Science, Service, Stewardship

2022 5-Year Review: Summary & Evaluation of **Snake River Sockeye Salmon**

National Marine Fisheries Service
West Coast Region

5-Year Review: Snake River Sockeye Salmon

Species Reviewed	Evolutionarily Significant Unit or Distinct Population Segment
Sockeye Salmon (*Oncorhynchus nerka*)	*Snake River Sockeye Salmon*

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1. General Information

1.1 Introduction

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

The ESA, under section 4(c)(2), directs the Secretary of Commerce to review the listing classification of threatened and endangered species at least once every 5 years. A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12; 50 CFR 223.102, 224.101) is accurate (USFWS and NMFS 2006; NMFS 2020a). 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 agency's 5-year review for ESA-listed Snake River (SR) sockeye 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; and
- A rulemaking.

1.1.1 Background on 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 salmon NMFS utilizes the "Policy on Applying the Definition of Species under the ESA to Pacific Salmon" (56 FR 58612). Under this policy NMFS identifies population groups that are "evolutionarily significant units" (ESUs) within taxonomically recognized species. NMFS considers a group of populations to be an ESU if it is substantially reproductively isolated from other populations within the taxonomically recognized species and represents an important component in the evolutionary legacy of the species. NMFS considers an ESU as constituting a DPS and therefore a "species" under the ESA (56 FR 58612).

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

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

SR sockeye salmon were first listed as endangered on November 20, 1991 (56 FR 58612). Because the revised Hatchery Listing Policy changed the way we considered hatchery fish in ESA listing determinations, we completed new status reviews and ESA listing determinations for West Coast salmon ESUs on June 28, 2005 (70 FR 37159), and for steelhead DPSs on January 5, 2006 (71 FR 834). On May 26, 2016, we published our 5-year reviews and listing determinations for 17 ESUs of Pacific salmon, 10 DPSs of steelhead, and the southern DPS of eulachon (*Thaleichthys pacificus)* (81 FR 33468), including reaffirming endangered status for SR sockeye salmon.

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

1.2 Methodology used to complete the review

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

To complete the reviews, we first asked scientists from our Northwest and Southwest Fisheries Science Centers to collect and analyze new information about ESU and DPS viability. To evaluate viability, our scientists used the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000). The VSP concept evaluates four criteria – abundance, productivity, spatial structure, and diversity – to assess species viability. Through the application of this concept, the science center considered new information for a given ESU or DPS relative to 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 team prepared reports detailing the results of their analyses (Ford 2022).

To further inform the reviews, we also asked salmon management biologists from the West Coast Region familiar with hatchery programs to consider new information available since the previous listing determinations. Among other things, they considered hatchery programs that have ended, new hatchery programs that have started, changes in the operation of existing programs, and scientific data relevant to the degree of divergence of hatchery fish from naturally spawning fish in the same area. Finally, we consulted salmon management biologists from the West Coast Region who are familiar with habitat conditions, hydropower operations, and harvest management. In a series of structured meetings, by geographic area, these biologists identified relevant information and provided their insights on the degree to which circumstances have changed for each listed entity.

In preparing this report, we considered the best available scientific information, including the work of the Northwest Fisheries Science Center (Ford 2022); the report of the regional biologists regarding hatchery programs; the SR sockeye salmon recovery plan (NMFS 2015a); technical reports prepared in support of the recovery plan for the SR sockeye salmon; the listing record (including designation of critical habitat and adoption of protective regulations); recent biological opinions issued for SR salmon and steelhead; information submitted by the public and other government agencies; and the information and views provided by the 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 1991, NMFS listed SR sockeye salmon under the ESA as an endangered species (Table 1).

Table 1. Summary of the listing history under the Endangered Species Act for the Snake River sockeye salmon ESU.

Salmonid Species	ESU/DPS Name	Original Listing	Revised Listing(s)
Sockeye Salmon (*O. nerka*)	Snake River sockeye salmon	**FR Notice:** 56 FR 58612 **Date:** November 20, 1991 **Classification:** Endangered	**FR Notice:** 70 FR 37159 **Date:** 6/28/2005 **Classification:** Endangered

1.3.3 Associated rulemakings

The ESA requires NMFS to designate critical habitat, to the maximum extent prudent and determinable, for species it lists under the ESA. Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical or biological features essential to the conservation of the species, and which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination by the Secretary that such areas are essential for the conservation of the species. We designated critical habitat for SR sockeye salmon in 1993 (Table 2).

Section 9 of the ESA prohibits the take of species listed as endangered. The ESA defines take to mean harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. For threatened species, the ESA does not automatically prohibit take, but instead authorizes the agency to adopt regulations it deems necessary and advisable for species conservation, and to apply the take prohibitions of section 9(a)(1) through ESA section 4(d). In 2000, NMFS adopted 4(d) regulations for threatened salmonids that prohibit take except in specific circumstances. In 2005, we revised our 4(d) regulations for consistency between ESUs and DPSs and to take into account our Hatchery Listing Policy (65 FR 42422).

Table 2. Summary of rulemaking for 4(d) protective regulations and critical habitat for the Snake River sockeye salmon ESU.

Salmonid Species	ESU Name	4(d) Protective Regulations	Critical Habitat Designations
Sockeye Salmon (*O. nerka*)	Snake River sockeye salmon	ESA section 9 prohibitions apply	**FR Notice:** 58 FR 68543 **Date:** 12/28/1993 **Type:** Final

1.3.4 Review History

Table 3 lists the numerous scientific assessments of the status of SR sockeye salmon. These assessments include the viability analyses and status reviews conducted by our Northwest Fisheries Science Center and technical reports prepared in support of recovery planning for this species.

Table 3. Summary of previous scientific assessments for the Snake River sockeye salmon ESU.

Salmonid Species	ESU Name	Document Citation
Sockeye Salmon (*O. nerka*)	Snake River Sockeye salmon	Ford 2022 NMFS 2016a NWFSC 2015 ICTRT 2007 Good et al. 2005 McClure et al. 2003 ICTRT 2003 Waples et al. 1991

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. For determining a recovery priority for recovery plan development and implementation, we assess 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) to assign a Recovery Priority number from 1 (high) to 11 (low). 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 subject species that was in effect at the time this 5-year review began (NMFS 2019a). In January 2022, NMFS issued a new report with updated recovery priority numbers. The number for the SR sockeye salmon ESU remained unchanged (NMFS 2022).

1.3.6 Recovery Plan or Outline

Table 4. Recovery Priority Number (NMFS 2019a) and Endangered Species Act Recovery Plan for the Snake River sockeye salmon ESU.

Salmonid Species	ESU Name	Recovery Priority Number	Recovery Plans/Outline
Sockeye Salmon (*O. nerka*)	Snake River Sockeye Salmon	**1C**	**Title:** ESA Recovery Plan for Snake River Sockeye Salmon (*Oncorhynchus nerka*) Available at: https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/snake-river-sockeye-salmon **FR Notice:** 80 FR 32365 **Date:** 6/8/2015 **Type:** Final

2. Review Analysis

In this section, we review new information to determine whether species' delineations remain appropriate.

2.1 Delineation of species under the Endangered Species Act

Is the species under review a vertebrate?

ESU Name	YES	NO
Snake River Sockeye Salmon	X	

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

ESU Name	YES	NO
Snake River Sockeye Salmon	X	

Was the ESU/DPS listed prior to 1996?

ESU Name	YES	NO	Date Listed if Prior to 1996
Snake River Sockeye Salmon	X		11/20/1991

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

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

2.1.1 Summary of relevant new information regarding the delineation of the Snake River Sockeye ESU.

ESU/DPS Delineation

This section provides a summary of 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 SR sockeye 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 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 before effecting any official change in hatchery membership.

In the 2016 5-year review, the SR sockeye salmon ESU was defined as all anadromous and residual sockeye salmon from the Snake River basin, Idaho, as well as artificially propagated sockeye salmon from the Redfish Lake Captive Broodstock program (70 FR 37159).

Since 2016, we added a new smolt production program to the ESU because the Redfish Lake Captive Broodstock Program currently produces the eggs used in the new smolt production program. Therefore, the smolts produced for this new hatchery program are a category 1a (Jones 2015) and should be included in the SR sockeye salmon ESU. We therefore listed this program under Idaho Department of Fish and Game's program name, the "Snake River Sockeye Salmon Hatchery Program." We also revised the description of the SR sockeye salmon ESU to read "Naturally spawned anadromous and residual sockeye salmon originating from the Snake River basin. Also, sockeye salmon from the Redfish Lake Captive Broodstock Program and the Snake River Sockeye Salmon Hatchery 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 is a revision to the ESU's composition to reflect the best available scientific information as considered under our Hatchery Listing Policy. Addition of 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 recovery plans be developed 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 develops criteria to assess progress toward alleviating the relevant threats (listing factor [threats] criteria). NMFS adopts the TRT's viability criteria as the biological criteria for a recovery plan, based on best available scientific information and other considerations as appropriate. For the SR Sockeye Salmon Recovery Plan (NMFS 2015a), NMFS adopted the viability criteria metrics defined by the Interior Columbia Technical Recovery Team (ICTRT) (ICTRT 2007) as the biological recovery criteria for the endangered SR sockeye salmon ESU.

As the recovery plan is implemented, additional information becomes available along with new scientific analyses that can increase certainty about whether the threats have been abated, whether improvements in population biological viability have occurred for sockeye 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 plan during the ESA 5-Year Review (USFWS and NMFS 2006; NMFS 2020a).

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

ESU/DPS Name	YES	NO
Snake River Sockeye 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 Sockeye 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 Sockeye Salmon	X	

2.2.3 List the biological recovery criteria as they appear in the recovery plan

NMFS adopted the SR Sockeye Salmon Recovery Plan (NMFS 2015a) on June 8, 2015 (80 FR 32365).

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

McElhany et al. (2000) defined an independent population as: "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season." For our purposes, not interbreeding to a "substantial degree" means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame. Independent populations exhibit different population attributes that influence their abundance, productivity, spatial structure and diversity. Independent populations are the units that are combined to form alternative recovery scenarios for multiple similar population groupings and ESU viability.

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. While the ESU/DPS is the listed entity under the ESA, the ESU/DPS-level viability criteria are based on the collective viability of the individual populations that make up the ESU/DPS – their characteristics and their distribution throughout the ESU/DPS geographic range. 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 NMFS-appointed 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 assist the readers to more easily 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 Interior Columbia Technical Recovery Team (ICTRT) identified independent populations for SR sockeye salmon, and then grouped them together into genetically similar major population groups (MPGs) (ICTRT 2003).

The ICTRT also developed species biological viability criteria for applications at the ESU, 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

(2007) are targeted to achieve, at a minimum, the ICTRT's biological viability criteria for each major population grouping. Accordingly, the criteria are designed "[t]o have all major population groups at viable (low risk) status with representation of all the major life history strategies present historically, and with the abundance, productivity, spatial structure, and diversity attributes required for long-term persistence." The sockeye 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.

Sockeye salmon are native to the Snake River basin and historically were abundant in several lake systems in Idaho and Oregon. Today, the last remaining SR sockeye salmon spawn in Sawtooth Valley[2] lakes high in the Salmon River drainage of the Snake River basin in Idaho (Figure 1). Five lakes in the Sawtooth Valley historically contained anadromous sockeye salmon: Alturas, Pettit, Redfish, Stanley, and Yellowbelly Lakes. Currently, only the Redfish Lake population, supported by a captive broodstock program, is considered extant. Reintroduction efforts, using Redfish Lake stock, have been occurring in Redfish Lake since 1993, Pettit Lake since 1995, and Alturas Lake since 1997.

The ESU includes all naturally spawned anadromous and residual sockeye salmon originating from the Snake River basin. Also, the ESU includes sockeye salmon from the Redfish Lake Captive Broodstock Program, and the Snake River Sockeye Salmon Hatchery Program (70 FR 37159; 85 FR 81822). Additional discussion on the importance of hatchery production for this ESU is provided in Section 2.1.1. The ESU was first listed as endangered under the ESA in 1991 (56 FR 58612); the endangered listing was reaffirmed in 2005 (70 FR 37159), 2014 (79 FR 20802), and most recently in 2016 (81 FR 33468). Figure 2 displays the population structure and species range in the Upper Salmon River.

For recovery planning and development of recovery criteria, the ICTRT defined Stanley Basin sockeye salmon as the single MPG within the SR sockeye salmon ESU. The MPG contains one extant population (Redfish Lake) and two to four extirpated, historical populations (Alturas, Petit, Stanley, and Yellowbelly Lakes). At the time of listing in 1991, the only extant population (the Redfish Lake population) had about 10 fish returning per year (NMFS 2015a). Hatchery SR sockeye salmon from the Snake River Sockeye Salmon Hatchery and the Redfish Lake Captive Broodstock programs are included in the ESU (81 FR 72759).

Specifically, to develop the biological viability criteria, the ICTRT adapted its approach to accommodate the biological characteristics and available data for SR sockeye salmon. Redfish Lake is approximately 62 percent of the size of Lake Wenatchee in the Upper Columbia Basin, yet the other Sawtooth Valley lakes are relatively small compared to other lake systems in the Columbia Basin that historically supported sockeye salmon production. The ICTRT developed a general approach for assigning individual populations to one of four size categories based on

[2] Previous studies frequently did not differentiate the Stanley Basin from the Sawtooth Valley, or they called the whole area the Stanley Basin. In this document, the term "Sawtooth Valley" will be used to encompass both the Sawtooth Valley and the associated lakes, except where the Stanley Basin specifically is referred to.

historical habitat intrinsic potential. For sockeye salmon, intrinsic potential was estimated in terms of lake surface area based on relationships reported for sockeye salmon lakes in Alaska and Canada. Stanley, Pettit, and Yellowbelly Lakes are assigned to the smallest size category. Redfish and Alturas Lakes are intermediate-sized.

The ICTRT developed viability curves that used quantitative metrics to evaluate the abundance and productivity of the populations. The ICTRT set the minimum spawning abundance threshold at 1,000 natural-origin spawners, measured as a 10-year geometric mean, for the Redfish and Alturas Lake populations, and 500 natural-origin spawners for the smaller Pettit, Yellowbelly, and Stanley Lake populations. For SR sockeye salmon, the ICTRT (2007) determined that risks to ESU life history diversity and spatial structure could be diminished by reestablishing or reintroducing independent sockeye salmon populations to Alturas and Pettit Lakes. Sockeye salmon reintroductions into Stanley and Yellowbelly Lakes are currently not a priority, but rather a potential long-term action (NMFS 2015a) which would still contribute to reduced spatial structure and diversity risk. Risks to ESU life history patterns could also be reduced by reestablishing historical life history patterns that may have been present in the natal lakes (NMFS 2015a). The Recovery Plan describes a long-term recovery scenario which includes restoring at least two of the three historical lake populations in the ESU to highly viable, and one to viable status, using Redfish Lake, Alturas Lake, and Pettit Lake. The Plan's recommended criteria (including minimum abundance thresholds) reflect the best information currently available. However, information gained from ongoing studies of the production potential in each of the Sawtooth Valley lakes, and the rates of exchange among them, should be periodically reviewed to determine if the basic assumptions behind the current criteria remain valid, or if updates would be warranted (NMFS 2015a).

