	2	0	0	0	139		132	
	AdClip	0		2	0	0	0	16	0	18		1	
Totals		268	7	67	0	57	1	16	0	**409**	0.38	**351**	0.38
2005	NAT	57		16	0	74	0	0	0	147		95	
	SUP	62		6	0	1	0	0	0	69		65	
	AdClip	0		2	0	0	0	3	0	5		1	
Totals		119	0	24	0	75	0	3	0	**221**	0.33	**161**	0.41

Year	Origin[a]	Esc. Abv. Weir[b]	SE	Esc. Bel. Weir[c]	Trib. Harvest	Brood Taken	Weir Morts[d]	Euthanized at Weir	Strays Trucked	Total Esc.[e]	Hatchery Fraction	SA[f]	% SUP
2006	NAT	40		24	0	60	0	0	0	124		64	
	SUP	73		14	0	0	0	0	0	87		87	
	AdClip	0		3	0	0	1	10	2	16		5	
Totals		113	0	41	0	60	1	10	2	**227**	0.45	**156**	0.59
2007	NAT	117		19	0	52	0	1	0	189		131	
	SUP	219		19	0	0	0	0	0	238		229	
	AdClip	0		0	0	0	0	11	0	11		0	
Totals		336	7	38	0	52	0	12	0	**438**	0.57	**360**	0.64
2008	NAT	243		17	0	77	0	1	0	338		261	
	SUP	309		14	0	0	0	50	0	373		328	
	AdClip	5		1	0	0	1	20	0	27		6	
Totals		557	2	32	0	77	1	71	0	**738**	0.54	**595**	0.56
2009	NAT	236		15	0	68	0	0	0	319		249	
	SUP	548		28	0	0	2	0	0	578		567	
	AdClip	2		3	0	0	0	27	0	32		4	
Totals		786	16	46	0	68	2	27	0	**929**	0.66	**820**	0.70
2010	NAT	485		50	0	70	0	0	0	605		533	
	SUP	495		40	0	0	0	0	0	535		524	
	AdClip	1		4	0	0	0	36	0	41		0	
Totals		981	4	94	0	70	0	36	0	**1,181**	0.49	**1,057**	0.50
2011	NAT	483		31	0	66	1	0	0	581		509	
	SUP	365		14	0	0	0	0	0	379		376	
	AdClip	18		12	0	0	0	158	0	188		30	
Totals		866	18	57	0	66	1	158	0	**1,148**	0.49	**915**	0.44
2012	NAT	510		69	18	72	0	0	0	669		572	
	SUP	207		24	6	0	0	0	0	237		231	
	AdClip	4		3	0	0	1	13	0	21		7	
Totals		721	11	96	24	72	1	13	0	**927**	0.28	**810**	0.29
2013	NAT	662		33	7	77	17	0	0	780		691	
	SUP	339		9	2	0	0	0	0	350		346	
	AdClip	0		1	0	0	0	14	0	16		2	
Totals		1,001	14	43	9	77	17	14	0	**1,146**	0.32	**1,039**	0.33
2014	NAT	977		19	12	93	1	0	0	1,102		984	
	SUP	533		1	0	1	0	0	0	535		531	
	AdClip	0		0	0	0	0	15	0	15		0	

Year	Origin[a]	Esc. Abv. Weir[b]	SE	Esc. Bel. Weir[c]	Trib. Harvest	Brood Taken	Weir Morts[d]	Euthanized at Weir	Strays Trucked	Total Esc.[e]	Hatchery Fraction	SA[f]	% SUP
Totals		1,510	4	20	12	94	1	15	0	**1,652**	0.33	**1,515**	0.35
2015	NAT	457		0	0	72	0	0	0	529		457	
	SUP	463		16	0	0	0	0	0	479		479	
	AdClip	0		4	0	0	0	25	0	29		4	
Totals		916	13	20	0	72	0	2	0	**1,037**	0.49	**940**	0.51
2016	NAT	442		17	6	67	0	0	0	**532**		453	
	SUP	182		3	2	0	0	0	0	**187**		184	
	AdClip	0		2	0	0	0	10	0	**12**		1	
		624	0	22	8	67	0	10	0	**731**	0.27	**638**	0.29

[a] Origin denotes rearing type: natural-origin (NAT), Johnson Creek SUP, and hatchery-origin strays (AD Clipped)

[b] Escapement (Esc.) above (abv.) weir estimate (calculated from multiple mark recaptures estimates) includes fish that are later determined to be pre-spawn mortality

[c] 1998-2013 values calculated by multiplying an adjusted above-weir fish per redd estimate by the number of redds counted below weir; 2014 value calculated using 'Chasco' approach.

[d] Mortalities (Morts) define the number of fish captured at adult weir that were subsequently determined to have died from handling at the weir or due to the weir (i.e., fish that were found dead in the trap box, or near the trap; carcasses collected off the upstream pickets were not classified as weir morts).

[e] Values calculated by summing the escapement above the weir, escapement below the weir, fish harvested in the tributary, fish removed for brood stock (including strays), weir mortalities, and strays that were euthanized or distributed to tribal members for subsistence purposes.

[f] Values calculated the same as total escapement except excludes fish removed for brood stock, weir mortality, pre-spawning mortality, and known strays (euthanized or removed from Johnson Creek). Refer to Appendix Table 14 for spawner abundance values.

Appendix Table 13. Summary of 'volitional' escapement to the East Fork South Fork Salmon River (above the Quartz Creek confluence) for return years 2009-2016. Estimates are based on methods discussed in Chasco (et. al., 2014) and in Appendix 2: List of Metrics and Indicators.

Return Year	Origin	Natural Origin								Hatchery Origin								Total
	Age	3		4		5		6		3		4		5		6		
	Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	
2009		0	22	11	33	33	11	0	0	0	25	14	10	0	0	0	0	160
2010		0	10	73	220	0	0	0	0	0	57	16	11	3	1	0	0	392
2011		0	4	0	9	53	26	0	0	0	5	19	8	3	1	0	0	128
2012		0	0	41	15	15	0	0	0	0	16	5	5	1	0	0	0	99
2013		0	0	38	10	14	0	5	5	0	0	0	0	0	0	0	0	72
2014		0	5	56	30	5	0	0	0	0	0	11	0	0	0	0	0	107

Return Year	Origin	Natural Origin								Hatchery Origin								Total
	Age	3		4		5		6		3		4		5		6		
	Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	
2015		0	0	22	11	22	0	0	0	0	0	18	0	0	0	0	0	72
2016		0	0	25	20	53	18	0	0	0	0	0	0	2	0	0	0	118
Mean		**0**	**5**	**33**	**44**	**24**	**7**	**1**	**1**	**0**	**13**	**10**	**4**	**1**	**0**	**0**	**0**	**144**

Appendix Table 14. Summary of spawner abundance in Johnson Creek, as it relates to origin, age, and sex (1998-2016).

Return Year	Origin	Natural Origin								Hatchery Supplementation Origin								Hatchery Stray Origin								Total
	Age	3		4		5		6		3		4		5		6		3		4		5		6		
	Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	
1998		0	2	10	13	66	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126
1999		0	8	16	19	5	6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56
2000		0	30	31	42	5	0	0	0	0	0	0	0	0	0	0	0	0	6	3	6	0	0	0	0	123
2001		15	49	387	515	16	8	0	0	0	232	0	0	0	0	0	0	0	2	18	13	0	1	0	0	1,256
2002		0	12	225	306	105	50	0	0	0	0	153	266	0	0	0	0	0	2	7	5	4	0	0	0	1,135
2003		0	29	41	59	251	177	0	0	0	75	0	0	88	35	0	0	0	6	0	0	1	0	0	0	762
2004		0	22	79	98	9	10	0	0	0	36	45	52	0	0	0	0	0	0	1	1	0	0	0	0	353
2005		0	2	14	69	9	1	0	0	0	14	20	22	8	0	0	0	0	0	1	0	1	0	0	0	161
2006		0	2	7	46	7	1	0	1	1	30	20	33	2	1	0	0	0	0	1	4	0	0	0	0	156
2007		0	31	4	46	41	9	0	0	0	157	24	48	2	1	0	0	0	0	0	0	0	0	0	0	363
2008		0	15	68	119	35	23	1	0	0	150	87	69	16	6	0	0	0	0	4	2	0	0	0	0	595
2009		0	93	46	81	25	4	0	0	0	324	138	100	4	1	0	0	0	1	2	2	0	0	0	0	821
2010		0	23	152	349	5	4	0	0	0	93	268	158	3	0	0	0	0	1	0	0	0	0	0	0	1,056
2011		0	191	71	148	76	16	3	0	0	248	58	49	20	1	0	0	0	6	21	3	0	0	0	0	911
2012		0	33	155	266	85	27	0	0	0	30	117	64	15	5	0	0	0	0	4	3	0	0	0	0	804
2013		0	313	69	218	60	28	0	0	0	236	55	45	12	0	0	0	0	0	1	1	0	0	0	0	1038
2014		3	93	370	491	18	12	0	0	0	328	124	71	4	0	0	0	0	0	0	0	0	0	0	0	1,514
2015		0	68	154	178	40	17	0	0	0	118	185	153	16	7	0	0	0	2	2	0	0	0	0	0	940
2016		0	37	140	159	88	29	0	0	0	0	76	34	43	31	0	0	0	0	1	0	0	0	0	0	638
Mean		**1**	**55**	**107**	**170**	**50**	**24**	**0**	**0**	**0**	**109**	**72**	**61**	**12**	**5**	**0**	**0**	**0**	**1**	**3**	**2**	**0**	**0**	**0**	**0**	**674**

Appendix Table 15. Summary of total spawner abundance in the East Fork South Fork Salmon River (above Quartz Creek), as it relates to origin, age, and sex (2009-2016). Estimates include hatchery outplants.

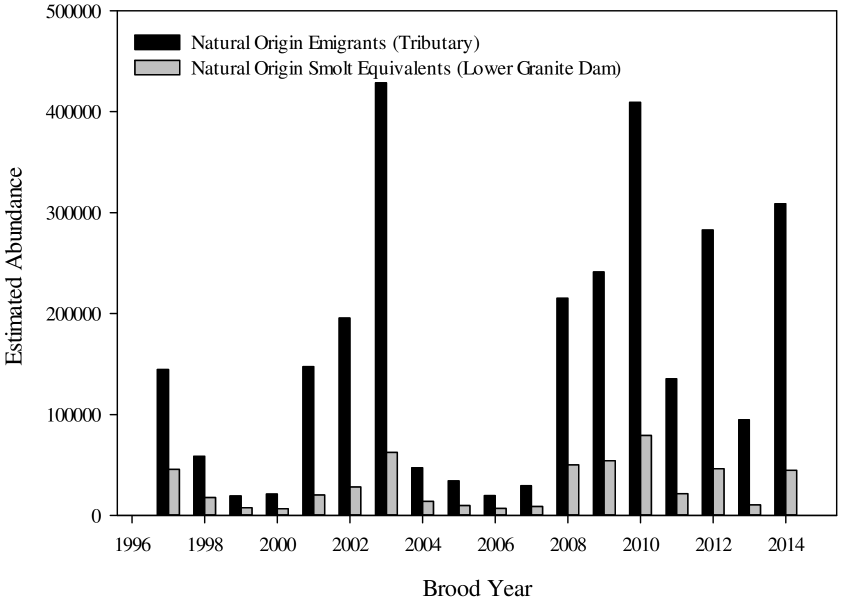
Return Year	Origin	Natural Origin								Hatchery Origin								Total Spawner Abundance
	Age	3		4		5		6		3		4		5		6		
	Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	
2009		0	22	11	33	33	11	0	0	0	44	89	115	0	0	0	0	359
2010		0	10	73	220	0	0	0	0	0	0	352	251	0	0	0	0	907
2011		0	4	0	9	53	26	0	0	0	0	330	165	0	0	0	0	587
2012		0	0	41	15	15	0	0	0	0	0	0	161	0	161	0	0	394
2013		0	0	38	10	14	0	5	5	0	65	0	65	0	0	0	0	202
2014		0	5	56	30	5	0	0	0	0	0	11	0	0	0	0	0	107
2015		0	0	22	11	22	0	0	0	0	0	208	0	0	0	0	0	262
2016		0	0	25	20	53	18	0	0	0	0	129	172	86	43	0	0	546
Mean		**0**	**5**	**33**	**44**	**24**	**7**	**1**	**1**	**0**	**14**	**140**	**116**	**11**	**26**	**0**	**0**	**421**

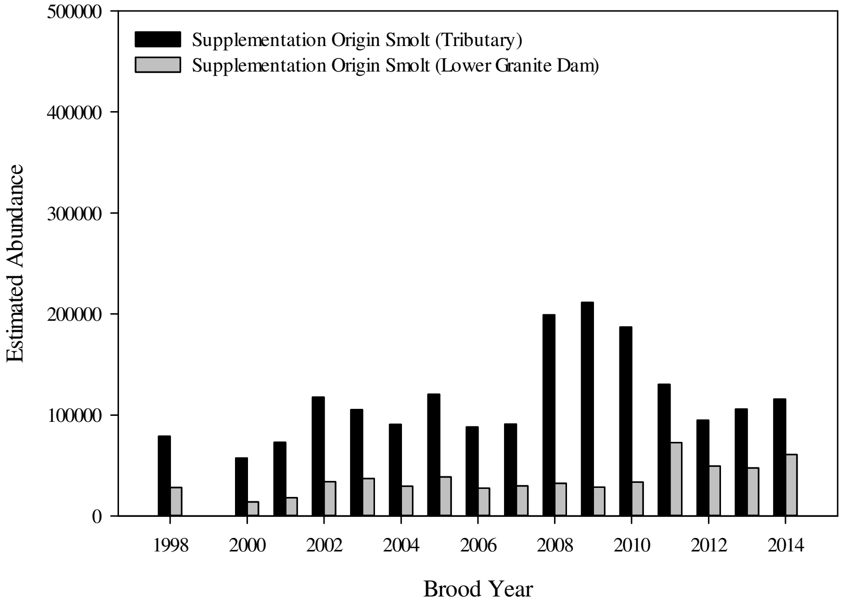
Juvenile Abundance

Appendix Table 16. Lifestage specific abundance estimates and associated standard errors (SE) for natural-origin (NAT) and hatchery-origin supplementation (SUP) juvenile Chinook salmon in Johnson Creek (brood years 1997-2014).

