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*

This page intentionally left blank

Table of Contents

List of Tables

List of Figures

This page intentionally left blank

Contributors
West Coast Region
(alphabetical)

Nora Berwick
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-231-6887
Nora.Berwick@noaa.gov

Diana Dishman
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
(503) 736-4466
diana.dishman@noaa.gov

Patty Dornbusch
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-230-5430
Patty.Dornbusch@noaa.gov

Chad Fealko
1205 South Challis Street
Salmon, ID 83467
208-753-5105
Chad.Fealko@noaa.gov

Sarah Fesenmyer
800 E. Park Blvd, Plaza IV, Suite 220
Boise, ID, 83712
208-378-5660
Sarah.Fesenmeyer@noaa.gov

Ritchie Graves
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-231-6891
Ritchie.Graves@noaa.gov

Lynne Krasnow
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-231-2163
Lynne.Krasnow@noaa.gov

Aurele LaMontagne
800 E. Park Blvd, Plaza IV, Suite 220
Boise, ID, 83712
208-378-5686
Aurele.Lamontagne@noaa.gov

Nancy Munn
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-231-6269
Nancy.Munn@noaa.gov

Natasha Preston
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-231-2178
Natasha.Preston@noaa.gov

Anthony Siniscal
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
971-322-8407
Anthony.Simiscal@noaa.gov

Northwest Fisheries Science Center (alphabetical)

Chris Jordan, PhD
Newport Research Station, Bldg 955
2032 S.E. OSU Drive
Newport, Oregon 97365-5275
541-754-4629
Chris.Jordan@noaa.gov

Mari Williams
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232
503-231-6880
Mari.Williams@noaa.gov

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

[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.

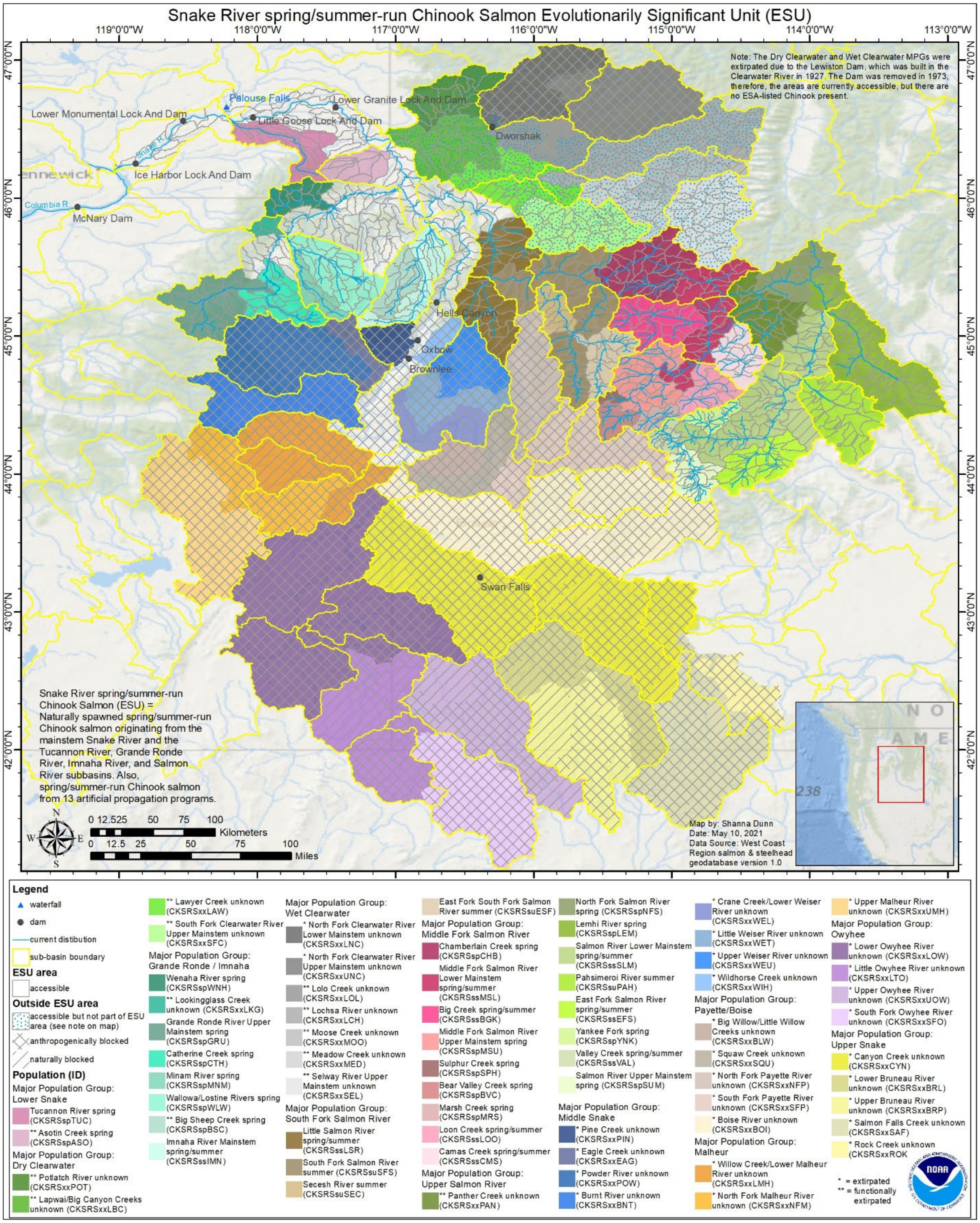


Figure 2. Snake River spring/summer Chinook salmon populations and major population groups.

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

[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. Viabilitykey: 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. Viabilitykey: 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%)		*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.

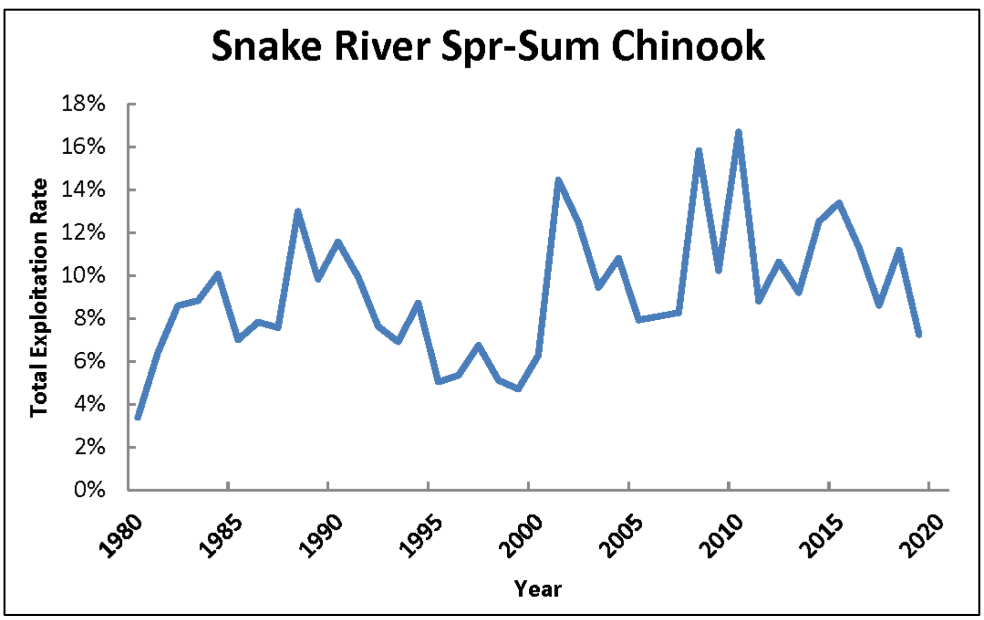


Figure 8. Total exploitation rates for Snake River spring/summer Chinook salmon in the mainstem Columbia River fisheries. Data from the Columbia River Technical Advisory Team, as presented in NWFSC (2021).

