Science, Service, Stewardship

2024 5-Year Review: Summary & Evaluation of **Sacramento River Winter-Run Chinook Salmon**

National Marine Fisheries Service
West Coast Region

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5-Year Review: California Central Valley Species

Species Reviewed	Evolutionarily Significant Unit
Chinook Salmon *(Oncorhynchus tshawytscha)*	*Sacramento River Winter-run Chinook Salmon*

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Acronyms

AIS	Aquatic Invasive Species
CDFW	California Department of Fish and Wildlife
DPS	Distinct Population Segments
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
ESU	Evolutionarily Significant Units
FMEP	Fisheries Management and Evaluation Plan
FMPs	Fishery Management Plans
GSA	Groundwater Sustainability Agencies
GSP	Groundwater Sustainability Plan
LSNFH	Livingston Stone National Fish Hatchery
MMPA	Marine Mammal Protection Act
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Service
NPDES	National Pollution Discharge Elimination System
PCBs	Polychlorinated Biphenyls
PFMC	Pacific Fishery Management Council
RCP	Representative Concentration Pathway
SGMA	Sustainable Groundwater Management Act
SWFSC	Southwest Fisheries Science Center
TMDL	Total Maximum Daily Loads
TRT	Technical Recovery Teams
TDC	Thiamine Deficiency Complex
U.S.	United States of America
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
VSP	Viable Salmonid Population

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1. General Information

1.1 Introduction

Many West Coast salmon and steelhead (*Oncorhynchus spp.*) stocks have declined substantially from their former numbers and now are at a fraction of their historical abundance. Several factors 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: (1) be 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 2024 review of the ESA-listed Sacramento River (SR) winter-run Chinook salmon.

A 5-year review is:

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

A 5-year review is not:

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

1.1.1 Background on Salmonid Listing Determinations

The ESA defines species to include subspecies and distinct population segments (DPS) of vertebrate species. A species may be listed as threatened or endangered. To identify taxonomically recognized species of Pacific salmon NMFS utilizes the Policy on Applying the Definition of Species under the ESA to Pacific Salmon (56 FR 58612). Under this policy, we identify population groups that are evolutionarily significant units (ESUs) within taxonomically recognized species. We consider a group of populations to be an ESU if it is substantially reproductively isolated from other populations within the taxonomically recognized species and represents an important component in the evolutionary legacy of the species. We consider an ESU as constituting a DPS and, therefore, a species under the ESA (56 FR 58612). Under the DPS policy (61 FR 4722) a DPS of steelhead must be discrete from other populations, and it must be significant to its taxon.

Artificial propagation programs (hatcheries) are common throughout the range of ESA-listed West Coast salmon and steelhead. Prior to 2005, our policy was to include in the listed ESU or DPS only those hatchery fish deemed essential for conservation of a species. We revised that approach in response to a United States (U.S.) District Court decision in 2001 and on June 28, 2005, announced a final policy addressing the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204) (Hatchery Listing Policy[1]). This policy establishes criteria for including hatchery stocks in ESUs and DPSs. In addition, it (1) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (2) requires that hatchery fish determined to be part of an ESU or DPS be included in any listing of the ESU or DPS; (3) affirms our commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (4) affirms our commitment to fulfilling trust and treaty obligations 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.

Because the new Hatchery Listing Policy changed the way we considered hatchery fish in ESA listing determinations, we completed new 5-year reviews and ESA listing determinations for West Coast salmon ESUs on June 28, 2005 (70 FR 37160), and for steelhead DPSs on January 5, 2006 (71 FR 834). On August 15, 2011, we published our 5-year reviews and listing determinations for 11 ESUs of Pacific salmon and 6 DPSs of steelhead from the Pacific

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

Northwest (76 FR 50448). On May 26, 2016, we published our 5-year reviews and listing determinations for 17 ESUs of Pacific salmon, 10 DPSs of steelhead, and the southern DPS of eulachon (*Thaleichthys pacificus)* (81 FR 33468).

1.2 Methodology Used to Complete the Review

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

To complete the reviews, we first asked scientists from our Northwest and Southwest Fisheries Science Centers to collect and analyze new information about ESU and DPS viability. The scientists used the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000) to evaluate species viability using the four criteria – abundance, productivity, spatial structure, and diversity. By applying this concept, the science centers 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 delineations. At the end of this process, the science teams prepared reports detailing the results of their analyses (SWFSC 2022).

To further inform the reviews, we also asked our 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 our California biologists and other salmon management specialists familiar with hatchery programs, habitat conditions, hydropower operations, and harvest management. In a series of structured meetings, by geographic area, these biologists identified relevant information and provided insight on how circumstances have changed for each listed entity.

This report reflects the best available scientific information, including the work of the Southwest Fisheries Science Center (SWFSC)(SWFSC 2022); the report of the regional biologists regarding hatchery programs; recovery plans for the species in question; technical reports prepared in support of recovery plans for the species in question; the listing record (including designation of critical habitat and adoption of protective regulations); recent biological opinions issued for the SR winter-run Chinook salmon; information submitted by the public and other government agencies; and, the information and views provided by the geographically based management teams. The report describes the agency’s findings based on all 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 1989 (54 FR 32085), NMFS listed Sacramento River (SR) winter-run Chinook salmon under the ESA and classified it as a threatened species (Table 1). This initial classification, as threatened, was re-affirmed in 1990 (55 FR 46515), but the species was subsequently uplisted to endangered in 1994 (59 FR 440). The classification as endangered was reaffirmed in 2005 (70 FR 37160).

Table 1. Summary of the listing history under the Endangered Species Act for the SR winter-run Chinook salmon ESU.

Salmonid Species	ESU/DPS Name	Original Listing	Revised Listing(s)
Chinook Salmon (*O. tshawytscha*)	Sacramento River winter-run Chinook salmon	**FR Notice:** 54 FR 32085 **Date:** 8/4/1989 **Classification:** Threatened (emergency interim rule)	**FR Notice:** 55 FR 12191 **Date:** 4/2/1990 **Re-affirmation:** Threatened (emergency interim rule) **FR notice:** 55 FR 46515 **Date listed:** 11/5/1990 **Classification**: Threatened **FR notice:** 59 FR 440 **Date:** 1/4/1994 **Re-classification**: Endangered **FR notice:** 70 FR 37160 **Date listed:** 6/28/2005 **Classification**: reaffirmed classification as 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 winter-run Chinook salmon in 1993.

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

Table 2. Summary of rulemaking for 4(d) protective regulations and critical habitat for SR winter-run Chinook salmon.

Salmonid Species	ESU/DPS Name	4(d) Protective Regulations	Critical Habitat Designations
Chinook Salmon (*O. tshawytscha*)	Sacramento River winter-run Chinook salmon	**FR notice:** 55 FR 46515 **Date:** 11/5/1990*	**FR notice:** 58 FR 33212 **Date**: 6/16/1993

***Note:** The 1990 4(d) rule was later superseded by the 1994 reclassification of this ESU as endangered (see Table 1).

1.3.4 Review history

Table 3 lists the numerous scientific assessments of the status of the SR winter-run Chinook salmon ESU. These assessments include status reviews conducted by our Southwest Fisheries Science Center and technical reports prepared to support recovery planning for this ESU.

Table 3. Summary of previous scientific assessments for SR winter-run Chinook salmon.

Salmonid Species	ESU/DPS Name	Document Citation
Chinook Salmon (*O. tshawytscha)*	Sacramento River winter-run Chinook salmon	SWFSC 2022; Williams et al. 2016; Williams et al. 2011; Lindley et al. 2007; National Marine Fisheries Service 2005; Good et al. 2005; Lindley et al. 2004; National Marine Fisheries Service 1999; Myers et al. 1998; U.S. Fish and Wildlife Service and National Marine Fisheries Service 1996

1.3.5 Species' recovery priority number at start of 5-year review process

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

1.3.6 Recovery plan or outline

Table 4. Recovery Priority Number and Endangered Species Act Recovery Plans for the SR winter-run Chinook salmon (NMFS 2019a).

Salmonid Species	ESU/DPS Name	Recovery Priority Number	Recovery Plans/Outline
Chinook Salmon (*O. tshawytscha)*	Sacramento River winter-run Chinook salmon	1C	**Title:** Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead Available at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/california_central_valley/california_central_valley_recovery_plan_documents.html **Date:** 07/22/2014 **Type:** Final **FR Notice:** 79 FR 42504

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2. Review Analysis

This section reviews new information to determine whether the SR winter-run Chinook salmon ESU delineation remains appropriate.

2.1 Delineation of Species under the Endangered Species Act

Is the species under review a vertebrate?

ESU Name	YES	NO
Sacramento River winter-run Chinook salmon	X	

Is the species under review listed as an ESU?

ESU Name	YES	NO
Sacramento River winter-run Chinook salmon	X	

Was the ESU listed prior to 1996?

ESU Name	YES	NO	Date Listed if Prior to 1996
Sacramento River winter-run Chinook salmon	X		1989

Prior to this 5-year review, was the ESU 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 being substantially reproductively isolated from other con-specific populations, and it represents an important component in the evolutionary legacy of the biological species. The 1996 joint NMFS-Fish and Wildlife Service (USFWS) "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. NMFS considers its ESU policy to be a detailed extension of the joint DPS policy and, consequently, will continue to use its ESU policy with respect to Pacific salmon.

2.1.1 Summary of Relevant New Information Regarding Delineation of the SR Winter-Run Chinook Salmon ESU

ESU Delineation

This section summarizes information presented in SWFSC 2022: Viability Assessment for Pacific salmon and steelhead listed under the Endangered Species Act: Central Valley winter-run Recovery Domain.

We found no new information that would justify a change in the delineation of the SR winter-run Chinook salmon ESU (SWFSC 2022).

Membership of Hatchery Programs

For West Coast salmon and steelhead, many ESU and DPS descriptions include fish originating from specific artificial propagation programs (e.g., hatcheries) that, along with their naturally produced counterparts, are included as part of the listed species. NMFS' Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead (Hatchery Listing Policy) (70 FR 37204, June 28, 2005) guides our analysis of whether individual hatchery programs should be included as part of the listed species. The Hatchery Listing Policy states that hatchery programs will be considered part of an ESU/DPS if they exhibit a level of genetic divergence relative to the local natural population(s) that is not more than what occurs within the ESU/DPS.

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

At the 2016 5-year review, we defined the SR winter-run Chinook salmon ESU as including all naturally spawned winter-run Chinook salmon originating from the Sacramento River and its tributaries, as well as winter-run Chinook salmon from one artificial propagation program: the Livingston Stone National Fish Hatchery (LSNFH; 70 FR 37160, June 28, 2005).

Since 2016, the description of the hatchery program at LSNFH has been revised to add the captive broodstock component, which was restarted in 2015 after being implemented from 1991 to 2007 and then discontinued (85 FR 81822; December 17, 2020). The revised description now defines the SR winter-run Chinook salmon ESU as: "Naturally spawned winter-run Chinook salmon originating from the Sacramento River and its tributaries. Also, winter-run Chinook salmon from the following artificial propagation programs: The Livingston Stone National Fish Hatchery (supplementation and captive broodstock)." (85 FR 81822; December 17, 2020). The source of fish for both the captive broodstock program and the supplementation program is local, natural-origin winter-run Chinook salmon from the Upper Sacramento River.

The addition or removal of an artificial propagation program from an ESU does not necessarily affect the listing status of the ESU. The 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, June 28, 2005). 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; December 17, 2020).