Brood Year	NAT parr	SE	NAT presmolt	SE	NAT Smolt	SE	Total Natural	SE	SUP Smolt
1997	102,088	15,132	26,757	2,214	15,999	1,397	144,844	15,655	0
1998	33,993	4,560	18,481	1,918	6,318	588	58,792	4,717	78,950
1999	10,206	794	4,166	98	5,114	264	19,486	842	0
2000	8,854	747	10,707	379	1,983	371	21,544	873	57,390
2001	113,756	13,507	23,459	615	10,267	669	147,482	14,474	73,000
2002	175,424	35,814	9,785	222	10,382	980	195,591	36,617	112,870
2003	400,725	83,837	15,576	329	12,303	631	428,604	81,297	105,230
2004	14,213	1,352	9,737	263	9,585	633	33,535	4,690	90,450
2005	26,671	7,754	5,852	441	1,671	222	34,194	7,873	120,415
2006	10,283	2,984	7,203	522	2,505	336	19,991	2,899	88,085
2007	18,226	2,087	7,776	260	3,632	507	29,634	2,196	91,080
2008	167,099	24,306	34,685	2,329	13,616	1,897	215,400	23,043	99,618

Brood Year	NAT parr	SE	NAT presmolt	SE	NAT Smolt	SE	Total Natural	SE	SUP Smolt
2009	195,382	33,579	40,181	980	6,514	580	242,077	34,503	105,707
2010	313,306	14,356	87,951	3,081	7,905	611	409,162	14,748	93,456
2011	106,394	8,284	22,991	1,593	6,178	835	135,563	10,712	130,284
2012	214,986	10,198	62,388	14,651	5,373	810	282,747	25,659	94,968
2013	78,052	7,142	15,976	756	783	181	94,811	7,018	105,990
2014	226,409	5,700	77,635	1,875	5,785	1,095	310,461	6,092	115,662
10-Year Geomean:	**85,414**		**24,289**		**4,173**		**117,168**		**103,728**





Appendix Figure 1. Juvenile migrant abundance at the tributary and at Lower Granite Dam ('smolt equivalents'), for natural origin (top plot) and supplementation origin (bottom plot) Chinook (brood years 1998-2014).

Juvenile Survival

Appendix Table 17. Natural (Fry/Parr, Presmolt, and Smolt) and supplementation (SUP) origin juvenile survival from Johnson Creek to Lower Granite Dam (brood years 1997-2014). Standard errors (SE) are calculated for each point estimate.

Brood Year	Fry/Parr	SE	Presmolt	SE	Smolt	SE	SUP Smolt	SE
1997	0.27	0.026	0.31	0.011	0.63	0.025		
1998	0.27	0.025	0.30	0.014	0.50	0.030	0.36	0.012
1999	0.31	0.014	0.34	0.010	0.62	0.011		
2000	0.32	0.029	0.27	0.010	0.51	0.042	0.24	0.007
2001	0.12	0.009	0.13	0.008	0.39	0.013	0.25	0.009
2002	0.13	0.008	0.17	0.006	0.40	0.010	0.30	0.005
2003	0.14	0.005	0.20	0.005	0.43	0.009	0.35	0.006
2004	0.22	0.016	0.26	0.013	0.56	0.022	0.33	0.017
2005	0.29	0.044	0.28	0.017	0.45	0.048	0.32	0.024
2006	0.28	0.029	0.40	0.016	0.59	0.039	0.33	0.030
2007	0.24	0.011	0.35	0.012	0.54	0.031	0.32	0.021
2008	0.19	0.013	0.30	0.017	0.51	0.024	0.33	0.020
2009	0.20	0.008	0.29	0.010	0.56	0.024	0.27	0.016
2010	0.18	0.008	0.22	0.012	0.46	0.029	0.36	0.017
2011	0.14	0.011	0.20	0.016	0.41	0.032	0.57	0.027
2012	0.14	0.006	0.22	0.018	0.51	0.030	0.52	0.040
2013	0.09	0.012	0.22	0.033	0.28	0.084	0.45	0.101
2014	0.12	0.008	0.23	0.018	0.21	0.022	0.53	0.034

Smolt to Adult Ratio

Appendix Table 18. Tributary to tributary- and Lower Granite to tributary-smolt to adult return rates (%SAR) for natural (NAT) and supplementation origin (SUP) Johnson Creek spring/summer Chinook (brood years 1997-2011).

Brood Year	**Tributary to Tributary SAR**						**Lower Granite to Tributary SAR**					
	NAT Juv.	NAT Adult	NAT SAR (%)	SUP Juv.	SUP Adult	SUP SAR (%)	NAT Juv.	NAT Adult	NAT SAR (%)	SUP Juv.	SUP Adult	SUP SAR (%)
1997	144,844	1,432	**0.99**	NA	NA	**NA**	45,830	1,432	**3.12**	NA	NA	**2.88**
1998	58,792	1,186	**2.02**	78,950	818	**1.04**	17,800	1,186	**6.66**	28,422	818	**0.00**
1999	19,486	157	**0.81**	NA	NA	**NA**	7,802	157	**2.01**	NA	NA	**1.33**
2000	21,544	254	**1.18**	57,392	186	**0.32**	6,789	254	**3.74**	14,009	186	**0.46**
2001	147,482	165	**0.11**	73,000	83	**0.11**	20,408	165	**0.81**	18,097	83	**0.21**
2002	195,591	182	**0.09**	112,870	73	**0.06**	28,288	182	**0.64**	34,075	73	**0.35**
2003	428,604	158	**0.04**	105,230	128	**0.12**	62,551	158	**0.25**	36,862	128	**1.09**
2004	47,518	325	**0.68**	90,450	319	**0.35**	14,104	325	**2.30**	29,342	319	**1.16**
2005	34,194	207	**0.61**	120,415	449	**0.37**	10,051	207	**2.06**	38,689	449	**2.85**
2006	19,991	793	**3.97**	88,085	784	**0.89**	7,245	793	**10.95**	27,553	784	**0.75**
2007	29,634	419	**1.41**	91,080	223	**0.24**	9,072	419	**4.62**	29,856	223	**1.38**
2008	215,400	818	**0.38**	99,618	446	**0.45**	50,407	818	**1.62**	32,266	446	**0.49**
2009	242,077	404	**0.17**	105,757	141	**0.13**	54,273	404	**0.74**	28,523	141	**1.36**
2010	409,162	1,353	**0.33**	93,456	458	**0.49**	79,480	1,353	**1.70**	33,560	458	**1.02**
2011	135,563	643	**0.47**	130,284	740	**0.57**	21,593	643	**2.98**	72,581	740	**2.88**

Recruit per Spawner

Appendix Table 19. Johnson Creek natural origin emigrant per spawner (Tributary) and smolt equivalent per spawner (at Lower Granite Dam (LGD)) for brood years 1998-2014.

Brood Year	Female Ratio	Total Spawner Abundance	Redds	Spawners per Redd	Redds above Trap	Spawners above Trap	Emigrants	Emigrant per Spawner	Smolts at LGD	Smolt per Spawner
1998	0.72	126	96	1.31	82	108	144,844	1,341	17,800	165
1999	0.45	56	24	2.33	27	63	58,792	933	7,802	124
2000	0.39	123	32	3.84	29	111	19,486	176	6,789	61
2001	0.42	1,256	384	3.27	352	1,151	21,544	19	20,408	18
2002	0.46	1,135	358	3.17	291	923	147,482	160	28,288	31
2003	0.55	762	363	2.10	355	745	195,591	263	62,551	84
2004	0.44	353	129	2.74	123	337	428,604	1,272	14,104	42
2005	0.20	161	55	2.93	50	146	33,535	230	10,051	69
2006	0.20	156	38	4.11	34	140	34,194	244	7,245	52
2007	0.35	363	74	4.91	73	358	19,991	56	9,072	25
2008	0.42	595	223	2.67	217	579	29,634	51	50,407	87
2009	0.32	821	251	3.27	241	788	215,400	273	54,273	69
2010	0.29	1,056	397	2.66	378	1,005	242,077	241	79,480	79
2011	0.30	911	235	3.88	222	861	409,162	475	21,593	25
2012	0.47	804	297	2.71	280	758	135,563	179	46,530	61
2013	0.25	1,038	235	4.42	217	958	282,747	295	10,577	11
2014	0.46	1,514	417	3.63	407	1,478	94,811	64	44,940	30

Appendix Table 20. Johnson Creek supplementation origin smolt per spawner (Tributary) and smolt equivalent per spawner (at Lower Granite Dam (LGD)) for brood years 1998-2014.

Brood Year	Number of Spawners	Smolt Released	Smolt per Spawner (Tributary)	Smolt Equivalents per Spawner (LGD)
1998	45	78,950	1,754	632
1999	0	0	0	0
2000	41	57,392	1,400	342
2001	76	73,000	961	238
2002	77	117,646	1,528	448
2003	53	105,230	1,985	696
2004	48	90,450	1,884	611
2005	65	120,415	1,853	595
2006	50	88,085	1,762	551
2007	48	91,080	1,898	622
2008	61	99,618	1,633	529
2009	54	105,757	1,958	528
2010	61	93,456	1,532	550
2011	56	130,284	2,327	1,296
2012	60	94,968	1,583	824
2013	60	105,990	1,767	794
2014	58	115,662	1,994	1,047

Progeny per Parent Ratios

Appendix Table 21. Progeny per parent ratios for Johnson Creek natural (NAT) and hatchery origin supplementation (SUP) summer Chinook (brood years 1998; 2000-2011) that returned to Johnson Creek.

	Natural Origin Progeny per Adult Parent						**Supplementation Progeny per Parent**				
Brood Year	Adult Spawner	Age 3 NAT Total Esc.	Age 4 NAT Total Esc	Age 5 NAT Total Esc	Age 6 NAT Total Esc	(P:P)	Adults Spawned for brood stock	Age 3 SUP Total Esc.	Age 4 SUP Total Esc	Age 5 SUP Total Esc	(P:P)
1998	124	72	613	501	0	9.56	44	240	447	131	18.59
1999	48	14	114	29	0	3.27	0	0	0	0	
2000	87	30	201	22	1	2.92	39	75	103	8	4.77
2001	958	22	122	21	0	0.17	72	36	44	3	1.15
2002	1,121	3	99	79	1	0.16	75	17	53	3	0.97
2003	652	3	75	79	1	0.24	51	31	75	22	2.51
2004	295	35	242	47	1	1.10	47	160	151	8	6.79
2005	145	16	175	12	4	1.43	64	200	246	3	7.02
2006	123	96	569	127	1	6.45	50	324	439	21	15.68
2007	175	23	259	135	2	2.39	47	93	110	20	4.74
2008	430	191	499	128	0	1.90	61	248	186	12	7.31
2009	403	34	336	34	0	1.00	51	31	102	8	2.76
2010	939	314	972	67	0	1.44	61	236	199	23	7.51
2011	466	96	394	153		1.38	56	328	338	74	13.21
10-Year Geometric Mean						**1.14**					**5.30**

Appendix Table 22. Adult progeny per adult parent ratios for Johnson Creek natural (NAT) and hatchery origin supplementation (SUP) summer Chinook (brood years 1998; 2000-2011) that returned to Johnson Creek.

	Natural Origin Adult to Adult						**Supplementation Adult to Adult**				
Brood Year	Adult Spawners	Age 3 NAT Total Esc.	Age 4 NAT Total Esc	Age 5 NAT Total Esc	Age 6 NAT Total Esc	(P:P)	Adults Spawned for brood stock	Age 3 SUP Total Esc.	Age 4 SUP Total Esc	Age 5 SUP Total Esc	PROPORTION (P:P)
1998	124		613	501	0	8.98	44		447	131	13.14
1999	48		114	29	0	2.98	0		0	0	
2000	87		201	22	1	2.57	39		103	8	2.85
2001	958		122	21	0	0.15	72		44	3	0.65
2002	1,121		99	79	1	0.16	75		53	3	0.75
2003	652		75	79	1	0.24	51		75	22	1.90
2004	295		242	47	1	0.98	47		151	8	3.38
2005	145		175	12	4	1.32	64		246	3	3.89
2006	123		569	127	1	5.67	50		439	21	9.20
2007	175		259	135	2	2.26	47		110	20	2.77
2008	430		499	128	0	1.46	61		186	12	3.25
2009	403		336	34	0	0.92	51		102	8	2.16
2010	939		972	67	0	1.11	61		199	23	3.64
2011	466		394	153	0	1.17	56		338	74	7.36
10-Year Geometric Mean						**1.01**					**3.13**

Appendix Table 23. Female progeny per female parent ratios for Johnson Creek natural (NAT) and hatchery origin supplementation (SUP) summer Chinook (brood years 1998; 2000-2011) that returned to Johnson Creek.

	Natural Origin Adult to Adult						**Supplementation Adult to Adult**				
Brood Year	Adult Female Spawners	Age 3 NAT Total Esc.	Age 4 NAT Total Esc	Age 5 NAT Total Esc	Age 6 NAT Total Esc	(P:P)	Female brood stock spawned	Age 3 SUP Total Esc.	Age 4 SUP Total Esc	Age 5 SUP Total Esc	PROPORTION (P:P)
1998	76	16	256	310	0	7.66	28	0	180	95	9.82
1999	22	0	48	19	0	3.05	0	0	0	0	
2000	39	0	99	21	0	3.08	16	0	51	8	3.69
2001	421	0	39	19	0	0.14	26	0	22	2	0.92
2002	494	0	23	65	1	0.18	32	0	20	2	0.69
2003	381	0	12	50	1	0.17	25	1	28	16	1.80
2004	134	0	93	38	1	0.99	23	0	84	7	3.96
2005	53	0	68	8	4	1.51	33	0	145	3	4.48
2006	37	0	183	101	1	7.70	25	0	281	20	12.04
2007	71	0	90	96	1	2.63	25	0	61	15	3.04
2008	211	0	196	88	0	1.35	30	0	120	12	4.40
2009	215	0	83	20	0	0.48	27	0	56	5	2.26
2010	428	0	428	48	0	1.11	29	0	128	16	4.97
2011	249	3	182	112	0	1.19	29	0	185	43	7.86
10-Year Geometric Mean						**0.97**					**3.54**

Distribution

Appendix Table 24. Female carcass distribution in Johnson & Burnt Log Creeks, stratified by year, origin, and section. Carcass collections were made by Nez Perce Tribe JCAPE employees (2002-2016).