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/). 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.

---

[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.

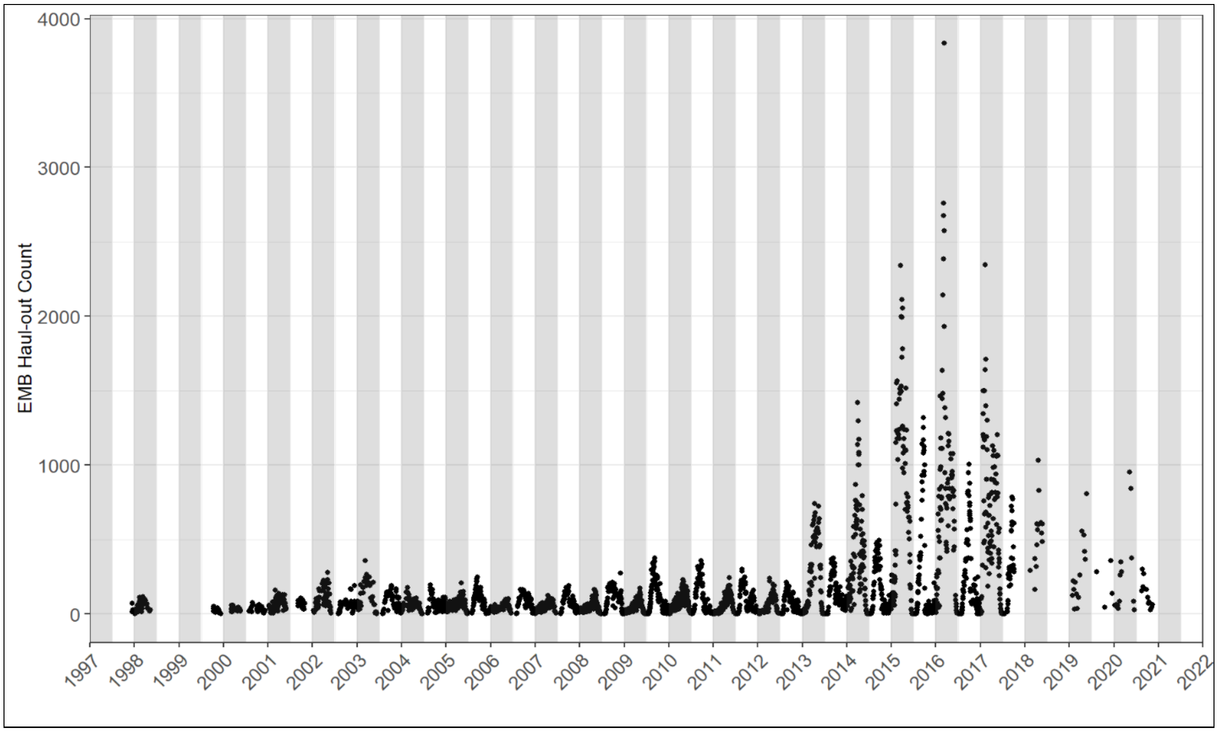


Figure 9. Estimated peak counts (spring and fall) of California sea lions in the East Mooring Basin in Astoria, Oregon, 1998 through 2020.[5]

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

[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).

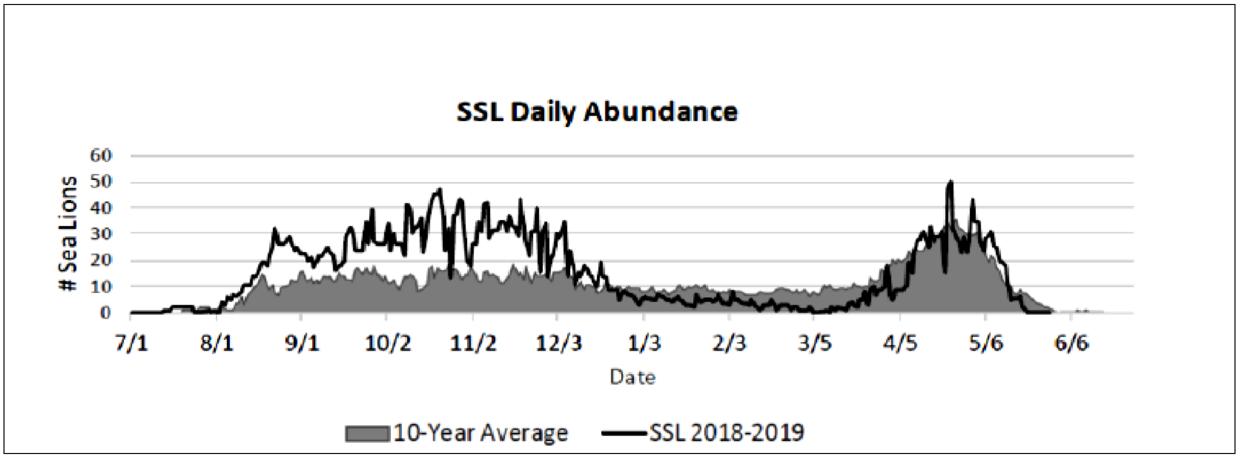


Figure 10. Maximum daily count of Steller sea lions at Bonneville Dam from 1 July 2018 through 30 June 2019 compared to the 10-year maximum daily average (Tidwell et al. 2020).

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

---

[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

---

[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).

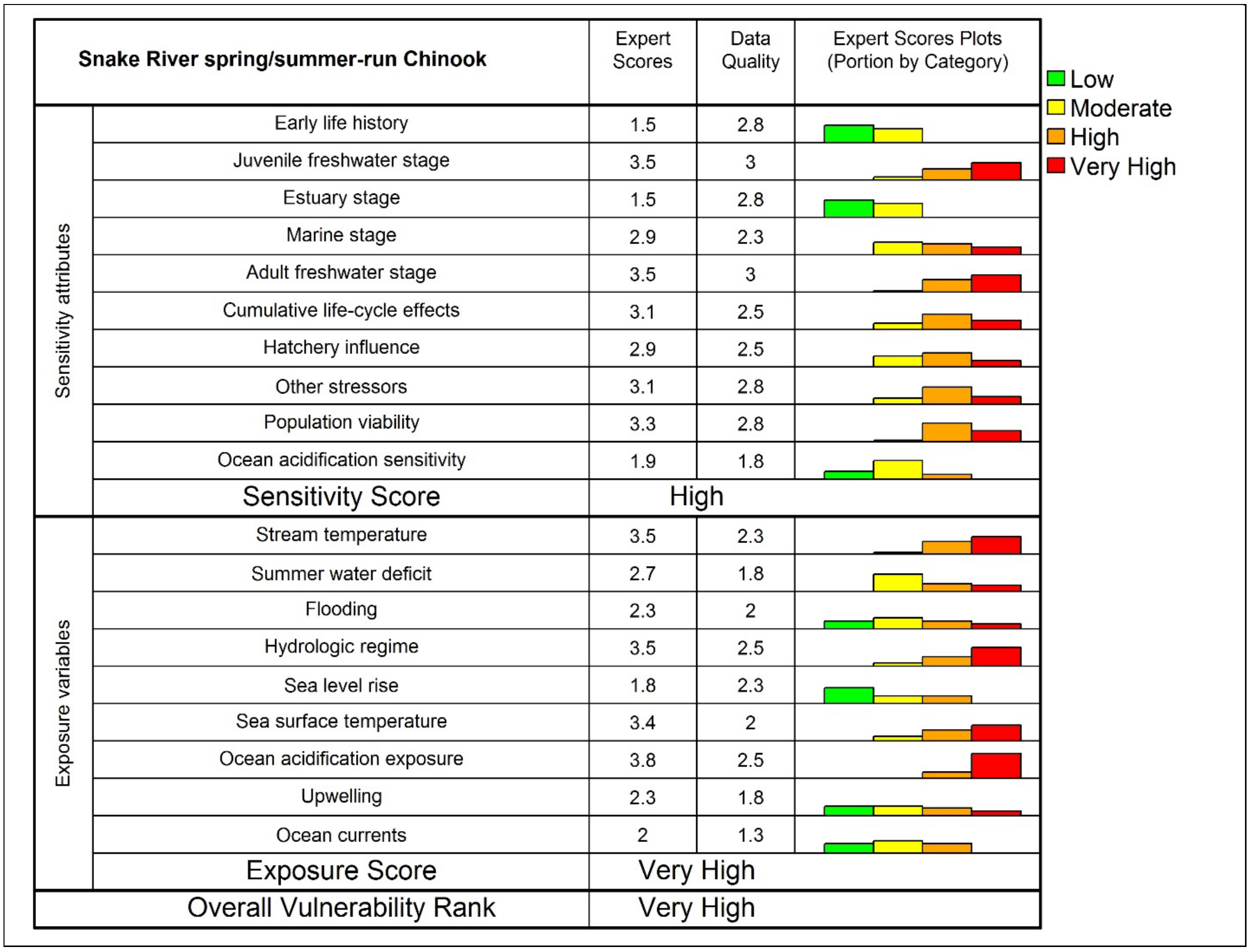
Populations within this ESU that migrate later are called summer-run fish. Examples are the Pahsimeroi and South Fork Salmon River populations, which encounter stressful temperatures during the adult migration. However, both spring- and summer-run populations are at risk for prespawn mortality while 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
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.