2.2 Recovery Criteria

The ESA requires NMFS to develop recovery plans for each listed 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 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 winter-run Chinook salmon ESU, the recovery plan consists of biological objectives and criteria that are applied at the Population, Diversity Group, and ESU/DPS levels (NMFS 2014). In that plan, NMFS adopted the viability criteria metrics defined by the TRT (Lindley et al. 2004) as the biological recovery criteria for the ESU.

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

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

ESU Name	YES	NO
Sacramento River winter-run Chinook salmon	X	

2.2.2 Adequacy of recovery criteria

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

ESU Name	YES	NO
Sacramento River winter-run Chinook salmon	X	

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

ESU Name	YES	NO
Sacramento River winter-run Chinook salmon	X	

2.2.3 Biological recovery criteria as they appear in the recovery plan

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

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/DPS viability.

The VSP concept (McElhany et al. 2000) is based on the biological parameters of abundance, productivity, spatial structure, and diversity for an independent salmonid population to have a negligible risk of extinction over a 100-year time frame. The VSP concept identifies the attributes, provides guidance for determining the conservation status of populations and larger-scale groupings of Pacific salmonids, and describes a general framework for how many and which populations within an ESU/DPS should be at a particular viability level for the ESU/DPS to have an acceptably low risk of extinction.

The NMFS-appointed Central Valley Technical Recovery Team (CVTRT) delineated independent CV Chinook salmon populations and grouped them into four diversity groups based on climatological, hydrological, and geological characteristics: Basalt and Porous Lava, Northern Sierra Nevada, Northern California, and Southern Sierra Nevada (Lindley et al. 2004, Lindley et al. 2007) (Figure 1). For the SR winter-run Chinook salmon ESU, the CVTRT delineated four historical independent populations and one remnant population, all within the Basalt and Porous Lava diversity group (Lindley et al. 2004, Lindley et al. 2007) (Table 5). The spawning areas of the three historical populations above the impassable Keswick and Shasta dams include the Little Sacramento, McCloud, and Pit rivers, while Battle Creek (location of the fourth, historic population) is currently being restored (Figure 2).

Table 5. Population presence, risk of extinction, and classification of watersheds with historic populations of SR winter-run Chinook salmon.
"Core 1": a watershed that possesses the known ability or potential to support a viable population. "Primary": a top priority for reintroduction; "Candidate": a possible area for reintroduction; "Non-candidate": reintroduction should not be attempted here. "NA": not applicable (NMFS 2014).

Diversity Group	River, Creek or sub-reach	Historic Population	Current Population	Population Extinction Risk (from Williams et al. 2016)	Classification
Basalt and Porous Lava	Battle Creek	Yes	No	NA	Primary
	Mainstem Sacramento River (below Keswick)	No	Yes	moderate	Core 1
	McCloud River	Yes	No	NA	Primary
	Pit River	Yes	No	NA	Non-Candidate
	Little Sacramento River	Yes	No	NA	Candidate

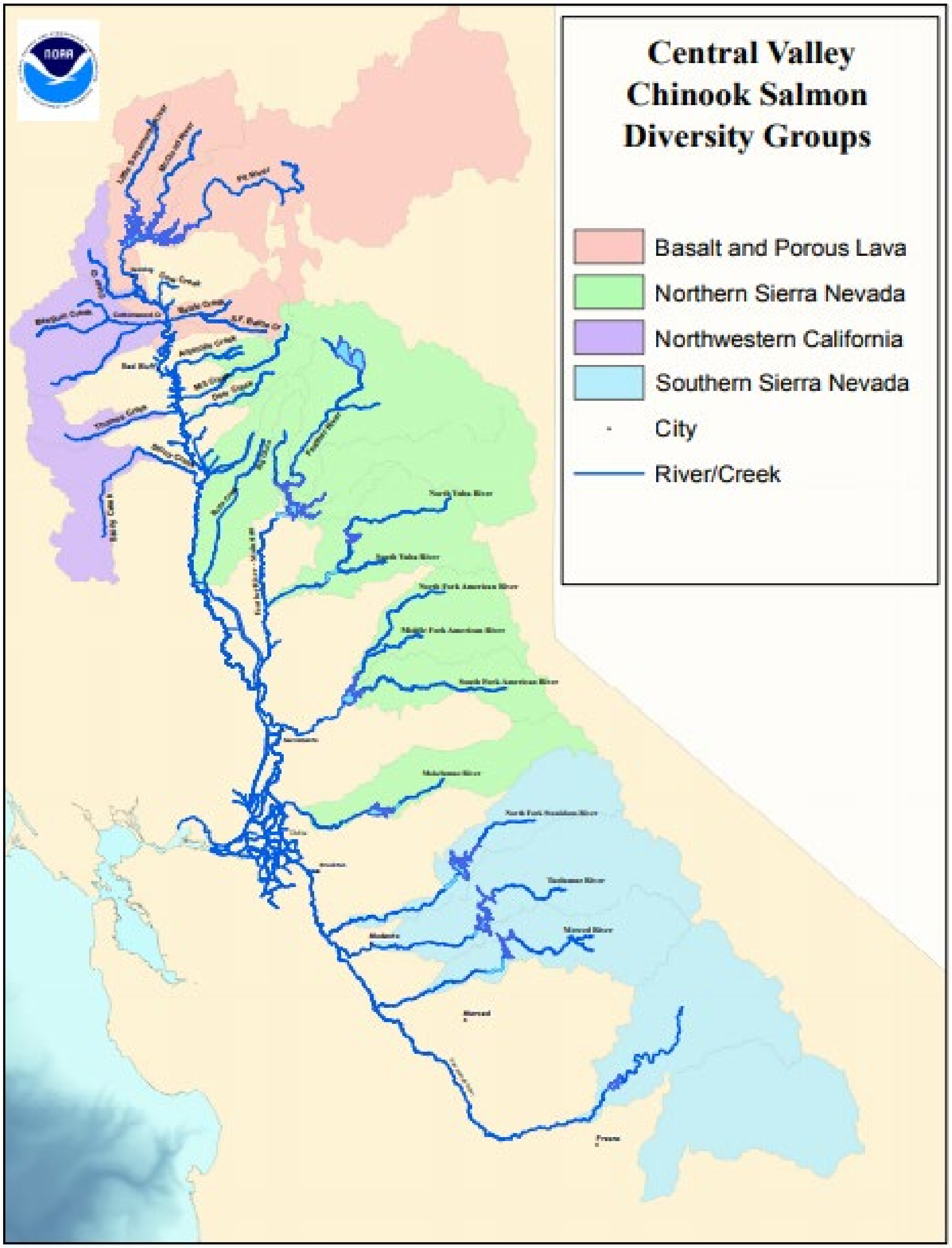

Figure 1. Central Valley Chinook Salmon diversity group structure (Lindley et al. 2007).

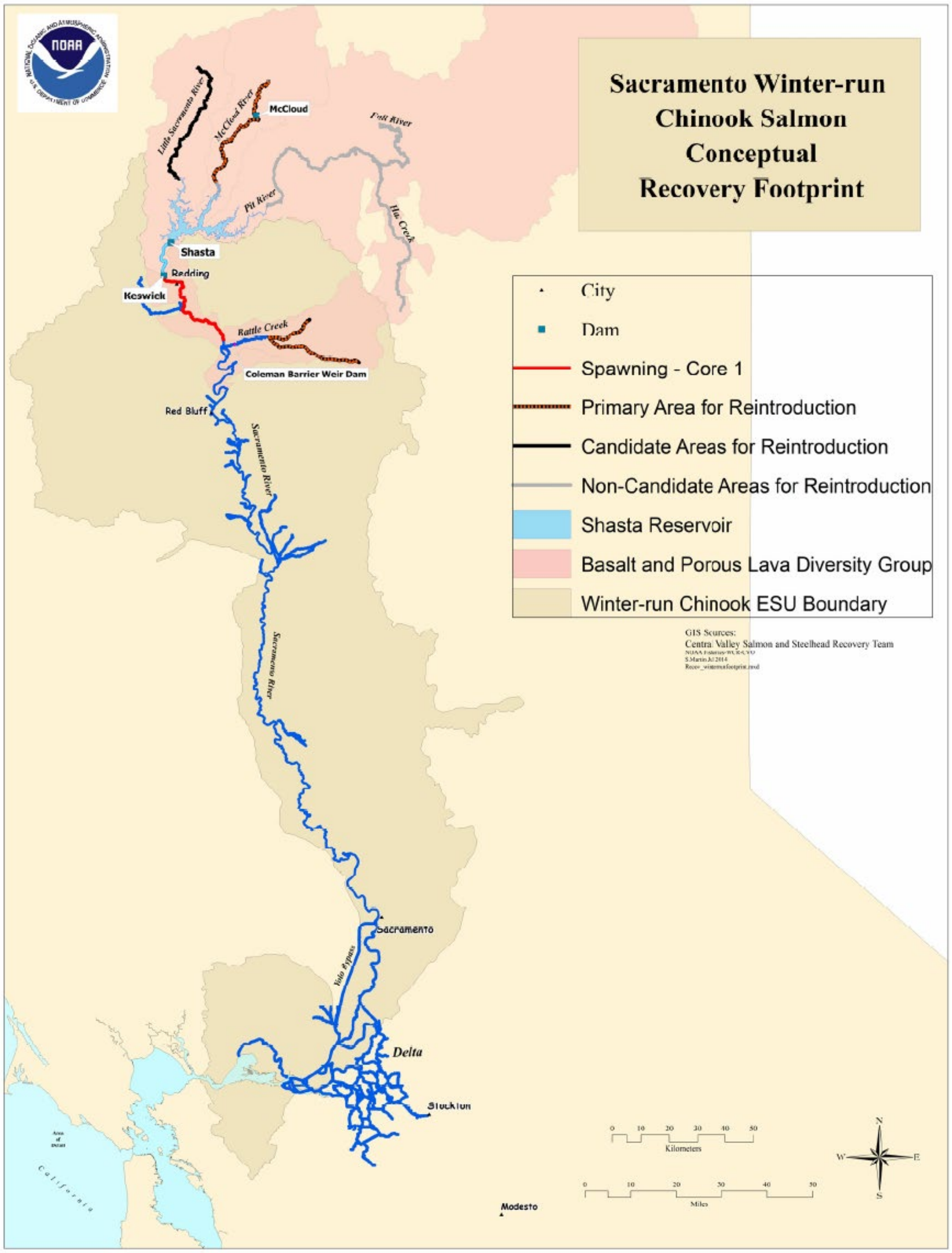

Figure 2. Sacramento River winter-run Chinook salmon Recovery Footprint (NMFS 2014).

Criteria for assessing population extinction risk were developed by the CVTRT (Lindley et al. 2007) and have been incorporated into the recovery plan (Table 6). A population that meets the low extinction risk criteria described in Table 6 is considered viable (NMFS 2014). The CVTRT incorporated the four viable salmonid population parameters from McElhany et al. (2000) into assessments of population viability. Two sets of population viability criteria were developed, expressed in terms of extinction risk. The first set of criteria deals with direct estimates of extinction risk from population viability models. If data are available and such analyses exist and are deemed reasonable for individual populations, such assessments may be efficient for assessing extinction risk. In addition, the CVTRT also provided simpler criteria. The simpler criteria include population size (and effective population size), population decline, risk and relative effect of a catastrophic event, and hatchery influence. For a population to be considered at low risk of extinction (i.e., defined as < 5 percent chance of extinction within 100 years), the population viability assessment must demonstrate that the low risk level or all of the following criteria have been met:

- Effective population size is > 500 -or- census population size is > 2,500,
- No productivity decline is apparent,
- No catastrophic events occurring or apparent within the past 10 years, and
- Hatchery influence is low (as determined by levels corresponding to different amounts, durations, and sources of hatchery strays) (Figure 3).