Year	**Origin**	**Section**							
		1	**2**	**3**	**4**	**5**	**5a**	**6**	**Burnt Log**
2002	Hatchery		1	8	66	1			
	Natural	3	13	10	175	5		1	
2003	Hatchery		1	3	44				1
	Natural	1	21	12	189	2			
2004	Hatchery				11				
	Natural		2		21				
2005	Hatchery			2	16				
	Natural	1	1	1	6				
2006	Hatchery		1		7				1
	Natural		3	2	1				
2007	Hatchery		1		6	2			
	Natural		7		12				
2008	Hatchery		1	2	47	5		1	3
	Natural	3	2	2	63				
2009	Hatchery	1	1	7	58	4			1
	Natural	1	1	1	32	3			2
2010	Hatchery	3	4	11	110	19			7
	Natural	2	8	5	69	1			2
2011	Hatchery			1	19	1			3
	Natural	6	4	7	43	1			2
2012	Hatchery	3	4	4	35	2	1		3
	Natural	2	14	6	71	5	1		2
2013	Hatchery			5	17	4			2
	Natural	5	4	3	44	3			2
2014	Hatchery		1	1	37	1			1
	Natural	1	5	8	192	5			3
2015	Hatchery		2		28				
	Natural		1		20	3			
2016	Hatchery	2	1		33				
	Natural	1	4	6	105				5

Life History Characteristics

Age Class Structure

Appendix Table 25. Age class structure of natural origin, hatchery origin supplemented, and hatchery origin stray spring/summer Chinook that returned to Johnson Creek (1998-2016) and were subsequently collected as carcasses and provided a known age.

Return Year	Natural Origin				Hatchery Origin Supplemented				Hatchery Origin Stray			
	3	4	5	6	3	4	5	6	3	4	5	6
1998	0.01	0.04	0.95	0.00					0.00	0.00	1.00	0.00
1999	0.18	0.47	0.35	0.00					0.00	0.00	0.00	0.00
2000	0.17	0.69	0.14	0.00					0.50	0.50	0.00	0.00
2001	0.06	0.75	0.20	0.00	1.00	0.00	0.00	0.00	0.20	0.80	0.00	0.00
2002	0.00	0.87	0.13	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00
2003	0.04	0.16	0.79	0.00	0.36	0.00	0.64	0.00	0.50	0.50	0.00	0.00
2004	0.05	0.69	0.26	0.00	0.17	0.83	0.00	0.00	0.00	1.00	0.00	0.00
2005	0.02	0.79	0.18	0.01	0.18	0.73	0.09	0.00	0.00	1.00	0.00	0.00
2006	0.01	0.80	0.18	0.01	0.28	0.64	0.08	0.00	1.00	0.00	0.00	0.00
2007	0.16	0.45	0.37	0.02	0.62	0.34	0.04	0.00	0.28	0.72	0.00	0.00
2008	0.04	0.68	0.27	0.01	0.54	0.39	0.07	0.00	0.25	0.75	0.00	0.00
2009	0.13	0.66	0.20	0.01	0.47	0.52	0.01	0.00	0.70	0.30	0.00	0.00
2010	0.03	0.95	0.03	0.00	0.16	0.83	0.01	0.00	0.43	0.57	0.00	0.00
2011	0.28	0.39	0.32	0.01	0.62	0.34	0.04	0.00	0.09	0.88	0.03	0.00
2012	0.03	0.71	0.26	0.00	0.11	0.77	0.12	0.00	0.00	1.00	0.00	0.00
2013	0.27	0.46	0.26	0.00	0.63	0.18	0.19	0.00	0.50	0.50	0.00	0.00
2014	0.07	0.89	0.03	0.00	0.60	0.40	0.01	0.00	0.67	0.33	0.00	0.00
2015	0.02	0.84	0.15	0.00	0.20	0.77	0.03	0.00	1.00	0.00	0.00	0.00
2016	0.03	0.65	0.32	0.00	0.01	0.75	0.24	0.00	0.00	1.00	0.00	0.00

Appendix Table 26. Age class structure of natural origin, hatchery origin supplemented, and hatchery origin stray spring/summer Chinook that returned to the East Fork South Fork Salmon River (2009-2016) and were subsequently collected as carcasses and provided a known age.

Return Year	Natural Origin			Hatchery Origin		
	3	4	5	3	4	5
2009				0.19	0.81	0.00
2010	0.05	0.92	0.03	0.00	1.00	0.00
2011	0.05	0.09	0.86	0.00	1.00	0.00
2012	0.00	0.80	0.20	0.00	0.33	0.67
2013	0.00	0.63	0.16			
2014	0.05	0.89	0.05	0.00	1.00	0.00
2015	0.00	0.60	0.40	0.00	1.00	0.00
2016	0.00	0.39	0.61	0.00	1.00	0.00

Age at Return

Appendix Table 27. Age at return for adult (includes jacks) Chinook to Johnson Creek (Brood Years 1995-2010).

Brood Year	Natural Origin					Hatchery Origin Supplementation				
	Total Recruits	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Total Recruits	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)
1995	44	0.07	0.80	0.14	0.00					
1996	154	0.05	0.78	0.17	0.00					
1997	1,432	0.04	0.84	0.12	0.00					
1998	1,186	0.06	0.52	0.42	0.00	818	0.29	0.55	0.16	0.00
1999	157	0.09	0.73	0.18	0.00	0	0.00	0.00	0.00	0.00
2000	254	0.12	0.79	0.09	0.00	186	0.40	0.55	0.04	0.00

Brood Year	Natural Origin					Hatchery Origin Supplementation				
	Total Recruits	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Total Recruits	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)
2001	165	0.13	0.74	0.13	0.00	83	0.43	0.53	0.04	0.00
2002	182	0.02	0.54	0.43	0.01	73	0.23	0.73	0.04	0.00
2003	158	0.02	0.47	0.50	0.01	128	0.24	0.59	0.17	0.00
2004	325	0.11	0.74	0.14	0.00	319	0.50	0.47	0.03	0.00
2005	207	0.08	0.85	0.06	0.02	449	0.45	0.55	0.01	0.00
2006	793	0.12	0.72	0.16	0.00	784	0.41	0.56	0.03	0.00
2007	419	0.05	0.62	0.32	0.00	223	0.42	0.49	0.09	0.00
2008	818	0.23	0.61	0.16	0.00	446	0.56	0.42	0.03	0.00
2009	404	0.08	0.83	0.08	0.00	141	0.22	0.72	0.06	0.00
2010	1,353	0.23	0.72	0.05	0.00	458	0.52	0.43	0.05	0.00
2011	643	0.15	0.61	0.24	0.00	740	0.44	0.46	0.10	0.00

Size at Return

Appendix Table 28. Size at return for adult (includes jacks), natural origin Chinook to the Johnson Creek picket weir (1998; 2000-2016).

Fork Length (cm)	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
43		1											2						3
44			1		1						1		2		2		1		8
45		4		1	1	1			1		2		5	3	1	1	1		21
46		2	1		1	1			2				5	3	11		2		28
47		3				1					1		8	1	5	1			20
48		2	1			1			5		2		6		7		2		26
49			3			2	1		1		5	1	7		13	2	3	1	39
50		1	1	2	1	3	1		2				7	1	15	3	1		38
51		2	3	1	2			1	3	1	4	2	12	2	20	3	3		59
52		4	1		3	1			4			4	16	5	25	3	2	2	70

Fork Length (cm)	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
53		6	2			1		1	3		5	2	16	1	30	4	5	5	81
54		2	1	1					2		7	2	19	2	29	8	5	2	80
55		9	2	2	1	1		1	3		7		12	1	23	14	5	1	82
56		5	1	1					3	6	4	1	12		24	4	6	1	68
57		3	3		1	1				1	5	1	11	3	20	8	4	6	67
58		7	1	2	1	1			1	2	5	1	10		17	3	7	1	59
59	1	1	1	1					1	3	5	1	6	2	11	6	1		40
60		4	1	1					1	1	4	2	7	1	8	10	3		43
61		1	2	2					1	1	2			2	10	8	2		31
62	1		2	2		1	1			1	2		2	1	6	4	1	1	25
63	1	1	3	1						1	3		3	5	7	9	6	5	45
64			2	2		2	1	3	1		1	2		8	5	2	1	3	33
65		1	6	1		3	3	2	2			4	2	9	4	9	7	4	57
66		1	4	2		2		1	1	1		1	1	11	7	4	2	6	44
67			2	6		4	2	1	2	3	1	3	5	16	7	10	6	7	75
68			10	10		5	1	2	1	5	1	12	6	13	13	8	5	6	98
69		1	4	8	2	12		4	5	5	2	16	4	18	8	13	9	8	119
70		1	18	8		9	3	5	5	15	3	13	9	25	12	25	16	15	182
71		3	28	15	1	9	5	2	2	8	4	19	11	42	21	33	18	25	246
72		2	31	12	1	6	7	8	4	13	5	22	9	24	26	37	26	20	253
73		4	36	23		10	6	8	3	9	8	24	13	25	24	48	20	22	283
74		8	49	18	1	19	6	3	3	25	7	50	16	30	20	71	32	26	384
75	1	8	51	33	2	14	7	5	10	18	9	32	16	37	16	63	30	24	376
76		8	74	34	3	9	11	6	2	14	14	29	21	36	34	72	33	28	428
77		6	92	35	5	18	11	4	5	9	16	38	18	34	22	74	34	28	449
78	2	8	106	34	4	6	8	7	2	23	16	40	14	22	17	89	31	27	456
79		3	88	34		10	8	8	5	13	19	40	13	21	21	67	28	27	405
80	1	8	96	43	4	8	7	3	4	15	12	46	6	9	11	76	24	22	395
81	1	8	112	30	4	5	8	5	1	20	16	19	5	5	15	59	17	16	346
82	1	2	95	24	3	4	6	6	4	12	10	35	11	10	4	48	17	15	307
83		3	76	25	6	6	4		4	11	7	18	5	11	8	44	13	11	252
84	2	4	66	23	5	1	3	3	1	4	5	14	4	6	7	26	11	17	202
85	4		39	15	3		2	1	5	9	9	12	2	8	9	17	2	18	155
86	5		42	25	5	1	1	4	2	7	5	13	6	13	7	17	13	17	183

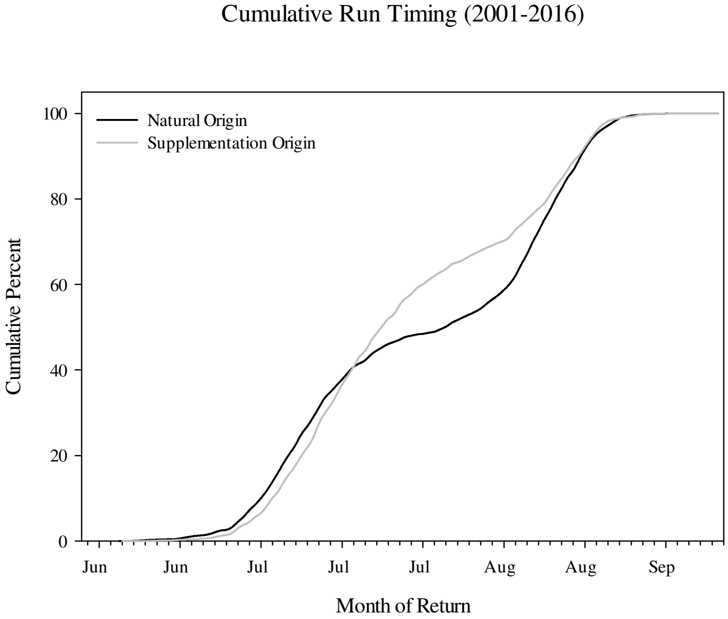
Fork Length (cm)	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
87	3		21	25	4	2	3	2	9	4	1	2	9	8	2	15	6	13	129
88	3		18	20	3	2	2	1	6	10		4	12	4	4	9	6	8	112
89	7		12	27	10	4		1	4	7	3	1	11	3	13	7	9	10	129
90	7		12	28	11		5	1	4	9	8	2	19	5	10	9	10	14	154
91	5		2	30	18		4		4	4	5	3	6	4	13	4	7	5	114
92	7		2	20	10	2		1	2	3	1	2	9	5	10	8	8	7	97
93	4	1	2	20	8	2	2		4	6	7	1	9	3	4	3	5	7	88
94	11		3	20	14	4		1	3	7	4	2	7	7	5	4	6	7	105
95	9		2	22	18	1	1		1	3	5		8	3	1	1	4	8	87
96	7		3	17	4	2			1	4	1	1	9	3	6		2	5	65
97	7		2	6	10		1		1	2	2	1	1	2	1	1		2	39
98	4		1	9	9	3			1	4		1	2	2	3	1	3	4	47
99	4			7	7	1			1		1	1	1	1	2			1	27
100	5			3	1					1				1	1		1		13
101	1			5	5				1	2			3	2			1		20
102	1			2	3				2		1						4	1	14
103	3			1	2					1					1				8
104	1			1	2														4
105	1			2	1								1		1		1		7
106			1	1	3												1		6
107	1					1							1						3
108	1					1			1					1					4
109	1												1	1					3
115					1														1
Grand Total	**113**	**138**	**1238**	**743**	**205**	**203**	**131**	**101**	**152**	**323**	**273**	**540**	**474**	**521**	**679**	**1065**	**529**	**509**	**7,937**

Appendix Table 29. Size at return for adult (includes jacks), hatchery-origin supplementation Chinook to the Johnson Creek picket weir (2001-2016).