This page intentionally left blank.

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.

This page intestinally left blank

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.

5.2 Literature Cited

Adkison, M. D. 1995. Population differentiation in Pacific salmon: local adaptation, genetic drift, or the environment. Canadian Journal of Fisheries and Aquatic Sciences 52: 2762–2777.

Anttila, K., A. P. Farrell, D. A. Patterson, S. G. Hinch, and E. J. Eliason. 2019. Cardiac SERCA activity in sockeye salmon populations: an adaptive response to migration conditions. Canadian Journal of Fisheries and Aquatic Sciences 76(1):1-5.

Arthaud, D., C. Greene, K. Guilbault, and J. Morrow. 2010. Contrasting life-cycle impacts of stream flow on two Chinook salmon populations. Hydrobiologia. 655. 171-188. 10.1007/s10750-010-0419-0.

Beechie, T. J., D. A. Sear, J. D. Olden, G. R. Pess, J. M. Buffington, H. Moir, P. Roni, and M. M. Pollock. 2010. Process-based Principles for Restoring River Ecosystems. BioScience 60(3):209-222. DOI:10.1525/bio.2010.60.3.7, 3/1/2010.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2013. Restoring Salmon Habitat for a Changing Climate. River Research and Application 29:939-960. DOI: 10.1002/rra.2590.

Biomark ABS, Applied Science and Engineering, U.S. Department of Interior Bureau of Reclamation, Idaho Governor's Office of Species Conservation, Trout Unlimited, and The Nature Conservancy. 2019. Upper Salmon Subbasin Habitat Integrated Rehabilitation, Assessment, June 2019. 297 p.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptista, D. A. Jay, K. K. Jones, et al. 2005. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-68, 8/1/2005.

Bowerman, T., M. L. Keefer, and C. C. Caudill. 2016. Pacific salmon prespawn mortality: patterns, methods, and study design considerations. Fisheries 41:738-749.

BPA (Bonneville Power Administration), USBR (U.S. Bureau of Reclamation), and USACE (U.S. Army Corps of Engineers). 2020. Biological Assessment of Effects of the Operations and Maintenance of the Federal Columbia River System on ESA-Listed Species. Bonneville Power Administration, Portland, Oregon, 1/1/2020.

Brodeur, R. D., T. D. Auth, and A. J. Phillips. 2019. Major Shifts in Pelagic Micronekton and Macrozooplankton Community Structure in an Upwelling Ecosystem Related to an Unprecedented Marine Heatwave. Front. Mar. Sci. 6:212. doi: 10.3389/fmars.2019.00212.

Brophy L. S., C. M. Greene, V. C. Hare, B. Holycross, A. Lanier, W. N. Heady, et al. 2019. Insights into estuary habitat loss in the western United States using a new method for mapping maximum extent of tidal wetlands. PLoS ONE 14(8): e0218558.

Buehrens, T. and N. Kendall. 2021. PART I: Status and Trends Analysis of Adult Abundance Data. Prepared in Support of Governor's Salmon Recovery Office 2020 State of Salmon in Watersheds Report. State of Washington, Department of Fish and Wildlife, Olympia, Washington. 22p.

Busack, C. 2015. Extending the Ford model to three or more populations. August 31, 2015. Sustainable Fisheries Division, West Coast Region, National Marine Fisheries Service. 5p.

Camacho, C. A., T. Delomas, M. Davison, M. E. Dobos, W. C. Schrader, T. Copeland, et al. 2019a. Wild adult steelhead and Chinook salmon abundance and composition at Lower Granite Dam, spawn year 2018. Annual Progress Report. Idaho Department of Fish and Game Report Number 19-09, 3/2019.

Camacho, C. A., T. Delomas, M. Davison, M. E. Dobos, W. C. Schrader, M. R. Campbell, et al. 2019b. Wild juvenile steelhead and Chinook salmon abundance and composition at Lower Granite Dam, migratory year 2018. Annual Progress Report. Idaho Department of Fish and Game Report Number 19-12, 5/2019.

Carretta, J. V., K. A. Forney, E. M. Oleson, D. W. Weller, A. R. Lang, J. Baker, M. M. Muto, B. Hanson, A. J. Orr, H. Huber, M. S. Lowry, J. Barlow, J. E. Moore, D. Lynch, L. Carswell, and R. L. Brownell Jr. 2019. U.S. Pacific Marine Mammal Stock Assessments: 2018. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-617.

Carr-Harris, C. N., J. W Moore, A. S. Gottesfeld, J. A. Gordon, W. M. Shepert, J. D. J. Henry Jr., H. J. Russell, W. N. B. Helin, D. J. Doolan, and T. D. Beacham. 2018. Phenological diversity of salmon smolt migration timing within a large watershed. Transactions of the American Fisheries Society 147(5):775-790.

Chasco, B. E., I. C. Kaplan, A. C. Thomas, A. Acevedo-Gutiérrez, D. P. Noren, M. J. Ford, M. B. Hanson, J. J. Scordino, S. J. Jeffries, K. N. Marshall, A. O. Shelton, C. Matkin, B. J. Burke, and E. J. Ward. 2017a. Competing tradeoffs between increasing marine mammal predation and fisheries harvest of Chinook salmon. Scientific Reports 7:15439. https://doi.org/10.1038/s41598-017-14984-8

Chasco, B., I. C. Kaplan, A. Thomas, A. Acevedo-Gutiérrez, D. Noren, M. J. Ford, M. B. Hanson, J. Scordino, S. Jeffries, S. Pearson, K. N. Marshall, and E. J. Ward. 2017b. Estimates of Chinook salmon consumption in Washington State inland waters by four marine mammal predators from 1970–2015. Canadian Journal of Fisheries and Aquatic Sciences. 74(8): 1173-1194. https://doi.org/10.1139/cjfas-2016-0203

Climate Impacts Group. 2004. Overview of Climate Change Impacts in the U.S. Pacific Northwest, 7/29/2004.