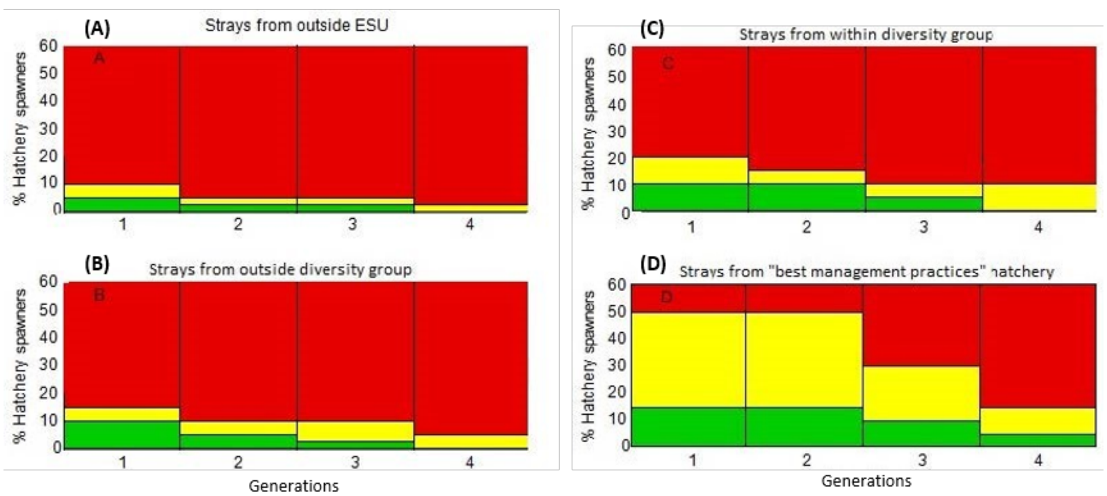

Figure 3. Extinction risk levels corresponding to different amount, duration and source of hatchery strays. Green bars indicate the range of low risk, yellow bars moderate risk, and red areas indicate high risk. Which chart to use depends on the relationship between the source and recipient populations. (A) Hatchery strays are from a different ESU than the wild population. (B) Hatchery strays are from the same ESU but from a different diversity group within the ESU. (C) Hatchery strays are from the same ESU and diversity group, but the hatchery does not employ "best management practices." (D) Hatchery strays are from the same ESU and diversity group, and the hatchery employs "best management practices." (from Lindley et al. 2007)

Table 6. Criteria for assessing the level of risk of extinction for populations of Pacific salmonids in the Central Valley of California.
Overall risk is determined by the highest risk score for any category (Lindley et. al. 2007).

	Risk of Extinction		
Criterion	**High**	**Moderate**	**Low**
Extinction risk and population viability analysis	> 20% within 20 yrs	> 5% within 100 yrs	< 5% within 100 yrs
	- or any ONE of -	- or any ONE of -	- or ALL of -
Population size[a]	$N_e \leq 50$	$50 < N_e \leq 500$	$N_e > 500$
	- or -	- or -	- or -
	$N \leq 250$	$250 < N \leq 2500$	$N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate, and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[c]	Not apparent
Hatchery influence[f]	High	Moderate	Low

a – Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
b – Decline within last two generations to annual run size ≤ 500 spawners or run size > 500 but declining at ≥ 10% per year over the past 10 years. Historically small but stable population not included.
c – Run size has declined to ≤ 500, but now stable.
d – Catastrophes occurring within the last 10 years.
e – Decline < 90% but biologically significant.
f – See Figure 3 for assessing hatchery impacts.

The 2014 Central Valley Salmonid Recovery Plan identifies ESU-level downlisting criteria and recovery criteria for the SR winter-run Chinook salmon ESU. Downlisting is the reclassification of a species from endangered to threatened. Two criteria have been identified with regard to downlisting of winter-run Chinook salmon from endangered to threatened:

- The single Mainstem Sacramento River (below Keswick) population should meet each of the low extinction risk criteria described in Table 6 above; and
- In addition to the one existing viable population, the ESU should include one other spawning population that meets the moderate extinction risk criteria.

The 2014 Central Valley Salmonid Recovery Plan identified these SR winter-run Chinook salmon downlisting criteria because, when achieved, the species' viability would be notably improved from its current status, but would still be far from recovered (i.e., delisted). Currently, there is only one population of SR winter-run Chinook salmon, and the population is supported by a conservation hatchery supplementation program that employs best management practices. To achieve the downlisting criteria, the species would need to be composed of two populations – one viable and one other spawning population that meets the moderate extinction risk criteria described in Table 6. Having a second population would improve the species' viability, particularly through increased spatial structure and abundance, but further improvement would be needed to reach the goal of recovery. To delist winter-run Chinook salmon, three populations in the Basalt and Porous Lava Diversity Group should be at low risk of extinction. Thus, the downlisting criteria represent an initial key step along the path to recovering SR winter-run Chinook salmon (NMFS 2014).

2.3 Updated Information and Current Species' Status

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

Information provided in this section is summarized from SWFSC 2022 — Viability Assessment for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Southwest.

Updated Biological Risk Summary

The biological status of the SR winter-run Chinook salmon population has declined since the 2016 5-year review, with the single spawning population on the mainstem Sacramento River at a high risk of extinction (Table 7). New information indicates the population – which had experienced a declining trend in abundance through 2017 – is beginning to rebuild such that the population decline viability criteria would indicate a low risk of extinction for SR winter-run Chinook salmon. The population, however, remains at an increased risk of extinction due to the influence of the hatchery broodstock. Although at the time of this review hatchery influence is declining, it remains at a level above which would indicate a low or moderate extinction risk.

Table 7. Summary of SR winter-run Chinook salmon extinction risk by population criteria described in Lindley et al. (2007) for the 2010, 2015, and 2020 review periods.
Overall risk is determined by the highest risk score for any criterion.

Criteria	2011 5-Year Review	2016 5-Year Review	2024 5-Year Review
Population Size	Low risk	Low risk	Low risk
Population Decline	Low risk	Moderate risk	Low risk
Catastrophe, rate and effect	Low risk	Low risk	Low risk
Hatchery Influence	Low risk	Moderate risk	High risk

Many of the factors originally identified as being responsible for the decline of this ESU are still present, though, in some cases, they have been reduced by regulatory actions (e.g., NMFS biological opinions on the CVP/SWP, an ocean harvest biological opinion in 2010, and actions implemented under the CVPIA). It is likely that these efforts to reduce the threats to the ESU (e.g., controlling water temperatures with cold water releases, annual spawning gravel augmentation, stabilizing mainstem flows, unimpeded fish passage at the Red Bluff Diversion Dam, harvest restrictions, and scalable Delta water export rules) have resulted in an ESU abundance considered to be a low extinction risk. Harvest-related impacts are generally lower than compared to the period before the ocean fishery closures in 2008 and 2009 and a significantly limited fishery in 2010 (See section 2.3.2.4 Listing Factor D of this document for harvest control rule information). Similarly, impacts from predation, disease, and Delta survival have generally remained unchanged since the last 5-year review. In contrast, habitat conditions have improved, with increased availability of spawning and floodplain-rearing habitats which have supported the species' resiliency.

SR winter-run Chinook salmon abundance has declined during recent periods of unfavorable ocean conditions (2005-06) and droughts (2007-09 and 2012-16), which have underscored the risk posed by catastrophic events to a species that is currently comprised of a single population. The low adult returns in 2011 created a potential increase in vulnerability to a year class, yet the progeny from this cohort had relatively high survival resulting in a positive cohort replacement rate (3.5) from this numerically weak brood (Azat 2019). Poor early life stage survival during the subsequent drought years (2012-16) coupled with potential poor ocean conditions and hatchery production practices have further impacted SR winter-run Chinook salmon survival-to-adulthood and risk of extinction. Temperature conditions during egg development and fry emergence were suboptimal over the duration of SR winter-run Chinook salmon rearing in 2014 and 2015 due to the reduced availability of cold water to manage temperatures downstream of Shasta Reservoir. The egg-to-fry survival estimates at the Red Bluff Diversion Dam (RBDD) for brood years 2014 and 2015 were 5.6% and 4.2%, respectively. As expected, the returning adults from those brood years were also low, with 795 adults in 2017 and 2,458 in 2018.

In 2019 the total number of mainstem in-river spawners observed was 7,852. This number included 2,873 hatchery-origin fish (36.6%) and 4,979 natural-origin fish (63.4%). Since 1996, the total number of in-river spawners of both hatchery and natural origin has averaged 4,679 fish. This average is primarily influenced by 2 years of substantially higher escapement, which occurred in 2005 and 2006 when over 15,000 fish returned each year. In 2019, a total of 180 natural-origin fish were collected for hatchery broodstock, and one fish was documented during a tributary survey (Azat 2019). This resulted in a system-wide estimate of 8,033 total adult spawners in 2019. Since 2010, an average of 173 fish have been taken annually for hatchery broodstock at LSNFH.

Because of the sustainable LSNFH population and a naturally spawning population, the SR winter-run Chinook salmon ESU is likely at a lower extinction risk than it would be with just a single naturally spawning population, at least in the near term. Yet, reliance on production from LSNFH can result in introgression with natural-origin SR winter-run Chinook salmon at a level that results in a "high" extinction risk (Figure 3). Because of the declines in SR winter-run Chinook salmon during the 2012-16 drought, the natural population was bolstered by increasing hatchery supplementation. In 2014 and 2015, to avoid pre-spawn mortality and increase juvenile production and survival, the number of adult SR winter-run Chinook salmon returning to the Upper Sacramento River and taken as LSNFH broodstock (12.8% and 7.5% of the total mainstem run, respectively) was increased, as were the subsequent releases of hatchery-origin juveniles. As of 2019, natural-origin fish represented 31% of hatchery broodstock, while the number of hatchery fish contributing to the natural spawning population was 2,873 (36%). Both the number of natural-origin fish in the hatchery broodstock and the number of hatchery-origin fish in the natural spawning population contributed to the Proportionate Natural Influence (PNI) calculation for the SR winter-run Chinook salmon population. The PNI metric is an important indicator of genetic risk to the natural population associated with hatchery fish. In 2019, the PNI was 0.46, well below the recommended PNI for SR winter-run Chinook salmon of greater than or equal to 0.67. This disparity in the observed versus recommended PNI indicates a greater than recommended risk of hatchery influence. Additional research assessing the influences of the hatchery program on the natural population is ongoing. To date, genetic studies have found no evidence to suggest any differences in adult reproductive success by origin, or that hatchery broodstock relatedness is resulting in reduced offspring survival (Thompson 2019).

In summary, the most recent biological information suggests that the extinction risk of this ESU has increased since the last 5-year review due to high hatchery influence on the species. The best available information on the biological status of the ESU and new threats to the ESU indicate that its ESA classification as an endangered species is appropriate and should be maintained.

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.

2.3.2.1 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, and local levels have been implemented to improve degraded habitat conditions and restore fish passage. While these efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations, we do not yet have evidence demonstrating that improvements in habitat conditions have led to improvements in population viability. The effectiveness of habitat restoration actions and progress toward meeting the viability criteria continues to be monitored and evaluated with new reporting techniques. Generally, it takes years to decades to demonstrate such increases in viability (Ford et al. 2022).