The SR sockeye salmon ESU is at a high risk of extinction. The recovery strategy aims to reintroduce and support adaptation of naturally self-sustaining sockeye salmon populations in the Sawtooth Valley lakes. The recovery strategy has three phases: (1) Preservation with the captive broodstock program; (2) reintroduction; and (3) a program emphasizing natural adaptation and viability. At this time, we are still working on the first two phases; reintroduction efforts using Redfish Lake stock have been ongoing in Redfish Lake since 1993, Pettit Lake since 1995, and Alturas Lake since 1997.

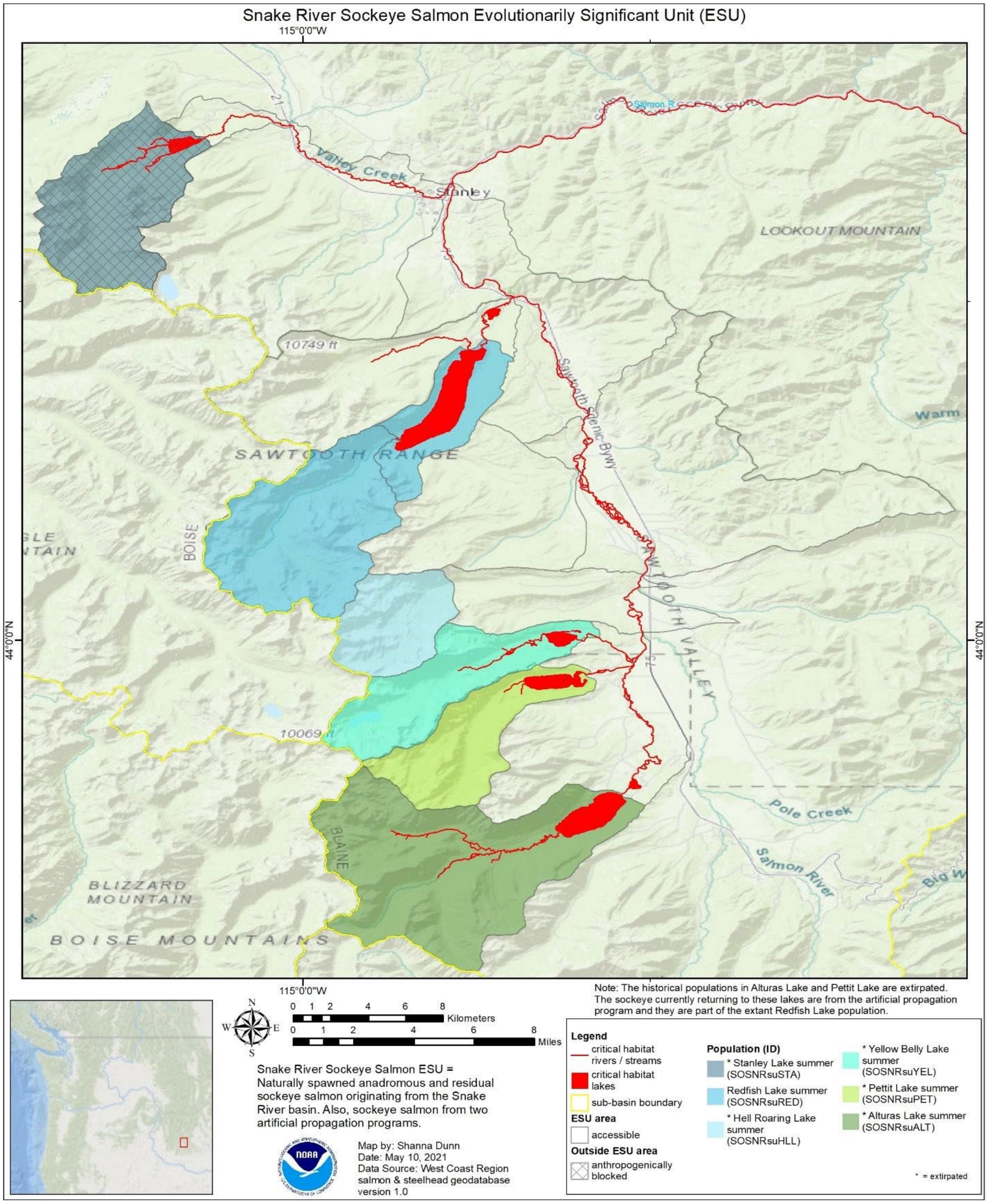

Figure 2. Snake River Sockeye Salmon ESU population structure**.**[3]

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[3] The map above generally shows the accessible and historically accessible areas for the SR Sockeye Salmon. The area displayed is consistent with the regulatory description of the delineation of the SR Sockeye Salmon found at 50 CFR17.11, 223.102, and 224.102.

2.3 Updated Information and Current Species' Status

Information provided in this section is summarized from Ford (2022) – Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest.

2.3.1 Analysis of Viable Salmonid Population (VSP) Status

Updated Biological Risk Summary

Adult returns of sockeye salmon to the Sawtooth Basin crashed in 2015 and natural returns have remained low (Table 5 and Figure 3). The low returns of fish collected at the Redfish Lake and Sawtooth weirs have limited anadromous releases into Redfish Lake to 311 anadromous hatchery fish in 2016. No natural anadromous fish have been released since 2014 as they are required to be spawned in the captive broodstock program under NMFS Section 10 permit 1454. Captive adult releases have continued to support spawning in Redfish Lake. Smolt-to-adult return rates suggest that volitional spawning within Redfish Lake appears to be important to the success of the Snake River sockeye salmon captive broodstock program (Kozfkay et al. 2019).

Natural production occurring within Redfish Lake had the highest overall survival rates from the smolt-to-adult life stage, despite having lower emigration survival from the Sawtooth Valley basin to Lower Granite Dam (Johnson et al. 2019). Increases in smolt abundances have not led to increases in natural adult returns (Kozfkay et al. 2019).

Table 5. Five-year geometric mean of raw natural return counts. In parentheses, 5-year geometric mean of raw total return counts is shown. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5). A minimum of 2 values was used to compute the geometric mean. Percent change between the 2 most-recent 5-year periods is shown on the far right.

Population	2000-04	2005-09	2010-14	2015-19	% change
Snake River sockeye	4 (26)	9 (33)	137 (699)	16 (113)	-89 (-84)

Annual basin-to-basin estimates of smolt-to-adult return (SAR) rates through brood year 2014 (returns completed in 2019) have been generated for Snake River sockeye through a combination of Parental Based Tagging (PBT) and a length-at-age key for fish that assign as unknown. Natural production from Redfish Lake SARs averaged 0.41 percent for the five most recent brood years (2010-2014) that have completed returns, with a 10-year average of 0.86 percent. Natural production from Pettit and Alturas Lakes, from anadromous and captive releases averaged 0.86 percent for the five most recent brood year returns, and 0.53 percent for the ten most recent. Hatchery production smolts averaged 0.30 and 0.43 percent for Oxbow Reservoir smolts and 0.08 and 0.21 percent for Sawtooth Valley smolts in 5- and 10-year averages respectively (Johnson et al. 2020a). There are two brood years of Springfield Hatchery smolt releases completed now, with no adult returns due to the water chemistry acclimation issues.

The Lower Granite Dam (LGD) SARs reflect aggregate return rates across two major downstream migration routes: in-river passage and downstream transport to below Bonneville Dam. The median estimated survival of juvenile in-river migrants downriver from LGD through the lower Snake River to McNary Dam on the mainstem Columbia River was 67 percent for the period 1996−2010 and 69 percent for 2012-2018 (Widener et al. 2019). The median estimates of juvenile passage survivals for the McNary-to-Bonneville Dam reach (1998−2003, 2006−2010) were 0.54 and (2012-2018) 0.62, which should be interpreted with caution due to small sample sizes and associated low detection probabilities for many of the individual year estimates. The median estimated survival from LGD to Bonneville Dam for the period 2012-2018 was 0.47 (Widener et al. 2019).

Sockeye transported through the hydrosystem have a much lower adult survival than run-of-the-river. Adult migration through the Columbia reach was half the observed survival for those transported as juveniles than not (0.30 vs 0.59; Crozier et al. 2020). Fallback (i.e., when a fish ascends a dam and then drops back below the dam) occurs at much higher rates in sockeye than other salmon, and has been a significant predictor of sockeye survival, slowing travel and increasing thermal exposure (Crozier et al. 2018). No transported sockeye survived upstream migration to LGD in 2015.

Long term recovery objectives for this ESU are framed in terms of natural production. At this point in time, natural production of anadromous Snake River sockeye salmon remains limited to extremely low levels in Redfish Lake, one of five Sawtooth Valley lakes believed to have historically supported production, with a few thousand outmigrants each year from Pettit and Alturas Lakes. As a result, the overall biological status relative to recovery goals is high risk. Substantial progress has been made with the Snake River sockeye salmon captive broodstock-based hatchery program.

Limnological studies and direct experimental releases are being conducted to elucidate production potential in three of the Stanley Basin lakes that are candidates for sockeye restoration. The availability of increased numbers of adults and juveniles has supported direct evaluation of lake habitat rearing potential, juvenile downstream passage survivals, and adult upstream survivals. Although the captive broodstock program has been successful in providing substantial numbers of hatchery-produced sockeye salmon for use in supplementation efforts, substantial increases in survival rates across life-history stages must occur in order to re-establish sustainable natural production (e.g., Hebdon et al. 2004; Keefer et al. 2008). The increased abundance of hatchery-reared Snake River sockeye salmon reduces the risk of immediate loss, but levels of naturally produced sockeye salmon returns remain extremely low and at high risk from climate change.

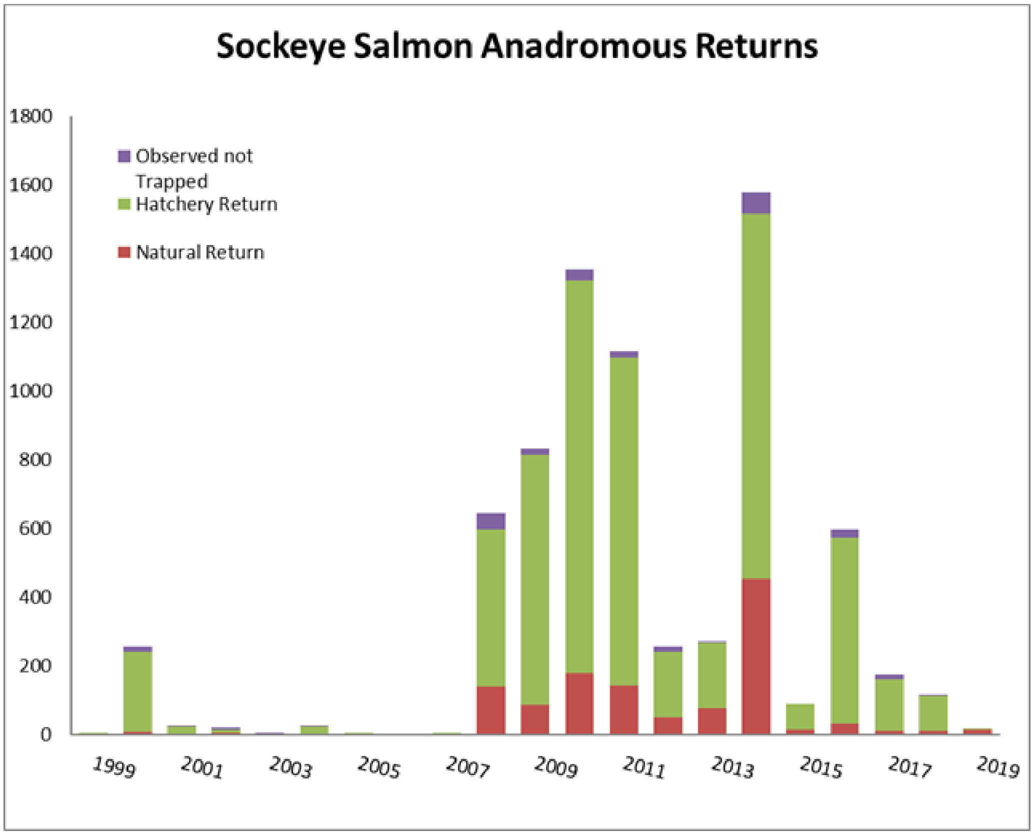

Figure 3. Snake River sockeye salmon anadromous returns, 1999-2019 (figure from Johnson et al. 2020a).

In terms of natural production, the SR sockeye salmon ESU remains at extremely high risk (>25 percent risk of extinction in 100 years), although there has been substantial progress on the first phase of the proposed recovery approach – developing a hatchery-based program to amplify and conserve the stock to facilitate reintroductions. Current climate change modeling supports the extremely high-risk rating with the potential for extirpation in the near future (Crozier et al. 2020). Thus, Ford (2022) found that the viability of the Snake River sockeye salmon ESU has likely declined since the time of the prior review, and the extinction risk category remains "high."

2.3.2 ESA Listing Factor Analysis

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

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

Significant habitat restoration and protection actions at the Federal, state, tribal, and local levels have been implemented to improve the degraded habitat conditions and fish passage issues described in the Snake River recovery plans. While these efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations, we do not yet have evidence demonstrating that improvements in habitat conditions have led to improvements in population viability. The effectiveness of habitat restoration actions and progress toward meeting the viability criteria should be/continues to be monitored and evaluated with the aid of newly implemented monitoring and evaluation programs. Generally, it takes one to five decades to demonstrate increases in viability.

Current Status and Trends in Habitat

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

> **(1)** the **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)** the **population-specific geographic areas** (e.g., independent population major/minor spawning areas) where key emergent or ongoing concerns about this habitat condition remain;
>
> **(3) population-specific key protective measures and major restoration actions taken since the 2016 5-year review** toward achieving the recovery plan viability criteria established by the ICTRT (2007) and adopted by NMFS in the SR sockeye salmon recovery plan (NMFS 2015a) as efforts that substantially address a key concern noted in **above #1 and # 2**, or, that represent a noteworthy conservation strategy;
>
> **(4) key regulatory measures that are either adequate, or, inadequate** and contributing substantially to the key concerns summarized above; and
>
> **(5) recommended future recovery actions over the next 5 years toward achieving population viability**, including: key near-term restoration actions that would address the key concerns summarized above; projects to address monitoring and research gaps; fixes or initiatives to address inadequate regulatory mechanisms, and addressing priority habitat areas when sequencing priority habitat restoration actions.