Conley, K. R. and Denny, L. P. 2019. Annual report on monitoring and evaluation of the Panther Creek Chinook Salmon Project – 2018. Shoshone Bannock Tribes, Fort Hall, Idaho. Available from: https://www.cbfish.org/Document.mvc/Viewer/P167789

Copeland, T., D. Blythe, W. Schoby, E. Felts, and P. Murphy. 2020. Population effect of a large-scale stream restoration effort on Chinook salmon in the Pahsimeroi River, Idaho. River Res Applic. 2021; 37:100–110. https://doi.org/10.1002/rra.3748

Crozier, L. 2016. Impacts of Climate Change on Salmon of the Pacific Northwest: A Review of the Scientific Literature Published in 2015. Northwest Fisheries Science Center. October 2016.

Crozier, L. and R. W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon. J Anim Ecol 75:1100-1109.

Crozier, L. and R. W. Zabel. 2013. Population responses of spring/summer Chinook salmon to projected changes in stream flow and temperature in the Salmon River Basin, Idaho.in R. W. Zabel, T. D. Cooney, and C. E. Jordan, editors. Life cycle models of interior Columbia River populations. U.S. Dep Commerce NWFSC Draft Technical Report, Seattle, WA.

Crozier, L. G., A. P. Hendry, P. W. Lawson, T. P. Quinn, N. J. Mantua, J. Battin, R. G. Shaw, and R. B. Huey. 2008a. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evol Appl 1:252-270.

Crozier, L. G., R. W. Zabel, and A. F. Hamlett. 2008b. Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. Global Change Biol 14:236-249.

Crozier, L. G., M. M. McClure, T. Beechie, S. J. Bograd, D. A. Boughton, M. Carr, T. D. Cooney, et al. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

Crozier, L. G., J. E. Siegel, L. E. Wiesebron, E. M. Trujillo, B. J. Burke, B. P. Sandford, and D. L. Widener. 2020. Snake River sockeye and Chinook salmon in a changing climate: Implications for upstream migration survival during recent extreme and future climates. PLoS One. 2020 Sep 30;15(9).

Crozier, L. G., B. J. Burke, B. E. Chasco, D. L. Widener, and R. W. Zabel. 2021. Climate change threatens Chinook salmon throughout their life cycle. Commun Biol 4, 222 (2021). https://doi.org/10.1038/s42003-021-01734-w

Dwire, K. A., S. Mellmann-Brown, and J. T. Gurrieri. 2018. Potential effects of climate change on riparian areas, wetlands, and groundwater-dependent ecosystems in the Blue Mountains, Oregon, USA. Climate Services, 44-52.

Espinasse, B., B. P. V. Hunt, Y. D. Coll, and E. A. Pakhomov. 2019. Investigating high seas foraging conditions for salmon in the North Pacific: insights from a 100-year scale archive for Rivers Inlet sockeye salmon. Canadian Journal of Fisheries and Aquatic Sciences 76(6):918-927.

Faulkner, J. R., D. L. Widener, S. G. Smith, T. M. Marsh, and R. W. Zabel. 2018. Survival estimates for the passage of spring migrating juvenile salmonids through Snake and Columbia River dams and reservoirs, 2017. Draft report of the to the Bonneville Power Administration, U.S. Dep Commerce report of research by the Fish Ecology Division, Northwest Fisheries Science Center, Seattle, WA.

Fleming, I. A. and M. R. Gross. 1993. Breeding Success of Hatchery and Wild Coho Salmon (Oncorhynchus Kisutch) in Competition. Ecol Appl. 1993 May;3(2):230-245. doi: 10.2307/1941826. PMID: 27759325.

Ford, M. J. (Ed.), T. Cooney, P. McElhany, N. Sands, L. Weitkamp, J. Hard, M. McClure, R. Kope, J. Myers, A. Albaugh, K. Barnas, D. Teel, P. Moran and J. Cowen. 2011. Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NOAA-TM-NWFSC-113. November 2011.

Ford, M. J., editor. 2022. Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-171.

Gliwicz, Z. M., E. Babkiewicz, R. Kumar, S. Kunjiappan, and K. Leniowski. 2018. Warming increases the number of apparent prey in reaction field volume of zooplanktivorous fish. Limnology and Oceanography 63:S30-S43.

Good, T. P., R. S. Waples, and P. Adams (Editors). 2005. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

Gourtay, C., D Chabot, C. Audet, H. Le Delliou, P. Quazuguel, G. Claireaux, and J. L. Zambonino-Infante. 2018. Will global warming affect the functional need for essential fatty acids in juvenile sea bass (Dicentrarchus labrax)? A first overview of the consequences of lower availability of nutritional fatty acids on growth performance. Marine Biology 165(9):165:143.

GRMW (Grande Ronde Model Watershed). 2020. NOAA Fisheries requesting habitat trend information for salmon and steelhead from local partners: Response from Grande Ronde Model Watershed, April 2020. Grande Ronde Model Watershed, Enterprise, Oregon. 3 p.

Hamann, E. J. and Kennedy, B. P. 2012. Juvenile dispersal affects straying behaviors of adults in a migratory population. Ecology, 93: 733-740. https://doi.org/10.1890/11-1009.1

Haskell, C. A., K. Griswold, and A. L. Puls. 2019. Key findings and lessons learned from Pacific Northwest intensively monitored watersheds. Pacific Northwest Aquatic Monitoring Partnership. U.S. Geological Survey, Cook, Washington, 98605. Prepared by Pacific States Marine Fisheries Commission, Portland, Oregon, December 2019.

Herring, S. C., N. Christidis, A. Hoell, M. P. Hoerling, and P. A. Stott, eds. 2018. Explaining extreme events of 2016 from a climate perspective. Bulletin of the American Meteorological Society 99.

Hill, A., S. Bennett, B. Bouwes, and S. Shahverdian. 2019. Panther Creek Riverscapes Conceptual Restoration Plan: Process-Based Restoration to Improve Chinook, Steelhead, and Bull Trout Habitat, February 28, 2019. Prepared for the Shoshone-Bannock Tribes. 74 p.

Hillman, T., P. Roni, and J. O'Neal. 2016. Effectiveness of tributary habitat enhancement projects. Report to Bonneville Power Administration, Portland, OR. Prepared by BioAnalysts, Inc., Cramer Fish Sciences, and Natural Systems Design. December 1, 2016.

Hostetter, N. and D. D. Roby. 2021. Chapter 7: Cumulative effects of avian predation on juvenile salmonids in the Columbia River basin in D. D. Roby, A. F. Evans, and K. Collis (editors). Avian Predation on Salmonids in the Columbia River Basin: A Synopsis of Ecology and Management. A synthesis report submitted to the U.S Army Corps of Engineers, Walla Walla, Washington; the Bonneville Power Administration, Portland, Oregon; the Grant County Public Utility District/Priest Rapids Coordinating Committee, Ephrata, Washington; and the Oregon Department of Fish and Wildlife, Salem, Oregon. 788 pp.

HSRG (Hatchery Scientific Review Group). 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. June 2014, (updated October 2014). 160p.

ICTRT (Interior Columbia Technical Recovery Team). 2003. Independent Populations of Chinook, Steelhead, and Sockeye for Listed Evolutionarily Significant Units within the Interior Columbia Domain.

ICTRT (Interior Columbia Technical Recovery Team). 2007. Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs. Interior Columbia Basin Technical Recovery Team Technical Review Draft. March 2007. 91 p. + Appendices and Attachments.

ICTRT (Interior Columbia Technical Recovery Team) and R. W. Zabel. 2007. Assessing the Impact of Environmental Conditions and Hydropower on Population Productivity for Interior Columbia River Stream-type Chinook and Steelhead Populations.

IDEQ (Idaho Department of Environmental Quality). 2016. Upper Salmon River Subbasin Assessment and TMDL, 2016 Addendum and Five-Year Review, Hydrologic Unit Code 17060201. State of Idaho Department of Environmental Quality. https://www.deq.idaho.gov/water-quality/surface-water/total-maximum-daily-loads/salmon-river-upper-subbasin

IDWR (Idaho Department of Water Resources). 2020. Idaho Water Transactions 2015-2020, unpublished. Spreadsheet provided to NOAA Fisheries in April 2020 by Amy Cassel, Idaho Department of Water Resources.