Fork Length (cm)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
40	1																1
41											1	2	1				4
42	1										3		1	1			6
43							1						1				2
44	2		1						1		1			1			6
45			1	1			1				3	1	2	1			10
46	13			2			1				2		5	1			24
47	9		2	1		1	4	3	2	1	8	1	2	4			38
48	11		3	3			8	3	1		13	3	1	3			49
49	14		3	4		3	4		9	4	7	1	2	3	2		56
50	17		2	2	2	1	11	2	6	3	16	5	6	6	3		82
51	22		3	1	2	1	17	3	6	4	19	1	8	5	3		95
52	16			1	3	2	16	3	5	6	17	1	17	15	4		106
53	25		3	3	1	4	12	7	9	7	18	2	19	16	3		129
54	20		6	1	2	4	12	9	8	8	12	1	27	23	11		144
55	14		7	3		2	8	13	15	4	14	1	24	18	7		130
56	11		3		1	2	9	12	23	8	14	1	21	20	11		136
57	15		2	3	1		14	16	29	8	7	1	10	31	8	1	146
58	10			4		2	10	13	26	5	11	1	26	33	11	1	153
59	3	1	1		1	2	9	22	30	8	5	2	16	36	12		148
60	10	1		1	1	2	5	16	22	9	7		5	28	4		111
61	6			2			3	17	24	4	5	2	8	25	4		100
62	4	1	1	1			1	17	19	4	3	4	4	14	5		78
63	4	2		2	1	1	1	9	13		2	2		16	4		57
64	1	1		1		1		5	9	1	2		2	9	5	2	39
65	2	1		1				11	4	2	3	2		8	8		42
66	2			1				4	3	1	2	5	2	7	1	1	29
67	2	4		1		3	1	7		1		1	1	5	4	2	32
68	1	9		2	1	2	2	1	1	1	1	1	2	3	3	1	31
69		10		2		1		1		1	3	4			5	2	29
70		13		4	1	2	1	3	2	4	1	8	1	2	10	2	54
71		6		5	1	2	2	3	1	2	4	4	5	3	9	2	49

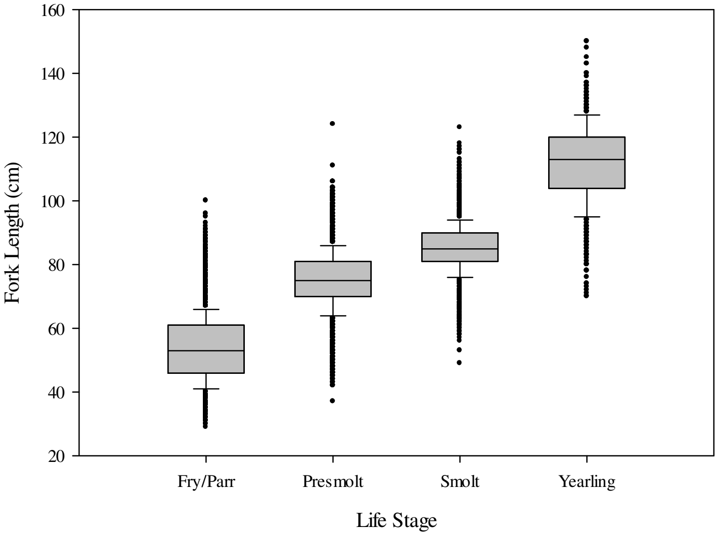
Fork Length (cm)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
72		15		3	3	3	3	5	2	4	2	14	3	4	7	1	69
73		12		4	3		5	3	2	14	2	8	3	11	9	2	78
74		18		6	3	2	4	3	6	16	8	11	12	13	16	5	123
75		22		5	2		4	5	9	16	5	15	6	14	14	8	125
76		25		7	3	3	3	11	12	14	7	23	17	15	27	13	180
77		40		9	6	7	7	8	24	30	7	16	7	13	27	8	209
78		27		6	1	2	4	12	26	37	8	11	5	23	19	15	196
79		29		3	4	4	11	12	25	40	5	8	3	9	30	12	195
80		24		4	3	4	5	15	24	39	13	7	8	22	29	10	207
81		43		8	5	3	7	12	24	32	1	5	2	20	32	10	204
82		19		5	1	2	5	12	28	50	11	3	2	10	21	16	185
83		30		5	2	3	3	11	19	28	3	2	1	10	19	13	149
84		31		1	1	1	1	8	8	23	2	4	2	15	13	13	123
85		13	1	1				6	10	19	5	2	1	5	17	7	87
86		11			1			6	11	13	2	1	2	5	10	5	67
87		11	1				1	6	4	11			1	4	1	6	46
88		7	1		1			5	3	4	2	2	2	2	2	5	36
89		2	4		2			2		2		1		5	4	3	25
90		3	3		1			2	3	2	2	3	3	7		3	32
91			5			1		1	2	1	1	2	1	2	1	4	21
92		1	3		2			3			2		3			5	19
93			9				1	1	1		2	2	1		2	5	24
94			7					2			3		1		1	2	16
95			5		1			3			1					2	12
96			3					2			1	1			1	2	10
97			2					1					1				4
98			3					1			1						5
99			1					2									3
100			2					1				1					4
101							1									1	2
102			1					1								2	4
104			1					1						1			3
105							1										1
109			1														1
Grand Total	**236**	**432**	**91**	**119**	**63**	**73**	**219**	**363**	**511**	**491**	**300**	**199**	**306**	**547**	**439**	**192**	**4,581**

Adult Run Timing



Appendix Figure 2. Adult run timing (cumulative percent) for natural and supplementation origin Chinook to the Johnson Creek weir (2001-2016).

Size at Emigration



Appendix Figure 3. Size at emigration of natural origin juveniles trapped at the Johnson Creek rotary screw trap (brood years 1996-2014). Data are stratified by life history stage (fry/parr, presmolt, smolt, and yearling), which are defined by date (refer to Appendix Table 44 for additional information).

Percent Female

Appendix Table 30. Percent females in the total escapement to Johnson Creek (1998-2016). Percentages reflect origin-based, percent total (by origin), and overall.

Year	Natural Origin	Supplementation Origin	Stray Origin	%Total (Natural)	%Total (Supplementation)	%Total (Stray)	%Total (OVERALL)
1998	0.62		1.00	0.61		0.01	0.62
1999	0.39		0.00	0.39		0.00	0.39
2000	0.31		0.20	0.28		0.01	0.30
2001	0.41	0.00	0.51	0.33	0.00	0.01	0.35
2002	0.47	0.40	0.63	0.30	0.14	0.01	0.45
2003	0.56	0.46	0.16	0.41	0.11	0.00	0.52
2004	0.47	0.37	0.56	0.29	0.12	0.02	0.44
2005	0.41	0.43	0.60	0.27	0.14	0.01	0.42
2006	0.34	0.26	0.31	0.19	0.10	0.02	0.31
2007	0.41	0.13	0.00	0.18	0.07	0.00	0.24
2008	0.43	0.27	0.56	0.20	0.14	0.02	0.35
2009	0.34	0.26	0.34	0.12	0.16	0.01	0.29
2010	0.32	0.53	0.24	0.16	0.24	0.01	0.41
2011	0.34	0.21	0.46	0.17	0.07	0.07	0.32
2012	0.44	0.57	0.62	0.32	0.15	0.01	0.48
2013	0.22	0.19	0.06	0.15	0.06	0.00	0.21
2014	0.41	0.25	0.33	0.27	0.08	0.00	0.36
2015	0.43	0.42	0.52	0.22	0.19	0.01	0.43
2016	0.51	0.64	0.50	0.37	0.16	0.01	0.54

Appendix Table 31. Percent females in the spawner abundance in Johnson Creek (1998-2016). Percentages reflect origin-based, percent total (by origin), and overall.

Year	Natural Origin	Supplementation Origin	Stray Origin	%Total (Natural)	%Total (Supplementation)	%Total (Stray)	%Total (OVERALL)
1998	0.60		0.00	0.60	0.00	0.00	0.60
1999	0.39		0.00	0.39	0.00	0.00	0.39
2000	0.33		0.20	0.29	0.00	0.02	0.32
2001	0.40	0.00	0.53	0.33	0.00	0.01	0.34
2002	0.43	0.37	0.50	0.25	0.15	0.01	0.40
2003	0.52	0.41	0.14	0.39	0.10	0.00	0.49
2004	0.40	0.34	0.50	0.25	0.13	0.00	0.38
2005	0.24	0.43	1.00	0.14	0.17	0.01	0.32
2006	0.22	0.26	0.20	0.09	0.15	0.01	0.24
2007	0.35	0.11	0.00	0.13	0.07	0.00	0.20
2008	0.40	0.31	0.67	0.17	0.17	0.01	0.35
2009	0.29	0.25	0.50	0.09	0.17	0.00	0.26
2010	0.29	0.52	0.00	0.15	0.26	0.00	0.41
2011	0.30	0.21	0.70	0.17	0.09	0.02	0.28
2012	0.43	0.57	0.57	0.30	0.16	0.00	0.47

Year	Natural Origin	Supplementation Origin	Stray Origin	%Total (Natural)	%Total (Supplementation)	%Total (Stray)	%Total (OVERALL)
2013	0.19	0.19	0.50	0.13	0.06	0.00	0.19
2014	0.40	0.24	0.00	0.26	0.08	0.00	0.34
2015	0.42	0.42	0.50	0.21	0.21	0.00	0.42
2016	0.50	0.65	1.0	0.36	0.19	0.00	0.55

Juvenile Run Timing

Appendix Table 32. Johnson Creek juvenile arrival timing to Lower Granite Dam (Brood Year 1997 – 2014).

Brood Year	Life Stage	LGD Detections	Cumulative Percent Detection Date				
			0%	10%	50%	90%	100%
1997	Natural Parr (bseine)	58	4/17/1999	4/26/1999	5/15/1999	6/9/1999	6/27/1999
	Natural Parr	52	3/31/1999	4/20/1999	5/1/1999	5/27/1999	6/3/1999
	Natural Presmolt	297	4/1/1999	4/22/1999	5/3/1999	5/29/1999	6/21/1999
	Natural Smolt	558	4/20/1999	5/3/1999	5/27/1999	6/16/1999	7/21/1999
	Total Natural	907	3/31/1999	4/23/1999	5/6/1999	5/31/1999	7/21/1999
1998	Natural Parr (bseine)	49	4/11/2000	4/21/2000	5/9/2000	5/28/2000	6/13/2000
	Natural Parr	91	4/12/2000	4/15/2000	4/29/2000	5/21/2000	5/28/2000
	Natural Presmolt	307	4/10/2000	4/15/2000	4/30/2000	5/25/2000	7/7/2000
	Natural Smolt	167	4/13/2000	4/28/2000	5/20/2000	6/16/2000	7/22/2000
	Hatchery Smolt	876	4/14/2000	5/3/2000	5/14/2000	6/17/2000	8/9/2000
	Total Natural	565	4/10/2000	4/16/2000	5/2/2000	5/25/2000	7/22/2000
	Overall Total	1441	4/10/2000	4/23/2000	5/10/2000	5/30/2000	8/9/2000
1999	Natural Parr (bseine)	134	4/27/2001	5/5/2001	5/18/2001	5/31/2001	6/19/2001
	Natural Parr	290	4/23/2001	4/28/2001	5/13/2001	5/22/2001	6/17/2001
	Natural Presmolt	663	4/12/2001	4/28/2001	5/13/2001	5/26/2001	8/10/2001
	Natural Smolt	1137	4/23/2001	5/11/2001	5/22/2001	6/9/2001	8/14/2001
	Total Natural	1087	4/12/2001	4/29/2001	5/16/2001	6/1/2001	8/14/2001
2000	Natural Parr (bseine)	10	4/17/2002	4/18/2002	5/10/2002	6/3/2002	6/8/2002
	Natural Fry/Parr	76	4/11/2002	4/15/2002	4/19/2002	5/9/2002	5/31/2002
	Natural Presmolt	341	4/9/2002	4/15/2002	4/26/2002	5/22/2002	6/5/2002
	Natural Smolt	60	4/17/2002	5/4/2002	5/22/2002	6/3/2002	6/14/2002
	Hatchery Smolt	563	4/15/2002	5/11/2002	5/22/2002	6/4/2002	7/5/2002
	Total Natural	477	4/9/2002	4/15/2002	4/25/2002	5/23/2002	6/14/2002
	Overall Total	1040	4/9/2002	4/18/2002	5/20/2002	6/2/2002	7/5/2002
2001	Natural Parr (bseine)	52	4/13/2003	4/23/2003	5/20/2003	5/31/2003	6/13/2003
	Natural Fry/Parr	164	4/3/2003	4/17/2003	5/7/2003	5/27/2003	7/13/2003

Brood Year	Life Stage	LGD Detections	Cumulative Percent Detection Date				
			0%	10%	50%	90%	100%
	Natural Presmolt	273	3/31/2003	4/18/2003	5/5/2003	5/28/2003	6/24/2003
	Natural Smolt	392	4/8/2003	5/6/2003	5/27/2003	6/8/2003	7/18/2003
	Hatchery Smolt	1095	4/14/2003	4/28/2003	5/17/2003	5/27/2003	7/9/2003
	Total Natural	829	3/31/2003	4/19/2003	5/11/2003	5/30/2003	7/18/2003
	Overall Total	1924	3/31/2003	4/22/2003	5/16/2003	5/29/2003	7/18/2003
2002	Natural Parr	190	4/1/2004	4/22/2004	5/5/2004	5/23/2004	6/25/2004
	Natural Presmolt	606	4/1/2004	4/23/2004	5/5/2004	5/23/2004	6/30/2004
	Natural Smolt	772	4/14/2004	5/2/2004	5/16/2004	6/10/2004	7/10/2004
	Hatchery Smolt	2704	4/11/2004	4/27/2004	5/5/2004	5/18/2004	7/7/2004
	Hatchery Presmolt	166	4/14/2004	5/2/2004	5/9/2004	5/29/2004	6/26/2004
	Total Natural	1568	4/1/2004	4/23/2004	5/6/2004	5/24/2004	7/10/2004
	Total Hatchery	2870	4/11/2004	4/27/2004	5/5/2004	5/18/2004	7/7/2004
	Overall Total	4438	4/1/2004	4/25/2004	5/5/2004	5/21/2004	7/10/2004
2003	Natural Parr	445	4/8/2005	4/23/2005	5/5/2005	5/13/2005	6/13/2005
	Natural Presmolt	1048	4/4/2005	4/23/2005	5/5/2005	5/14/2005	6/18/2005
	Natural Smolt	977	4/21/2005	5/5/2005	5/13/2005	6/4/2005	6/20/2005
	Hatchery Smolt	2520	4/19/2005	5/3/2005	5/9/2005	5/24/2005	6/19/2005
	Total Natural	2470	4/4/2005	4/24/2005	5/5/2005	5/20/2005	6/20/2005
	Overall Total	4990	4/4/2005	4/26/2005	5/6/2005	5/21/2005	6/20/2005
2004	Natural Parr	85	4/4/2006	4/24/2006	5/2/2006	5/17/2006	5/20/2006
	Natural Presmolt	368	4/5/2006	4/19/2006	5/1/2006	5/17/2006	6/12/2006
	Natural Smolt	360	4/19/2006	4/29/2006	5/11/2006	5/24/2006	6/18/2006
	Hatchery Smolt	900	4/6/2006	5/2/2006	5/14/2006	5/20/2006	6/22/2006
	Total Natural	813	4/4/2006	4/25/2006	5/6/2006	5/19/2006	6/18/2006
	Overall Total	1713	4/4/2006	4/29/2006	5/11/2006	5/20/2006	6/22/2006
2005	Natural Parr	36	4/14/2007	4/18/2007	5/6/2007	5/17/2007	5/25/2007
	Natural Presmolt	165	4/12/2007	4/19/2007	5/8/2007	5/18/2007	5/28/2007
	Natural Smolt	50	4/18/2007	5/3/2007	5/12/2007	5/21/2007	5/26/2007
	Hatchery Smolt	825	3/29/2007	5/2/2007	5/10/2007	5/18/2007	6/11/2007
	Total Natural	251	4/12/2007	4/18/2007	5/7/2007	5/17/2007	5/28/2007
	Overall Total	1076	3/29/2007	4/27/2007	5/10/2007	5/18/2007	6/11/2007
2006	Natural Fry/Parr	51	4/21/2008	4/30/2008	5/9/2008	5/19/2008	6/26/2008
	Natural Presmolt	339	4/8/2008	4/29/2008	5/8/2008	5/19/2008	6/30/2008
	Natural Smolt	74	5/4/2008	5/9/2008	5/20/2008	5/29/2008	6/11/2008
	Hatchery Smolt	789	4/15/2008	5/5/2008	5/14/2008	6/2/2008	7/3/2008
	Total Natural	464	4/8/2008	4/30/2008	5/9/2008	5/23/2008	6/30/2008
	Overall Total	1253	4/8/2008	5/4/2008	5/13/2008	5/29/2008	7/3/2008
2007	Natural Fry/Parr	227	4/6/2009	4/24/2009	5/1/2009	5/19/2009	5/29/2009
	Natural Presmolt	402	4/6/2009	4/24/2009	4/30/2009	5/19/2009	6/12/2009
	Natural Smolt	125	4/25/2009	4/29/2009	5/15/2009	5/26/2009	6/27/2009