We did not identify any new habitat limiting factors or concerns for SR sockeye salmon since our prior 5-year review (NMFS 2016a). Key staff at IDFG involved in sockeye management also concluded no new habitat limiting factors had been identified since our prior review (Powell 2020). However, since then additional information has increased our concern regarding the influence of climate on SR sockeye survival. Adult SR sockeye migrate later than other salmon species in the Snake River, exposing them to both lower volumes of water and higher water temperatures throughout the corridor. They also migrate further inland than any other sockeye species in the world and to higher elevations and further from the ocean than nearly all other populations of anadromous salmonids in the Columbia River Basin. SR sockeye are also the smallest anadromous salmonid in the basin, resulting in lower energy reserves to successfully propel them through warmer waters to high elevation spawning lakes in the Sawtooth Valley. Once reaching these high elevation lakes, they find thermal refugia until spawning in late fall. The extreme low abundance of the ESU for several decades has also reduced the variability in run timing that may have historically been present, reducing the ability of the species to successfully adapt to changing climatic conditions and mainstem habitat impacts. This was particularly evident in 2015 when the entire adult run collapsed due to high water temperatures in the migration corridor, both in the CRS and upstream of it.

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

For the single extant Redfish Lake population that comprises the single MPG of the SR Sockeye salmon ESU, the primary habitat concerns continue to be those identified in the recovery plan (NMFS 2015a), and the influence of climate change on these concerns:

1) Increasing Temperatures in Freshwater Migration Corridors.

<u>Climate</u>

Climate-related water temperature increases within the migration corridors, including areas upstream of the hydrosystem, are a critical emergent habitat concern (Crozier et al. 2018, 2020; Isaak et al. 2018). Adult sockeye experience substantially higher adult mortality in migration corridors from heat stress than other species (Crozier et al. 2018, 2020; Isaak et al. 2018). In 2015, record warm water temperatures reduced adult survival from Bonneville Dam to LGD to just 4 percent and from Bonneville to the Upper Salmon to just 1 percent (Crozier 2016; NMFS 2016b, 2019b). Average survival for the 2010 and 2019 runs was 57.4 percent for the Bonneville to Lower Granite Reach. Between 2010 and 2019, approximately 70.8 percent of the total adult mortality between Bonneville and Lower Granite Dams occurred downstream of McNary Dam (NMFS 2020b) and the proportion was much higher in 2015 and 2013. Adult survival improves from Lower Granite Dam to the Sawtooth Valley (73 percent between 2008 and 2012) (NMFS 2020b) but the losses are still substantial considering the extremely low abundance. Recent projections suggest adult sockeye salmon survival may further decline as much as 80 percent due to climate related impacts to water temperature, with significant impacts occurring upstream of the hydrosystem (Crozier et al. 2020). Based on climate-related temperatures observed in the last 5 years, which influence migratory conditions that are highly modified by the CRS, coupled with recent climate change modeling, our concerns about the persistence of the anadromous life history form has increased. See *Listing Factor E: Other natural or manmade factors affecting its continued existence* for further discussion of climate change impacts.

Irrigation Diversions and Land Use Practices

Irrigation diversions, degraded riparian habitat, reduced floodplain connectivity, and simplified channel morphology throughout the species range also contribute to increased water temperatures and reduced quantity of flow (Keefer et al. 2008; NMFS 2015a, 2015b, 2016a, 2016c, 2016d; IDEQ 2018). In addition to direct impacts from water removal at diversions, increases in water temperature from reduced flow or warmed irrigation returns likely contributes to reduced adult survival, primarily above Lower Granite Dam. Irrigation related flow reductions may also impair juvenile migrant survival, which has been demonstrated for other salmonids, either as a function of increased travel time (Connor et. al 1998, 2003) or increased predator exposure (Hostetter et al. 2012). Juvenile survival increases with mean May discharge in the Salmon River, likely due to reduced travel time (Griswold et al. 2011). Irrigation season overlaps with juvenile migrations and juveniles are routinely entrained in mainstem diversion screens. Cumulative delay caused by multiple entrainments and reduced flows may contribute to reduced juvenile survival. Water temperature changes are likely also related to degraded riparian habitat, reduced floodplain connectivity, and narrowed and simplified channels across the species range (NMFS 2015a). Much of the mainstem Salmon River, particularly upstream of North Fork, Idaho, has lost riparian vegetation, been channelized, and lacks floodplain connectivity – each contributing to warmer temperatures.

While some water diversions have improved in the last 5 years (NMFS 2014a, 2015b, 2016c, 2016d, 2021), the availability of water during migration, as well as elevated water temperatures from land use practices (and exacerbated by climate change) continues to be a substantial threat.

2) Impaired Passage (Mainstem Lower Snake and Columbia River dams, and upstream).

Both adult and juvenile SR sockeye salmon are subject to passage effects at mainstem Lower Snake and Columbia River dams. For adults, these effects include reduced survival during migration, migration delay as fish search for fishway entrances and navigate through fishways, and fallback (i.e., adult fish that fall back over a dam once they have passed it). Low adult sockeye survival rates in the migration corridor are discussed above under climate. However, habitat conditions in the migratory corridor contribute to the high mortality of adults passing through the corridor to the Sawtooth Valley. These impacts may increase travel time for adults transported as juveniles as the adults may be exposed to larger cumulative thermal exposures and other mainstem stressors and fisheries, decreasing their survival.

For juveniles, effects include delayed downstream passage and increased direct and indirect mortality compared to a free-flowing river reach (NMFS 2015a). Juvenile survival from natal lakes downstream to approximately North Fork, Idaho is low (Axel et al. 2015, 2017; Johnson et al. 2020b). Causal factors remain poorly understood, although two reaches (release site to Valley Creek Confluence and Deadwater Slough) appeared to have higher mortality relative to others (Axel et al. 2017). Transporting juvenile fish can also have impacts that carry over into adult life stages. Though juveniles barged through hydrosystem survive at higher rates to the estuary than non-transported fish, these transported fish experience higher mortality in the estuary and ocean relative to non-transported fish (NMFS 2020b). While annual variability exists, adult sockeye survival between Bonneville and Ice Harbor Dams is as much as 50 percent lower for fish transported through the hydrosystem as juveniles than for in-river migrants (NMFS 2016b; Crozier et al. 2020).

3) Lack of Marine-derived Nutrients in Natal Spawning and Rearing Lakes.

The lack of marine derived nutrients, historically provided by robust sockeye returns, may reduce carrying capacity of the three occupied and two unoccupied lakes (Evans et al. 2020). Continued low adult spawner abundance may constrain lake productivity, potentially affecting the lakes' carrying capacity and potentially reducing sockeye salmon growth and fitness. Ongoing nutrient supplementation and release of captive-reared adults likely support current production levels.

4) Unsafe Migration Corridors (Aging Fish Screen Infrastructure).

Aging fish screen infrastructure is a threat to successful fish migration. As identified in our prior review, the Upper Salmon River basin, as well as mainstem Snake and Columbia River segments, contain extensive irrigation screening programs that are critically important to migrating sockeye salmon smolts – but many of the existing structures are nearing the end of their design life. Costs to maintain and/or replace structures continue to rise and screening budgets have remained flat. Any reduction in screen efficacy, either from structure failure or poor maintenance, is a potential threat to current population status in the area.

5) Inaccessible Habitat due to Fish Passage Barriers

The Stanley Lake Creek fish barrier prevents Stanley Lake from being occupied by SR sockeye salmon (NMFS 2015a, IDFG 2019). The barrier prevents all native fish immigration. Although emigration is possible, the barrier is believed to have moderated the risk of non-native lake trout emigrating out of Stanley Lake and invading other Sawtooth Valley lakes by maintaining a stable food balance (IDFG 2019). See Listing Factor C for more information as this threat is actively being reduced. The Sawtooth Hatchery Weir and water diversion intake (two total structures), prevents natural adult migration to Alturas and Pettit Lakes. The hatchery weir requires additional capture and handling of returning fish which increases risk of injury (NMFS 2015a). The diversion intake barrier prevents upstream migration for most species and life stages.

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

The ESU remains poorly distributed within its geographical range and is almost completely reliant on the captive broodstock program for survival and any potential future expansion. Recent studies have highlighted specific reaches of concern for SR sockeye salmon in the migration corridor above Lower Granite Dam (Axel et al. 2017) and the entire adult freshwater migration corridor (Crozier et al. 2020), which includes the Mainstem Snake River as well as the lower

Columbia and the entire Salmon River. More detail on currently identified important geographic areas is presented below. So much critical habitat is overlapping among the SR sockeye salmon populations that all of the specific geographic areas of concern impact all populations.

Mainstem Columbia, Snake, and Salmon River Migration Corridors

Columbia, Snake, and Salmon River migration corridors continue to present challenges for the entire ESU because of high summer water temperatures, influence of predation from native and non-native species, and lower survival of adult sockeye that were transported as juveniles. These factors individually and cumulatively reduce fish survival across juvenile and adult freshwater life stages. The reach between Bonneville and McNary Dams accounts for the majority of adult mortality and may require special emphasis to address potential synergistic impacts of hydropower operations, reduced water volume, degraded water quality, juvenile fish transport, and climate induced water temperature increases. In addition, based on PIT-tag-based survival estimates, substantial losses of adult sockeye salmon are occurring between Bonneville and McNary Dams. Fallback and straying have been ruled out because they affect too few fish to account for the losses. In some years, high temperatures and associated disease and stress likely contribute substantially to adult losses, but in others, there is little or no indication of this source of mortality.

Lower mainstem Snake River

Water quantity and quality (e.g., pesticides and urban runoff, temperatures, etc. [NMFS 2020b]) remain critical for migrating juvenile and adult sockeye salmon. Degraded water quality may be contributing to reduced juvenile and adult survival.

Upper reaches of the mainstem Salmon River and its tributaries

Upper reaches of the mainstem Salmon River and its tributaries (e.g., Valley Creek, East Fork Salmon River, etc.) continue to experience high summer water temperatures. This affects adult migrants in the mainstem and at stream confluence areas, where thermal refugia may otherwise exist. Reduced spring and summer flows throughout the Salmon River affect juvenile and adult migrants. The extent of flow depletion across the landscape, the magnitude of over-allocation in many streams, and limitations in Idaho water right laws to prevent downstream junior water users from using water ‘saved’ by individual projects, continue to limit success of ongoing flow enhancement activities. Axel et al. (2017) also found unexplained high mortality for juvenile releases in this reach that may be limiting productivity. High mortality may be related to water temperatures, predation, reduced flows, habitat degradation/loss or a combination of these factors but more research is needed to pinpoint the cause and identify remedial actions.

Columbia River Estuary

Juvenile sockeye enter the Columbia River estuary as 1 to 3 years old with peak entry occurring in mid-May to mid-July (NMFS 2015a). Juvenile sockeye are large at estuary entry due to extended lake residency before smolting and they likely spend one to two days moving through it as they acclimate to the ocean environment. Juveniles likely depend on the estuary habitat to avoid predation, mostly avian (NMFS 2015a). NMFS' recovery plan (2015a) suggests SR sockeye mortality is high in the estuary, but estuary conditions likely affect SR sockeye less than other Pacific salmonids due to shorter periods of use.

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

- Installation of permanent cooling systems for the water supply to the adult fish ladders at Lower Granite Dam in 2016 and Little Goose Dam in 2017 (NMFS 2020b).
- Implementation of the Columbia River System (CRS) action agencies flexible spill agreement in 2019, to reduce powerhouse encounter rates and increase juvenile passage survival through the CRS migratory corridor (NMFS 2020b).
- The 2020 Idaho Department of Fish and Game (IDFG) implementation of the planned transition of Stanley Lake's non-native Lake Trout population to a sterile population (IDFG 2019); in an effort to reduce the threat of lake trout invasion into other Sawtooth Valley lakes (discussed further in Listing Factor C). This action sets the stage for potential future expansion of sockeye salmon into historical habitat in Stanley Lake, which would improve spatial distribution.
- Shoshone Bannock Tribes'/BPA's reconstruction of the Pettit Lake Creek weir (NMFS 2020c) will allow co-managers to better monitor juvenile and adult sockeye migrations to/from Pettit Lake and inform future efforts to maximize natural production/survival.
- The CRS action agencies and co-manager's development of the infrastructure and methods necessary to capture adult sockeye from Lower Granite Dam and transport them to the Sawtooth Valley to avoid additional mortality in increasingly warm habitats upstream of the CRS (NMFS 2016b, 2020b).
- The BPA and U.S. Army Corps of Engineers (Corps) completed 64 projects reconnecting more than 6,200 acres of historical Columbia River floodplain and another 2,000 acres of floodplain lakes (Karnezis 2019; BPA et al. 2020). The agencies also acquired conservation easements protecting about 2,500 acres of currently functioning floodplain habitat from development. These actions likely improved SR Sockeye forage availability (see Johnson et al. 2018; PNNL and NMFS 2018, 2020) and increased their ability to avoid predation while moving through the estuary.

4) Key Regulatory Measures since the 2016 5-year Review

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 stayed the same on average, with some mechanisms showing the potential for some improvement whereas others have made it more challenging to protect and recover our species. See *Listing Factor D: Inadequacy of Existing Regulatory Mechanisms* in this document for details.

5) Recommended Future Habitat Actions Over the Next 5 Years Toward Achieving Population Viability

For habitat, the greatest opportunities to advance recovery of SR sockeye salmon are:

- Measurably reduce water temperatures in mainstem migratory habitats during adult sockeye salmon migration timing and establish cold-water refugia along the entire migratory corridor (EPA 2003; Crozier et al. 2020; NMFS 2020b). Co-managers should develop and implement plans addressing multiple spatial scales, from headwater habitats through the mainstem migration corridor (see NMFS 2016b for specifics) to moderate modeled increases in summer water temperature and low flows influenced by projected changes in climate.
- Increase Federal, state, local governments, and private organizations' efforts to improve water quantity and water quality in sockeye salmon migratory reaches. Efforts should address appropriate regulatory controls, land management practices, and hydropower operations (NMFS 2016b).
- Investigate causal factors for poor juvenile smolt survival in the Upper Salmon River basin (i.e., natal lakes downstream through Deadwater Slough) and initiate actions to improve survival.
- Continue fertilizing and monitoring natal lakes to maximize carrying capacity and growth of naturally produced sockeye salmon, which exhibit higher SARs than hatchery releases and provide greater opportunity for adaptive selection to cope with a changing environment.
- Continue to protect, and where possible restore, natural ecological processes, including free passage, in natal lakes and their inlet and outlet streams. Restoring passage at the Sawtooth Fish Hatchery weir and water intake structure should be pursued in the next 5 years. The entire migration corridor has been impaired by various forms of development. Where project sponsors determine measurable benefits can be attained, they are encouraged to implement riparian and floodplain restoration along the entire migration corridor, particularly where States or the EPA have identified existing impairments (IDEQ 2018; EPA 2020).
- Monitor in-river survival of returning adults in concert with current and projected environmental conditions (i.e., temperature) and continue to initiate adult transport at CRS facilities as necessary to maximize fish survival through migration corridors (NMFS 2016b). Evaluate and implement adult trap/haul downstream of McNary Dam if possible to account for higher mortality downstream of that point and maximize adult conversion to the Sawtooth Valley in potentially catastrophic years.

- Identify appropriate funding levels necessary to maintain an effective fish screening program throughout the species' mainstem migration corridor, and prioritize screening maintenance and/or replacement to provide the greatest protection for SR sockeye salmon as well as considering each screening location in context of other anadromous ESA-listed fish present at the site.