IPCC (Intergovernmental Panel on Climate Change). 2014. Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (Intergovernmental Panel on Climate Change). 2018. Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

Isaak, D. J. and Thurow R. F. 2006. Network-scale spatial and temporal variation in Chinook salmon (Oncorhynchus tshawytscha) redd distributions: patterns inferred from spatially continuous replicate surveys. Can. J. Fish. Aquat. Sci. 63(2): 285–296.

Isaak, D. J., C. H. Luce, D. L. Horan, G. L. Chandler, S. P. Wollrab, and D. E. Nagel. 2018. Global warming of salmon and trout rivers in the northwestern U.S.: Road to ruin or path through purgatory? Transactions of the American Fisheries Society 147:566-587.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. In: Climate Change Report, ISAB 2007-2. Independent Scientific Advisory Board, Northwest Power and Conservation Council, Portland, Oregon, 5/11/2007.

ISAB (Independent Science Advisory Board). 2015. Density dependence and its implications for fish management and restoration programs in the Columbia River basin. ISAB Report 2015-1, Portland, Oregon, 2/25/2015.

Islam, S. U., R. W. Hay, S. J. Dery, and B. P. Booth. 2019. Modelling the impacts of climate change on riverine thermal regimes in western Canada's largest Pacific watershed. Scientific Reports 9:14.

Johnson. G. E., K. L. Fresh, and N. K. Sather, eds. 2018. Columbia estuary ecosystem restoration program: 2018 Synthesis memorandum. Final Report. submitted by Pacific Northwest National Laboratory to U.S. Army Corps of Engineers, Portland District, Portland, Oregon, 6/1/2018.

Justice, C., White, S. M., McCullough, D. A., Graves, D. S., & Blanchard, M. R. 2017. Can stream and riparian restoration offset climate change impacts to salmon populations? Journal of Environmental Management, 212-227.

Karnezis, J. 2019. FW: [EXTERNAL] Re: FW: [Non-DoD Source] Re: checking with you re. edits to env baseline Communication to L. Krasnow (NMFS) from J. Karnezis (BPA), 12/19/2019.

Keefer, M. L., T. S. Clabough, M. A. Jepson, E. L. Johnson, C. A. Peery, and C. C. Caudill. 2018. Thermal exposure of adult Chinook salmon and steelhead: Diverse behavioral strategies in a large and warming river system. PLoS ONE 13(9): e0204274. https://doi.org/10.1371/journal.pone.0204274

Krosby, M., D. M. Theobald, R. Norheim, and B. H. McRae. 2018. Identifying riparian climate corridors to inform climate adaptation planning. Plos One 13(11):e0205156.

Kukulka, T. and D. A. Jay. 2003. Impacts of Columbia River discharge on salmonid habitat: 2. Changes in shallow-water habitat. Journal of Geophysical Research 108(C9): 3294. DOI: 10.1029/2003JC001829.

Lawes, T. J., K. S. Bixler, D. D. Roby, D. E. Lyons, K. Collis, A. F. Evans, A. Peck-Richardson, B. Cramer, Y. Suzuki, J. Y. Adkins, K. Courtot, and Q. Payton. 2021. Chapter 4: Double-crested cormorant management in the Columbia River estuary in D. D. Roby, A. F. Evans, and K. Collis (editors). Avian Predation on Salmonids in the Columbia River Basin: A Synopsis of Ecology and Management. A synthesis report submitted to the U.S. Army Corps of Engineers, Walla Walla, Washington; the Bonneville Power Administration, Portland, Oregon; the Grant County Public Utility District/Priest Rapids Coordinating Committee, Ephrata, Washington; and the Oregon Department of Fish and Wildlife, Salem, Oregon. 788 pp.

Leach, J. A. and R. D. Moore. 2019. Empirical Stream Thermal Sensitivities May Underestimate Stream Temperature Response to Climate Warming. Water Resources Research 55(7):5453-5467.

Levin, P. S., S. Achord, B. Feist, and R. W. Zabel. 2002. Non-indigenous brook trout and the demise of threatened Snake River salmon: a forgotten threat? Proc. R. Soc. London Ser. B. 269:1663–70.

Lichatowich, J. A. and L. E. Mobrand. 1995 Analysis of Chinook Salmon in the Columbia River from an Ecosystem Perspective. Final Report.

Lindsey, R. and L. Dahlman. 2020. Climate Change: Global Temperature. January 16. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature.

Lott, B., K. See, M. Ackerman, and N. Porter. 2020. Deadwater Predator Assessment. BioMark, Applied Biological Services. January 31. 12 pgs. Available at: https://htmlpreview.github.io/?https://github.com/mackerman44/deadwateR/blob/master/reporting/Deadwater_Slough_Tech_Report.html

Lynch, A. J., B. J. E. Myers, C. Chu, L. A. Eby, J. A. Falke, R. P. Kovach, T. J. Krabbenhoft, T. J. Kwak, J. Lyons, C. P. Paukert, and J. E. Whitney. 2016. Climate Change Effects on North American Inland Fish Populations and Assemblages. Fisheries 41(7):346-361. DOI: 10.1080/03632415.2016.1186016, 7/1/2016.

Maier, G. O. and C. A. Simenstad. 2009. The role of marsh-derived macrodetritus to the food webs of juvenile Chinook salmon in a large altered estuary. Estuaries and Coasts 32:984-998. DOI: 10.1007/s12237-009-9197-1.

Marcoe, K. and S. Pilson. 2017. Habitat change in the lower Columbia River estuary, 1870-2009. Journal of Coastal Conservation 21:505-525. DOI: 10.1007/s11852-017-0523-7.

Marshall, K. N., A. C. Stier, J. F. Samhouri, R. P. Kelly, and E. J. Ward. 2016. Conservation challenges of predator recovery. Conservation Letters. 9(1):70-8.

Martins, E. G., S. G. Hinch, D. A. Patterson, M. J. Hague, S. J. Cooke, K. M. Miller, M. F. Lapointe, K. K. English, and A. P. Farrell. 2011. Effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River sockeye salmon (Oncorhynchus nerka). Global Change Biology 17(1):99–114. DOI:10.1111/j.1365-2486.2010.02241.x.

Martins, E. G., S. G. Hinch, D. A. Patterson, M. J. Hague, S. J. Cooke, K. M. Miller, D. Robichaud, K. K. English, and A. P. Farrell. 2012. High river temperature reduces survival of sockeye salmon (Oncorhynchus nerka) approaching spawning grounds and exacerbates female mortality. Canadian Journal of Fisheries and Aquatic 69:330–342. DOI: 10.1139/F2011-154.

McClure, M., T. Cooney and the ICTRT (Interior Columbia Technical Recovery Team). 2005. Memorandum To: NMFS NW Regional Office, Co-managers and Other Interested Parties re: Updated Population Delineation in the Interior Columbia Basin. May 11, 2005.

McElhany, P., M. Ruckleshaus, M. J. Ford, T. Wainwright and E. Bjorkstedt. 2000. Viable Salmon Populations and the Recovery of Evolutionarily Significant Units. U. S. Department of Commerce, National Marine Fisheries Service, Northwest Fisheries Science Center, NOAA Technical Memorandum NMFS-NWFSC-42. 156 p. http://www.nwfsc.noaa.gov/publications/techmemos/tm42/tm42.pdf

Morgan, C. A., B. R. Beckman, L. A. Weitkamp, and K. L. Fresh. 2019. Recent Ecosystem Disturbance in the Northern California Current. 2019 American Fisheries Society.

Mote, P. W., E. A. Parson, A. F. Hamlet, et al. 2003. Preparing for Climatic Change: The Water, Salmon, and Forests of the Pacific Northwest. Climatic Change 61:45-88.