Brood Year	Life Stage	LGD Detections	Cumulative Percent Detection Date				
			0%	10%	50%	90%	100%
	Hatchery Smolt	164	4/23/2009	5/7/2009	5/20/2009	5/28/2009	6/23/2009
	Total Natural	754	4/6/2009	4/24/2009	5/3/2009	5/20/2009	6/27/2009
	Overall Total	918	4/6/2009	4/29/2009	5/19/2009	5/27/2009	6/27/2009
2008	Natural Parr (bseine)	32	4/23/2010	4/25/2010	5/12/2010	5/23/2010	6/4/2010
	Natural Fry/Parr	177	4/21/2010	4/25/2010	5/6/2010	5/21/2010	6/6/2010
	Natural Presmolt	224	4/19/2010	4/25/2010	5/11/2010	5/23/2010	6/7/2010
	Natural Smolt	275	4/24/2010	5/5/2010	5/21/2010	6/6/2010	6/24/2010
	Hatchery Smolt Late	168	4/30/2010	5/16/2010	5/21/2010	5/28/2010	6/8/2010
	Hatchery Smolt Early	117	4/23/2010	4/28/2010	5/19/2010	6/4/2010	6/14/2010
	Hatchery Smolt	285	4/23/2010	5/4/2010	5/20/2010	5/30/2010	6/14/2010
	Total Natural	676	4/19/2010	4/25/2010	5/10/2010	5/24/2010	6/24/2010
	Overall Total	961	4/19/2010	4/26/2010	5/19/2010	5/26/2010	6/24/2010
2009	Natural Parr (bseine)	5	4/5/2011	4/6/2011	5/7/2011	5/17/2011	5/17/2011
	Natural Fry/Parr	306	4/3/2011	4/22/2011	5/10/2011	5/22/2011	6/12/2011
	Natural Presmolt	468	4/4/2011	4/19/2011	5/10/2011	5/21/2011	6/14/2011
	Natural Smolt	293	4/8/2011	5/7/2011	5/20/2011	6/4/2011	6/27/2011
	Hatchery Smolt Late	132	5/8/2011	5/14/2011	5/21/2011	6/8/2011	6/23/2011
	Hatchery Smolt Early	102	5/1/2011	5/11/2011	5/18/2011	6/9/2011	6/26/2011
	Hatchery Smolt	234	5/1/2011	5/12/2011	5/20/2011	6/8/2011	6/26/2011
	Total Natural	1067	4/3/2011	4/22/2011	5/10/2011	5/23/2011	6/27/2011
	Overall Total	1301	4/3/2011	4/27/2011	5/14/2011	5/28/2011	6/27/2011
2010	Natural Parr	301	3/25/2012	4/18/2012	4/26/2012	5/18/2012	6/9/2012
	Natural Presmolt	180	3/31/2012	4/20/2012	4/27/2012	5/20/2012	6/20/2012
	Natural Smolt	128	4/20/2012	4/26/2012	5/17/2012	5/28/2012	6/14/2012
	Hatchery Smolt Late	234	4/25/2012	5/13/2012	5/18/2012	5/25/2012	6/11/2012
	Hatchery Smolt Early	145	3/27/2012	5/3/2012	5/17/2012	5/26/2012	6/23/2012
	Hatchery Smolt	379	3/27/2012	5/10/2012	5/18/2012	5/25/2012	6/23/2012
	Total Natural	609	3/25/2012	4/19/2012	4/27/2012	5/19/2012	6/20/2012
	Overall Total	988	3/25/2012	4/20/2012	5/3/2012	5/22/2012	6/23/2012
2011	Natural Fry/Parr	84	4/6/2013	4/16/2013	5/8/2013	5/15/2013	5/24/2013
	Natural Presmolt	106	4/11/2013	4/23/2013	5/12/2013	5/18/2013	5/28/2013
	Natural Smolt	96	4/19/2013	5/8/2013	5/14/2013	5/22/2013	6/8/2013
	Hatchery Smolt	369	5/3/2013	5/10/2013	5/13/2013	5/17/2013	5/31/2013
	Total Natural	286	4/6/2013	4/19/2013	5/10/2013	5/17/2013	6/8/2013
	Overall Total	655	4/6/2013	5/7/2013	5/13/2013	5/17/2013	6/8/2013

Brood Year	Life Stage	LGD Detections	Cumulative Percent Detection Date				
			0%	10%	50%	90%	100%
2012	Natural Fry/Parr	307	4/2/2014	4/15/2014	4/22/2014	5/8/2014	5/25/2014
	Natural Presmolt	85	4/10/2014	4/16/2014	4/26/2014	5/20/2014	6/8/2014
	Natural Smolt	152	4/14/2014	4/23/2014	5/8/2014	5/25/2014	6/26/2014
	Hatchery Smolt	228	4/17/2014	4/30/2014	5/8/2014	5/20/2014	5/30/2014
	Total Natural	544	4/2/2014	4/15/2014	4/24/2014	5/11/2014	6/26/2014
	Overall Total	772	4/2/2014	4/17/2014	5/5/2014	5/19/2014	6/26/2014
2013	Natural Fry/Parr	46	3/30/2015	4/10/2015	4/25/2015	5/11/2015	5/27/2015
	Natural Presmolt	50	4/1/2015	4/18/2015	4/25/2015	5/11/2015	5/17/2015
	Natural Smolt	6	5/11/2015	5/12/2015	5/13/2015	5/17/2015	5/17/2015
	Hatchery Smolt	60	4/24/2015	5/6/2015	5/11/2015	5/19/2015	6/9/2015
	Total Natural	102	3/30/2015	4/11/2015	4/25/2015	5/11/2015	5/27/2015
	Overall Total	162	3/30/2015	4/25/2015	5/10/2015	5/18/2015	6/9/2015
2014	Natural Fry/Parr	115	4/5/2016	4/12/2016	4/22/2016	5/9/2016	6/12/2016
	Natural Presmolt	228	4/7/2016	4/13/2016	4/23/2016	5/9/2016	6/10/2016
	Natural Smolt	145	4/1/2016	4/16/2016	5/6/2016	5/22/2016	6/15/2016
	Hatchery Smolt	399	4/14/2016	4/25/2016	5/5/2016	5/10/2016	6/9/2016
	Total Natural	488	4/4/2016	4/13/2016	4/27/2016	5/13/2016	6/15/2016
	Overall Total	877	4/6/2016	4/15/2016	4/28/2016	5/12/2016	6/15/2016

Appendix 2: List of Metrics and Indicators

Appendix 2 is intended to provide greater detail for the various procedures listed in the Methods section. Appendix 2 is organized by approaches used for Field Operations and those used in the calculation of Performance Measures. For additional detail, refer to Vogel et al. (2005).

Field Operations

Field operations consisted of the operation of a removable picket-style weir for trapping adults, operation of a rotary screw trap, to trap juveniles, completion of spawning ground surveys to enumerate redds and collect adult carcasses, and marking/tagging of hatchery-origin Chinook.

Adult Weir

Operation of a temporary picket-style weir on Johnson Creek was used for the collection of natural origin brood stock and to manage the composition of spawners above the weir. The location of the weir was approximately 1.62 km below the primary production area (aka "index area"), and 8.2 kilometers upstream of the confluence of Johnson Creek and the East Fork South Fork Salmon River (N 44.901166º W 115.488842º; WGS84 datum). The weir was installed as soon as flows allowed, or sufficiently early to capture the majority of the return, and operated through late September, or seven days after the last fish was captured. The trap box and weir (Appendix Figure 4), was checked daily during its period of operation for fish and/or loose and bent pickets. Origin was used to determine the appropriate management action, including:

(1) All fish that scanned positive for a coded wire tag (CWT) and had an adipose fin present were presumed to be of Johnson Creek supplementation origin. These fish were marked with an opercle punch and released above the weir to spawn naturally.

(2) Fish that possessed an adipose fin and lacked a CWT were presumed to be natural origin Johnson Creek Chinook. These fish were either marked with an opercle punch and released above the weir to spawn naturally, or selected for brood stock and transported to the IDFG-operated Lower Snake River Compensation Plan South Fork Salmon River satellite adult facility. A sliding scale (Appendix Table 33) was used to guide brood stock selection protocol.

(3) All fish that lacked an adipose fin were identified as strays and were euthanized and placed into Johnson Creek for nutrient enhancement or given to Nez Perce Tribal Members for subsistence distribution (as per NOAA ESA Section 10 Permit #1134).

All captured fish were anesthetized with Tricaine Methanesulfonate (MS-222) and examined for length (fork), sex, marks (radio tags, passive integrated transponder tags, coded wire tags, visual implant elastomer), and origin type. Caudal fin tissue samples for genetic analysis were collected from all fish trapped. Sequentially numbered tags were applied to all fish selected as brood stock. All trapping data was entered into the 'FINS' database (http://www.finsnet.org).

Appendix Figure 4. Adult picket weir, upstream trap box, holding and workup area located on Johnson Creek used for capturing Chinook salmon.

Appendix Table 33. Sliding scale for JCAPE brood stock collection

Number of Natural Origin Adult Returns	Number of Adults Retained for Brood stock	Number of Adults Released for Natural Spawning
<100	Consult with NOAA Fisheries on collection and release protocols	Consult with NOAA Fisheries on collection and release protocols
100 - 208	Up to 50% of females and similar number of males	Remainder
>208	Up to 52 pairs, as necessary to produce 150,000 smolts	Remainder

Weir efficiency ($\hat{E}$) was calculated using the following formula:

$$\hat{E} = \frac{H}{\hat{N} + R}$$

where H equals the total number of fish handled at the weir (e.g., removed or passed), $\hat{N}$ equals the population estimate at the weir (e.g., mark/recapture), while R accounts for any weir removals (e.g., fish removed for brood stock, euthanized fish).

Adult outplants

A select number of adult Chinook salmon trapped at the LSRCP South Fork Salmon River weir were transported by IDFG and NPT personnel to the East Fork South Fork Salmon River and outplanted above the Yellow Pine Pit[3]. The practice of outplanting 'excess' adult Chinook from the South Fork Salmon to the East Fork Salmon has occurred for more than 10 years. It represents a collaborative effort between the Idaho Department of Fish and Game and the Nez Perce Tribe to help boost natural spawning in under-utilized spawning habitat and to maximize spawner success. 'Excess' Chinook include those that were not needed for harvest, brood stock, or subsistence requirements. Prior to outplant, fish are sexed to ensure an equal sex ratio. The timing occurs late enough to (1) encourage fish to remain in outplant sites for intended spawning (i.e., after July 25), and (2) ensure that fish are sufficiently mature to decrease chances of fish straying into other tributaries (IDFG et al. 2015). The desired outplant location is above the Yellow Pine Pit, since it represents a partial migratory barrier and can be used to separate volitional returns from non-volitional returns (refer to *Spawner Abundance* calculation methods discussion below). The success of the outplant efforts is evaluated annually via multiple-pass spawning ground surveys conducted by the Nez Perce Tribe.

Rotary Screw Traps

Operation of rotary drum screw traps throughout the migratory year were used to capture, measure, and mark/tag natural origin (NAT) juvenile Chinook salmon. The traps, which were

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[3] The Yellow Pine Pit, also known as the Glory Hole, is a historic mining pit constructed in the 1940s. Upon the cessation of industrial-scale mining in the 1950's, the pit was 'reclaimed' by the East Fork South Fork Salmon River and filled with water to form a small lake. The Yellow Pine Pit currently poses an upstream barrier to adult Chinook salmon migration; downstream movement is not impeded.

manufactured by E.G. Solutions Inc., Corvallis, OR, are located 6.2 kilometers above the confluence of Johnson Creek at river kilometer (RKM) 522.303.215.060.024 (N44.91764, W115.48336) and 7.4 kilometers upstream of the confluence of the Secesh River with the South Fork Salmon River (N45.05952° W115.756908°; Appendix Figure 5 and Appendix Figure 6). The screw traps were attached to a cable suspension system anchored by gabion baskets, which allowed side to side and upstream/downstream movement of the traps. This setup permitted the traps to be fished in the optimum position during most flow conditions. The traps consisted of a trapping cone (1.5 m diameter) supported by a metal A-frame, live box, two six-meter by one-meter pontoons, and a clean-out drum.

Although we attempted to fish the traps continuously, there were times when the traps could not be operated due to low flow or freezing conditions, excessive flow/debris, or mechanical breakdowns. We assume comparatively minimal downstream migration past our traps during December and January. Attempts to adjust population estimates for non-operation periods factor in amount of downtime and required extrapolation, although we typically limited unneeded extrapolation to control for associated bias. For this reason, our estimates represent a minimum number of migrants.

The live box of the screw trap was checked every morning (several times throughout each night and day during high water, storms, or ice-up events). Piscivorous fish and large numbers of incidentally captured fish were removed from the live box and scanned for PIT tags. Mortality due to trapping was noted and recorded.

Processing procedures were similar to those used by Ashe et al. (1995) and Prentice et al. (1990b). On a daily basis, juvenile summer Chinook salmon captured in the trap were removed, placed in 18.9-liter plastic holding buckets, and transported (40 meters) to a data processing area. Fish were then transferred to flow-through work-up vats where they were held prior to being moved to an aerated work-up tub.

Appendix Figure 5. Rotary screw trap located on Johnson Creek used for capturing migrating juvenile Chinook salmon.

Appendix Figure 6. Rotary screw trap located on the lower Secesh River used for capturing migrating juvenile Chinook salmon.

All fish were interrogated for PIT tags using a Destron® loop-style detector and reader, examined for PIT tag scars, marks, and overall physical condition. Fish were measured to the nearest millimeter and weighed to the nearest gram. Fish were anaesthetized in a plastic tub filled with 6 liters of water, 15 milliliters of standard stock solution (15 grams/liter) of MS-222, and buffered with 15 milliliters standard stock solution (30 grams/liter) of sodium bicarbonate to decrease stress and mortality (e.g., McCann et al. 1994). We also used Stress Coat® (1 part Stress Coat® per 1 part distilled water) in work up tubs, on measurement boards and scale tubs in an effort to replace the natural protective slime coating that may have been compromised by handling or measurement-related stress.