Because of actions taken since the last 5-year review, which directly address some of the major habitat concerns elucidated therein, the risk to the species' persistence because of habitat destruction or modification has declined. The major habitat concerns identified in the last 5-year review include (1) blockage of access to historical habitat, unscreened water diversions, and other passage impediments; (2) degradation of remaining habitat, heavy metal pollution from mine runoff, disposal of contaminated dredge sediments in San Francisco Bay; (3) losses of juveniles from routing to the interior Sacramento-San Joaquin Delta (Delta) because of the Central Valley Project (CVP) and State Water Project (SWP) south Delta pumping facilities; (4) drought effects and elevated water temperatures at the spawning grounds. Since 1994, several of the original listing factors have been addressed, or at least impacts have been reduced, through regulatory and other mechanisms (e.g., reduced harvest impacts, Iron Mountain Mine clean up, Anderson-Colusa Irrigation District fish ladder, screening of water diversions, altered CVP water operations that improve passage and reduce predation, and construction of a temperature control device on Shasta Dam). The last 5-year review described numerous threats to this ESU, with the primary threat being that the ESU consists of only one population, which is wholly dependent on artificially created spawning and rearing conditions (i.e., cold water releases and gravel augmentation below Shasta Dam). New information relating to these five listing factors is discussed below, including a discussion of important conservation efforts being made to protect the species.

The primary geographic areas of concern for the SR winter-run Chinook salmon ESU include the Upper Sacramento River (Keswick Dam to RBDD); the Middle Sacramento River (RBDD to Sacramento including Sutter and Yolo Bypass); and the Bay-Delta (Tidal Delta, Estuary, and bays). These discrete geographic areas, which correspond to specific Chinook salmon life-stages, comprise the extent of designated critical habitat for SR winter-run Chinook salmon. Given their critical importance, each of the following geographic areas remains a concern, as do the site-specific habitat features that continue to pose a threat to the recovery of the SR winter-run Chinook salmon ESU:

- Upper Sacramento River: The reach of the river, generally referred to as the Upper Sacramento River, extends from Keswick Dam (River Mile (RM) 302) downstream to the RBDD (RM 243). This reach of the river provides habitat for adult holding and spawning, as well as egg and alevin incubation and rearing (NMFS 2014; Windell et al. 2017).

- Middle Sacramento River: The Middle Sacramento River reach runs from RBDD to the I Street Bridge in the City of Sacramento, where the I Street Bridge is used to delineate the upstream extent of tidal forces and reverse flows that occur during the daily tidal cycle. Juvenile SR winter-run Chinook salmon will use this habitat to rear and as a migratory route to the Delta. Given their complementary function as rearing habitats and migratory corridors, the Sutter and Yolo bypasses are included in the Middle Sacramento River geographic area description.

- Bay-Delta: The Bay-Delta geographic area includes the tidal Sacramento River downstream of the I Street Bridge in the City of Sacramento, the Sacramento-San Joaquin Delta, and the Suisun, San Pablo, and San Francisco bays. The Bay-Delta and its habitats are important areas for out-migrating salmon, serving as an area of transition where fish can acclimate to saltier conditions, and nursery areas where fish can forage and grow to improve their chance of ocean survival (Gray et al. 2002; Moyle et al. 2008). Juvenile SR winter-run Chinook salmon enter the Delta as early as September, when the majority have yet to undergo smoltification (Miller et al. 2010) and leave the Delta at Chipps Island between January and April (del Rosario et al. 2013).

Current Status and Trends in Habitat

Below, we summarize information on the current status and trends in habitat conditions by Diversity Group since our 2016 5-year review. We specifically address: (1) the key emergent or ongoing habitat concerns (threats or limiting factors) focusing on the top concerns that potentially have the greatest 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 CVTRT (Lindley et al. 2004) and adopted by NMFS in the 2014 Central Valley Salmonid Recovery Plan (NMFS 2014) 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.

Basalt and Porous Lava Diversity Group

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

For the four historical independent SR winter-run Chinook salmon populations (Upper Sacramento River, McCloud River, Pit River, and Battle Creek) comprising the Basalt and Porous Lava diversity group, the primary habitat concerns reported in the 2016 5-year review (NMFS 2016a) continue to affect the populations:

- Blocked access to historical spawning and early rearing habitat in the tributaries of the Sacramento River system (Little Sacramento, Pit, McCloud, and Fall rivers) above Shasta and Keswick dams (NMFS 2014; NMFS 2016a).
- Lack of downstream transport of mobile sediment and spawning gravel resulting from the construction of the Shasta and Keswick dams.
- Impeded upstream migration to North Fork Battle Creek spawning habitat. A series of small hydroelectric dams (e.g., Eagle Canyon Diversion Dam and North Battle Creek Feeder Diversion Dam), without a commitment to operate the newly constructed fish ladders, block access to some of the most suitable spawning habitat in the North Fork of Battle Creek (NMFS 2014; NMFS 2016a; Willis et al. 2016).

- Warm water temperatures in the Sacramento River that limit successful spawning, egg incubation, fry development and emergence, especially during periods of drought. As well as the variable, low flows, limiting the downstream transport of juveniles from the remnant population of SR winter-run Chinook salmon. These temperature and flow conditions continue to occur in the river reach below Shasta and Keswick dams, the only location that the population spawns (NMFS 2014; NMFS 2016a).

- Reduced access to, and activation of Central Valley floodplain/wetland rearing habitats due to levee construction and maintenance in the Middle Sacramento River and Bay-Delta (Herbold et al. 2018) and flow alterations caused by an artificial hydrograph from intense water management (San Francisco Estuary Partnership 2019).

- Diminished south Delta rearing and migratory corridor habitat caused by CVP and SWP operations that include upstream reservoir releases and diversions at the export facilities in the South Delta. These operations affect Bay-Delta salmon habitat in two primary ways:

  - water-project-related changes to south Delta hydrodynamics that affect the suitability of the south Delta habitat for supporting successful rearing or migration of SR winter-run Chinook salmon (Newman & Brandes 2010; CAMT SST 2017; Reis et al. 2019), and

  - a mortality sink at the south Delta export facilities where entrainment at the facilities causes measurable mortality (Kimmerer 2008; NMFS 2019b).

- Unscreened and poorly screened water diversions impair rearing and migratory corridor habitat and entrain young migrants in the California Central Valley (Moyle and Israel 2005). Mussen et al. (2013) identified over 3,700 water diversions in the Sacramento and San Joaquin rivers, their tributaries, and the Delta, with most of these being unscreened and posing a potential threat to early life stages of fish.

- Diminished water quality from point and non-point sources of contaminants, including:

  - Heavy metals (Leatherbarrow et al. 2005; Brooks et al. 2012; Johnson et al. 2013; McKee et al. 2016; Lehman et al. 2017; Tian et al. 2020);

  - Dissolved solids, nitrite, nitrate, mercury, and methylmercury (Domagalski et al. 2004; Davis et al. 2018);

  - Polychlorinated biphenyls (PCBs), organochlorine pesticides, polycyclic aromatic hydrocarbons (PAHs) (Leatherbarrow et al. 2005; Brooks et al. 2012; McKee et al. 2016);

  - High ammonia levels in the Delta related to the proliferation of harmful algal blooms (Lehman et al. 2010; Lehman et al. 2015); and

  - Synergistic toxicity of chemical mixtures (Laetz et al. 2009, 2015).

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

There are no additional population-specific geographic areas of habitat concern identified beyond the list enumerated above in Section 2.3.2.1 Listing Factor A:

- Upper Sacramento River (Keswick Dam to RBDD)
- Middle Sacramento River (RBDD to Sacramento, including Sutter and Yolo Bypass)
- Bay-Delta (Tidal Delta, Estuary, and Bays)

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

Protective measures and restoration actions addressing SR winter-run Chinook salmon population-specific habitat concerns in the Basalt and Porous Lava diversity group since the 2016 5-year review include:

- Annual implementation of gravel augmentation projects under the Central Valley Project Improvement Act (CVPIA) in coordination with state and local entities. The projects address the lack of downstream transport of erodible sediment and gravel resulting from the construction of the Shasta and Keswick dams. Since 2011, spawning gravel has been added annually downstream of Keswick Dam, with approximately 20,000 tons added in September 2019. Gravel has also been added further downstream and under the Market Street Bridge to improve spawning habitat availability, including approximately 13,000 tons of gravel in 2016, and another 11,900 tons added in 2019 (GCID 2016; RD108 2019).
- Continued progress in completing the Battle Creek Salmon and Steelhead Restoration Project, including a jumpstart reintroduction of SR winter-run Chinook salmon into their historical spawning habitat in 2018 (ICF 2016; USFWS 2018).
- Implementation of the U.S. Bureau of Reclamation's (USBR) Shasta Reservoir Temperature Management Pilot Study 2017 – 2019, resulting in efficient utilization of Shasta Reservoir's limited supply of cold water by targeting the spatial extent of protective water temperatures to the within-season spatial distribution of winter-run Chinook salmon redds (USBR 2019).
- Implementation of the Sacramento Valley Salmon Recovery Program (SVSRP, http://www.norcalwater.org/salmon) and CVPIA Fish Program (https://www.usbr.gov/mp/cvpia/) habitat restoration projects to support juvenile rearing and migration in the Upper and Middle Sacramento River:
    - The 2017 completion of the Cypress Avenue Bridge North Side Channel Habitat Restoration & Enhancement Project by the Glenn-Colusa Irrigation District, with the USBR, Western Shasta Resource Conservation District, California Department of Water Resources, and the California Department of Fish and Wildlife restored access to 1.5 acres of side channel rearing habitat in the Upper Sacramento River (GCID 2017).

- The 2017 completion of River Garden Farms' Salmon Rearing Habitat Project installed 25 salmon refugia structures for juvenile salmon to avoid predators and utilize improved rearing conditions in the Upper Sacramento River.
- The April 2018 completion of the Kapusta 1a Side Channel Project restored river access to upper river salmon rearing habitat near Sacramento RM 288.
- The 2019 completion of the Reading Island Side Channel Project created 11,500 linear feet of perennial habitat for salmon and steelhead near Sacramento RM 275.
- The 2017 completion of the Lake California Side Channel Reconnection Project reconnected side channel habitat to the Upper Sacramento River between RM 269 and 270.
- The 2016 establishment of the Bullock Bend Mitigation Bank reconnected and restored 120 acres of off-channel salmon-rearing habitat to the Sacramento River through a breach in the farm berm that allows for the natural flooding of the area.

- Implementation of several projects to minimize the potential for entrainment and stranding of adult SR winter-run Chinook salmon during their upstream migration:
  - The 2015-2016 completion of the Knights Landing Outfall Gates, a positive fish barrier downstream of the Colusa Basin Drain (CBD), limits the potential for adult salmonids to enter the drain (NMFS 2015a).
  - The 2018 completion of the Wallace Weir Fish Rescue Facility provides a barrier and fish rescue facility. The permanent Wallace Weir barrier limits adult salmon entering the CBD via the Knights Landing Ridge Cut, and the adjacent fish rescue facility allows for the relocation of fish otherwise stranded at the weir (NMFS 2016b).
  - The 2019 completion of the Fremont Weir Adult Fish Passage Modification Project widened and deepened the existing fish ladder to improve the passage of salmon and sturgeon (NMFS 2017).
- Several major fish screen improvements and installations, coordinated and funded through the CVPIA and Anadromous Fish Screen Program (AFSP), improved fish migration:
- The 2015 completion of the Pritchard Lake Fish Screen and Intake Facility by the Natomas Mutual Water Company and its partners, including the U. S. Fish and Wildlife Service and the USBR, screened a previously unscreened 150 cubic feet per second (cfs) water diversion off the Middle Sacramento River about 12 miles North of the City of Sacramento (USBR 2014).
  - The 2016 completion of Reclamation District 2035 (RD 2035) and Woodland-Davis Clean Water Agency (WDCWA) combined diversion and fish screen facility screened a previously unscreened 400 cfs water diversion on the Sacramento River (NMFS 2013).