Muto, M. M. et al. 2017. Alaska Marine Mammal Stock Assessments: 2017. Government Reports Announcements and Index. Issue 03, 2005. doi: 10.7289/V5/TM-AFSC-378.

Muto, M. M., et al. 2019. U.S. Pacific Marine Mammal Stock Assessments: 2019. NOAA Technical memorandum NMFS-AFSC-393. P. 399.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, S. W. Grant, W. F. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dep Commerce NOAA Tech Memo NMFS NWFSC 35, Seattle, WA.

Naiman, R. J., R. E. Bilby, D. E. Schindler, and J. M. Helfield. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems Ecosystems, pp. 399-417.

Naiman, R. J., J. R. Alldredge, D. A. Beauchamp, P. A. Bisson, J. Congleton, C. J. Henny, N. Huntly, R. Lamberson, C. Levings, E. N. Merrill, W. G. Pearcy, B. E. Rieman, G. T. Ruggerone, D. Scarnecchia, P. E. Smouse, and C. C. Wood. 2012. Developing a broader scientific foundation for river restoration: Columbia River food webs. Proceedings of the National Academy of Sciences of the United States of America 109(52):21201-21207.

NMFS (National Marine Fisheries Service). 2008a. Endangered Species Act 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: consultation on remand for operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (Revised and reissued pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon)). NMFS, Portland, Oregon, 5/5/2008.

NMFS (National Marine Fisheries Service). 2008b. Endangered Species Act – Section 7 Consultation Final Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation Implementation of the National Flood Insurance Program in the State of Washington Phase One Document – Puget Sound Region. NMFS Tracking No.: 2006-00472

NMFS (National Marine Fisheries Service). 2010. Endangered Species Act - Section 7 Consultation Supplemental Biological Opinion. Supplemental Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin, and ESA Section 10(a)(I)(A) Permit for Juvenile Fish Transportation Program. NMFS, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2012. National Marine Fisheries Service Endangered Species Act Section 7 Jeopardy and Adverse Modification of Critical Habitat Biological Opinion for the Environmental Protection Agency's Proposed Approval of Certain Oregon Administrative Rules Related to Revised Water Quality Criteria for Toxic Pollutants. NMFS Tracking Number WCR-2008-00148.

NMFS (National Marine Fisheries Service). 2014. Endangered Spection Act Section 7 and Magnuson-Stevens Fishery Conservation Act Essential Fish Habitat Consultation for Water Quality Toxics Standards for Idaho. NMFS Tracking Number WCR 2000-1484.

NMFS (National Marine Fisheries Service). 2016a. 2016 5-Year Review: Summary & Evaluation of Snake River Sockeye Snake River Spring-Summer Chinook Snake River Fall-Run Chinook Snake River Basin Steelhead. National Marine Fisheries Service, West Coast Region, Portland, OR. 127 p.

NMFS (National Marine Fisheries Service). 2016b. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation Six Lower Snake River Spring/Summer Chinook Salmon Hatchery Programs. June 24, 2016. NMFS Consultation No.: WCR-2013-21. 142p

NMFS (National Marine Fisheries Service). 2016c. Endangered Species Act (ESA) Section 7(a)(2) Jeopardy and Destruction or Adverse Modification of Critical Habitat Biological Opinion and Section 7(a)(2) "Not Likely to Adversely Affect" Determination for the Implementation of the National Flood Insurance Program in the State of Oregon. NMFS Consultation Number: NWR-2011-3197

NMFS (National Marine Fisheries Service). 2017a. ESA Recovery Plan for Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) & Snake River basin steelhead (*Oncorhynchus mykiss*). National Marine Fisheries Service, West Coast Region, November 1, 2017. 284 p.

NMFS (National Marine Fisheries Service). 2017b. ESA Recovery Plan for Northeast Oregon Snake River Spring and Summer Chinook Salmon and Snake River Steelhead Populations, November 2017 (Appendix A to Snake River Recovery Plan). National Marine Fisheries Service, West Coast Region. 567 p. https://www.fisheries.noaa.gov/resource/document/recovery-plan-snake-river-spring-summer-chinook-salmon-and-snake-river-basin

NMFS (National Marine Fisheries Service). 2017c. ESA Recovery Plan for Snake River Idaho Spring/Summer Chinook Salmon and Snake River Basin Steelhead: Appendix C, Idaho Management Unit. NMFS West Coast Region, Portland, Oregon. November 2017.

NMFS (National Marine Fisheries Service). 2017d. Final Endangered Species Act Section 7 Consultation Biological Opinion. December 12, 2017. Five Clearwater River Basin Spring/Summer Chinook Salmon and Coho Salmon Hatchery Programs. NMFS Consultation No.: WCR-2017-7303. 145p.

NMFS (National Marine Fisheries Service). 2017e. Endangered Species Act Section 7 Consultation Biological Opinion. Four Salmon River Basin Spring/Summer Chinook Salmon Hatchery Programs in the Upper Salmon River Basin. NMFS Consultation No.: WCR 2017-7432.

NMFS (National Marine Fisheries Service). 2018. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response. Consultation on effects of the 2018-2027 U.S. v. Oregon Management Agreement. February 23, 2018. NMFS Consultation No.: WCR-2017-7164. 597p.

NMFS (National Marine Fisheries Service). 2019a. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. Five Snake River Basin Spring/Summer Chinook Salmon Hatchery Programs (Reinitiation 2018). February 8, 2019. NMFS Consultation No.: WCR-2017-7319. 155p.

NMFS (National Marine Fisheries Service). 2019b. Recovering Threatened and Endangered Species, FY 2017 - 2018 Report to Congress. National Marine Fisheries Service. Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2020a. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Continued Operation and Maintenance of the Columbia River System. National Marine Fisheries Service, West Coast Region, July 24, 2020.

NMFS (National Marine Fisheries Service). 2020b. Shapefile of fish screens maintained by Idaho Department of Fish and Game at water diversions in the upper Salmon River, vector data. National Marine Fisheries Service, Boise, Idaho.

NMFS (National Marine Fisheries Service). 2020c. Recovery Planning Handbook. Version 1.0. U.S. Department of Commerce, NOAA National Marine Fisheries Service. October 29, 2020.

NMFS (National Marine Fisheries Service). 2021. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for Authorizing Operation and Maintenance of Water Diversions located on the Salmon-Challis National Forest in the Lemhi River Watershed, HUC 17060204, Lemhi County, Idaho. NMFS Tracking Number WCR 2021-00020.

NMFS (National Marine Fisheries Service). 2022. Recovering Threatened and Endangered Species, FY 2019–2020 Report to Congress. National Marine Fisheries Service. Silver Spring, MD.

NPT (Nez Perce Tribe). 2020a. Nez Perce Tribe NOAA 5-Year Review Answers. Nez Perce Tribe, McCall Watershed Program, April 2, 2020.

NPT (Nez Perce Tribe). 2020b. Nez Perce Tribe NOAA 5-Year Review Answers for Big Creek. Nez Perce Tribe, McCall Watershed Program, April 2, 2020.

NWFSC (Northwest Fisheries Science Center). 2015. Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Pacific Northwest. December 21, 2015.

OCCRI (Oregon Climate Change Research Institute). 2019. Fourth Oregon climate assessment report. P. W. Mote, J. Abatzoglou, K. D. Dello, K. Hegewisch, and D. E. Rupp, editors. Oregon State University, Corvallis, Oregon. https://oregonstate.app.box.com/s/vcb1tdkxvisghzsom445l5wpu256ecqf

OCCRI (Oregon Climate Change Research Institute). 2021. Fifth Oregon climate assessment. M. M. Dalton and E. Fleishman, editors. Oregon State University, Corvallis, Oregon. https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka

ODFW (Oregon Department of Fish and Wildlife). 2019. Annual Report: Pinniped Management at Bonneville Dam, 2019.