Upon anesthetization, unmarked or non-tagged summer Chinook salmon were identified for tagging (PIT tagging protocols follow those described previously) or marking. Earlier in the field season, a large portion of the young of the year (YOY) juveniles collected in the screw traps were too small to be PIT-tagged (e.g., PIT Tag Steering Committee 2014). In order to represent the entire population, we uniquely marked a sub-sample of all fish for trap efficiency estimates with a mark that could be applied to any size fish that were captured.

Freshly marked or tagged fish were placed into an ‘upstream’ live box, while recaptures or incidental catches were placed into a ‘downstream’ live box. Larger or piscivorous specimens were placed into a separate live box to reduce the potential of predation. The live boxes were large, drilled-out plastic shipping boxes with lids, which provided containment, protection, and acclimation of the fish back to the riverine environment. Marked fish spent no less than 12 h in the live boxes and were released at dusk. These protocols helped ensure complete recovery from anesthetic, minimized risk of predation, and promoted reintegration and mixing with other NAT fish during peak movement periods. Following their release, boxes were checked for mortalities and shed PIT tags.

Marked or tagged fish that were placed into the ‘upstream’ live box were used to derive estimates of trap efficiency through their subsequent recapture at the screw trap. The ‘upstream’ fish were released approximately 800 m upstream of the trap or at least two riffles and a pool upstream of the trap. All other fish were held in separate live boxes and released 183 m downstream of the trap. Trap efficiency was determined by releasing a known number of marked or tagged fish above the trap and enumerating recaptures. Trap efficiency was calculated below, where *m* was equal to the number of marked fish and *r* was equal to the number of recaptures. (Murphy et al. Unpublished):

$$\hat{E} = \frac{m+1}{r+1}$$

Spawning Ground Surveys

Multiple-pass spawning ground (a.k.a. *redd*), and carcass surveys were conducted in Johnson Creek and one of its tributaries (Burnt Log Creek). The surveys were conducted to provide researchers an ***index of spawner abundance,*** among other information. Surveys, which initiated in August and concluded mid-September, were conducted weekly on seven discrete sections of Johnson Creek (Appendix Table 34) and three sections of Burnt Log Creek (Appendix Table 35). Nez Perce Tribe staff also conducted spawning ground surveys on the East Fork South Fork Salmon River and two of its primary tributaries (Appendix Table 36-Appendix Table 38) and on mainstem sections of the Secesh River (Appendix Table 39), Grouse Creek (Appendix Table 40), Summit Creek (Appendix Table 41), and Lake Creek (Appendix Table 42).

Appendix Table 34. Transects surveyed in Johnson Creek in 2016. Included are the transect names, lengths, number of passes, and WGS 84 GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Johnson	Transect 1- JC Confluence to NPT screw trap	6.31 km	3	44.917599	-115.483303	44.962469	-115.502462
Johnson	Transect 2 – NPT screw trap to NPT weir	1.94 km	3	44.901133	-115.488911	44.917599	-115.483303
Johnson	Transect 3 – NPT weir to top of Deadhorse rapids	1.62 km	3	44.891857	-115.497874	44.901133	-115.488911
Johnson	Transect 4 – Top of Deadhorse rapids to mouth of Moose Creek	5.46 km	5	44.852421	-115.509112	44.891857	-115.497874
Johnson	Transect 5 – Mouth of Moose Creek to	6.36 km	3	44.802991	-115.518556	44.852421	-115.509112

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
	mouth of Burnt Log Creek						
Johnson	Transect 5a- Burnt Log Cr. to Whitehorse rapids	2.04	2	44.786479	-115.522837	44.802991	-115.518556
Johnson	Transect 6 - Old Burnt Log trail crossing to Landmark bridge	6.61 km	1	44.652479	-115.542345	44.697426	-115.545943
Total Surveyed Length		30.3 km					

Appendix Table 35. Transects surveyed in Burnt Log Creek in 2016. Included are the transect names, lengths, number of passes, and WGS 84 GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Burnt Log	Transect 1 - Mouth of Burnt Log Creek to 2.5 km upstream of Buck Cr.	2.8 km	3	44.780192	-115.52083	44.802991	-115.518556
Burnt Log	Transect 2 – 2.5 km upstream of Buck Cr. to EF Burnt Log	5.3 km	3	44.737409	-115.50138	44.780192	-115.520833
Burnt Log	Transect 3 – EF Burnt Log Cr. to 1st tributary	0.7 km	3	44.731555	-115.4994	44.737409	-115.501385
Total Surveyed Length		8.8 km					

Appendix Table 36. Transects (downstream to upstream boundary) surveyed in the East Fork South Fork Salmon River in 2016. Included are the transect names, lengths, number of passes, and WGS 84 GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
EFSFSR	Transect 1- Lower EFSFSR Bridge to Quartz Cr.	2.51 km	3	44.962422	-115.460072	44.970341	-115.478665
EFSFSR	Transect 2 – Profile Cr. to Lower EFSFSR Bridge	3.45 km	3	44.957856	-115.429275	44.962422	-115.460072
EFSFSR	Transect 3 – Tamarack Cr. to Profile Cr.	4.06 km	3	44.95958	-115.39009	44.957856	-115.429275
EFSFSR	Transect 4 – Salt Cr. to Tamarack Cr.	3.72 km	3	44.9495	-115.352348	44.95958	-115.39009
EFSFSR	Transect 5 – Sugar Cr. Confluence to Salt Cr.	2.23 km	3	44.936109	-115.337985	44.9495	-115.352348
EFSFSR	Transect 6 - Glory Hole to Sugar Cr. Confluence	1.11 km	3	44.927802	-115.334361	44.936109	-115.337985
EFSFSR	Transect 7 - Meadow Cr. to Fiddle Cr. Confluence	2.3 km	1	44.902277	-115.32791	44.921653	-115.33079
Total Surveyed Length		19.38 km					

Appendix Table 37. Transects surveyed in Sugar Creek in 2016. Included is the transect name (upstream to downstream boundary), length, number of passes, and GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.; WGS 84).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Sugar Creek	Transect 1- Cinnibar Cr. to Sugar Cr. Mouth	4.99 km	3	44.952353	-115.293528	44.936109	-115.337985
Total Surveyed Length		4.99 km					

Appendix Table 38. Transects surveyed in Meadow Creek in 2016. Included is the transect name (upstream to downstream boundary), length, number of passes, and GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.; WGS 84).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Meadow Creek	Transect 1- Bottom of Rip Rap – Tailings to Meadow Cr. Mouth	2.1 km	1	44.894399	-115.341151	44.902277	-115.32791
Total Surveyed Length		2.1 km					

Appendix Table 39. Transects surveyed in the Secesh River in 2016. Included are the transect names, lengths, number of passes, and WGS 84 GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Secesh River	Transect 1- DIDSON Weir to Alex Creek	1.82 km	3	45.212399	115.811138	45.2017438	-115.8157537
Secesh River	Transect 2 – Long Gulch Bridge to DIDSON Weir	2.98 km	3	45.2328013	-115.8108184	45.212399	115.811138
Secesh River	Transect 3 – Piah Cr. to Long Gulch Bridge	4.6 km	3	45.2616887	-115.8231827	45.2328013	-115.8108184
Secesh River	Transect 4 – Grouse Jct. Bridge to Piah Cr.	2.5 km	3	45.266856	-115.8460301	45.2616887	-115.8231827
Secesh River	Transect 5 – Lake Cr. Mouth to Grouse Jct. Bridge	5.0 km	4	45.2560432	-115.8970175	45.266856	-115.8460301
Secesh River	Loon - Alex Cr. to Whangdoodle Cr.	6.7 km	3	45.2017438	-115.8157537	45.149503	-115.796661
Total Surveyed Length		23.6 km					

Appendix Table 40. Transects surveyed in Grouse Creek in 2016. Included are the transect names (upstream to downstream), lengths, number of passes, and GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.; WGS 84).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Grouse Creek	Transect 1- 2nd culvert to Grouse Cr. mouth	3.0 km	3	45.2888021	-115.8359747	45.265166	-115.8307318
Total Surveyed Length		3.0 km					

Appendix Table 41. Transects surveyed in Summit Creek in 2016. Included are the transect names, lengths, number of passes, and GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.; WGS 84).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Summit Creek	Transect 1- Lake Rock Bridge to Summit Cr. Mouth	5.5 km	3	45.222756	-115.9294498	45.2560432	-115.8970175
Summit Creek	Transect 2 – Sharp corner to Lake Rock Bridge	3.5 km	3	45.2002074	-115.9552869	45.222756	-115.9294498
Total Surveyed Length		9.0 km					

Appendix Table 42. Transects surveyed in Lake Creek in 2016. Included are the transect names, lengths, number of passes, and GPS coordinates (upstream/downstream (US/DS) latitude (Lat.), longitude (Long.; WGS 84).

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Lake Creek	Transect 1- Three Mile Cr. to Lake Cr. mouth	7.0 km	3	45.2988748	-115.9295377	45.2560432	-115.8970175
Lake Creek	Transect 2a – Willow Cr. to Three Mile Cr.	5.0 km	3	45.3310271	-115.9500034	45.2988748	-115.9295377

Stream	Transect	Transect Length	# of Passes	US Lat.	US Long.	DS Lat.	DS Long.
Lake Creek	Transect 2b – Corduroy Jct. Bridge to Willow Cr.	1.56 km	3	45.3415374	-115.9472394	45.3310271	-115.9500034
Lake Creek	Transect 3 – 0.5 km upstream Corduroy Cr. to Corduroy Jct. Bridge	3.7 km	3	45.366144	-115.933461	45.3415374	-115.9472394
Total Surveyed Length		17.26 km					

Pre-spawn mortality ($\hat{p}$) was calculated as the number of female carcasses recovered during spawning ground surveys that were zero to 25% percent spawned (n_p) divided by the number of female carcasses with a prespawn determination ($n_{f,p}$), which becomes:

$$\hat{p} = \frac{n_p}{n_{f,p}}$$

This percentage can be expanded to an estimated abundance of pre-spawn mortality by multiplying the percentage by the estimated adult escapement. Accurate determination of pre-spawn status of males was not possible due to sperm regeneration. Procedures for spawning ground surveys were based on standardized protocol developed by the NPT Department of Fisheries Resources Management (unpublished) and Hassemer (1993).

Personnel initiated spawning ground surveys mid-morning to ensure adequate light conditions, and proceeded up the stream channel on opposing sides. Chinook salmon redds were enumerated and marked with flagging (on stream bank) and with a Global Positioning System (GPS) unit (in-river, proximal to structure), so that the number of new redds could be determined with each additional survey. Marks on flagging included redd number (chronologically-based), observer's initials, agency initials, and date observed. Conservative counts were made in areas with multiple redds. Redds were directly enumerated and summarized as a total number per stream with no estimate of variation. Number of redds were evaluated temporally and/or spatially (supports index area time series data).

In 2016, fish captured at the Johnson Creek weir were marked with opercle punches, which provided an indication for surveyors that collected the fish as a carcass, that the fish had been processed at the weir (e.g., biological measurements taken and biological samples collected). The opercle punch replaced the opercle tag, which had previously been applied to identify fish that had been worked up and passed above the weir to spawn naturally.

All recovered carcasses were checked for marks, scanned for presence of passive integrated transponder (PIT) tags and the snout scanned for presence of coded wire tags (CWT). Fork lengths were taken to the nearest 0.5 centimeter on all carcasses. Dorsal fin rays were removed from natural-origin carcasses and placed in labeled envelopes for ageing analysis (e.g., Kiefer et al. 2004). Scales were not collected in 2016, which was consistent with protocol from previous years. Carcasses were cut open to verify sex and determine percent spawned. Snouts were removed from all hatchery-origin supplementation carcasses to enable collection of CWT. Prior to their return to the stream, tails were cut off carcasses to prevent sample duplication.

Hatchery Marking and Tagging

All brood year 2014 juvenile supplementation-origin Chinook salmon received a coded wire tag (CWT) during juvenile rearing at the Lower Snake River Compensation Program's McCall hatchery (tag code 22-01-63); the CWT was administered in July (10 months prior to their release). A total of 2,100 juveniles also received a PIT tag in October 2015, approximately five months prior to their direct release in mid-March. Pacific States Marine Fisheries Commission (PSMFC) personnel applied all CWT's. Coded wire tags were implanted using an automated tagging system (AutoFish System) developed by Northwest Marine Technology Inc (NMT). Procedures for operation of the tagging system were followed by PSMFC personnel and are available online through the NMT website (NMT 2007).

All PIT tags were implanted using methods similar to those described by Prentice et al. (1990a, 1990b) and the CBFWA PIT Tag Steering Committee (2014). The SUP fish were taken off feed 24 h prior to treatment. Tagging was done manually using a modified 10cc syringe hand injector unit that consisted of a steel rod, compression spring, push rod and 12-gauge hypodermic needle. Tagging needles and PIT tags were disinfected before each use by soaking them for 10 minutes in 70% ethyl alcohol, and subsequently dried for 10 minutes. The needles, which were manually pre-loaded with PIT tags, were inserted into the fish so that the beveled tip completely penetrated beneath the surface of the skin at a point on the midline of the ventral surface posterior to the pectoral fins. Fish were measured to the nearest millimeter (fork lengths), weighed to the nearest gram using an electronic scale, and placed in a flow-through recovery vat.

Before the March smolt release, fish were sampled to estimate CWT [and VIE tag] retention**.** The PIT tag retention was determined from tags recovered in raceways after tagging. The number of PIT tagged fish was adjusted to account for in-hatchery mortalities and lost/rejected tags. The PIT tag release files were then updated before submitting them to the PIT Tag Information System (PTAGIS). The mortality of fish with marks or tags was also recorded throughout the rearing process so that numbers reportedly released were as accurate as possible.

Performance Measures

Adult Abundance

The Johnson Creek ***tributary escapement*** estimate incorporated two independent estimates; one above the weir and one below the weir. The two estimates were derived and summed to yield a ***tributary escapement*** estimate for the Johnson Creek spawning aggregate. Escapement for the East Fork South Fork Salmon spawning aggregate was calculated using the below-weir methodology, and then combined with the Johnson Creek ***tributary escapement*** estimate to yield an overall population-based ***total escapement*** estimate.