Listing Factor A Conclusion

New information available since the last 5-year review (NMFS 2016a) indicates there is improvement in freshwater habitat conditions because of changes in hydropower operations that increased juvenile survival rates through the mainstem Columbia River corridor, improvements to fish passage (Pettit Lake Creek), and numerous small tributary habitat improvement projects (Pole Creek, Valley Creek, etc.). However, habitat concerns remain throughout the Snake River basin, particularly with regard to mainstem and tributary stream flow, floodplain management, and water temperature standard exceedances. Numerous small diversions cumulatively contribute to low flow and high temperature problems exist across the species range, affecting adult and juvenile life stages. Some small and mid-sized Salmon River tributaries (e.g., Challis, Garden, Morgan, Carmen, etc.) which provide potential thermal refugia, are often dry during the summer because of private demand for surface water. In addition, climate change's projected influence on mainstem migration corridor streamflow and water temperature poses a serious threat to the species' ability to survive freshwater migrations necessary to reproduce (See *Listing Factor E: Other natural or manmade factors affecting its continued existence*). Immediate identification and implementation of measures that reduce water temperatures or reduce duration of SR sockeye salmon exposure to warm temperatures during adult migrations is needed.

We therefore conclude that the risk to the species' persistence because of habitat destruction or modification has improved slightly since the 2016 5-year review. However, these improvements are still not sufficient to address the threats this ESU faces. Our understanding of the significance of the migration corridor's temperature modifications on sockeye salmon has increased substantially since the prior review, highlighting the substantial risk of extinction faced by SR sockeye salmon. In addition to continuing current habitat preservation/restoration actions (e.g., nutrient supplementation of natal lakes, improved streamflow) further actions must be taken to reduce the currently substantial risk of extinction to this ESU. We provide further discussion and evaluation of current migration corridor habitat conditions under *Listing Factor C (Disease and Predation)* and *Listing Factor D (Inadequacy of Existing 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, which replaces the previous 10-year agreement. This new agreement maintains the limits and reductions in harvest impacts for the listed ESUs/DPSs that were secured in previous agreements (NMFS 2018b).

Ocean fisheries do not significantly affect SR sockeye salmon. The ocean distribution of SR sockeye salmon is such that the fish are not present in near shore areas where ocean salmon fisheries traditionally occur (NMFS 2019c). SR sockeye salmon are encountered incidentally in fisheries in the mainstem Columbia River and are managed under the *U.S. v. Oregon* Management Agreement. Fisheries are limited to an incidental take of 6 to 8 percent (depending on run size) of the sockeye returning to the Columbia River mouth (NMFS 2018b). Actual incidental take has decreased since the last 5-year review and averaged 4.5 percent for the years 2014 - 2019 (TAC 2015, 2016, 2017, 2018, 2019, 2020).

Research and Monitoring

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

Any time we seek to issue a permit for scientific research, we consult on the effects that the proposed work would have on each listed species' natural- and hatchery-origin components. However, because research has never been identified as a threat or a limiting factor for any listed species, and because hatchery fish production can be modulated in response to species' recovery needs, we only discuss the research-associated take of naturally-produced fish in the following sections.

From 2015 through 2019, researchers were approved to take a yearly average of fewer than 9,300 SR sockeye salmon juveniles (<500 lethally). For adults during this same period, researchers were approved to take a yearly average of fewer than 140 SR sockeye salmon (<13 lethally) per year (NMFS APPS database; https://apps.nmfs.noaa.gov/).

For the vast majority of scientific research actions, history has shown that researchers generally take far fewer salmonids than are authorized every year. Reporting from 2015 through 2019 indicates that the average actual yearly total (non-lethal and lethal) take for naturally-produced SR sockeye salmon was 11 percent of the number of juveniles authorized, and only one adult was reported as taken of the 676 adults authorized to be captured over the entire 5-year period (0.1 percent). The actual lethal take was also a small fraction of what was authorized during this period. Average yearly lethal take of juveniles (61 mortalities) was 13 percent of the average amount authorized per year (468 mortalities) for SR sockeye salmon from 2015 through 2019. No adults were reported to be lethally taken during this 5-year period, despite an annual average of 13 adults authorized for lethal take (64 total over 5 years).

The majority of the requested take for naturally-produced juvenile SR sockeye salmon has primarily been (and is expected to continue to be) capture via screw traps, electrofishing units, and trawls, with smaller numbers collected as a result of hook and line sampling, weirs, beach and purse seines, incline plane traps, and those intentionally sacrificed. Adult take for SR sockeye salmon has primarily been (and is expected to continue to be) capture via weirs or fish ladders, 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 (for all four ESA-listed species of SR salmon and steelhead).

Compared to 2010-2014, the most recent total authorized take for naturally produced SR sockeye salmon (2015-2019) increased by over 60 percent, and authorized lethal take was twice as high (increased by 99 percent) over that same period as in the previous 5 years. The actual take that occurred from 2015 through 2019 was also twice as high as from 2010 through 2014, for both total (increased by 116 percent) and lethal (increased by 106 percent) take. However, the absolute numbers of individuals taken remain relatively low, with a total of 4,968 juveniles and only a single adult captured over the past 5 years, and only 305 juveniles and no adults killed over that time. For sockeye salmon, much of the research related take is directly tied to evaluation of hatchery production and release strategies. Recent increases in research-related requests for authorization and reported take mirror increased monitoring related to increased hatchery smolt production and release.

Overall, research impacts remain minimal due to the low mortality rates authorized under research permits. Therefore, the overall effect on SR sockeye salmon has not changed substantially, and we conclude that 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

New information available since the last 5-year review indicates harvest impacts have remained relatively constant (TAC 2015, 2016, 2017, 2018, 2019, 2020). Since the last 5-year review, authorized scientific research impacts on SR sockeye salmon have increased, although absolute numbers of fish captured or killed remain very low relative to the authorized take (NMFS APPS database; https://apps.nmfs.noaa.gov/). Impacts from these sources of mortality are not considered to be major limiting factors for this ESU. Therefore, the risk to the species' persistence because of overutilization remains essentially unchanged since the 2016 5-year review, with harvest and research/monitoring sources of mortality continuing to have little to no impact on the viability of SR sockeye salmon. Maintaining the recent low observed incidental harvest levels will benefit the species. Significant and ongoing unexplained adult losses between Bonneville and McNary Dams should be a subject of additional research to clarify causes and facilitate improved survival to the Sawtooth Valley. Any possible methods to reduce future incidental fishery impacts (e.g., reducing juvenile sockeye transport, which may reduce adult sockeye travel time through zone 6 of the fishery) will improve the species likelihood of recovery.

Listing Factor C: Disease or Predation

Disease

Disease rates over the past 5 years are believed to be consistent with the previous review period. Increasing temperatures associated with our changing climate increase sockeye salmon's susceptibility to diseases (NMFS 2016c, 2020b; Crozier et al. 2020). The almost complete loss of the 2015 adult return was associated with abnormally high-water temperatures. Those temperatures appear to exacerbate both the prevalence and severity of multiple diseases affecting salmon, including; *Flavobacterium columnare* (commonly known as columnaris disease), *Aeromonas salmonicida,* and *A. hydrophila* (infective agents for furnunculosis), and *Ceratomyxa shasta* (NMFS 2016b). Considering our changing climate, current models suggest more of our future years will be similar to the 2015 climate than historical climate conditions, and adult sockeye survival may decrease up to 80 percent from already low levels (Crozier et al. 2020).

Summer water temperatures in natal lakes temporarily spike to levels that make sockeye salmon more susceptible to disease and infection (NMFS 2020b), but with limited anthropogenic impacts influencing lake water temperature, this may primarily be a natural factor. Climate change impacts are likely to exacerbate this condition in the future and rearing conditions should continue to be monitored.

For the 2016 5-year review (NMFS 2016a), we reported that the spread of a new strain (i.e., M clade) of infectious hematopoietic necrosis virus (IHNV) along the Pacific coast may increase disease-related concerns for SR salmon and steelhead in the future. Since then, the M clade of IHNV has not appeared in sockeye salmon anywhere 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.) Sockeye continue to be affected by the U clade of IHNV, but this risk has not changed since the prior 5-year review.

Handling and transport of juveniles results in them being held at much higher densities than are observed in the wild, increasing the risk of disease transmission. Juvenile transport continues through the CRS and adult sockeye that were transported as adults survived the Columbia River reach at half the rate of non-transported juveniles (Crozier et al. 2020). Transported fish also fall back over mainstem dams and stray more frequently than non-transported fish. This could expose adult migrants to warmer water for longer periods of time, potentially increasing disease susceptibility. Since adoption of the CRS operations in 2020, fewer sockeye are transported since they can pass the hydro projects via in-river routes. Overall, this risk appears relatively static across the time period evaluated.

Projections for increasing water temperatures across the species range, and sockeye salmon's higher susceptibility to disease when in warmer water (relative to other salmonids) suggests the risk of disease may increase in the future.

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. Caspian terns on Rice Island, an artificial dredged-material disposal island in the estuary, consumed about 5.4 to 14.2 million juvenile salmon 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 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. (2012) found that body size affects susceptibility to tern predation. Yearling SR sockeye salmon are smaller than steelhead and predation rates are relatively low. There are no estimates of sockeye salmon predation rates before the reduction in tern colony size on East Sand Island, but more recently rates have averaged 1.8 percent of available PIT-tagged smolts (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 further up-river than East Sand Island, these birds are likely to be consuming more juvenile salmonids per capita than when they were foraging further downstream with access to 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 SR sockeye salmon decreased from 4.2 percent to 0.9 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 sockeye salmon also have been vulnerable to predation by terns nesting in the interior Columbia plateau, including islands in McNary Reservoir and in the Hanford Reach. The Corps has successfully prevented terns from nesting on Crescent Island since 2015. 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 sockeye salmon did not change. To improve survival for this and other salmonids, the Corps raised the elevation of John Day Reservoir during the spring smolt migration in 2020, inundating the Blalock Islands to prevent its use by terns. This operation will continue under the 2020 CRS proposed action (BPA et al. 2020).

The 2008 FCRPS (now CRS) biological opinion first required that the Action Agencies implement avian predation control measures at mainstem dams in the lower Snake and Columbia Rivers. Since then, each of the CRS projects has used hazing and passive deterrence including wire arrays across tailrace areas, spike strips along the edge of the concrete, water sprinklers at juvenile bypass outfalls, pyrotechnics, propane cannons, and limited amounts of lethal take. These measures have reduced the number of smolts consumed by birds at the dams and will continue to be implemented, with improvements as new techniques become available.

Until recently, predation by gulls was not considered to warrant management actions. However, Cramer et al. (2021) reported that annual predation rates by gulls nesting on Miller Rocks in John Day Reservoir averaged 6.2 percent of available SR sockeye salmon during the last decade. There are no management plans to reduce the size of the Miller Rocks colony at this time, in part because ownership of the property is unclear.

Overall, during the past 5-years, mainstem avian predation rates appear to be lower than the predation rates reported in our previous 2016 5-year review. Ongoing management practices such as water elevation adjustments, avian predation control/hazing measures have helped drive this change. However, avian predation continues to be a significant source of juvenile mortality in this reach.

Marine Mammal Predation

Recent research over the past 5 years suggests that predation pressure on ESA-listed salmon and steelhead from seals, sea lions, and killer whales has been increasing in the northeastern Pacific over the past few decades (Chasco et al. 2017a, 2017b). Killer whales are known to selectively prey on Chinook salmon, so they are not considered a major predator of SR sockeye salmon (Hanson et al. 2021). The three main seal and sea lion (pinniped) predators of ESA-listed salmonids in the eastern Pacific Ocean are harbor seals (*Phoca vitulina richardii*), California sea lions (*Zalophus californianus*), and Steller sea lions (*Eumetopias jubatus*). 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).

Pinniped Predation Impacts

With their increasing numbers and expanded geographical range, pinnipeds are consuming more Pacific salmon and steelhead, and some are having an adverse impact on some ESA-listed species (Marshall et al. 2015; Thomas et al. 2016; Chasco et al. 2017a). California sea lions, Steller sea lions, and harbor seals all consume salmonids from the mouth of the Columbia River and its tributaries up to the tailrace of Bonneville Dam. The ODFW counted the number of individual California sea lions hauling out in the Columbia River mouth at the East Mooring Basin in Astoria, Oregon, from 1998 through 2017. The data is our best evidence that California sea lion abundance within the Columbia River has increased markedly since SR sockeye were listed as endangered in 1991 (Wright 2018). Upstream migrating sockeye salmon are likely encountering outmigrating California and Steller sea lions as they move toward breeding grounds outside of the Columbia River basin. There are no estimates for the proportion of sockeye salmon that are consumed by pinnipeds in the Columbia River; however, the overall impact of pinniped predation on salmon is likely related to overall pinniped abundance and their overlap with the adult salmon migration. Additional information on SR sockeye predation by pinnipeds in the Columbia River would better inform future 5-year reviews and help formulate appropriately targeted recovery actions during this life stage.

In the Columbia River Basin, California sea lions are generally present from December through April. Although California sea lions have been the primary focus of management efforts at Bonneville Dam to date, the presence of Steller sea lions has been increasing over time, and 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. Numbers of pinnipeds counted during June, when sockeye salmon are migrating, have increased substantially in recent years, from about 45 pinnipeds in 2008-2009 to over 500 in 2014-2017 (Wright 2018). Rub et al. (2019) found evidence that recent increases in pinniped abundance in the Columbia River have likely resulted in increased salmon predation (not specific to sockeye). Tidwell et al. (2020) also found Steller sea lion predation on the total run of all Pacific salmon and steelhead stocks has increased during this review period.

Most recent research on pinniped predation has focused on spring-run Chinook salmon (Rub et al. 2019; Sorel et al. 2020). Although spring-run Chinook salmon typically migrate earlier than SR sockeye salmon, these studies provide valuable inference for sockeye predation. Rub et al. (2019) estimated non-harvest mortality of spring-run Chinook salmon varied from 20-44 percent between the mouth of the Columbia River and Bonneville Dam, attributing the majority of this mortality to pinniped predation. Sorel et al. (2020) evaluated seasonal relationships of California sea lion abundance and spring/summer Chinook salmon migration survival for 18 population-specific migration timing. For years with high California sea lion abundance, they estimated the latest migrating stocks of spring/summer Chinook salmon, which are the closest in migration timing to SR sockeye (i.e., first week of June vs last week of June to early July), experienced an additional 10.1 percent mortality compared to baseline sea lion abundance. Although later migrating salmon stocks experienced about half the additional mortality as early arriving stocks, the study suggests recent increases in pinniped abundance are likely increasing SR sockeye salmon predation in the Columbia River.

Although pinniped presence in the Bonneville tailrace has increased in the last decade (Tidwell et al. 2020), most pinnipeds leave the area before the June peak of the sockeye salmon migration through Bonneville Dam. Thus, while consumption of SR sockeye salmon may have increased in the Columbia River, predation of adult SR sockeye salmon in the Bonneville tailrace is rarely observed (Tidwell et al. 2020) and is likely low. A small number (less than five) of California sea lions have also been observed in the Bonneville Reservoir. Management actions intended to reduce pinniped predation in the Columbia River are discussed in Listing Factor D.