- Several Bay-Delta rearing and migration corridor habitat improvement projects were implemented under California EcoRestore. Established in 2015, EcoRestore is a state-sponsored portfolio of critical habitat restoration and enhancement projects in the Delta, Suisun Marsh, and Yolo Bypass region. These projects are intended to help reverse habitat loss and enhance the remaining floodplain and wetland rearing habitats available to Central Valley species. As of May 2020, the total combined acreage of completed and planned projects is over 30,000 acres (California EcoRestore 2020); some key projects are described below. See factsheets at: https://resources.ca.gov/Initiatives/California-EcoRestore/California-EcoRestore-Projects
    - The 2018 completion of the Decker Island Tidal Habitat Restoration Project restored 140 acres of tidal wetland habitat along the Sacramento River.
    - The 2019 completion of the Tule Red Tidal Restoration Project restored 420 acres of tidal habitat on the eastern edge of Grizzly Bay in the Suisun Marsh.
    - The 2019 completion of the Winter Island Tidal Habitat Restoration Project restored unrestricted tidal activity to 589 acres of estuarine-rearing habitat near the confluence of the Sacramento and San Joaquin rivers.
    - The 2018 completion of the Yolo-Flyway Farms Tidal Habitat Restoration Project reestablished access to 359 acres of tidal freshwater and seasonal wetlands at the southern end of the Yolo Bypass in the northwestern Sacramento River Delta.

Another clearinghouse summarizing projects in the Delta, many of which may benefit salmonids, is EcoAtlas (CWMW 2020): https://www.ecoatlas.org/regions/ecoregion/bay-delta/projects

4) Key Regulatory Measures Since the 2016 5-Year Review

The NMFS 2014 Central Valley Salmonid Recovery Plan (NMFS 2014) and the previous 5-year review did not identify inadequate regulatory mechanisms as contributing to the decline of the SR winter-run Chinook salmon ESU. Laws relevant to the protection and restoration of winter-run Chinook salmon are the ESA, the Magnuson-Stevens Fishery Conservation and Management Act, the CVPIA, the Federal Power Act, the Fish and Wildlife Coordination Act, the Clean Water Act, the National Environmental Policy Act, and numerous State laws administered by CDFW, DWR, or the SWRCB. These laws and associated regulations generally provide adequate mechanisms for recovering winter-run Chinook salmon (52 FR 6041, 6046; February 27, 1987); however, some of the goals of these existing mechanisms have not yet been achieved. Likewise, many of these mechanisms have been improved and updated since the last 5-year review, such as the unanimous decision by the California Fish and Game Commission in April of 2017 to annually close a section of the Sacramento River from 650 feet below Keswick Dam to the Highway 44 bridge (RM 295) to fishing from April 1 to July 31 to limit the disturbance of SR winter-run Chinook salmon redds by anglers who may inadvertently trample on eggs incubating in the river gravels during that time. However, the overall implementation and effectiveness of the existing regulatory mechanisms have not been adequately documented. ***See Listing Factor B: Overutilization for commercial, recreational, scientific, or educational purposes, and Listing Factor D: Inadequacy of Existing Regulatory Mechanisms in this document for details.***

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

The greatest opportunities to advance recovery of SR winter-run Chinook salmon are to:

- Open up SR winter-run Chinook salmon historical spawning and rearing habitats above Shasta and Keswick dams to increase their spatial structure and reduce the risk of extinction.
- Complete the remainder of the Battle Creek Salmon and Steelhead Restoration Project and continue with full implementation of the associated Battle Creek Winter-Run Chinook Salmon Reintroduction Plan to enhance the spatial structure of the ESU. Principle remaining components of the Restoration Project include:
    - complete fail-safe testing, and seek a durable commitment to operate the fish ladder at the North Battle Creek Feeder Diversion Dam,
    - complete fail-safe testing, and seek a durable commitment to operate the fish ladder at Eagle Canyon Diversion Dam,
    - remove the South Diversion Dam and facilities,
    - remove the Soap Creek Feeder Diversion Dam and facilities,
    - remove the Inskip Diversion Dam,
    - remove the Lower Ripley Creek Feeder Diversion Dam, and
    - remove the Coleman Diversion Dam and construct the Inskip Powerhouse bypass facility.
- Coordinate with the USBR and other Sacramento River recovery partners to improve the monitoring, modeling, and management of Shasta Reservoir cold water releases to provide temperatures suitable for SR winter-run Chinook salmon spawning, egg incubation, fry emergence and juvenile rearing in the Upper Sacramento River.
- Continue to implement Upper Sacramento River gravel augmentation actions that replenish spawning substrate.
- Restore access to floodplains and flood control bypasses of the Middle Sacramento River to accommodate increased SR winter-run Chinook salmon floodplain rearing potential and aquatic food web production.

- Operate the CVP/SWP export facilities and associated project infrastructure to maximize the efficiency of salvage operations at the export facilities while maintaining and enhancing the function of the Sacramento River and Delta as a migration corridor and as freshwater and estuarine rearing habitat free of human-made obstructions and with suitable flow, cover, forage, and water quality for SR winter-run Chinook salmon.

ESU Summary

Conservation measures and habitat improvement actions taken since the last 5-year review have improved the overall condition of available habitat on which the SR winter-run Chinook salmon ESU depends. Likewise, the improved habitat conditions and increased access to restored habitats in the Upper and Middle Sacramento River and the Bay-Delta have likely increased the resiliency of the ESU, reducing the risk posed by habitat loss and degradation to the species' persistence. The Battle Creek Salmon and Steelhead Restoration Project has great potential to expand the available habitat for the ESU. This project offers access to, and a significant enhancement of, available historical spawning habitat off the Upper Sacramento River. The project and associated reintroduction efforts aim to restore a self-sustaining population of SR winter-run Chinook salmon (as well as spring-run and steelhead) by restoring their habitat in the Battle Creek watershed and by providing access to it. While PG&E's decision to not seek relicensing of the Battle Creek Hydroelectric Project introduced uncertainty about the timing and completion of habitat restoration actions in Battle Creek, a new agreement has been reached. The 2019 Proposition 50 CALFED Ecosystem Restoration Program Grant Agreement was executed between CDFW and USFWS to financially support and assist with the implementation of the Project. The tasks completed under this new agreement will restore access to the upper limits of North Fork Battle Creek, which will provide optimal habitat for SR winter-run Chinook salmon. The Agreement also includes tasks that will be completed to allow the current SR winter-run Chinook salmon reintroduction efforts to continue and transition into the formal Reintroduction Program. Furthermore, the 2019 CVP/SWP biological opinion commits Reclamation to provide up to $14,500,000 over ten years to reintroduce SR winter-run Chinook salmon to Battle Creek and accelerate the implementation of the Battle Creek Salmon and Steelhead Restoration Project (NMFS 2019b).

Despite these improvements, major habitat concerns remain. Primary among them is the continued lack of access to historical spawning habitats above Shasta and Keswick dams that relegate the species to a single spawning population below Keswick Dam. Although there have been many habitat improvements since the last 5-year review, the following threats remain an issue for the ESU's viability:

- warm water temperatures and variable flows below Keswick Dam in the Upper Sacramento River, especially during drought and low storage conditions;

- the relative lack and reduction of Central Valley floodplain/wetland rearing habitats in the Middle Sacramento River and Bay-Delta;

- water exports in the southern Bay-Delta affecting Delta hydrodynamics and potential for direct mortality at the export facilities; and,
- water quality concerns from point and non-point sources of contaminants.

Listing Factor A Conclusion

The risk to species persistence posed by the present or threatened destruction, modification, or curtailment of its habitat or range is decreasing. As discussed above, habitat restoration, fish passage programs, and other projects are being implemented to expand SR winter-run Chinook salmon spawning and rearing habitat. However, large-scale fish passage and habitat restoration actions are still needed to improve the SR winter-run Chinook salmon ESU viability.

While some conservation measures have been successful in improving habitat conditions for the SR winter-run Chinook salmon ESU, particularly in the Upper Sacramento River, fundamental problems with the quality of remaining habitat remain (see Cummins et al. 2008; Lindley et al. 2009; NMFS 2014; NMFS 2016a). As such, large portions of the habitat supporting this ESU remain inaccessible or in a degraded state. Despite major habitat expansion and restoration for SR winter-run Chinook salmon completed or underway as of this review, the loss of historical habitat and the degradation of remaining habitat continue to threaten the SR winter-run Chinook salmon ESU.

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

Harvest

Ocean Harvest Impacts

SR winter-run Chinook salmon have a more southerly ocean distribution relative to other California Chinook salmon stocks and are primarily impacted by fisheries south of Point Arena, California. SR winter-run Chinook salmon age-3 ocean fishery impact rates for the region south of Point Arena, an approximation of the exploitation rate, are estimated annually using cohort reconstruction methods (O'Farrell et al. 2012). Age-3 impact rates have remained relatively stable, averaging 15.6% (Figure 4). Fisheries in 2008 and 2009 were closed south of Point Arena owing to the collapse of the Sacramento River fall Chinook stock, and sufficient data do not exist to estimate the impact rate in 2010 and 2015. If impact rates in 2008-2010 and 2015 are omitted, the average age-3 impact rate is 17.3% (PFMC 2023).

Several layers of ocean salmon fishery regulations have been implemented for SR winter-run Chinook salmon beginning in the early 1990s. For example, a substantial portion of the SR winter-run Chinook salmon ocean harvest impacts once occurred in February and March recreational fisheries south of Point Arena, but fisheries at that time of the year have been closed since the early 2000s. O'Farrell and Satterthwaite (2015) hindcasted SR winter-run Chinook salmon age-3 ocean impact rates back to 1978, extending the impact rate time series beyond the range of years where direct estimation is possible. Their results suggest that there were substantial reductions in ocean impact rates before 2000 and that the highest impact rates occurred between the mid-1980s and late 1990s.