Ohlberger, J., D. E. Schindlera, E. J. Ward, T. E. Walsworth, and T. E. Essington. 2019. Resurgence of an apex marine predator and the decline in prey body size. Proceedings of the National Academy of Sciences Dec 2019, 116 (52) 26682-26689; DOI: 10.1073/pnas.1910930116.

Payette National Forest. 2020. Request for salmon and steelhead habitat information from local partners: responses from the Payette National Forest. Payette National Forest, McCall, Idaho, April 8, 2020.

Pess, G. and C. E. Jordan, eds. 2019. Characterizing watershed-scale effects of habitat restoration actions to inform life cycle models: Case studies using data-rich vs. data-poor approaches. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-151.

PFMC (Pacific Fishery Management Council). 2016. Pacific Coast Salmon Fishery Management Plan for Commercial and Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California as Amended through Amendment 19. PFMC, Portland, OR. 91 p.

PFMC (Pacific Fishery Management Council). 2020. Review of 2019 Ocean Salmon Fisheries: Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan. PFMC, Portland, OR. 337 p.

PNNL (Pacific Northwest National Laboratory) and NMFS (National Marine Fisheries Service). 2020. Restoration Action Effectiveness Monitoring and Research in the Lower Columbia River and Estuary, 2016-2017. Final technical report submitted by PNNL and NMFS to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon. 6/1/2020.

Pollock, M., G. Pess, T. Beechie, and D. Montgomery. 2004. The Importance of Beaver Ponds to Coho Salmon Production in the Stillaguamish River Basin, Washington, USA. North American Journal of Fisheries Management. 24. 749-760. 10.1577/M03-156.1.

Pollock, M. M., G. M. Lewallen, K. Woodruff, and C. E. Jordan. 2017. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 2.0. Portland: United States Fish and Wildlife Service

Powers, P. D., M. Helstab, and S. L. Niezgoda. 2018. A process-based approach to restoring depositional river valleys to Stage 0, an anastomosing channel network. River Research and Applications, 1-11.

Rehage, J. S. and J. R. Blanchard. 2016. What can we expect from climate change for species invasions? Fisheries 41(7):405-407. DOI: 10.1080/03632415.2016.1180287.

Roby, D. D., K. Collis, P. J. Loschl, Y. Suzuki, D. Lyons, T. J. Lawes, et al. 2017. Avian predation on juvenile salmonids: Evaluation of the Caspian Tern Management Plan in the Columbia River estuary, 2016 Final annual report. U.S. Geological Survey, Oregon State University, Corvallis, Oregon, 3/21/2017.

Roby, D. D., T. J. Lawes, D. E. Lyons, K. Collis, A. F. Evans, K. S. Bixler, S. Collar, O. A. Bailey, Y. Suzuki, Q. Payton, and P. J. Loschl. 2021. Chapter 1: Caspian tern management in the Columbia River estuary in D. D. Roby, A. F. Evans, and K. Collis (editors). Avian Predation on Salmonids in the Columbia River Basin: A Synopsis of Ecology and Management. A synthesis report submitted to the U.S Army Corps of Engineers, Walla Walla, Washington; the Bonneville Power Administration, Portland, Oregon; the Grant County Public Utility District/Priest Rapids Coordinating Committee, Ephrata, Washington; and the Oregon Department of Fish and Wildlife, Salem, Oregon. 788 pp.

Roni, P., G. Pess, T. Beechie, and S. Morley. 2010. Estimating changes in coho salmon and steelhead abundance from watershed restoration: How much restoration is needed to measurably increase smolt production. North American Journal of FisheriesManagement, 30, 1469–1484.

Rub, A. M. Wargo-, N. A. Som, M. J. Henderson, B. P. Sandford, D. M. Van Doornik, D. J. Teel, M. J. Tennis, O. P. Langness, B. K. van der Leeuw, and D. D. Huff. 2019. Changes in adult Chinook salmon (Oncorhynchus tshawytscha) survival within the lower Columbia River amid increasing pinniped abundance. Canadian Journal of Fisheries and Aquatic Sciences 76 (10), 1862-1873, 10.1139/cjfas-2018-0290.

Sanderson, B. L., K. A. Barnas, and A. M. W. Rub. 2009. Non-indigenous Species of the Pacific Northwest: An Overlooked Risk to Endangered Salmon? Bioscience. 59:245-256.

Scheuerell, M. D. and J. G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (Oncorhynchus tshawytscha). Fisheries Oceanography 14(6):448–457.

Scheuerell, M. D., R. W. Zabel, and B. P. Sandford. 2009. Relating juvenile migration timing and survival to adulthood in two species of threatened Pacific salmon (Oncorhynchus spp.). J Appl Ecol 46:983–990.

Schoennagel, T., T. T. Veblen, W. H. Romme, J. S. Sibold, and E. R. Cook. 2005. ENSO and PDO variability affect drought-induced fire occurrence in Rocky Mountain subalpine forests. Ecological Applications 15, no. 6 (2005): 2000-2014.

Schtickzelle, N. and T. P. Quinn. 2007. A Metapopulation Perspective for Salmon and Other Anadromous Fish. Fish and Fisheries. 8: 297-314.

Siegel, J. and L. Crozier. 2019. Impacts of Climate Change on Salmon of the Pacific Northwest: A review of the scientific literature published in 2018. Fish Ecology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA. December.

Siegel, J. and L. Crozier. 2020. Impacts of Climate Change on Salmon of the Pacific Northwest: A Review of the Scientific Literature Published in 2019. National Marine Fisheries Service. https://doi.org/10.25923/jke5-c307.

Simenstad, C. A., L. F. Small, and C. D. McIntyre. 1990. Consumption processes and food web structure in the Columbia river estuary. Progress in Oceanography 25:271-298.

Sorel, M. H., R. W. Zabel, D. S. Johnson, A. M. Wargo-Rub, and S. J. Converse. 2020. Estimating population-specific predation effects on Chinook salmon via data integration. Journal of Applied Ecology. DOI: 10.1111/1365-2664.13772.

Sridhar, V., M. M. Billah, and J. W. Hildreth. 2018. Coupled surface and groundwater hydrological modeling in a changing climate. Groundwater 56(4):618-635.

SRSRB (Snake River Salmon Recovery Board). 2011. Snake River Salmon Recovery Pan for SE Washington. Prepared by the Snake River Salmon Recovery Board for the Washington Governor's Salmon Recovery Office. 2011 Version. 598pp.

Sykes, G. E., C. J. Johnson, and J. M. Shrimpton. 2009. Temperature and Flow Effects on Migration Timing of Chinook Salmon Smolts. Transactions of the American Fisheries Society 138:1252-1265.

TAC (U.S. v. Oregon Technical Advisory Committee). 2015. TAC Annual Report. Abundance, Stock Status and ESA Impacts. 2014 Summary. May 13-14, 2015.

TAC (U.S. v. Oregon Technical Advisory Committee). 2016. TAC Annual Report. Abundance, Stock Status and ESA Impacts. Summary of 2015 fisheries and fish runs. May 20, 2016.

TAC (U.S. v. Oregon Technical Advisory Committee). 2017. TAC Annual Report. Abundance, Stock Status and ESA Impacts. Summary of 2016 fisheries and fish runs. October 13, 2017.

TAC (U.S. v. Oregon Technical Advisory Committee). 2018. TAC Annual Report. Abundance, Stock Status and ESA Impacts. Summary of 2017 fisheries and fish runs. May 10-11, 2018.

TAC (U.S. v. Oregon Technical Advisory Committee). 2019. TAC Annual Report. Abundance, Stock Status, Harvest, and Endangered Species Act Impacts. Summary of 2018 Fisheries and Fish Runs. May 9-10, 2019.