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 ESA-listed fish species. While pinniped populations in Oregon and Washington have continued to grow, new information has indicated predation risk may be higher in the Columbia River Estuary primarily for salmon and steelhead with run timing that overlaps with peak pinniped presence. At this time, we do not have information available that would allow us to quantify the change in extinction risk due to predation for SR sockeye salmon. Therefore, we conclude that the risk to the species' persistence because of predation has remained relatively static since the 2016 5-year review. While there are management efforts underway to reduce pinniped predation on Pacific salmon and steelhead in select areas of the Columbia River Basin (see Listing Factor D), these management efforts alone may be insufficient to reduce the severity that pinniped predation poses to the species' recovery.

Northern Pikeminnow

Some indigenous fish species are also recognized as significant predators of ESA-listed salmonids in the lower Columbia River basin, such as the northern pikeminnow. The construction of dams and dredging of waterways in the Columbia River basin has created reservoirs and islands from dredged spoils that have facilitated population explosions of the native Northern pikeminnow (Waples et al. 2008). In 1990, a sport fishing reward program was implemented to reduce the numbers of Northern pikeminnow in the Columbia River basin to reduce predation upon juvenile salmon and steelhead (NMFS 2010). Further, NMFS' 2008 FCRPS Opinion recommended the Northern Pikeminnow Management Program (RPA Action 43) to continue the sport-reward fishery while evaluating its effectiveness (NMFS 2008a) which was further expanded in the 2014 FCRPS Supplemental Opinion (NMFS 2014b) and is carried forward in the most recent CRS Opinion (NMFS 2020b).

The native Northern pikeminnow (*Ptychocheilus oregonensis*) is a significant predator of juvenile salmonids in the Columbia and Snake Rivers followed by non-native smallmouth bass and walleye (reviewed in Friesen and Ward 1999; ISAB 2011, 2015). Before the start of the Northern Pikeminnow Management Plan in 1990, this species was estimated to eat about 8 percent of the 200 million juvenile salmonids that migrated downstream in the Columbia River each year. Williams et al. (2017) estimated a median reduction in Northern pikeminnow predation rates on juvenile salmonids of 30 percent compared to before the start of the program. In addition to the Sport Reward Fishery, the Action Agencies conduct a Dam Angling Program to remove large pikeminnow from the tailraces of The Dalles and John Day Dams. Angling crews removed an average of 5,728 northern pikeminnow from these two projects per year during 2015 to 2019 (Williams et al. 2015, 2016, 2017, 2018; Winther et al. 2019).

Removal of piscivorous-sized Northern pikeminnow could mean a continued improvement in juvenile SR sockeye salmon survival. But that is true only if the remaining Pikeminnow, walleye, smallmouth bass and other piscivorous fish populations do not offset the improvement through a compensatory response. As noted in NMFS' recent CRS Opinion (NMFS 2020b), recent data indicates populations of smallmouth bass and walleye are higher in some mainstem reaches of the Columbia and Snake Rivers than ever before, at least suggesting that compensatory predation may be occurring. These increases could be a compensatory response to the NPMP removal efforts or could be due to factors such as alterations in other parts of the food web or environmental conditions like warmer temperatures which affect this species' consumption rates. Despite the recent increasing trends in other predatory fish "the evidence of compensatory response to pikeminnow removal remains unclear NMFS 2020b)." The program remains effective at reducing predatory-sized pikeminnow and overall consumption rates are approximately 30 percent lower than pre-program. Despite all the other factors affecting adult sockeye salmon returns, the magnitude of the program's impact on juvenile salmon survival is likely to benefit the ESUs productivity to some degree. The program has not changed during the past 5 years though, and thus the program's benefit to the ESU is the same as during our 2016 5-year review.

Recent evidence indicates the Deadwater Slough, just downstream of North Fork, Idaho, contains high numbers (about 13,000) of predatory sized Northern pikeminnow (Lott et al. 2020). Juvenile sockeye salmon travel time and survival is routinely lower in this reach than adjacent reaches (Axel et al. 2015, 2017). Predation may account for the observed low survival. Lott et al. (2020) also found evidence of avian predation on juvenile salmon in this location, which supports a blue heron rookery and other native birds. Deadwater Slough is believed to be at least partially formed by a mining dam failure in Dump Creek in 1897 (Lott et al. 2020); as such it is anthropogenic and may present a unique treatment opportunity.

Overall, native fish predation on SR sockeye salmon does not appear to have changed since the 2016 5-year review. New information since then appears to confirm the sportfish reward program is reducing predation compared to 1990 levels. Effects of compensatory predation remain poorly understood. Other new information is identifying specific locations (i.e., Deadwater Slough) where Pikeminnow numbers may be higher due to historic human impacts and could thereby lead to future treatments.

Non- Indigenous Species Impacts

Non- indigenous fishes affect salmon and their ecosystems. A number of studies have concluded that many established non-indigenous species 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. Smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*M. salmoides*) channel catfish (*Ictalurus punctatus*), walleye (*Sander vitreus*), and lake trout are documented predators (Erhardt and Tiffan 2018; Erhardt et al. 2018; Tiffan et al. 2020), brook trout (*Salvelinus fontinalis*) are known competitors and American shad (*Alosa sapidissima*) may have food web impacts (Sanderson et al. 2009; NMFS 2010; Naiman et al. 2012).

Thermal conditions may influence current and future spatial and temporal overlap with smallmouth and largemouth bass, which ultimately drives the potential for species interactions, including predation (Rubenson and Olden 2016, 2020; Hawkins et al. 2020). Elevated water temperatures are likely to increase overlap with non-indigenous species in the future. Non-native and highly predatory Northern pike (*Esox lucius*), currently located upstream of Grand Coulee Dam, pose an additional predation threat if they establish populations further downstream.

Management Actions:

- January 1, 2016, WDFW and ODFW lifted limits on smallmouth bass, channel catfish, and walleye in the Columbia River in an effort to reduce predator populations. See http://wdfw.wa.gov/fishing/regulations/ that list the lack of a catch limit on these species.
- In 2020, the IDFG began implementing a program to convert the fertile lake trout population in Stanley Lake to a sterile population (IDFG 2019). The effort has substantially reduced the lake trout threat since the last review. Trap gear does not capture fish that are too small for available net sizes and some lake trout do not recruit for unknown reasons (e.g., mid-depth suspension). This creates a need for repeated trap and replacement efforts, triggering a long-term financial investment to maintain a non-native top tier predatory fish species in habitat ultimately targeted for SR sockeye reintroduction. This may jeopardize the transition to a completely sterile population and

may also compromise the ability to remove the Stanley Lake outlet barrier – delaying the opportunity to reintroduce sockeye to Stanley Lake; a long-term recovery plan action (NMFS 2015a).

- In 2017, the Confederated Colville Tribe, Spokane Tribe, and Washington Department of Fish and Wildlife, with BPA and public utility funding, initiated a Lake Roosevelt Northern Pike Suppression and Monitoring Strategy to: (1) Eradicate or control Northern Pike; (2) conduct research to fill data gaps; and (3) implement outreach and education to inform the public of the adverse effects Northern Pike pose on native ecosystems. To date, Northern Pike have not been detected below Lake Roosevelt, suggesting the effort is likely suppressing their spread to downstream salmon habitat (https://invasivespecies.wa.gov/priorityspecies/northern-pike-2/).

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 (in addition to 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).

Idaho State Department of Agriculture coordinates a statewide aquatic invasive species management and control program, acting to protect the integrity of the state's water bodies from the biological degradation caused by aquatic plants and pests. They operate a large array of inspection stations across the state, including one at Redfish Lake. Annually, contaminated boats are intercepted prior to launching on Idaho waters. Contaminated boats have been intercepted at the Redfish Lake inspection site, likely preventing invasive species introductions that could upset the trophic balance and which could impair sockeye growth and survival.

Recommended Future Actions

- Encourage Federal and state agencies, tribes, landowners, watershed councils, private organizations, and other recovery partners 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, and-or minimizing the use of manmade haul outs used by pinnipeds in select areas (e.g., river mouths, migratory pinch points, etc.).
- Encourage Federal and state agencies, tribes, landowners, watershed councils, private organizations, and other recovery partners to expand, develop, and implement monitoring efforts in the Columbia River Basin, Puget Sound, and California to identify pinniped predation interactions in select areas (e.g., river mouths, migratory pinch points etc.) and quantitatively assess predation impacts on SR sockeye salmon.

- Continue evaluating effective methods to reduce avian predation in the mainstem Columbia and Snake Rivers.
- Continue to implement recommendations NMFS (2016a) made to reduce migratory corridor water temperature and the duration of time sockeye salmon are exposed to elevated temperatures during migrations, to reduce the mortality associated with disease.
- Continue research on juvenile sockeye mortality upstream of Lower Granite Dam to definitively determine if Northern pikeminnow or smallmouth bass predation is substantially limiting survival. Develop and implement proposed treatments – physical or biological – where anthropogenic changes to habitat can be rectified to successfully reduce predation where it is occurring.
- Encourage NMFS, the states, and Federal agencies, and local governments to continue current aquatic invasive species management and control programs.

Listing Factor C 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 last 5-year review, although more information is now available for some of these threats. Avian predation of SR sockeye smolts has decreased in some areas (e.g., Caspian terns at East Sand Island), while increasing in other areas (e.g. cormorants at the Astoria-Megler Bridge). Predation by northern Pikeminnow and other piscivorous species in the mainstem migration corridor has likely occurred for decades, but ongoing data collection is slowly identifying specific reaches of concern where management actions may be effective. Increasing temperatures and range expansion of non-native predatory fish suggest this threat could increase in the future. The State of Idaho's efforts to convert Stanley Lake's lake trout to a sterile population suggests the threat of lake trout invading other Sawtooth Valley Lakes, where predation and ecological imbalances could occur, is diminishing. Climate change is expected to continue to increase disease prevalence and SR sockeye salmon's susceptibility to disease; with recent climate evaluation models (Crozier et al. 2020) suggesting SR sockeye salmon survival may decrease markedly in the future.

Predation by pinnipeds continues to pose an adverse impact on SR sockeye salmon and the threat now appears to be larger than we understood in our last review (NMFS 2016a). Available data is primarily limited to other salmon species, but if we assume SR sockeye migration timing is roughly coincident with late arriving spring/summer Chinook salmon, pinniped predation on SR sockeye salmon may have increased by approximately 10 percent from the prior review period. While management efforts to reduce pinniped predation are occurring in select Columbia River reaches, these management efforts alone may not sufficiently reduce the current threat to the species' recovery.

Listing Factor D: Inadequacy of Existing Regulatory Mechanisms

One factor affecting habitat conditions across all land or water ownerships is climate change, the effects of which are discussed under *Listing Factor E (Other natural or manmade factors affecting its continued existence).* We reviewed summaries of national and international regulations and agreements governing greenhouse gas emissions, which indicate that while the number and efficacy of such mechanisms have increased in recent years there has not yet been a substantial deviation in global emissions from the past trend, and upscaling and acceleration of far-reaching, multilevel, and cross-sectoral climate mitigation will be needed to reduce future climate-related risks (IPCC 2014, 2018). These findings suggest that current regulatory mechanisms, both in 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.

Most of the land in the Snake River basin is managed by the Federal government (about 64 percent), including the U.S. Forest Service (USFS), U.S. Bureau of Land Management (BLM), and the U.S. Department of Energy. The U.S. Bureau of Reclamation, along with other state and federal agencies and private groups manage the water resources for the Columbia River's many, and sometimes competing, uses. Starting in the 1890s, fifteen major dams have been built on the Snake River to generate hydroelectricity, enhance navigation, and provide irrigation water. Dams on the Snake and Columbia Rivers affect water quality and quantity of tributaries and mainstem rivers (NWPCC 2021).

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 sockeye salmon. These include both federal and state regulatory mechanisms:

1. Endangered Species Act Section 7 Biological Opinions

<u>1.1 Columbia River System</u>

Improved Juvenile Passage

NMFS completed two biological opinions, one in 2019 (NMFS 2019b) and the second in 2020 (NMFS 2020b), 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 2020 opinion increased the amount of spill to improve passage conditions for juvenile salmon. The action agencies hypothesize that spill improvements may increase adult returns between 28 percent (SR steelhead) to 35 percent (SR spring/summer Chinook salmon) (no estimate was provided for SR sockeye salmon). These increases are estimates only and will require validation as the program is implemented. If the change in spill affects SR sockeye similarly, increases in productivity may be substantial. Additional improvements in survival are possible from a revised juvenile transport program, and more estuary restoration. Since the last 5-year review, increased spring spill rates have and will continue to decrease the proportion of juveniles from the Snake River that are transported. This is anticipated to improve adult SR sockeye salmon survival through the CRS since fish transported as juveniles survive at roughly half the rate of non-transported fish (Crozier et al. 2020) during their upstream migrations.

Improved Floodplain and Estuary Habitat

The CRS Action Agencies are implementing an estuary habitat improvement program (the Columbia Estuary Ecosystem Restoration Program, CEERP), reconnecting the historical floodplain below Bonneville to the mainstem Columbia River. From 2007 through 2019, the Action Agencies implemented 64 projects, including dike and levee breaching or lowering, tide-gate removal, and tide-gate upgrades that reconnected over 6,100 acres of historical tidal floodplain habitat to the mainstem and another 2,000 acres of floodplain lakes (Karnezis 2019; BPA et al. 2020). This represents more than a 2.5 percent net increase in the connectivity of habitats that produce prey used by juvenile Snake River salmon and steelhead (Johnson et al. 2018). In addition to this extensive reconnection effort, about 2,500 acres of currently functioning floodplain habitat have been acquired for conservation.

Floodplain habitat restoration can affect the performance of juvenile salmonids whether they move onto the floodplain or stay in the mainstem. Wetland food production supports foraging and growth within the wetland (Johnson et al. 2018), but these prey items (primarily chironomid insects) (PNNL and NMFS 2018, 2020) are also exported to the mainstem and off-channel habitats behind islands and other landforms, where they become available to salmon and steelhead migrating in these locations. Thus, while most of the smolts produced by sockeye salmon 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 during the ocean life stage through larger body size. The CEERP strategy includes a robust monitoring program that provides the basis for adaptive management. This includes action effectiveness monitoring at each restoration site. Monitoring will continue at completed sites and will be initiated for sites constructed during the period of the proposed action. Johnson et al. (2018) found that the action effectiveness monitoring data collected since 2012 generally indicated that the restoration of physical and biological processes was underway at these sites. Continued evaluation of these monitoring data will confirm that these floodplain reconnections are enhancing conditions for juvenile salmonids as they migrate through the mainstem or provide sufficient information that site selection or project design will improve.