Above Weir Escapement

As discussed previously, all fish trapped at the removable picket weir that were passed above to spawn naturally were marked with an opercle (OP) punch. This mark was either present or absent upon recovery of carcasses during extensive area, multiple-pass spawning ground/carcass surveys. Carcass data (adults and age 3 jacks) was applied to the following terms:

$$\widehat{N} = \frac{(\mathrm{M}+1)(\mathrm{C}+1)}{(\mathrm{R}+1)} - 1$$

Where ***M*** was the number of Chinook salmon marked (OP) and released above the weir with possibility of recapture, ***C*** was the total number of carcasses recovered (marked and unmarked) above the weir during multiple pass spawning ground surveys, and ***R*** was the number of marked

(OP) carcasses found above the weir. For our mark-recapture estimate, the following assumptions were made:

- The OP is not lost; tissue regrowth does not prohibit mark identification.
- Chinook passed above the weir are unable to escape below the weir.

All carcass recoveries that were unidentifiable for marks were removed from analysis. The variance for this estimate was calculated as:

$$Var_N = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}$$

The below-weir abundance estimate and that for the East Fork South Fork Salmon River (above Yellow Pine, ID) used a proportional approach (described in Chasco et al. 2014), which, similar to the mark-recapture approach, incorporated carcasses and redds into the following terms:

$$\widehat{N} = \frac{\#Redds}{\%Female * (1 - PSM)}$$

Where ***#Redds*** were the total number of redds enumerated from spawning ground surveys in a specific area, ***%Female*** was the proportion of the total number of carcasses collected that were determined to be female (through internal examination of gonads), and ***PSM*** was the number of females that had expelled <25% of their gametes upon collection and were termed pre-spawn mortalities. In Johnson Creek, the below-weir estimate was added to the above-weir estimate to yield a ***tributary escapement*** estimate. In the East Fork South Fork, the 'Chasco' estimator was applied to yield an abundance estimate. Estimates from both aggregates (Johnson Creek and the East Fork South Fork) were subsequently added to yield an overall population estimate.

Assumptions associated with the estimator included:

- All redds were enumerated without error
- All females built exactly one redd
- All carcasses were available for recovery
- All carcasses had the same probability of recovery
- Prespawn mortality was equal for males and females

The estimated number of Chinook in the East Fork South Fork Salmon River (above Yellow Pine, ID) only included fish that were deemed to have returned to the river on their own volition.

The estimate excludes hatchery-origin fish (adipose fin-clipped, 2 right opercle punched) that were outplanted from the South Fork Salmon River into Meadow Creek, a tributary to the EFSFSR. Since some of the female outplants could have potentially created redds in the same location as females that returned on their own volition (i.e., downstream from the Glory Hole[4]), we adjusted the total number of redds variable in the 'Chasco' estimator (i.e., ***#Redds***) by 'assigning' origin to the females that were assumed to have created the structures. We assigned origin to the redds by estimating the number of 'viable' outplanted females below the Glory Hole by multiplying the known number of outplants by a pre-spawn mortality rate (e.g., in 2009 there were 133 females outplanted below the Glory hole; 38 of these fish were recovered as carcasses; 71% were determined to be pre-spawn mortalities, yielding 39 'viable' females below the Glory Hole). We then subtracted the number of viable females from the total number of redds below the Glory Hole, again, working under the assumption that females equated to redds, and vice versa.

Methods to estimate escapement in the Secesh are reported in Kinzer (et al., 2012).

Methods to estimate ***total spawner abundance*** differed somewhat from those described in Vogel et al. (2005). Spawner abundance was defined as the number of adults (jacks included) present in Johnson Creek that were available at the time of spawning. Spawner abundance (SA) accounted for changes in the total escapement to the tributary (N) due to fish removed at the weir for brood stock ($BS_{removed}$), additions of fish that were returned to Johnson Creek from brood stock ($BS_{returned}$), additions of Johnson Creek fish that strayed to the South Fork and were subsequently trucked back and released into Johnson Creek ($S_{returned}$), reductions due to fish euthanized at the weir (WE), reductions due to weir mortalities (WM), and reductions due to pre-spawn mortalities (PSM). The formula used in the calculation is shown below;

$$SA = N - BS_{removed} + BS_{returned} + S_{returned} - WE - WM - PSM$$

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[4] The possibility for outplanted females to create redds below the Glory Hole existed for two reasons: 1) females were outplanted below the Glory Hole in 2009 and 2010, and 2) fish were able to migrate downstream of the Glory Hole – just not upstream.

Similar to the formula above, ***total spawner abundance*** calculations for the East Fork South Fork Salmon River spawning aggregate account for changes in total escapement, but instead of reductions, such as those common in Johnson Creek, they account for the additions contributed through the outplants of South Fork Salmon Chinook to the system. The formula used in the total spawner abundance calculation in the East Fork South Fork is shown below;

$$SA = TE + (O * (1 - PSM))$$

where ***TE*** is equal to total escapement, ***O*** represents the number of outplants added to the system, and ***PSM*** represents the proportion of females that are deemed to be pre-spawn mortality.

Juvenile Abundance

Natural origin, brood year-based, ***juvenile emigrant abundance*** was estimated for individual life stages and as a total brood year estimate. Estimates were made from seasonal data collected at rotary screw traps. The three life stages include; fry/ parr, presmolt and smolt. Each life stage was determined by age, biological development and arbitrary seasonal trapping dates. The fry stage consists of newly emerged fry captured during the spring trap season prior to July 1st. Juveniles captured during the summer trap season between July 1 and August 31 were considered parr. The presmolt life stage consists of juvenile fish caught between September 1 and December 31. Smolts were fish captured at age one in the act of migration between January 1 and June 30.

Abundance for each life stage and brood year total was estimated with a software package developed for the Gauss programming language by the University of Idaho (Steinhorst 2004). The program uses three inputs to iteratively maximize the log likelihood until the estimate does not change significantly. The three inputs include; 1) the number of unmarked fish captured, 2) number of marked fish released upstream, and 3) the number of marked recaptures. Since the estimators do not have a finite expectation the Bailey (1951) modified estimator was used to determine abundance (Steinhorst 2004).

The maximum likelihood estimates of abundance and the corresponding confidence intervals require two assumptions. These assumptions include; 1) fish being captured independently and 2) marked fish thoroughly mix with unmarked fish. To meet both assumptions marked fish were released at least three habitat breaks upstream to ensure adequate mixing with unmarked fish. And in order to decrease the variation of seasonal or life stage capture efficiencies, each season was divided into strata with similar environmental conditions and at least seven recaptures. Estimates of abundance for each strata within a season was then summed for a life stage estimate.

The ***smolt abundance*** estimates, which result from juvenile emigrant trapping and PIT tagging, are derived by estimating the proportion of the total juvenile abundance at the tributary comprised of each juvenile life stage (parr, presmolt, smolt) that survive to first mainstem dam encountered (or other common point in mainstem). It is calculated by multiplying the life stage specific abundance estimate (with standard error) by the life stage specific survival estimate to first mainstem dam (with standard error). The standard error around the smolt equivalent estimate is calculated using the following formula; where X = life stage specific juvenile abundance estimate and Y = life stage specific juvenile survival estimate:

$$Var(X * Y) = E(X)^2 * Var(Y) + E(Y)^2 * Var(X) + Var(X) * Var(Y)$$

Hatchery production abundance estimates were based on counts made in the hatchery. Initial abundance estimates were based on female fecundity. Abundance estimates were refined at eye-up, when all eggs were run through a counter. Fish were subtracted from this estimate following subsequent mortality. Another inventory occurred when fish received a CWT mark, during which all hatchery-origin fish were counted. CWT verification occurred when a portion of the hatchery population received passive integrated transponder (PIT) tags.

Juvenile Survival

Estimates of ***juvenile survival to Lower Granite Dam*** were made for three tag groups of BY13 natural-origin (NAT) juvenile Chinook salmon: (1) NAT parr, (2) NAT presmolt, and (3) NAT smolt. Survival estimates for supplementation smolt were conducted independent of natural origin smolt. Survival estimates were calculated using a Cormack Jolly Seber capture-recapture model in the Survival Under Proportion Hazards (SURPH) program (version 3.5; Lady et al. 2013), and were produced by PITPRO 4.19.8 (CI estimated as 1.96*SE). Life stage-based survival to the first mainstem dam (Lower Granite) was calculated and multiplied by the respective tributary abundance estimates. The products were summed to provide an estimate of total smolt abundance surviving to first mainstem dam (a.k.a. ***smolt equivalent survival***).

Productivity

The ***smolt to adult return rate*** or SAR represents the number of adult returns from a given brood year returning to a point (stream mouth, weir) divided by the number of smolts that left this point 1-5 years prior (Beasley et al., 2008). We calculate SAR's for wild and hatchery-origin Chinook separately, and all calculations rely upon abundance values rather than PIT tags (as discussed in Beasley et al., 2008). Our SAR's represent two discreet performance periods: Johnson Creek to Johnson Creek and Lower Granite Dam to Johnson Creek. Johnson Creek to Johnson Creek SAR estimates for natural and hatchery-origin fish are calculated using direct counts of fish returning to the drainage. Direct counts are calculated by dividing the estimated number of natural and hatchery-origin adults returning to the tributary (using run reconstructions) by the estimated number of natural-origin fish and the known number of hatchery-origin fish leaving the tributary. Lower Granite Dam to Johnson Creek SAR estimates are calculated by dividing the number of adults returning to the tributary by the estimated number of PIT tagged juveniles at Lower Granite dam. The estimated number of PIT tagged juveniles at Lower Granite dam is calculated by multiplying life stage specific survival estimates (with standard errors) by the number of juveniles PIT tagged in the tributary. The variance for the estimated number of PIT tagged juveniles at first mainstem dam is calculated as follows:

$$Var(X * Y) = x^2 * Var(Y)$$

where X = the number of PIT tagged fish in the tributary and Y = the variance of the life stage specific survival estimate. The variance around the SAR estimate is calculated as follows:

$$Var\left(\frac{X}{Y}\right) = \left(\frac{EX}{EY}\right)^2 * \left(\frac{Var(Y)}{(EY^2)}\right)$$

where X = the number of adult PIT tagged fish returning to the tributary and Y = the estimated number of juvenile PIT tagged fish at first mainstem dam.

The ***recruits per spawner*** measure represented the number of juvenile fish resulting from adults that spawned in 2012. Several forms of recruit/spawner were applicable. We include four ratios: 1) tributary juvenile abundance to spawner (includes jacks), 2) tributary juvenile abundance to female, 3) juvenile abundance at LGD to spawner (includes jacks), and 4) juvenile abundance at LGD to female.

As described in Vogel et al. (2005; section 1a, and method 1.a.10), ***progeny per parent*** (P:P) ratios for natural and hatchery/supplementation-origin Chinook were calculated from run reconstructions over time. The progeny per parent ratios were evaluated using three variants: ***total progeny per parent, adult per adult, and female per female.*** The ***total progeny per parent*** ratio for natural origin Chinook was calculated as the brood year ratio of total tributary returns to parent spawner abundance; the ratio was expressed by the following terms:

$$\frac{Total\ Progeny\ (Years\ 3{,}4{,}\&5)}{Parent\ (Brood\ Year\ n)} = \frac{Age3_{Esc} + Age4_{Esc} + Age5_{Esc}}{Age4_{Spawners} + Age5_{Spawners}}$$

where brood year ***n*** represented the year the parents spawned, ***Age3, Age4,*** and ***Age5 Esc*** corresponded to the sum total escapement of Chinook that returned to the tributary three (i.e., $Age3_{Esc}$), four ($Age4_{Esc}$), and five ($Age5_{Esc}$) years after the given brood year. The sum of $Age4_{Spawners}$ and $Age5_{Spawners}$ was based on the single brood year, excluded age-three Chinook (i.e., jacks), and excluded fish that were determined to be a pre-spawn mortality. An important distinction to make between the numerator and denominator in this calculation was that the numerator was based on ***total tributary escapement*** values whereas the denominator was based on ***spawner abundance*** values. The ***total progeny per parent*** ratio for hatchery/supplementation-origin Chinook was calculated similar to natural origin Chinook, and used the brood year ratio of total tributary returns to adult brood stock spawned; the ratio was expressed by the following terms:

$$\frac{Total\ Progeny\ (Years\ 3{,}4{,}\&5)}{Parent\ (Brood\ Year\ n)} = \frac{Age3_{Esc} + Age4_{Esc} + Age5_{Esc}}{Age4_{Brood\ Spawned} + Age5_{Brood\ Spawned}}$$

where brood year ***n*** represented the year the brood stock parents spawned, ***Age3, Age4,*** and ***Age5 Esc*** corresponded to the sum total escapement of Chinook that returned to the tributary three (i.e., $Age3_{Esc}$), four ($Age4_{Esc}$), and five ($Age5_{Esc}$) years after the given brood year. The sum of $Age4_{Brood\ Spawned}$ and $Age5_{Brood\ Spawned}$ was based on the single brood year, excluded age-three Chinook (i.e., jacks), and excluded fish that were permanently removed from the tributary and did not contribute to spawning (i.e., ***pre-spawn mortality***). The other variants of the P:P ratio, ***adult to adult*** and ***female to female*** were calculated using the same methods described above, but did not include jacks in the numerator, or males in either the denominator or numerator (respectively).

Genetics

The ***relative reproductive success*** performance measure was a derived measure assessed by the Columbia River Inter Tribal Fisheries Commission (CRITFC), Hagerman Genetics Laboratory. The CRITFC geneticists used molecular markers to track the pedigrees of six complete generations and to investigate differences in reproductive success (i.e., the number of returning adult offspring produced per adult individual) of wild and hatchery-reared Chinook salmon spawning in the natural environment. Three objectives regarding the demographic and genetic impacts of supplementation to a natural population were evaluated: (1) whether the supplementation program provided a demographic boost to the population, (2) whether there were differences in reproductive success between hatchery-reared and wild-origin fish spawning naturally, and (3) to assess the effect of hatchery-reared fish on the fitness of wild-origin fish. Assessments were made through BY08 (includes adult offspring from BY08 and grand-offspring from BY03). Specific methods used are available in Hess et al. (2012).

To address our first objective and determine whether the supplementation program provided a demographic boost to the natural population, we compared the numbers of offspring produced by fish that were removed from the wild and taken into the hatchery intended for use as brood stock versus individuals that were allowed to spawn in the natural environment. The numbers of adult offspring produced each year (1998–2008) and the numbers of adult grand-offspring produced from BY 1998, BY 2000-2003 were calculated based on parentage exclusion results for both artificially and naturally spawning individuals.

Our second objective was to determine whether there were differences in reproductive success between hatchery-reared and wild-origin fish spawning naturally (reproductive success of F1 fish produced from BY 1998 and 2000-2003). Mean reproductive success was estimated separately for males and females by age class. To compare reproductive success separately for jacks, males and females in each year, we calculated RRS by dividing the average reproductive success of hatchery-reared fish by the average reproductive success of wild fish of the same gender and age.