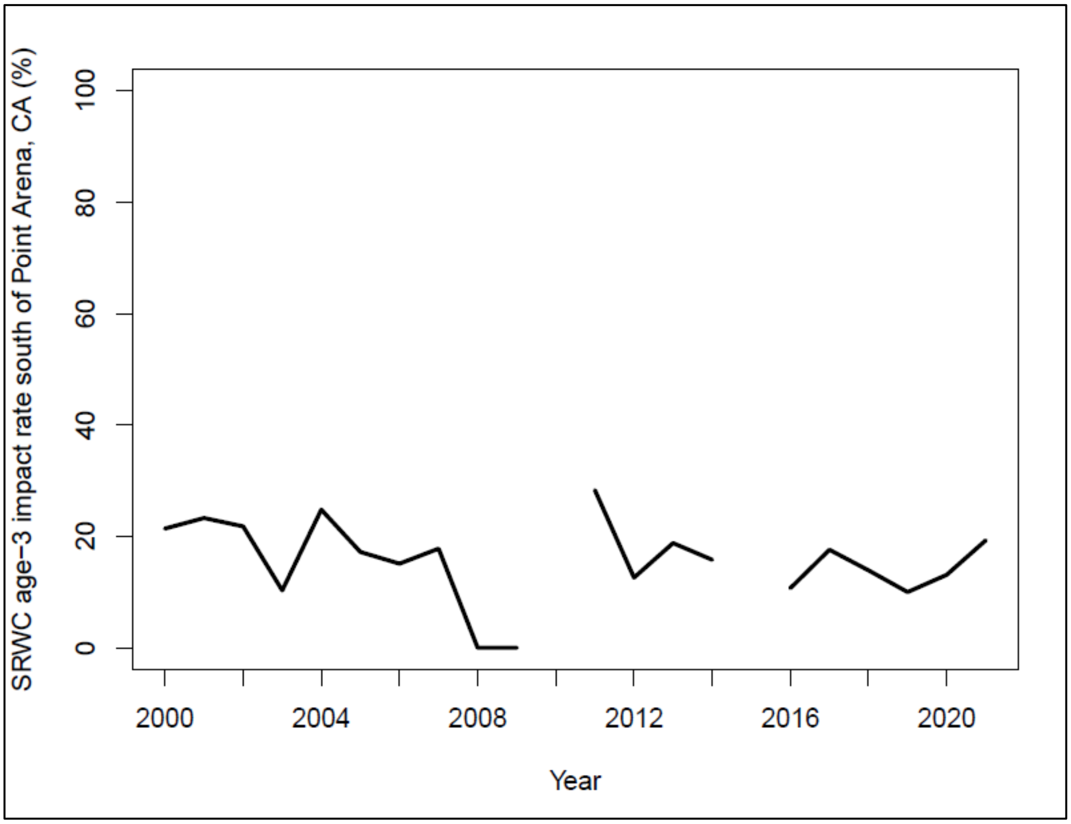

Figure 4. SR winter-run Chinook salmon age-3 ocean impact rate south of Point Arena for years 2000–2021. Estimates are sourced from PFMC (2023). The impact rate could not be estimated in 2010 and 2015 due to insufficient coded-wire tag recovery data.

The Reasonable and Prudent Alternative (RPA) from the 2010 Biological Opinion (NMFS 2010a) on ocean harvest specified that new fishery management objectives must be established. The implementation of the RPA resulted in the development of an impact rate control rule, first used for ocean fishery management in 2012. That impact rate control rule specified reductions in the age-3 ocean impact rate south of Point Arena when the geometric mean number of spawners from the previous three years is reduced (NMFS 2016a). The limits to the impact rate imposed by the harvest control rule was an additional control on ocean fisheries which still included previously existing constraints on fishery opening and closing dates and minimum size limits south of Point Arena.

A more recent Biological Opinion (NMFS 2018) on ocean harvest specifies a new SR winter-run Chinook impact rate control rule for use in managing ocean fisheries (Figure 5). This control rule, first implemented in 2018, specifies the maximum allowable age-3 impact rate south of Point Arena as a function of forecasted abundance, defined as the expected age-3 SR winter-run Chinook escapement in the absence of fisheries. The use of an abundance forecast rather than a mean of past abundance levels to set allowable impact rates is a key feature of the current control rule, enabling fisheries management to be more responsive to recent conditions (e.g., low juvenile abundance and survival rates associated with drought). As before, the constraints on fishery opening and closing dates and minimum size limits south of Point Arena remain in place.

Figure 5. Current SR winter-run Chinook salmon harvest control rule.
Between 2012 and 2023, SR winter-run Chinook salmon harvest control rules specified maximum forecast impact rates ranging from 12.9% to 20.0% (PFMC 2023).

Freshwater Angling Impacts

While little SR winter-run Chinook freshwater harvest existed historically, it was nearly eliminated beginning in 2002, when Sacramento Basin Chinook salmon fishery season openings were adjusted so there would be little temporal overlap with the SR winter-run Chinook salmon spawning migration and spawning period. Since then, there have been very few coded-wire tag recoveries of winter-run Chinook salmon in Sacramento Basin river fisheries. However, early-arriving fish may still be harvested prior to January 1. Additionally, higher fish densities in this portion of the river may lead to higher early harvest rates. Higher fish densities, particularly below dams, likely create opportunities for both the illegal poaching of salmon and the inadvertent or unintentional snagging of fish. The Upper Sacramento River supports substantial angling pressure for rainbow trout, where historically rainbow trout fishers would concentrate in locations and at times where winter-run Chinook are actively spawning. However, the decision by the California Fish and Game Commission in 2017 to annually close the Upper Sacramento River to fishing from April 1 to July 31 has greatly reduced the risk of disturbance of SR winter-run Chinook salmon redds by anglers who may inadvertently trample on eggs incubating in the river gravels during that time. By law, any SR winter-run Chinook salmon inadvertently hooked in this section of river must be released without removing it from the water; however, SR winter-run Chinook salmon are impacted as a result of disturbance and the process of hook-and-release. Also, because the taking of salmon is permitted after August 1, some late-spawning winter-run Chinook salmon may be taken.

Scientific Research and Monitoring

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

Any time we seek to issue a permit for scientific research, we consult under Section 7(a)(2) of the ESA on the effects the proposed work would have on each listed species' natural- and hatchery-origin components. However, since research has never been identified as a threat or a limiting factor for any listed species and most hatchery fish are considered excess to their species' recovery needs, examining the quantity of hatchery fish taken for scientific research would not inform our analysis of the threats to a species' recovery. Therefore, we only discuss the research-associated take of naturally produced fish in these sections.

Database records (NMFS APPS database; https://apps.nmfs.noaa.gov/) show that from 2015 through 2019, researchers were approved to take a yearly average of fewer than 260 adult (<17 lethally) and fewer than 177,000 juvenile (<5,100 lethally) SR winter-run Chinook salmon per year. For the vast majority of scientific research actions, history has shown that researchers generally take far fewer salmonids than are authorized every year. Reporting from 2015 through 2019 indicates that over those 5 years, the average actual (reported) yearly total (lethal and non-lethal) take for naturally produced juveniles was 21% (37,711 of 176,216) and for adults was 9% (23 of 255) of the average annual amount authorized for SR winter-run Chinook salmon. The lethal take reported was also low compared to the amount authorized over the same period. Average lethal take of juveniles was 12% (596 of 5,054) of the average amount authorized each year, and lethal take of adults was less than one per year of the average of 16 authorized annually (3 killed out of 81 total authorized, or 4%, over the entire 5-year period).

The majority of the requested take for naturally produced juveniles from SR winter-run Chinook salmon has been (and is expected to continue to be) capture via screw traps, electrofishing units, beach seines, hand or dip netting, hook and line sampling, incline plane traps, and midwater trawls. Smaller numbers of juveniles have been collected as a result of capture via fyke nets, minnow traps, trammel or hoop nets, weirs, other seines, trawling, fish screens, and those intentionally sacrificed. Adult take has primarily been (and is expected to continue to be) capture via fish ladders, hook and line angling, and weirs, with smaller numbers captured via trawls, fyke nets, or hand or dip nets, and other methods targeting juveniles, such as screw traps or seining, which may unintentionally capture adults (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 rates are typically less than three percent. Unintentional mortality rates from seining, hand or hoop netting, fyke nets, minnow traps, weirs, and hook and line methods are also limited to no more than three percent. Also, a small number of adult fish may die as an unintended result of research because of interactions with trawl sampling equipment.

The quantity of take authorized since the last 5-year review has increased for juvenile and adult SR winter-run Chinook salmon. Total (lethal and non-lethal) authorized take from 2015 through 2019 increased by 139% and lethal take increased by 150% compared to the previous 5-year period (2010-2014). Total reported take (both lethal and non-lethal) also increased compared to what was reported from 2010 through 2014; total take reported from 2015 through 2019 was over ten times higher and lethal take was over five times higher than the previous 5 years. This indicates researchers are now using a larger proportion of the lethal and non-lethal capture and handling take they had requested (and been authorized to use) in 2010 through 2014. As described above, take actually used still remains a fraction of what was authorized.

Overall, research impacts remain minimal due to the low mortality rates authorized under research permits and the fact that research is spread out geographically throughout the California Central Valley, Sacramento-San Joaquin Rivers Delta, and San Francisco Bay. While research take authorized through the West Coast Region has been increasing, the absolute numbers of fish impacted generally remain relatively low compared to the abundance of the ESU. Still, the proportion of SR winter-run Chinook salmon affected is approaching thresholds that may be of concern for this highly sensitive species. Therefore, it is recommended that total take and unintentional mortality rates authorized continue to be closely monitored.

The overall effect on listed populations is still not considered to have changed substantially. 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

The risk to species persistence due to overutilization for commercial, recreational, scientific, or educational purposes continues to be moderate to low. Because regulatory mechanisms designed to minimize the impacts of ocean harvest, freshwater angling, and scientific research on SR winter-run Chinook salmon are in place, overutilization has not been a key factor limiting this

ESU since the last 5-year review. Although scientific research impacts, authorized through the West Coast Region, have increased for SR winter-run Chinook salmon compared to 2014 through 2019 (NMFS APPS database; https://apps.nmfs.noaa.gov/), due to the small number of individuals affected relative to the species abundance and the dispersed nature of research activities the impacts from these sources of mortality are not considered to be major limiting factors for this ESU. 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 recovery of the SR winter-run Chinook salmon ESU.

2.3.2.3 Listing Factor C: Disease and Predation

Predation

Fish

Predation is an ongoing threat to this ESU throughout the Sacramento River and Delta, where there are high densities of non-native fish (e.g., striped bass, large-mouth bass, and catfish species) that predate on out-migrating juvenile salmon (Michel et al. 2018, Michel et al. 2020a). Indeed, these densities are such that bioenergetic modeling for striped bass (*Morone saxatilis*) has shown that even if this species consumed every Chinook salmon in the system, the salmon population could not support the energetic demand of the striped bass population (Loboschefsky et al. 2012). Some native species, such as Sacramento pikeminnow, also predate on out-migrating juvenile salmon (Stompe et al. 2020), however native fish generally have been declining in abundance, especially in the Delta (Moyle and Williams 1990; Feyrer and Healey 2003).

The presence of human-made structures, including water diversions, in the Sacramento River and Delta contribute to increased predator densities, which results in increased predation levels (Demetras et al. 2013; Michel et al. 2014; Lehman et al. 2019). In addition, the altered hydrology of the Delta, which is influenced by CVP and SWP water project operations in the South Delta, has created favorable conditions for non-native predators (e.g., decreased salinity, decreased turbidity, increased water clarity) (Conrad et al. 2016; Henderson et al. 2019; Michel 2019). Available data has provided valuable information regarding aspects of the predation process in the Delta; however, it does not provide unambiguous and comprehensive estimates of fish predation rates on juvenile salmon nor on population-level effects for SR winter-run Chinook salmon in the Delta (Grossman 2016). Likewise, despite regional estimates of predator densities and predation 'hot spots' having been identified (Michel et al. 2020b), there has yet to be a comprehensive estimate of predation rates on juvenile salmon for the entire Bay-Delta.