TAC (U.S. v. Oregon Technical Advisory Committee). 2020. TAC Annual Report. Abundance, Stock Status, Harvest, and Endangered Species Act Impacts. Summary of 2019 Fisheries and Fish Runs. May 14-15, 2020.

Tetra Tech, Inc. 2017. Catherine Creek and Upper Grande Ronde River Atlas Restoration Prioritization Framework: Users Manual. Bothell: Tetra Tech.

Thom, B. 2020. Letter from NMFS West Coast Regional Administrator to Phil Anderson, Chair of the Pacific Fishery Management Council, regarding ESA consultation standards and guidance on the effects of the 2015 fishing season on ESA listed species. February 27, 2020.

Thomas, A. C., B. Nelson, M. M. Lance, B. Deagle and A. Trites. 2017. Harbour seals target juvenile salmon of conservation concern. Can. J. Fish. Aquat. Sci. 74(6):907-921.

Thurow, R. F. 2000. Dynamics of Chinook Salmon populations within Idaho's Frank Church Wilderness: implications for persistence. U.S. Department of Agriculture Forest Service Proceedings RMRS-P-15- VOL-3. 2000:143–151.

Tidwell, K. S., R. I. Cates, D. A. McCanna, C. B. Ford, and B. K. van der Leeuw. 2020. Evaluation of Pinniped Predation on Adult Salmonids and Other Fish in the Bonneville Dam Tailrace, 2019.

USACE (U.S. Army Corps of Engineers). 1984. Special Flood Hazard Information, Salmon River Ice Jams from Dump Creek Upstream Through the City of Salmon, Idaho. For Lemhi County, Idaho, February 1984. 56 pgs.

USACE (U.S. Army Corps of Engineers). 2015. Double-crested cormorant management plan to reduce predation on juvenile salmonids in the Columbia River estuary: Final Environmental Impact Statement. U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

USEPA (U.S. Environmental Protection Agency). 2021. Columbia River Cold Water Refuges Plan. January 2021. EPA-910-R-21-001

USFWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service). 2006. 5-Year Review Guidance: Procedures for Conducting 5-Year Reviews Under the Endangered Species Act. July 2006.

Uthe, P., B. Knoth, T. Copeland, A. Butts, B. Bowersox, and J. Diluccia. 2017. Intensively monitored watersheds and restoration of salmon habitat in Idaho: Ten-year summary report. Idaho Department of Fish and Game, Boise, Idaho, 12/1/2017.

Veilleux, H. D., J. M. Donelson, and P. L. Munday. 2018. Reproductive gene expression in a coral reef fish exposed to increasing temperature across generations. Conservation Physiology 6:12.

Vonde, A. Y., C. M. Bromley, M. M. Carter, A. L. Courtney, S. E. Hamlin, H. A. Hensley, S. J. Kilminster-Hadley, M. C. Orr, D. I. Stanish, and C. J. Strong. 2016. Understanding the Snake River Basin Adjudication. 52 Idaho L. Rev. 53.

Wainwright, T. C. and L. A. Weitkamp. Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. Northwest Science 87(3):219-242.

Ward, E. J., J. H. Anderson, T. J. Beechie, G. R. Pess, and M. J. Ford. 2015. Increasing hydrologic variability threatens depleted anadromous fish populations. Global Change Biology 21(7):2500-2509.

Weber, E. D. and K. D. Fausch. 2003. Interactions between hatchery and wild salmonids in streams: differences in biology and evidence for competition. Canadian Journal of Fisheries and Aquatic Sciences 60 (2003): 1018-1036.

Weitkamp, L. A., P. J. Bentley, and M. N. C. Litz. 2012. Seasonal and interannual variation in juvenile salmonids and associated fish assemblage in open waters of the lower Columbia River estuary. Fish Bull 110:426-450.

Weitkamp, L. A., D. J. Teel, M. Liermann, S. A. Hinton, D. M. Van Doornik, and P. J. Bentley. 2015. Stock-specific size and timing at ocean entry of Columbia River juvenile Chinook salmon and steelhead: Implications for early ocean growth. Mar Coast Fish 7:370-392.

Wheaton, J. M., S. N. Bennett, N. Bouwes, J. D. Maestas, and S. M. Shahverdian. (Editors). 2019. Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0. Utah State University Restoration Consortium. Logan, UT. 286 pp.

White, S., S. Brandy, C. Justice, K. Morinaga, L. Naylor, J. Ruzycki, E. Sedell, J. Steele, A. Towne, J. Webster, and I. Wilson. 2021. Progress Towards a Comprehensive Approach for Habitat Restoration in the Columbia Basin: Case Study in the Grande Ronde River. Fisheries, February 2021: 1-15.

Whitney, J. E., R. Al-Chokhachy, D. B. Bunnell, C. A. Caldwell, et al. 2016. Physiological Basis of Climate Change Impacts on North American Inland Fishes. Fisheries 41(7):332-345. DOI: 10.1080/03632415.2016.1186656.

Williams, S., E. Winther, and A. Storch. 2015. Report on the predation index, predator control fisheries, and program evaluation for the Columbia River basin Northern Pikeminnow Sport Reward Program. 2015 Annual Report, April 1, 2015 through March 31, 2016. Pacific States Marine Fisheries Commission, Portland, Oregon.

Williams, S., E. Winther, and C. M. Barr. 2016. Report on the predation index, predator control fisheries, and program evaluation for the Columbia River basin Northern Pikeminnow Sport Reward Program. 2016 Annual Report, April 1, 2016 through March 31, 2017. Pacific States Marine Fisheries Commission, Portland, Oregon.

Williams, S., E. Winther, C. M. Barr, and C. Miller. 2017. Report on the predation index, predator control fisheries, and program evaluation for the Columbia River basin Northern Pikeminnow Sport Reward Program. 2017 Annual Report, April 1, 2017 through March 31, 2018. Pacific States Marine Fisheries Commission, Portland, Oregon.

Williams, S., E. Winther, C. M. Barr, and C. Miller. 2018. Report on the predation index, predator control fisheries, and program evaluation for the Columbia River basin Northern Pikeminnow Sport Reward Program. 2018 Annual report, April 1, 2018 through March 31, 2019. Pacific States Marine Fisheries Commission, Portland, Oregon.

Winther, E., C. M. Barr, C. Miller, and C. Wheaton. 2019 Report on the predation index, predator control fisheries and program evaluation for the Columbia River basin Northern Pikeminnow Sport Reward Program. 2019 Annual Report, April 1, 2019 through March 31, 2020. Pacific States Marine Fisheries Commission, Portland, Oregon.

Wondzell, S. M., M. Diabat, and R. Haggerty. 2019. What Matters Most: Are Future Stream Temperatures More Sensitive to Changing Air Temperatures, Discharge, or Riparian Vegetation? Journal of the American Water Resources Association, 116-132.

Zabel, R. W., M. D. Scheuerell, M. M. McClure, and J. G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conserv Biol 20:190-200.

Zabel, R. W., J. Faulkner, S. G. Smith, J. J. Anderson, C. Van Holmes, N. Beer, S. Iltis, J. Krinke, G. Fredricks, B. Bellerud, J. Sweet, and A. Giorgi. 2008. Comprehensive passage (COMPASS) model: a model of downstream migration and survival of juvenile salmonids through a hydropower system. Hydrobiologia 609:289-300.

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
- [x] 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 Schaeffer Date: 06/30/2022
For Scott M. Rumsey, Ph.D., Acting Regional Administrator

Cooperating Regional Administrator, NOAA Fisheries

[ ] Concur [ ] Do Not Concur [x] N/A

Signature________________________________ Date: _______

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

[x] Concur [ ] Do Not Concur

Signature RAUCH.SAMUEL.D.III.1365850948 Digitally signed by RAUCH.SAMUEL.D.III.1365850948 Date: 2022.08.05 16:13:05 -04'00' Date: _______