1.2 Federally Authorized Water Diversions

In Idaho, the USFS has recently completed (NMFS 2016c, NMFS 2016d, NMFS 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 is likely to provide minor improvements, relative to baseline conditions, to water quantity and water temperature within the migratory corridor for SR sockeye salmon.

2. Federal Power Act - Pending Improvements in Operations and Fish Passage at FERC-licensed Hydropower Facilities and Dams

As part of the re-authorization process for the Hells Canyon Complex (HCC) of dams (i.e., Brownlee, Oxbow, and Hells Canyon dams), the Federal Energy Regulatory Commission (FERC) has issued annual operation licenses for each project since the original 50-year licenses expired in 2005. In 2019, Oregon Department of Environmental Quality (ODEQ) and Idaho Department of Environmental Quality (IDEQ) issued Clean Water Act Section 401 certifications for the project, an important component of a complete license application (IDEQ 2019; ODEQ 2019). 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 is expected to be accomplished primarily through habitat restoration activities upstream of the Hells Canyon Complex (both in the mainstem Snake River and in several tributaries) which will address return flows from irrigation projects, narrow the channel width, and restore more normative river processes between Swan Falls Dam and the upper end of Brownlee reservoir. The 401 certifications should also improve dissolved oxygen levels below Hells Canyon Dam in late summer and fall and reduce total dissolved gas levels downstream of Hells Canyon Dam in winter and spring.

In 2020, the Idaho Power Company amended their license application and provided FERC with a biological evaluation, assessing the impacts of the project. As of July 2021, FERC had not indicated how they intend to proceed with the relicensing of the Hells Canyon project. While aspects of future Hells Canyon Complex license requirements have become somewhat clearer as a result of the 401 certifications issued in 2019, substantial uncertainty regarding future operations and other protective measures will remain until a new license is issued (and a formal ESA section 7 consultation is completed), and the required measures are implemented.

3. Marine Mammal Protection Act and Endangered Salmon Predation Prevention Act - Improvements in Pinniped Predation

During the past 5 years, two Marine Mammal Protection Act (MMPA) section 120 authorizations were issued to the states of Oregon, Washington, and Idaho for removal of pinnipeds at Bonneville Dam. These authorizations complemented three separate authorizations made during prior review periods. Under these authorizations, the states have removed (transferred or killed) 238 California Sea Lions (Brown et al. 2017; Tidwell et al. 2018, 2020). Removal of sea lions at Bonneville Dam has protected (fish escaping sea lion predation) an estimated 12,516 to 50,064 salmon and steelhead (ODFW 2019).

The United States Congress (Congress) amended the MMPA in 1994 to include a new section, section 120 – Pinniped Removal Authority. This section provides an exception to the MMPA "take" moratorium and authorizes the Secretary of Commerce to authorize the intentional lethal taking of individually identifiable pinnipeds that are having a significant negative impact on the decline or recovery of salmonid fishery stocks. In 2018, Congress amended section 120(f) of the MMPA, which expanded the removal authority for removing predatory sea lions in the Columbia

River and tributaries.

To address the severity of pinniped predation in the Columbia River Basin, NMFS has issued six MMPA section 120 authorizations (2008, 2011, 2012, 2016, 2018, and 2019) and one section 120(f) permit (2020). Under these authorizations, as of May 13, 2022, the states have removed (transferred and killed) 278 California sea lions and 52 Steller sea lions. Removal of sea lions in the Columbia River has protected (fish escaping sea lion predation) an estimated 62,284 to 83,414 adult salmon and steelhead in the Columbia River Basin.

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

4. Clean Water Act (CWA)

4.1 Section 123 Improvements in Columbia River Basin Restoration Funding

In December 2016, Congress amended the CWA by adding Section 123, which requires EPA and Office and Management and Budget to take actions related to restoration efforts in the Columbia River Basin. The U.S. Government Accountability Office (GAO) reviewed restoration efforts in the Basin, and in 2018 its report, *Columbia River Basin, Additional Federal Actions Would Benefit Restoration Efforts*, found that since 2016, the EPA had not yet taken steps to establish the Columbia River Basin Restoration Program, as required by Section 123. EPA did develop a grants program in 2019, and in September of 2020 announced the award of $2 million in 14 grants to tribal, state and local governments, non-profits and community groups throughout the Columbia River Basin. These efforts should result in improved habitat for sockeye salmon in the Columbia River Basin.

4.2 Temperature Total Maximum Daily Load Requirements

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 as neither the State of Washington nor Oregon has provided a temperature TMDL. On May 18, 2020, EPA issued for public review and comment the TMDL for temperature on the Columbia and Lower Snake Rivers (EPA 2020). 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 sockeye salmon through improved thermal conditions in the migratory corridor.

- EPA released its final Columbia River Cold Water Refuges Plan on January 7, 2021. The plan focuses on the lower 325 miles of the Columbia River from the Snake River to the ocean. Cold water refuges serve an increasingly important role to some salmon and steelhead species as the Lower Columbia River has warmed over the past 50 years and will likely continue to warm in the future due to climate change. The Columbia River Cold Water Refuges Plan is a scientific document with recommendations to protect and restore cold water refuges. EPA issued this plan in response to consultation under section 7 of the ESA associated with its approval of Oregon's temperature standards for the Columbia River. This plan also serves as a reference for EPA's Columbia and Snake Rivers Temperature TMDL.

In December 2016, EPA approved IDEQ's Upper Salmon River Subbasin Assessment and TMDL: 2016 Addendum and 5-Year Review (IDEQ 2016). The TMDL addendum identified shade targets 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.

4.3 Toxic Substance Criteria

In 2012 and 2014, jeopardy biological opinions were issued for Idaho and Oregon for water quality standards for toxic substances (NMFS 2012, 2014c). These consultations called for 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.

5. State Water Management and Instream Flow Regulations

5.1 New Integrated Water Resources Strategy in Oregon

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 (https://www.oregon.gov/OWRD/programs/Planning/IWRS/Pages/default.aspx), thus we have no information as to whether the hoped-for improvements in flows and water quality are being realized through the implementation of the new strategy.

5.2 New Streamflow Restoration Law in Washington (90.94 RCW)

In January 2018, the Washington state legislature passed the Streamflow Restoration law that helps restore streamflows to levels necessary to support robust, healthy, and sustainable salmon populations while providing water for homes in rural Washington. 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. The Washington State Department of Ecology has 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. This new 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 water quantity in freshwater habitats is to set instream flow levels which are adopted into rule. Implementation of this law is expected to improve water quantity and temperatures in SR sockeye salmon migration corridors over the next 5 years, although to what degree is unknown.

5.3 Increased Administration of Water Rights in Idaho

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.

6.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 2008b 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 2018b). The parties to the agreement are the United States, the states of Oregon, Washington, and Idaho, and the Columbia River Treaty Tribes: Warm Springs, Yakama, Nez Perce, Umatilla, and Shoshone-Bannock. The agreement sets harvest rate limits on fisheries impacting ESA-Listed species and these harvest limits continue to be annually managed by the fisheries co-managers (TAC 2015, 2016, 2017, 2018, 2019, 2020). The current *U.S. v. Oregon* Management Agreement (2018-2027) has, on average, maintained reduced impacts of fisheries on the Snake River species (TAC 2015, 2016, 2017, 2018, 2019, 2020), and we expect that to continue with the abundance-based framework incorporated into the current regulatory regime.

Regulatory Mechanisms Resulting in Inadequate or Decreased Protection

We remain concerned about the adequacy of some existing regulatory mechanisms in terms of supporting the recovery of SR sockeye salmon. These include:

1. CWA –Change to Definition of 'Waters of the United States'

The Navigable Waters Protection Rule: Definition of Waters of the United States, which was finalized on June 22, 2020, has deleterious effects on SR sockeye salmon as the regulatory nexus to consult on potentially harmful actions has been reduced and redefined. Redefined language and increased exemptions reduce the ability to utilize ESA and EFH to avoid, minimize and mitigate effects that impact listed species and their designated critical habitats. However, on December 7, 2021, the EPA and U.S. Army Corps of Engineers published a proposed rule to revise the definition of "Waters of the United States" (86 FR 69372). The agencies propose to put back into place the pre-2015 definition of "Waters of the United States," updated to reflect consideration of Supreme Court decisions. This familiar approach would support a stable implementation of "Water of the United States" while the agencies continue to consult with states, Tribes, local governments, and a broad array of stakeholders in implementing the Waters of the United States rule and future regulatory actions.

Additionally, in 2021, the U.S. Army Corps of Engineers finalized the re-issuance of existing Nation-Wide Permits with modifications (86 FR 2744; 86 FR 73522). These modifications will allow an increase in the amount of fill and destruction of habitat for frequently used nationwide permits throughout the range of SR sockeye because of this change in definition of waters of the United States. Although regional conditions may address some of these issues, there has not been any indication that regional conditions will be developed or would address the impacts to listed species and their designated critical habitat.

2. CWA - Section 404 Permit Exemptions

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.

3. CWA – Section 303(d)

Idaho TMDL implementation remains uncertain. 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. This may reduce the likelihood that effective actions will be taken that reduce water temperature impacts. Recent indications from the Idaho Soil Conservation Commission suggest the required addendum may become a priority for Idaho by 2023, with restoration actions accruing thereafter.

4. National Flood Insurance Program

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. Under this program, development within floodplains continues to be a concern because it facilitates development in floodplains without mitigation for impacts on natural habitat values.

4.1 Minimum Criteria of the NFIP

All West Coast salmon species, including 27 of the 28 species listed under the ESA, are negatively affected by an overall loss of floodplain habitat connectivity and complex channel habitat. The reduction and degradation of habitat has progressed over decades as flood control and wetland filling occurred to support agriculture, silviculture, or conversion of natural floodplains to urbanizing uses (e.g., residential and commercial development). Loss of habitat through conversion was identified among the factors for decline for most ESA-listed salmonids. "NMFS believes altering and hardening stream banks, removing riparian vegetation, constricting channels and floodplains, and regulating flows are primary causes of anadromous fish declines (65 FR 42450)"; "Activities affecting this habitat include…wetland and floodplain alteration; (64 FR 50414)."

Development proceeding in compliance with NFIP minimum standards ultimately results in impacts to floodplain connectivity, flood storage/inundation, hydrology, and to habitat forming processes. Development consequences of levees, stream bank armoring, stream channel alteration projects, and floodplain fill, combine to prevent streams from functioning properly and result in degraded habitat. Most communities (counties, towns, cities) in Idaho, Washington, and Oregon are NFIP participating communities, applying the NFIP minimum criteria. This influences all inland habitat, including migration corridors. 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 standards has been found to jeopardize 18 listed species of salmon and steelhead (Chinook salmon, steelhead, chum salmon, coho salmon, sockeye salmon) (NMFS 2008c, 2016e). The Reasonable and Prudent Alternative provided in NMFS 2016e has not yet been implemented.

4.2 Modified Implementation of NFIP No Rise Exception

The NFIP (44 CFR 60.3(d)(3) and (4)), implemented by the Federal Emergency Management Agency (FEMA) previously allowed for exceptions to the no-rise analysis requirement for restoration-related projects – Policy on Fish Enhancement Structures in the Floodway (1999). In 2020, FEMA rescinded the policy due to inconsistencies with applicable CFRs. The result is that all habitat restoration projects within NFIP participating communities and in the regulatory floodway now require a hydraulic and hydrologic (i.e., no-rise) analysis and potentially a map revision from FEMA, if an increase in the base flood elevation will result. This creates a fiscal demand on habitat restoration projects that will reduce the number of restoration projects that can be implemented in important migratory habitat for sockeye salmon. Reduced restoration actions, particularly in the mainstem Columbia, Snake, and Salmon rivers could defer habitat improvements important for improving SR sockeye salmon survival in the migration corridor and in the estuary.

5. Inconsistent State and Local Land Use Planning Regulations

City, county, and state land use planning regulations remain inconsistent across the species' range and results 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 resulting in degraded habitat.

Listing Factor D Conclusion

The NMFS Recovery Plan (NMFS 2015a) and the previous 5-year review identified inadequate regulatory mechanisms as a priority issue affecting SR sockeye salmon recovery. 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 improved slightly since our prior review. There have also been regulatory changes that make species preservation more challenging and some programs continue that do not adequately support the persistence of SR sockeye salmon. These shortcomings do not cancel out the benefits that have accrued in the mainstem Snake and Columbia River and overall, we find existing regulatory mechanisms have improved slightly since 2016.

Recommended Actions:

- Consistent with the Congressional intent of the Endangered Salmon Predation Prevention Act and recent MMPA section 120 changes, we encourage Eligible Entities to develop and implement a long-term management strategy to deter the future recruitment of sea lions into the MMPA 120(f) geographic area, as well as continue the authorized removal program.
- Incorporate measures incentivizing habitat and floodplain functional improvements that provide meaningful habitat improvement that are not provided for in the current CWA Section 404 permit exemptions.
- Identify, through research, the role toxic pollutants (e.g., metals, urban and road runoff, pesticides, etc.) are having on the survival and productivity of SR sockeye salmon.
- Develop and begin implementing the addendum to Upper Salmon River subbasin assessment and TMDL (IDEQ 2016) to facilitate meaningful improvements to water temperature in the Salmon River migration corridor.
- Ensure the State of Idaho adopts NMFS' reasonable and prudent alternatives (NMFS 2012) for the adoption of new water quality criteria for mercury and arsenic and for the removal of the hardness floor.
- Implement the Reasonable and Prudent Alternative provided in NMFS 2016e to reduce NFIP minimum standard impacts on critical migration habitat functions and processes.

Consider the need for evaluating NFIP impacts on SR sockeye and their habitat in Idaho and take appropriate steps to implement regulations consistent with NMFS' reasonable and prudent alternative for the Oregon NFIP program (NMFS 2016e).

Listing Factor E: Other natural or manmade factors affecting its continued existence

Climate Change

One factor affecting the rangewide status of SR sockeye salmon and aquatic habitat is climate change. 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). Climate change has negative implications for SR sockeye 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 cold-water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, earlier emergence of fry, and increased competition among species.

Climate change is predicted to cause a variety of impacts to Pacific salmon and their ecosystems (Mote et al. 2003; Crozier et al. 2008a; Martins et al. 2012; Wainwright and Weitkamp 2013). The complex life cycles of anadromous fishes, including salmon, rely on productive freshwater, estuarine, and marine habitats for growth and survival, making them particularly vulnerable to environmental variation. Ultimately, the effects of climate change on salmon and steelhead across the Columbia 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 as well as altering life history characteristics and simplifying population structure.

The primary effects of climate change on Pacific Northwest salmon and steelhead are:

- Direct effects of increased water temperatures on fish physiology and increased susceptibility to disease.
- Temperature-induced changes to stream flow patterns which 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, which alter the availability and timing of food resources.
- Changes in estuarine and ocean productivity, which have changed the abundance and productivity of fish resources.