RRS estimates were calculated in two ways to include (i) all F1 potential parents and (ii) only successful F1 parents that contributed to the next generation by producing one or more returning adult offspring. To compare reproductive success of hatchery-reared males and females, we calculated RRS by dividing the average reproductive success of hatchery-reared males by the average reproductive success of hatchery-reared females of the same age.

Our third objective was to evaluate the effect of hatchery-reared fish on the fitness of wild-origin fish. To do this we compared the reproductive success among mating types in the wild for BY 2003 to 2008 (e.g., hatchery x natural (HxN), hatchery x hatchery (HxH), or natural x natural (NxN)). Age classes were combined in each return year (i.e. RS of all returns in a given year was evaluated), but comparisons were made separately for males and females in addition to an analysis of sexes combined. If hatchery rearing reduces the fitness of wild-origin fish, we would expect the H x N mating type to produce significantly fewer returning adult offspring than the N x N mating type.

Life History Characteristics

Age Class Structure**, **age at return, size at return, percent females (adults), adult run timing, age, size, and condition of juveniles at emigration, and ***juvenile emigration timing*** are life history performance measures used by the JCAPE M&E program to evaluate natural and hatchery/supplementation Chinook traits which affect growth, reproduction, and survivorship. The following life history performance measures used by the JCAPE M&E program are listed with the JCAPE M&E plan method section (e.g., Vogel et al. 2005) that pertains to the performance measure listed in parentheses and are described in Beasley (et al., 2008): ***age class structure*** (1.a.6), ***age at return*** (1.a.6), ***size at return*** (2.a.2), ***adult spawner sex ratio*** (2.a.3), ***fecundity by age*** (5.a.1), and ***adult run/spawn timing*** (2.a.4).

Age class structure is the proportion of the escapement composed of adult (includes jacks) individuals of different brood years. It is calculated for wild and hatchery-origin brood adult (includes jacks) returns. Various ageing methods are used to assign individuals to specific brood years, including those listed in Appendix Table 43. The ‘known-aged’ carcasses are proportionately applied to unknown-aged individuals to provide an *age class structure* for the entire escapement.

Age at return represents the age distribution of Chinook from individual cohorts returning from a common brood year. This performance measure is calculated using tributary escapement values for wild and hatchery-origin adult (includes jacks) returns. Ages are assessed via methods defined above (Appendix Table 43).

Appendix Table 43. Ageing methods used to assign 'known age' designations to carcasses collected during spawning ground surveys, brood stock collections, and/or weir mortalities.

Ageing via Marks and Tags	Calcified Structure Ageing	Other Ageing Methods
PIT tags	Dorsal fin rays	Genetics – parentage analysis
CWT	Scales	
VIE tags		

Age, size, and condition of juveniles at emigration are defined separately in Beasley (et. al. 2006), however due to their interrelatedness, are treated concurrently in this document. The age of Chinook emigrating past the Johnson Creek rotary screw trap (a*ge at emigration*) was based on a brood year designation (the year eggs were placed in the gravel) and determined using date and length criteria. Trapping seasons were broken into six time periods and used to evaluate various life stages of migrating fish. Appendix Table 44 provides an example of the age structure, life stages and time periods of Brood Year 2012 Chinook captured at the rotary screw trap.

Appendix Table 44. Definition of the age structure, life stage and season dates of Brood Year 2014 juvenile summer Chinook salmon captured at the Johnson Creek rotary screw trap.

Brood Year	**Age**	**Life Stage**	**Trapping Seasons**	**Season Dates**	**Definition**
2014	0+	Fry	1st Spring	01/01/2015 to 06/30/2015	Newly emerged progeny from adults that spawned in the summer/fall of 2012.
		Parr	1st Summer	07/01/2015 to 08/31/2015	Actively migrating progeny that are entering their first summer in fresh water.
		Presmolt	1st Fall	09/01/2015 to 12/31/2015	Actively migrating progeny that do not show typical smolt characteristics (e.g., lack a silvery color and the tendency to easily lose their scales).
	1+	Smolt	2nd Spring	01/01/2016 to 6/30/2016	Actively migrating progeny that are larger, exhibit a more fusiform shape than earlier life stages, and are more silvery in color. These migrants are greater than one year old.
		Yearlings I	2nd Summer 2nd Fall	07/01/2016 to 12/31/2016	Fish in their 2nd summer or 2nd fall. These fish tend to have a higher condition factors than 1st year progeny. Some of these fish are sexually mature (presence of milt) while others are not.
	2+	Yearlings II	3rd Spring	01/01/2017 to 06/30/2017	Migrating progeny that reared in freshwater for three springs.

From 2009 to 2011, we collected scale samples throughout the trapping seasons from various sized Chinook and sent them to the Idaho Department of Fish and Game Nampa Research station for analysis. Scales were aged using protocols outlined in their procedures manual (Wright et al., 2014). The length (*size at emigration*) of known aged fish was then fitted to the Von Bertalanffy Growth model (below) to develop a cohort-specific growth curve (Appendix Figure 7; Von Bertalanffy, 1938).

$$L_t = L_\infty \left(1 - e^{-K[t-t_o]}\right) + E$$

$L_\infty = asymptotic\ average\ maximum\ body\ size$

$K = growth\ rate\ coefficient$

$t_o = hypothetical\ age\ at\ which\ length\ is\ zero$

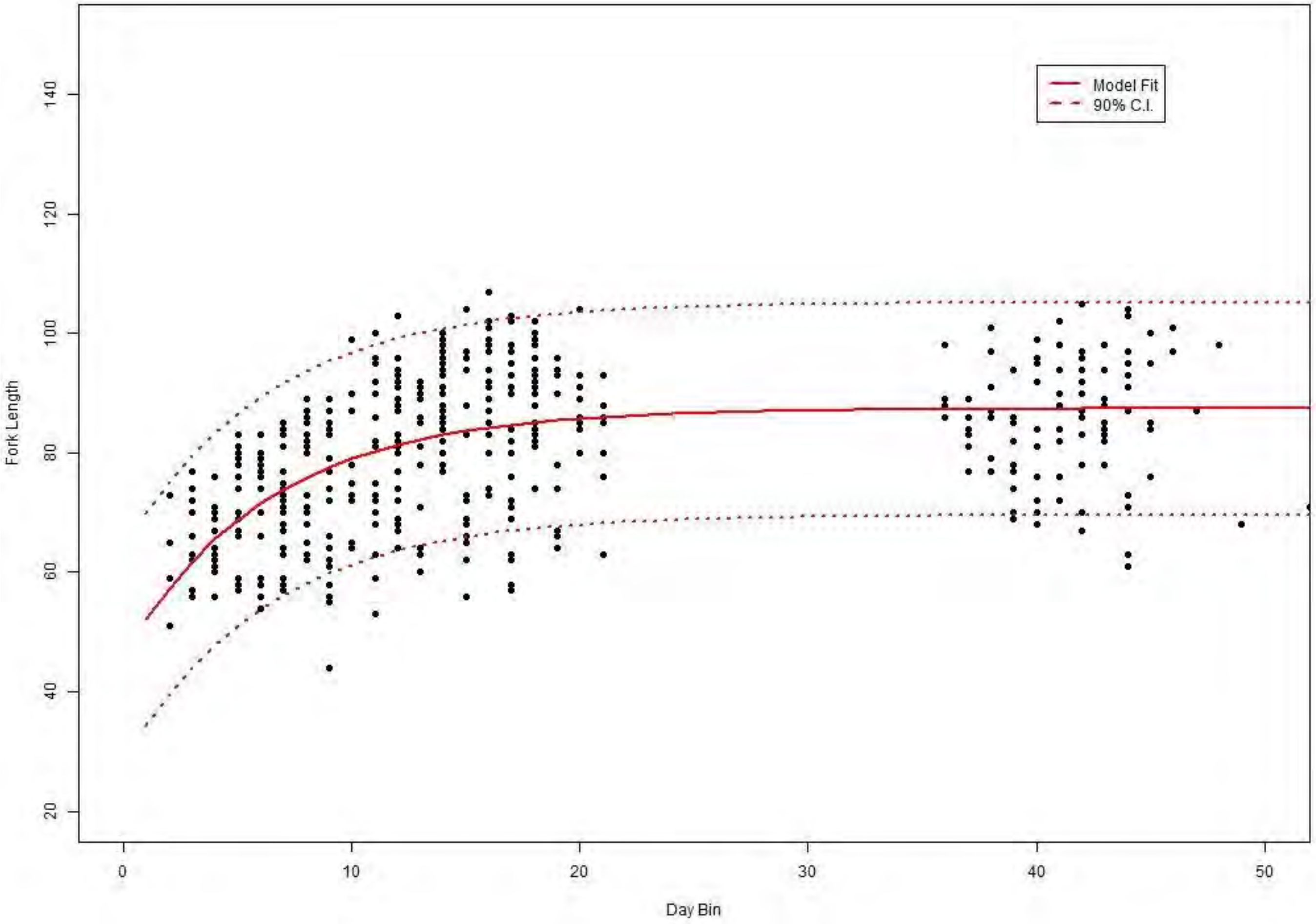
The results of the growth model allowed us to use the following cohort specific length at age key (Appendix Table 45) on fish captured at the trap.

The *condition of juveniles at emigration* performance measure is generated in the field from natural origin migrants captured at the Johnson Creek rotary screw trap. Fork length (mm) and weight (g) are representatively collected weekly from at least 100 migrating natural juveniles captured in migration traps. Mean fork length and variance for all samples within a lifestage-specific migration period are generated. The performance measure is generated using the Fulton condition factor (e.g., Everhart and Young's 1992), which is expressed by *K* and is calculated using the following terms:

$$K = (\frac{w}{l^3})(10^4)$$

where *w* is weight (g) and *l* is length (fork length, mm). Because of daily variation in the numbers of fish trapped and their associated weights and lengths, it was necessary to use weighted averages in summarizations of periodic (i.e. monthly or bi-monthly) data. Summaries of size (length and weight) and condition factor at migration incorporate the formula:

$$\bar{x} = \frac{\sum_{i-1}^{n} w_i x_i}{\sum_{i-1}^{n} w_i}$$



Appendix Figure 7. Johnson Creek juvenile Chinook growth curve. Curve was developed using the Von Bertalanffy growth model (Von Bertalanffy 1938) which incorporated scale-based age and fork length data collected from juvenile migrants that were trapped at the Johnson Creek rotary screw trap over the years 2009-2011.

Appendix Table 45. Length at age key for BY13 Johnson Creek natural-origin juvenile Chinook salmon.

Start Date	End Date	Age	Lifestage	Length (mm)	Lower 90% C.I.	Upper 90% C.I.
7/1/2015	7/7/2015	0+	Parr	52	34	70
7/8/2015	7/14/2015			57	39	75
7/15/2015	7/21/2015			62	44	80
7/22/2015	7/28/2015			66	48	84
7/29/2015	8/4/2015			69	51	87
8/5/2015	8/11/2015			72	54	90
8/12/2015	8/18/2015			74	56	92
8/19/2015	8/25/2015			76	58	94
8/26/2015	9/1/2015			78	60	96
9/2/2015	9/8/2015		Presmolt	79	61	97
9/9/2015	9/15/2015			80	62	98
9/16/2015	9/22/2015			81	63	99
9/23/2015	9/29/2015			82	64	100
9/30/2015	10/6/2015			83	65	101
10/7/2015	10/13/2015			84	66	102
10/14/2015	10/20/2015			84	66	102
10/21/2015	10/27/2015			85	67	103
10/28/2015	11/3/2015			85	67	103
11/4/2015	11/10/2015			85	67	103
11/11/2015	11/17/2015			86	68	104
11/18/2015	11/24/2015			86	68	104
11/25/2015	12/1/2015			86	68	104
2/24/2016	3/1/2016	1+	Smolt	87	69	105
3/2/2016	3/8/2016			87	69	105
3/9/2016	3/15/2016			87	69	105
3/16/2016	3/22/2016			87	69	105
3/23/2016	3/29/2016			87	69	105
3/30/2016	4/5/2016			87	69	105
4/6/2016	4/12/2016			87	69	105
4/13/2016	4/19/2016			87	69	105
4/20/2016	4/26/2016			87	69	105
4/27/2016	5/3/2016			87	69	105
5/4/2016	5/10/2016			87	69	105
5/11/2016	5/17/2016			87	69	105
5/18/2016	5/24/2016			87	69	105
5/25/2016	5/31/2016			87	69	105
6/1/2016	6/7/2016			87	69	105
6/8/2016	6/14/2016			87	69	105
6/15/2016	6/21/2016			87	69	105
6/22/2016	6/28/2016			87	69	105

For supplementation origin Chinook, fish per pound (FPP) counts were taken by hatchery personnel on a monthly basis. Fish were weighed using a suspended scale and individually counted to determine the respective FPP (e.g., Hill and Gebhards 2016). The FPP value was then applied to a condition factor (*C*) value (e.g., Piper et al. 1982) to obtain an estimated length (e.g., total length measured in inches). This conversion, however, was deemed to be non-representative of actual lengths of Johnson Creek fish, as the empirically-derived length values consistently differed from actual measurements obtained during marking/tagging events. And because the tagging events only occurred once per year (typically in January), it was impossible to use the values to characterize monthly length/weight relationships (condition factors) over the hatchery rearing period.

Size at return represents the size distribution of spawners. It is determined using fork lengths (to the nearest 0.5 cm) that are obtained at the adult picket weir and/or during spawning ground/carcass surveys.

The *percent females (adults)* performance measure represents the percentage of females in the total escapement to the tributary and for the spawning population. It is calculated using 1) weir data, 2) total known-origin carcass recoveries, and 3) weir data and unmarked carcasses above and below the weir. It is calculated for wild, hatchery, and total Chinook.

Adult run timing is the arrival timing of adults at the Johnson Creek weir (or other monitoring sites such as the East Fork South Fork PIT array). It is calculated as a range, 10%, median, and 90% percentiles. The *adult run timing* performance measure is calculated for wild and hatchery-origin fish separately, and total.

Juvenile emigration timing is characterized by individual life stages at the Johnson Creek rotary screw trap and at lower Granite Dam (LGD). Capture histories and relative proportions of PIT tagged, Johnson Creek juveniles were used in conjunction with seasonal population estimates (refer to *Juvenile Abundance to Tributary* methods section) to describe *juvenile emigration timing.* As described previously, total emigrants at Johnson Creek included fry/parr, presmolt, and smolt life stages, each of which were based on age, biological development, and seasonal trapping dates. Weekly population estimates are presented either as proportional or cumulative distributions over time relative to the total escapement. Run timing of BY14 NAT juveniles captured at the juvenile trap and that of PIT-tagged SUP and NAT juveniles detected at LGD are presented. Emigration timing at the rotary screw trap is expressed as the percent of total abundance over time while the median, 0%, 10, 50%, 90% and 100% detection dates are calculated for fish at LGD.

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