Managing predator populations is one potential tool for decreasing predation pressure on juvenile salmon. For example, since 2010, steps have been taken to reduce juvenile SR winter-run Chinook salmon predation in the CVP and SWP fish collection facilities in the southern Delta, including studies on the use of electric barriers, carbon dioxide, netting, aquatic weed control, electrofishing, a fishing incentive program, construction of a fishing pier, refurbishment of the

Curtis Landing fish salvage release site, and the completion of the Little Baja and Manzo Ranch fish salvage release sites in 2018 (CDWR 2018). In addition to those measures intended to reduce juvenile SR winter-run Chinook salmon predation at the CVP and SWP fish collection facilities, an ongoing concern is the level of pre-screen loss of protected fish species due to predation in Clifton Court Forebay (CCF; CDWR 2018). However, despite efforts to address predator 'hot spots,' several circumstantial factors may affect the success of predator management or removal in a given location. Factors affecting the study of the effectiveness of predator removal include relative baseline survival, selection biases, predator removal efficiency, and compensatory predation from residual predators (Michel et al. 2020a, Michel et al. 2020b). Habitat restoration, or improvement, is another management tool for decreasing predation pressure on juvenile salmon, and is more likely to be successful than predator removal (Henderson et al. 2019; Lehman et al. 2019). In the Sacramento River watershed, flow management is a habitat improvement tool that could decrease predation pressure on out-migrating juvenile salmon. Current research indicates that juvenile salmon survival increases through the Sacramento River with increased flows, by decreasing the time juveniles spend migrating through predation 'hotspots' (Henderson et al. 2019; Notch et al. 2020).

Marine Mammals

Pinniped populations on the West Coast have increased significantly since the MMPA was enacted in 1972. The four main marine mammal predators of salmonids in the eastern Pacific Ocean are California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina richardii*), and fish-eating (Resident) killer whales (*Orcinus orca*).

Recent research since the last 5-year review suggests that predation pressure on ESA-listed salmon and steelhead from seals, sea lions, and killer whales has been increasing in the northeastern Pacific Ocean over the past few decades (Chasco et al. 2017a, Chasco et al. 2017b). Models developed by Chasco et al. (2017a) estimate that consumption of Chinook salmon in the eastern Pacific Ocean by three species of seals and sea lions and Resident killer whales may have increased from 5 to 31.5 million individual salmon of varying ages since the 1970s, even as fishery harvest of Chinook salmon has declined during the same time period (Marshall et al. 2016; Chasco et al. 2017a; Ohlberger et al. 2018). This same modeling suggests that these increasing trends have continued across all regions of the northeastern Pacific since the last 5-year review. Using a juvenile-to-adult conversion for pinnipeds, Chasco et al. (2017a) estimate that the biomass of Chinook salmon consumed in central California by these marine mammals may have increased by almost tenfold from 1975 to 2015.

The increase among Resident killer whales appears to be predominantly driven by the Northern Resident population, which does not feed off the coast of California. Southern Resident killer whales, which do seasonally feed off the coast of California, must consume a substantial amount of Chinook salmon to maintain their population, although this group of whales has decreased in size in recent years. Resident killer whale selection for larger-adult Chinook salmon prey may be contributing to decreased size at return and productivity of these ESUs in Washington, Oregon, and California (Lewis 2015; Ohlberger et al. 2019).

On a Pacific coast-wide scale, converting juvenile Chinook salmon into adult equivalents, Chasco et al. (2017a) estimated that by 2015, pinnipeds consumed double the amount of Chinook salmon of Resident killer whales, and six times greater than the combined commercial and recreational catches. In California, pinnipeds occur seasonally in the American River and the Sacramento River; however, there are no qualitative or quantitative assessments of pinnipeds (i.e., number of seasonal animals) in these systems. In the Columbia River basin, recent research found that survival of adult spring-summer Chinook salmon through the estuary and lower Columbia River is negatively impacted by higher sea lion abundance for populations with run timing that overlaps with seasonal increases in Steller and California sea lions (Rub et al. 2019; Sorel et al. 2020). Whether increasing sea lion populations in California are associated with decreased survival of any ESA-listed salmonid ESU or DPS through estuarine and freshwater migration corridors in the state is currently unknown. There have not been any assessments of predation on Pacific salmon and steelhead populations in California estuaries/rivers to date.

Most authors have focused research on Chinook salmon because they have the highest energy value for predators (O'Neill et al. 2014). However, some study authors have found that pinnipeds like harbor seals can significantly impact other species of salmon (Thomas et al. 2016) and steelhead (Moore et al. 2021) through the consumption of outmigrating juveniles. Harbor seal predation data specific to California is not currently available, so whether predation of outmigrating juveniles is a threat to ESA-listed salmonids in California rivers and estuaries is currently unknown.

Invasive Species

A number of studies have concluded that many established non-indigenous species (including smallmouth bass, channel catfish, and American shad) pose a threat to the recovery of ESA-listed Pacific salmon. These threats are not restricted to direct predation alone (described above), as non-indigenous species compete directly and indirectly for resources, significantly altering food webs and trophic structure, and even potentially altering evolutionary trajectories (Sanderson et al. 2009; NMFS 2010a). The Bay-Delta is no exception as it is host to many non-native species. These non-native species can negatively affect native species by disrupting food webs, altering ecosystem function, introducing disease, or displacing native species (Mount et al. 2012).

In addition to the threat posed by non-native and invasive fish species, there is growing concern regarding the proliferation of invasive aquatic weeds in the Delta (Conrad et al. 2020). Historically, the conditions in the Delta were highly variable, favoring native plants, which are adapted to the seasonal fluctuations in ambient salinity. However, water project operations now maintain the Delta in an artificial freshwater condition to accommodate agricultural and municipal water diversions (Moyle et al. 2010). This artificially managed freshwater environment is now more favorable for invasive aquatic weeds, which are generally less salinity tolerant (Borgnis and Boyer 2016). From 2008 to 2014, the total invaded area of submersed and floating aquatic vegetation (SAV/FAV) in the Delta increased by 60%, from 7,100 acres to 11,360 acres (Ta et al. 2017). This overall trend of increasing SAV/FAV area negatively impacts native fish species where the beds of non-native SAV and FAV create habitat that disproportionately favors non-native fishes, such as black bass and sunfish (Brown and Michnuk 2007; Conrad et al. 2016). These non-native fishes both compete with and predate on native fishes, including SR winter-run Chinook salmon (Mount et al. 2012).

Disease

Naturally occurring pathogens pose a greater threat to this ESU compared to other Central Valley Chinook salmon runs. The ESU is comprised of only a single population, and its abundance is low. If the population abundance continues to be low or declines further, the probability increases that a disease outbreak could significantly impact the remaining wild population. Artificially propagated Chinook salmon have been impacted by disease outbreaks at some Central Valley hatcheries and, therefore, potential disease outbreaks at the LSNFH could pose a risk to wild fish. Infection hematopoietic necrosis virus (IHNV) is commonly detected in 51-81% of SR winter-run Chinook salmon returning to LSNFH and *Renibacterium salmoninarum*, the causative bacterium for bacterial kidney disease (BKD), can be detected in SR winter-run Chinook salmon adults at low levels of infection (i.e., 3-30%) (HSRG 2014).

Despite efforts to increase the number of SR winter-run Chinook salmon used for broodstock during 2015, pathologists from the USFWS California-Nevada Fish Health Center (CA-NV FHC) noted a dramatic decline in health, and an increase in the prevalence and severity of fish pathogens in the adults collected at Keswick Dam (Voss and True 2015). Poorer water quality, and possibly concentration of fish pathogens in the Sacramento River and Shasta Reservoir, contributed to multiple infections in adult SR winter-run Chinook salmon with compromised immune systems and decreased stamina, leading to a higher occurrence of pre-spawn mortality. In 2015, pre-spawn mortality was 27% compared to 16% in 2014, and pre-spawn mortality levels were generally below 20% in previous years. No single clear-cut infectious process appeared to be causing the overall elevated mortality. Rather, a mix of bacterial pathogens in adults contributed individually, or in multiple concurrent infections, to mortality despite antibiotic therapies that should have reduced the growth of these bacterial pathogens.

Monitoring of the wild population of SR winter-run Chinook salmon does not include routine assessment for disease despite the presence of two endemic myxozoan parasites, *Ceratonova shasta* and *Parvicapsula minibicornis*, in the Sacramento River. The CA-NV FHC conducted a pilot sentinel trial in late September 2015 to assess potential disease risk to wild SR winter-run Chinook salmon fry (Foott 2016). Results showed that sentinel late-fall Chinook salmon, exposed to the Sacramento River for 5 days in late September at Balls Ferry and Red Bluff, were highly infectious with *C. shasta*. The level of infectivity was sufficient to cause disease and mortality. Eighty juvenile SR winter-run Chinook salmon were collected at the RBDD rotary screw trap between October 15 – November 19, 2015 and sampled for histological examination. *C. shasta* were observed in 15% of the sample set (Foott 2016). These infections were largely at an early stage, indicating only recent exposure to the parasite and that fry had reared in locations with little to no *C. shasta* infectivity. These observations do not support a significant role for *C. shasta* infection in the low egg-to-fry estimates generated from the RBDD trap data in 2015.

However, the disease could have impaired survival out-migrant SR winter-run Chinook salmon fry in 2015 as *C. shasta* is a progressive disease and the early-stage infections could go to a disease state over time. Subsequent assessments of the Upper Sacramento River in 2016 and 2018 reinforced the conclusion that *C. shasta* poses a low to moderate risk to naturally produced SR winter-run Chinook salmon fry rearing above RBDD, especially in water years rated "Below Normal" or wetter (Foott et al. 2017; Foott et al. 2019).

In early 2020, staff at several salmon hatcheries in California's Central Valley noticed that recently hatched Chinook salmon fry were exhibiting abnormal behaviors, such as swimming in circles, and were dying at elevated rates. At that time, there were also reports of high mortality among naturally produced juvenile Chinook salmon in some Central Valley rivers. State and federal fish pathologists conducted rigorous testing and determined that pathogens were unlikely to have caused the early life stage mortality (Foott, 2020). The CA-NV FHC (located at Coleman National Fish Hatchery) began looking into nutritional deficiencies, specifically a vitamin B1 deficiency known as Thiamine Deficiency Complex or TDC. Symptomatic juvenile Chinook salmon at Coleman National Fish Hatchery were treated using thiamine baths. The juveniles improved in condition almost immediately following treatment. Other hatcheries throughout the Central Valley began treatments as well, with similar results.

Scientists hypothesize that TDC results from an ecological chain of events that led adult Central Valley Chinook salmon in the ocean to feed heavily on northern anchovy concentrated off the central California coast. Marine surveys off the West Coast in 2019 identified the highest abundances of northern anchovy off central and southern California since systematic surveys began in 1983. The 2019 annual report of the California Cooperative Oceanic Fisheries Investigations called it a "novel anchovy regime." In 2019, other typical salmon prey, such as krill, fell to unusually low levels. Reports from fishermen indicated salmon off California's coast fed almost exclusively on northern anchovy in the months before returning to their home rivers. Anchovy produce an enzyme called thiaminase, which breaks down thiamine in salmon, and is suspected of contributing to TDC. This simplification of what is typically a more diverse salmon diet exposed salmon to increased levels of thiaminase, leading to thiamine deficiency. Adult Chinook salmon that are thiamine deficient produce offspring with TDC, often resulting in elevated early life stage mortality.

Researchers from the NMFS Southwest Fisheries Science Center, along with agency and university partners, have initiated a rapid-response scientific investigation into the extent, cause, effects, and potential treatment of thiamine deficiency in returning adult Chinook salmon and their offspring. There is also an effort underway to begin cooperative research with fishermen and others to understand shifts in the marine food web that may contribute to thiamine deficiency. This collaborative research will help develop predictive and preventative measures to identify and possibly reduce the risk of thiamine deficiency. The extent to which TDC has affected naturally produced Chinook salmon in the Central Valley is currently unknown. Juvenile mortalities have been documented in wild populations in the Feather River, San Joaquin River, and Clear Creek, with some juveniles exhibiting the abnormal behaviors associated with

TDC. The full extent of the impact is not fully known since many monitoring efforts target later life stages (rather than recently emerged fry) and, therefore, are unlikely to detect early life stage mortality associated with TDC. The extent of the impacts may become more apparent during subsequent years as affected salmon cohorts mature to the point of being targeted in fisheries and as they return to rivers to spawn or are collected at hatcheries.