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, while 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). For example, a few weeks difference in migration timing can result in large differences in the thermal regime experienced by migrating fish (Martins et al. 2011). This occurred in 2015, when about 475,000 adult sockeye salmon (all ESUs) passed Bonneville Dam in the Columbia River, but only 2 to 15 percent of these adult sockeye, depending upon the population, survived to their spawning grounds. Most died in the lower Columbia River beginning in June when the water warmed to above 68°F, the temperature at which sockeye salmon begin to die. Water temperatures rose to 73°F in July, when the area experienced a combination of continued high summer temperatures and lower than average flows (due to the lower snowpack from the previous winter and drought conditions exacerbated due to increased occurrences of warm weather patterns) (NMFS 2016b). In 2015, only 14 percent of adult SR sockeye salmon survived from Bonneville to McNary Dam, and only 4 percent survived from Bonneville to Lower Granite Dam (NMFS 2016b).

A number of studies published in 2019, summarized in Siegel and Crozier (2020), examined models and predictions for the upstream migration stage through the Columbia River basin. These studies consistently predict warmer and drier conditions during upstream migration and downstream smolt migration, but all papers found that SR sockeye is at extremely high risk of losing the anadromous stage.

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. All of these processes are likely to reduce fitness of salmonids, including SR sockeye 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).

Climate change is predicted to increase the intensity of storms, reduce winter snow pack at low and middle elevations, and increase snowpack at high elevations in northern areas. Middle and lower-elevation streams will have larger fall/winter flood events and lower late-summer flows, while higher elevations may have higher minimum flows. How these changes will affect freshwater ecosystems largely depends on their specific characteristics and location (Crozier et al. 2008b; Martins et al. 2012). For example, within a relatively small geographic area (the Salmon River basin in Idaho), survival of some Chinook salmon populations was shown to be determined largely by temperature, while in others it was determined by flow (Crozier and Zabel 2006). Certain salmon populations inhabiting regions that are already near or exceeding thermal maxima will be most affected by further increases in temperature and, perhaps, the rate of the increases, while the effects of altered flow are less clear and likely to be basin-specific (Crozier et al. 2008b; Beechie et al. 2013). However, river flow is likely to become more variable in many rivers and is believed to negatively affect anadromous fish survival more than other environmental parameters (Ward et al. 2015). 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 establishment of exotic species. This will result in novel species interactions, including predator-prey dynamics, where juvenile native species may be either predators or prey (Lynch et al. 2016; Rehage and Blanchard 2016). How juvenile native species will fare as part of “hybrid food webs,” which are constructed from native, native invaders, and exotic species, is difficult to predict (Naiman et al. 2012).

New 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 sockeye 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 U.S. Brodeur et al. (2019) described the community response of the plankton community composition and structure, suggesting that forage fish diets had to shift in response to food resources that are considerably less nutritionally dense. This was supported by the work of Morgan et al. (2019) who stated that it was unclear whether these observations represented an anomaly or were a permanent change in the Northern California Current.

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

Groundwater Effects

The effect of climate change on ground water availability is likely to be uneven. Sridhar et al. (2018) coupled a surface-flow model with a ground-flow model to improve predictions of surface water availability with climate change in the Snake River basin. Combining the VIC and MODFLOW models (VIC-MF), they predicted flow for 1986-2042. Comparisons with historical data show improved performance of the combined model over the VIC model alone. Projections using RCP 4.5 and 8.5 emission scenarios suggested an increase in water table heights in downstream areas of the basin and a decrease in upstream areas. Such assessments will help stakeholders manage water supplies more sustainably, but ultimately will likely make it more challenging for adult sockeye 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 cited in Siegel and Crozier (2020), 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 sockeye 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 and 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.

Seigel 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. The lack of phenological diversity for SR sockeye salmon is a significant concern.

The biggest concern that affects the recovery of SR sockeye salmon is high water temperatures in the adult migration corridor. As described above, high water temperatures in 2015 resulted in catastrophic pre-spawning mortalities. 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 cardiac 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 sockeye) and experiencing higher temperatures have larger capacities.

Data from Goetz and Quinn (2019) align with information from Crozier et al. (2020) that sockeye are more sensitive to river temperatures than Chinook salmon during upstream migration, despite generally migrating at warmer temperatures, and thus sockeye will need refuges from temperature under future conditions.

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 as well as 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.

While we understand that sea surface temperature is tightly linked to marine survival, we do not yet understand the mechanism involved. The work described above are important steps in our understanding.

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

Climate Vulnerability Assessment

Crozier et al. (2019) recently completed a climate vulnerability assessment for Pacific salmon and steelhead, including SR sockeye salmon. The assessment was based on three components of vulnerability: (1) biological sensitivity, which is a function of individual species characteristics; (2) climate exposure, which is a function of geographical location and projected future climate conditions; and (3) adaptive capacity, which describes the ability of a DPS to adapt to rapidly changing environmental conditions. Objectives were to characterize the relative degree of threat posed by each component of vulnerability across DPSs and to describe landscape-level patterns in specific threats and cumulative vulnerability at the DPS level. Refer to Crozier et al (2019) for more information on the methodology they used to calculate climate vulnerability for each DPS.

They concluded that this species has a very high risk of overall climate vulnerability based on its very high biological sensitivity risk, high risk for climate exposure, and low 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. Rates of adult and juvenile migration survival are strongly correlated with temperature in the Columbia River, and catastrophic effects of temperature on the adult migration have been observed recently. Adult migration survival for SR sockeye salmon to spawning grounds ranged from 1 percent in the extremely warm year of 2015 to 60 percent in the more average year 2010 (Crozier et al. 2018). The anadromous run essentially disappeared altogether in the early 1990s, rebounded somewhat in early- to mid-2000s due to large releases of captive broodstock and improved ocean survival (Williams et al. 2014; NWFSC 2015), and has declined again recently. Ocean survival is well predicted by environmental climate indices, particularly upwelling and the Pacific Northwest Index (Williams et al. 2014). However, the impact of climate change specifically on marine survival is uncertain, leading to a moderate score for the marine stage.

SR sockeye salmon were scored low in estuary stage sensitivity because of their rapid migration from fresh water to the early marine stage (Crozier et al. 2019). Risk during early life history was also scored low because of the high elevation and relatively stable lake temperatures that influence the egg stage. Scores for the juvenile freshwater stage were spread across many bins (sd = 0.89) due to uncertainty in how juvenile rearing and migration would be affected by climate change. The primary rearing lake is likely to remain suitable for sockeye, but the long-distance migratory stage is sensitive to reduced freshets that will result from reduced snowpack. Because smolt production is now dependent on hatchery releases, there is great uncertainty in how management and fish condition will change in the future. Many juveniles are transported past the eight dams along their migration route, which improves juvenile survival but has negative effects on marine survival and adult migration success (Crozier et al. 2018, 2020). All these anthropogenic influences make predictions about natural-origin sockeye difficult. In exposure attributes, this ESU was scored as very high risk for stream temperature and ocean acidification and high risk for hydrologic regime and sea surface temperature.

Natural production for this ESU remains extremely low. Spatial diversity is limited to two main spawning areas within one lake, although some spawning occurs in other locations. Finally, genetic diversity has been maintained through careful breeding, but ultimately stems from very few anadromous individuals collected in the 1990s and a residual resident population that has continued to produce smolts. Thus, SR sockeye salmon was scored very high risk for the population viability attribute.

SR sockeye salmon scored low in adaptive capacity. Sockeye salmon are unlikely to respond to climate change by changing their life-history characteristics, other than reverting to a fully freshwater life history, which would constitute the complete loss of a fundamental characteristic of this ESU (Crozier et al. 2019). The resident population in Redfish Lake has already contributed significantly to the present anadromous broodstock. Furthermore, little potential habitat exists that might improve in suitability. Low population abundance and spatial diversity suggest limited genetic heterogeneity that would support rapid adaptation. Adult migration spans a broad temporal window (April to mid-August), which might contract to avoid high temperatures and low flows in summer, as has been observed in the larger Okanogan and Wenatchee sockeye ESUs (Crozier et al. 2011).

Marine Competition

There is also increasing evidence that competition with extremely large numbers of hatchery produced pink salmon, combined with a warm ocean, are substantially reducing the productivity (and abundance) of southerly populations of west coast sockeye salmon – especially in odd years, when adult pink salmon are most abundant (Connors et al. 2020). Their study estimated total pink salmon hatchery production reduced productivity of southern populations of sockeye salmon an average of 15 percent between 2005 and 2015, a period overlapping with warm ocean conditions. Additional evidence suggests current levels of Pacific Ocean hatchery fish releases can represent up to 40 percent of the total salmon biomass in the North Pacific (Ruggerone and Irvine 2018). This level of hatchery production may be contributing to heightened competition for ocean food resources (exasperated by climate change impacts) and potential adverse effects to the ocean ecosystem and may be partially indicative of the low SARs for this ESU.

Hatchery Effects

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

Currently, there are two ESA-listed sockeye hatchery programs in the Snake River basin (Table 6). The hatchery programs' priorities are genetic conservation and building sufficient returns to support sustained outplanting (NMFS 2013, 2015a). Now that Springfield hatchery is in full production and water chemistry issues have been resolved, the programs can transition into Phase 2 (population re-colonization phase) of the three-phased approach. During Phase 2, the goals of Phase 1 remain an important component of the hatchery programs (NMFS 2013, 2015a). There is not a proportion of hatchery origin spawners (pHOS) standard during Phase 2. The pHOS would likely be limited to less than 16 percent in Redfish Lake during Phase 3 (local adaptation phase). However, Phase 3 activities are not covered under the current permits.

Approximately two-thirds of the adults captured in recent years for the hatchery programs were taken at the Redfish Lake Creek weir; the remaining adults were captured at the Sawtooth Hatchery weir on the mainstem Salmon River upstream of the Redfish Lake Creek confluence. While 318 returning anadromous adults have been released into Redfish and Pettit Lakes since the most recent 5-year review, the captive broodstock program provides the majority of the volitional spawners outplanted into Redfish and Pettit lakes.

The number of SR sockeye salmon outmigrants continued to increase through 2019 (Johnson et al. 2020a). However, hatchery production was switched from the Oxbow and Sawtooth Hatcheries to Springfield Hatchery in 2014. Survival of the 2015 to 2017 hatchery releases during migration from Lower Granite to Bonneville Dam ranged from 12 to 37 percent, compared with the 2009 to 2014 average of 54 percent (Widener et al. 2019). Survival from release to Lower Granite Dam was also affected, ranging from 20 to 30 percent when releases from Oxbow and Sawtooth Hatcheries typically exceeded 50 percent. After investigating the potential causes for the reduced survival, Idaho Department of Fish and Game (IDFG) determined that the new hatchery site had much harder water (234 mg/l of calcium) than the original Sawtooth Hatchery site and the release locations (11 to 68 mg/l of calcium) (Trushenski et al. 2019). This caused stress in the juveniles when they were directly released into Redfish Lake Creek. Several mitigation strategies for addressing the water chemistry differences were tested, and the most biologically and logistically effective strategy was determined to be stepwise acclimation from high-to medium-hardness water and then from medium- to low-hardness water. Fish acclimated in this manner survived to Lower Granite Dam at a rate of 69 to 75 percent, while smolts directly released into Redfish Lake Creek survived at only 18 percent (Trushenski et al. 2019). In addition to poor transition survival, poor ocean conditions also contributed to low adult returns from these releases (Johnson et al. 2020b).

In 2020, there were only 26 adult hatchery returns (Baker 2020) out of 785,000 hatchery smolt/presmolts released (Johnson et al. 2019). For the same brood year, natural-origin smolt-to-adult survival was higher with 34,009 emigrants producing 126 adult returns to the Sawtooth Valley. Despite improved survival of outmigrants, the cause of poor returns remains uncertain but may be tied to unintentional changes to smolt release size. This may suggest room for improvement with current hatchery practices and/or poor ocean conditions.

Natural-origin smolts survive at slightly lower rates than Sawtooth Fish Hatchery produced smolts when migrating from Redfish Lake to Lower Granite Dam (natural survival = 42 percent [2000-2018]; hatchery survival = 50 percent [2004-2015]) (Johnson et al. 2020a). Differences in natural and hatchery smolt survival rates increase when measured at Bonneville Dam. For example, in 2019, natural smolt survival to Bonneville Dam's tailrace was about 16 percent while Sawtooth Hatchery smolt survival was 26 percent (Johnson et al. 2020a). Despite these differences, natural origin smolts exhibit higher SAR rates than other life histories. When ocean conditions are considered good, contemporary (2010s) SARs are similar to historically (1990s) observed SARs (Kozfkay et al. 2019).

Table 6. ESA Status of hatchery programs within the Snake River Sockeye salmon ESU; HGMP = Hatchery and Genetic Management C = Review under the ESA is complete; U = undergoing ESA review; M = Hatchery and Genetic Management Plan has not been submitted or is being modified by the applicant.

Program Stock Origin	Program	Run	Watershed Location of Release (State)	Currently Listed?	HGMP Status
Redfish Lake	Redfish Lake Captive Broodstock Program Snake River Sockeye Salmon Hatchery	NA	Upper Salmon River (ID)	Yes	C

To address the low observed smolt-to-adult survival of year 2016 Springfield Hatchery reared sockeye salmon, the Redfish Lake sockeye ocean survival working group has created an assessment plan to identify causes and solutions. There has been an unintentional change in release size of Springfield reared smolts due to acclimation of smolts at Sawtooth Hatchery. Based on past growth curves from rearing at Oxbow Hatchery, fish needed to be 12 fish-per-pound (fpp) by acclimation transport to meet a target release size of 10 fpp. However, smolts have not been appreciably growing at Sawtooth Hatchery during acclimation. This has resulted in releasing sockeye smolts at approximately 82 percent of their target size (37 grams instead of 45 grams) the past 3 years. IDFG has identified three brood year 2019 raceways whose density index would allow them to rear to 10 fpp prior to acclimation transport. This change in rearing profile would allow them to test the effects of meeting their target release size as early as this spring. There are 146,885 juveniles available for this potential test of increasing growth prior to acclimation transport. IDFG plans to use Passive Integrated Transponders (PIT) tags to tag 3,500 juveniles from the three treatment raceways to estimate survival during emigration.

Listing Factor E Conclusion

Climate Change. Climate change affects the rangewide status of SR sockeye salmon and aquatic habitat. The lifestage that appears to be the most vulnerable to climate change is adult migrants. SR sockeye salmon migrate during late summer when water temperatures can be at their highest and flows are low. In 2015, SR sockeye salmon experienced tremendous losses because of exposures to unprecedented warm water in the migration corridor. This situation is predicted to happen more frequently in the future with climate change.

Crozier et al. (2019) published a climate vulnerability analysis for Pacific salmon and steelhead. They concluded that this species has a very high risk of overall climate vulnerability based on its very high biological sensitivity risk ranking, high risk for climate exposure, and low 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.

Rates of adult and juvenile migration survival are strongly correlated with temperature in the Columbia River, and catastrophic effects of temperature on the adult migration have been observed recently. Increased exposure of freshwater migration stages to higher temperatures and lower flows is expected to decrease productivity and abundance for these populations with already low spatial and genetic diversity, and low potential to adapt to climate change impact. Climate change impacts are therefore a significant threat to the persistence of this ESU.

Terrestrial and Ocean Conditions and Marine Survival. Hatchery production of salmon, particularly pink salmon, appear to be reducing productivity of sockeye salmon in southern portions of their range by an average of 15 percent. SR sockeye salmon are the most southern population, suggesting hatchery fish production across the Pacific is likely significantly impacting this ESUs productivity. This is a newly identified, and apparently significant, threat to SR sockeye salmon since our previous 5-year review.

Hatchery Effects. In general, hatchery programs can provide short-term demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of risk depends 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 2018a).

The hatchery programs that affect the SR sockeye salmon ESU have changed over time, and these changes have likely reduced adverse effects on the growth and survival of ESA-listed species. In particular, the hatchery programs have made significant efforts to acclimate smolts to release sites' softer water prior to release; an issue that in recent years has contributed to poor outmigrant and smolt-to-adult survival. However, low hatchery-origin returns in 2020 (after adopting acclimation changes) compared to higher natural-origin returns indicate that uncertainties remain during this critical life stage. There is a need to continue to research evolving ocean conditions as well as hatchery impacts on both natural and hatchery-origin SR sockeye growth and survival.

Moreover, the hatchery programs continue to prioritize genetic conservation and building sufficient returns to support sustained outplanting (NMFS 2013, 2015a) as it begins to transition into Phase 2 (population re-colonization phase) of the three-phased approach. While there is currently not a pHOS target during this phase, it would likely be limited to less than 16 percent in Redfish Lake during Phase 3 (local adaptation phase). Phase 3 activities will be covered in future ESA section 7 consultations and permits.

We conclude that these hatchery programs should continue transitioning into Phase 2 of the hatchery plan, to ensure continued improvements in population viability until self-sustaining natural-origin populations are established. At which time, genetic management of pHOS would become appropriate as indicated above.

Future Recommendations

- Measurably reduce water temperatures in mainstem migratory habitats during adult sockeye salmon migration timing and establish cold-water refugia along the entire migratory corridor (EPA 2003; Crozier et al. 2020; NMFS 2020b). Co-managers should develop and implement plans addressing multiple spatial scales, from headwater habitats through the mainstem migration corridor (see NMFS 2016b for specifics), to moderate modeled increases in summer water temperature and low flows influenced by projected changes in climate (as described under Listing Factor A).
- Increase Federal, state, local governments, and private organizations' efforts to improve water quantity and water quality in sockeye salmon migratory reaches. Efforts should address appropriate regulatory controls, land management practices, and hydropower operations (NMFS 2016c) (as described under Listing Factor A).
- Continue monitoring mainstem survival of returning adults in concert with current and projected water temperatures as necessary to initiate adult transport at CRS facilities to maximize fish survival through mainstem migration corridors (as described under Listing Factor A).
- NMFS should explore options for international cooperation between countries around the Pacific Ocean to identify opportunities to reduce the apparent impact large-scale hatchery releases are having on all species of Pacific salmon, including ESA-listed endangered SR sockeye salmon.
- Continue transitioning into Phase 2 of the hatchery plan, to ensure continued improvements in population viability until self-sustaining natural-origin populations are established. At which time, genetic management of pHOS would become appropriate as indicated above.

Other Recommendations Research, Monitoring and Evaluation

- Continue evaluating SR Sockeye Salmon Hatchery Program rearing and release practices to maximize the value of the Springfield Hatchery's production on ESU recovery.
- Continue monitoring natal lake nutrient levels as necessary to maximize natural SR sockeye salmon productivity.
- Continue researching the relationship between juvenile sockeye salmon transport through the CRS and increased levels of fallback as adults and other factors (e.g., heat exposure, disease, zone 6 fishery, straying, etc.) contributing to reduced adult survival, particularly between Bonneville and McNary Dams.

- Investigate causal factors for poor juvenile smolt survival in the Upper Salmon River basin (i.e., natal lakes downstream through Deadwater Slough) and initiate actions to improve survival.
- Facilitate, through appropriate funding levels, an evaluation of mainstem fish screening infrastructure maintenance and replacement needs to maintain the program's effectiveness. Evaluation should culminate with a prioritization and schedule of maintenance/replacement activities necessary to sufficiently protect migrating sockeye smolts (and other ESA-listed fish) from entrainment loss.
- Evaluate and implement adult trap/haul downstream of McNary Dam if possible to account for higher mortality downstream of that point and maximize adult conversion to the Sawtooth Valley in potentially catastrophic years.
- Encourage Federal and state agencies, tribes, landowners, watershed councils, private organizations, and other recovery partners to expand, develop, and implement monitoring efforts in the Columbia River Basin, Puget Sound, and California to identify pinniped predation interactions in select areas (e.g., river mouths, migratory pinch points etc.) and quantitatively assess predation impacts on SR sockeye salmon.

2.4 Synthesis

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

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

The information analyzed for this 5-year review, including Ford 2022, indicates that the ESU continues to exhibit extreme low abundance of naturally produced SR sockeye salmon and low survival across multiple life-stages, reducing productivity, despite the improvements (e.g., CRS operational changes, improved water quality regulatory controls at the state level, increased hatchery production and improved hatchery practices) since the previous 2016 5-year review. The ESU continues to rely on hatchery broodstock and smolt production from just one population to sustain the current low abundance levels/distribution – resulting in the ESU retaining a "high risk" classification for spatial structure and diversity. In addition, increasing risks from climate change and broodstock practices that may hamper natural evolutionary changes in run timing necessary to adapt to a warming climate suggest viability of the species has declined and is facing increased risk to persistence. The combination of sustained low population sizes, current abundances only slightly higher than when the species was listed in the early 1990s, predicted negative impacts of climate change on all life stages, poor ocean conditions potentially exacerbated by increasing hatchery fish production across the Pacific, and high levels of predation by pinnipeds in the Lower Columbia River result in this ESU remaining at a high risk of extinction.

Our analysis of the ESA section 4(a)(1) factors indicates:

- *Listing Factor A (Habitat):* Restoration partners and co-managers have implemented some key restoration projects across the ESU since the last 5-year review, including improving habitat conditions for SR sockeye salmon spawning, rearing, and migration across the species freshwater range. However, widespread areas of degraded habitat persist across the basin, particularly in mainstem migratory habitats, with simplified channels, disconnected floodplains, impaired instream flow, loss of cold water refugia, elevated water temperatures, and other limiting factors (NMFS 2020b). Ongoing unexplained adult mortality between Bonneville and McNary Dams continues to suppress the number of adult returns and requires additional evaluation/action. Therefore, we conclude that since the 2016 5-year review, the risk to the species' persistence because of habitat conditions remains high.
- *Listing Factor B (Overutilization):* The risk to the species' persistence because of overutilization remains essentially unchanged since the 2016 5-year review, with harvest and research/monitoring sources of mortality continuing to have little to no impact on the viability of SR sockeye salmon.
- *Listing Factor C (Disease and Predation):* Information available since the last 5-year review suggests that pinnipeds predation of SR sockeye salmon may be higher than previously known, but there is too much uncertainty regarding spatial and temporal overlap to conclude increasing pinniped numbers is definitively increasing SR sockeye predation. Increasing our understanding of pinniped predation on SR sockeye will better inform future evaluations and recovery actions. Despite efforts to reduce avian predation, overall consumption rates appear to be relatively static since the last review period – suggesting current rates may still be limiting recovery of the ESU. Risk of increased disease can be correlated to a warming climate, suggesting future projections for warmer water temperatures and reduced sockeye survival may at least partially be tied to disease. Therefore, we conclude that since the 2016 5-year review, the risk to the species' persistence because of disease and predation has not changed since the 2016 5-year review.
- *Listing Factor D (Regulatory Mechanisms):* New information available since the last 5-year review indicates that the adequacy of many regulatory mechanisms has improved,

some have been reduced, and others remained static. Improvements in regulatory mechanisms in the mainstem Snake and Columbia Rivers, noted in the preceding discussion, lead us to conclude the risk to the species' persistence because of the inadequacy of regulatory mechanisms is decreasing slightly since that reported in 2016. However, a number of concerns remain regarding whether existing regulatory mechanisms are sufficient to address factors limiting recovery for this ESU.

- *Listing Factor E (Other natural or manmade factors):* The projected influence of climate change on water temperatures and flow and the resulting impacts on sockeye survival continue to pose an increasing risk to the species' persistence. Increased exposure of freshwater migration stages to higher temperatures and lower flows is expected to decrease productivity and abundance for all populations of SR sockeye, which already have low spatial and genetic diversity, and low potential to adapt to climate change impact. Climate change impacts are a significant and increasing threat to the persistence of this ESU. Increasingly volatile ocean conditions and increasing hatchery production of other salmonids across the Pacific Rim are also increasing threats to the future survival of SR sockeye salmon.

After considering the biological viability of the SR sockeye salmon ESU and the current status of its ESA section 4(a)(1) factors, we conclude that the status of the SR sockeye salmon ESU has decreased slightly since the 2016 review. Although some factors have improved since 2016, e.g., CRS operational changes, improved water quality regulatory controls at the state level, increased hatchery production and improved hatchery practices, climate change has emerged as higher risk to the species' persistence since our last 5-year review (NMFS 2016a). The combination of sustained low population sizes, current abundances only slightly higher than when the species was listed in the early 1990s, predicted negative impacts of climate change on all life stages, poor ocean conditions potentially exacerbated by increasing hatchery fish production across the Pacific, and predation by pinnipeds in the Lower Columbia River result in this ESU remaining at a high risk of extinction.

Implementation of sound management actions in hydropower, habitat, hatcheries, and harvest are essential to the recovery of the SR sockeye salmon ESU and must continue. The biological benefits of habitat restoration and protection efforts, in particular habitat restoration, have yet to be fully expressed and will likely take another five to 20 years to result in measurable improvements to population viability. By continuing to implement actions that address the factors limiting population survival and monitoring the effects of the action over time, we will ensure that restoration efforts meet the biological needs of SR Sockeye salmon and, in turn, contribute to the recovery of this ESU. The 2015 SR Sockeye Salmon Recovery Plan (NMFS 2015a) is the primary guide for identifying future actions to target and address SR sockeye salmon limiting factors and threats. Over the next 5 years, it will be important continue to implement these actions and monitor our progress.

2.4.1 Snake River Sockeye ESU 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 SR Sockeye salmon ESU.

The West Coast Regional Office's 2021 review of new information since the previous 2016 5-year review regarding the ESU/DPS membership status of various hatchery programs indicates no changes in the SR Sockeye salmon ESU are warranted.

2.4.2 ESU/DPS Viability and Statutory Listing Factors

- The information presented in the Northwest Fisheries Science Center's 2022 viability assessment indicates that the biological risk category for the only extant population of SR sockeye salmon remained high and that extinction risk increased since the last 5-year review (Ford 2022).
- Herein, our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the SR sockeye salmon's persistence has increased since our previous 5-year review.

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3. Results

3.1 Classification

Listing Status:

Based on the information identified above, we recommend that the SR Sockeye salmon ESU remain listed as endangered.

ESU/DPS Delineation:

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 SR Sockeye salmon ESU.

Hatchery Membership:

For the SR Sockeye 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 2019a, 2022). Table 4 indicates the number in place for the SR Sockeye salmon ESU at the beginning of the current review (1C). 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 1C.

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4. Recommendations for Future Actions

In our review of the listing factors, we identified several actions that are critical to improving the status of the SR sockeye ESU. The most important actions to be taken over the next 5 years include implementation of the high-priority strategies and actions in the SR Sockeye Salmon Recovery Plan (NMFS 2015a). Additional actions include 2020 CRS Biological Opinion (NMFS 2020b), continued efforts to reduce pinniped predation in the lower Columbia River, and formulating strategic plans to improve the species' ability to adapt to the changing climate conditions as well as reduce projected effects of the warming climate on the freshwater environment. To the degree interventions are necessary, continued co-manager commitment to transport of adults from the CRS to Sawtooth Valley should help the species while long-term climate response actions are identified and implemented. Hatchery programs should continue transitioning into Phase 2 of the hatchery plan, to ensure continued improvements in population viability until self-sustaining natural-origin populations are established.

- Improved coordination and cooperation of federal, state, tribal, and local partners is critical to the successful implementation of these plans and agreements. Efforts to improve instream flow management and floodplain and habitat conditions within the species' migratory habitat represent significant opportunities to advance recovery for the SR sockeye salmon ESU and should be aggressively pursued. Several federal agencies are currently pursuing such opportunities, including the U.S. Army Corps of Engineers, U.S. Forest Service, Bonneville Power Administration, Bureau of Land Management, and the Bureau of Reclamation. Although we identify additional recommended actions in Section 2, under each of the five listing factors' discussion, the greatest opportunity to advance recovery over the next 5 years is to: Measurably reduce water temperatures in mainstem migratory habitats during adult sockeye salmon migration timing and establish cold-water refugia along the entire migratory corridor.
- Continue State, Federal, and private regulatory, land management, and hydropower operations that improve water quantity and quality through SR sockeye salmon's migratory corridor.
- Identify and rectify mechanisms leading to poor juvenile smolt survival from the Sawtooth Valley downstream through Deadwater Slough.
- Continue researching the relationship between juvenile sockeye salmon transport through the CRS and increased levels of fallback as adults and other factors (e.g., heat exposure, disease, zone 6 fishery, straying, etc.) contributing to reduced adult survival, particularly between Bonneville and McNary Dams. If appropriate, explore and implement measures to reduce juvenile transport of SR sockeye salmon through the CRS.
- Develop and implement a long-term strategy to further reduce pinniped predation in the Columbia River.

- Continue transitioning into Phase 2 of the hatchery plan to ensure continued improvements in population viability until self-sustaining natural-origin populations are established.
- Continue evaluating SR Sockeye Salmon Hatchery Program rearing and release practices to maximize the value of the Springfield Hatchery's production on ESU recovery. Improved hatchery program SARs are necessary to build abundance and move into Phase 2 of the hatchery plan.
- Explore options for Pacific Rim international cooperation to identify opportunities to reduce the apparent impact large-scale hatchery releases are having on all species of Pacific salmon, including ESA-listed endangered SR sockeye salmon.
- Continue researching the relationship between juvenile sockeye salmon transport through the CRS and increased levels of fallback as adults and other factors (e.g., heat exposure, disease, zone 6 fishery, straying, etc.) contributing to reduced adult survival, particularly between Bonneville and McNary Dams.

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5.1 Federal Register Notices

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

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

65 FR 42422 (July 10, 2000). Final Rule: Endangered and Threatened Species; Final Rule Governing Take of 14 Threatened Salmon and Steelhead Evolutionarily Significant Units (ESUs).

70 FR 37159 (June 28, 2005). 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.

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Oncorhynchus nerka: Snake River Sockey

Current Classification: Endangered

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 Sockeye Salmon ESU Evaluation Team

REGIONAL OFFICE APPROVAL:

Lead Regional Administrator, NOAA Fisheries

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

Cooperating Regional Administrator, NOAA Fisheries

[ ] Concur [ ] Do Not Concur [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 16:12:23 -04'00' Date: _______