By early 2020, TDC had already been documented in a number of different Chinook salmon stocks throughout the Central Valley. NMFS has been working with its partner agencies (CDFW and USFWS) to rapidly research the recent thiamine deficiency issue in Central Valley salmon. Extra precautions were taken during 2020 to protect endangered SR winter-run Chinook salmon that may have been impacted by TDC. At LSNFH, USFWS injected approximately half of the adult female winter-run Chinook salmon broodstock with thiamine to determine whether supplementation can improve the development, physiology, and behavior in their progeny. The other half of the broodstock was injected with saline as a control. To better understand how egg thiamine levels affect development, early life stage measurements were also collected at LSNFH. This information will support an assessment of juvenile survival and health at varied thiamine levels to evaluate population-level impacts to winter-run Chinook salmon spawning in the wild. Despite an incomplete understanding of the population-level impacts, effective treatment options have been developed for reducing TDC impacts on hatchery populations of Central Valley salmon (Mantua et al. 2021).

Listing Factor C Conclusion

The risk to species persistence related to disease and predation is increasing. Disease and predation are persistent problems that continue to adversely affect SR winter-run Chinook salmon. Updated information from the USFWS and the LSNFH indicates that the threat of disease may only pose a significant risk to SR winter-run Chinook salmon in drought years where conditions such as low flows and high temperatures in the Sacramento River predominate. And although there have been actions to understand and reduce predation, it remains unclear whether these actions have substantially decreased the overall level of predation throughout the Sacramento River and Delta. In addition to the threats of disease and predation, other related factors have emerged, such as invasive vegetation and chronic thiamine deficiency, which are understood to negatively affect SR winter-run Chinook salmon survival. All of these factors are thought to be influenced by environmental conditions and are subject to a highly modified landscape and hydrology. Diseases like *C. Shasta* are more infectious during low flow periods during a drought. Invasive SAV/FAV are better adapted to the modified conditions of today’s Delta, which in turn provides habitat for piscivorous fish species.

With regard to predation by marine mammals, recent modeling efforts indicate predation by pinniped species has been on the rise, particularly for Chinook salmon, over the last few decades in Washington, Oregon, and California. However, given the lack of information currently available in California, further study of pinniped predation interactions is warranted to determine whether these impacts are limiting the recovery of ESA-listed salmon and steelhead in the state.

2.3.2.4 Listing Factor D: Inadequacy of Existing Regulatory Mechanisms

Various federal, state, county, and tribal regulatory mechanisms are in place to reduce habitat loss and degradation caused by human use and development and harvest impacts. New information available since the previous 5-year review indicates that the adequacy of several regulatory mechanisms has improved. For this 5-year review, we examine regulatory mechanisms that have either improved for SR winter-run Chinook salmon, or are still causing the most concern in terms of providing adequate protection for SR winter-run Chinook salmon.

Habitat

Habitat concerns are described throughout Listing Factor A as having either a system-wide influence or a more localized influence on the populations and Diversity Group that comprise the species. The habitat conditions across all habitat components (tributaries, mainstems, estuary, and marine) necessary to recover the listed SR winter-run Chinook salmon are influenced by a wide array of federal, state, and local regulatory mechanisms. The influence of regulatory mechanisms on listed salmonids and their habitat resources is largely based on the underlying ownership of the land and water resources as federal, state, or private holdings.

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 man-made factors affecting its continued existence. We reviewed summaries of national and international regulations and agreements governing greenhouse gas emissions. The findings 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 that upscaling and acceleration of far-reaching, multilevel, and cross-sectoral climate mitigation will be needed to reduce future climate-related risks (IPCC 2014; IPCC 2018). These findings suggest that current regulatory mechanisms, both in the U.S. and internationally, are not adequate to address the rate at which climate change is negatively impacting habitat conditions for many ESA-listed salmon and steelhead.

All of the SR winter-run Chinook salmon freshwater habitat is found within the Sacramento River watershed, which extends from southern Oregon, past Shasta Dam, continuing through the City of Sacramento and the Delta to the San Francisco Bay. The Sacramento River is a heavily-modified and used river, with multiple, large water diversions and flood-control structures along its banks, and with more numerous water removals for urban and agricultural uses in the lower river (Schilling et al. 2011).

Land ownership in the upper watershed, above Shasta Reservoir, is equally split between public (USFS and USBLM) and private ownership, where land use is comprised of timber management, hydroelectric energy production, grazing, and agriculture. In the portion of the watershed immediately below Keswick Dam (i.e., Upper Sacramento River), about 82% of the land is held privately, with the other 18% being public. In the portion of the watershed where the Middle Sacramento River runs (RBDD to the City of Sacramento), 74% of the land is private and 26% public (SRCAF 2003). The Sacramento Valley, surrounding the Upper and Middle Sacramento

River (i.e., Tehama, Glenn, Butte, Colusa, Sutter, Yuba, Yolo, Sacramento, and Solano Counties), is a mix of farmlands, cities and small communities, with managed wetlands and a network of tributary rivers, streams, canals, and agricultural drainages. Agriculture in the area is agrarian, comprised of 45% orchards (nuts and stone fruits), 26% field crops, 9% row crops, 8% pasture, and 12% mixed agricultural (Chaudhry et al. 2016). About 42% or 1.5 million acres of the farm lands are irrigated (USDA 2019). Federal management of the Sacramento River is mediated by BOR, and primarily through the operation of the Central Valley Project, a complex, multi-purpose network of dams, reservoirs, canals, hydroelectric power plants, and other facilities. The Corps, responsible for flood protection, constructs levees and maintains the navigable waterways of the Central Valley.

Laws relevant to the protection and restoration of SR winter-run Chinook salmon include the ESA, the Magnuson-Stevens Fishery Conservation and Management Act, the CVPIA, the Federal Power Act, the Fish and Wildlife Coordination Act, the Clean Water Act, the National Environmental Policy Act, and numerous State laws administered by CDFW, DWR, or the SWRCB. These laws and associated regulations generally provide adequate mechanisms for recovering winter-run Chinook salmon (52 FR 6041, 6046; February 27, 1987); however, some of the goals of these existing mechanisms have not yet been achieved.

Key Habitat Regulatory Mechanisms

New information available since the 2016 5-year review indicates that the adequacy of some habitat regulatory mechanisms is improving, and increasing the level of protection provided to SR winter-run Chinook salmon and the habitat on which it depends. However, while there are a number of improved protections for the species, NMFS remains concerned about the adequacy of some of the existing habitat regulatory mechanisms affecting in-river flows, groundwater sustainability, floodplain development, and regional water quality. Those regulatory mechanisms affect the available stream flow volume, limit habitat connectivity and availability, and/or impact habitat condition. The existing habitat regulatory mechanisms include both federal and state land and water management regulations as follows:

Central Valley Project (CVP) /State Water Project (SWP) Water Operations Regulatory Compliance

During the 2016-2020 evaluation period for this 5-year review, CVP/SWP water operations met regulatory compliance with the ESA under two temporally distinct regulatory environments. First, from 2016-2019 the coordinated long-term operation of the CVP/SWP followed the regulatory standards set in the ESA biological opinions issued by NMFS in 2009 for anadromous fish species and by USFWS in 2008 for delta smelt. No major changes to CVP/SWP water operations occurred during the 2016-2019 period relative to the previous 5-year review evaluation period (2011-2015); the CVP/SWP operated continuously under the regulatory context set in the 2008 and 2009 biological opinions.

The regulatory context changed in February 2020 when USBR signed a Record of Decision (ROD) for the Long-term Operations of the CVP/SWP, in response to USBR’s and DWR’s 2016 joint request to reinitiate the Endangered Species Act consultation on the coordinated long-term operation of the CVP/SWP. The 2020 ROD is based on USBR's December 2019 Final Environmental Impact Statement and biological opinions completed in October 2019 from the USFWS and NMFS to meet obligations under the ESA. Given the recent shift to CVP/SWP water operations under the 2020 ROD, the degree to which water operations and the conditions fish experience will change under the new operations remains to be determined. The state of California also issued a new Incidental Take Permit on CVP/SWP operations in 2019 to provide exemption from take according to the California Endangered Species Act. Additionally, operations in 2022 and 2023 were governed by a jointly-produced Interim Operations Plan that harmonized the operations identified in the 2019 Biological Assessments and the 2019 CDFW Incidental Take Permit.

Operations of the CVP and SWP per the 2019 Biological Assessment (USBR 2019), 2019 Biological Opinion (NMFS 2019b), and 2019 CDFW Incidental Take Permit include a suite of measures intended to avoid or minimize impacts of Delta water operations to salmonid migratory and rearing habitat, for example:

- closing the Delta Cross Channel during the core juvenile outmigration period to limit routing of juvenile salmonids from the mainstem Sacramento River into the interior Delta where survival is lower, and
- managing entrainment of salmonids by limiting negative flows in Old and Middle Rivers, a surrogate used to estimate how export pumping at Banks and Jones Pumping Plants influences hydrodynamics in the south Delta.
- implementing additional measures in the Delta, including, for example:
    - installing a barrier at Georgiana Slough to further limit routing of juvenile salmonids from the mainstem Sacramento River into the interior Delta, and
    - improving hydrodynamic conditions in the Delta for salmonid outmigration with a spring outflow action.

Although not a result of the 2020 ROD, one notable change to CVP/SWP water operations during the 2016-2020 evaluation period is the application of genetic testing for species identification to inform Delta water export decisions. Under the 2009 biological opinion, water exports could be reduced if run-specific thresholds for the number of wild Chinook salmon observed at the Delta export facilities were exceeded, based on fish length at date of observation. Starting in 2016, and subsequently incorporated into the 2020 ROD, the process used to assign Chinook salmon run identification was modified to include genetic testing rather than just length-at-date criteria. When length-at-date-based species identification indicated fish loss thresholds had been exceeded, water export reductions were scheduled, and genetic testing was immediately conducted. On occasion, the genetic-based species identification subsequently indicated the fish loss thresholds were not exceeded, so the export reductions scheduled based on the length-at-date criteria were not implemented. Using genetic testing allowed for slightly more water to be exported that otherwise would have by using the length-at-date method of identification. For example, in water year 2018, the application of genetics-based species identification resulted in an estimated 54 thousand acre-feet more water exported than would have occurred if the length-at-date criteria were used, representing approximately 1 percent of the 4.6 million acre-feet exported from the Delta pumps that year.

Components of CVP/ SWP water operations are intended to improve the protection of SR winter-run Chinook salmon by partially addressing a number of the threats to recovery. These include reducing routing and entrainment into the central Delta and improving Delta hydrodynamics to support juvenile salmonid migration survival. Nevertheless, USBR and NMFS have reinitiated consultation on the 2019 biological opinion on CVP/SWP, and will continue to evaluate and address the potential impact of project operations on SR winter-run Chinook salmon recovery.

Water Infrastructure Improvements for the Nation Act

In December 2016, the United States Congress (Congress) passed the Water Infrastructure Improvements for the Nation Act (WIIN Act, 2016). Subtitle J of the WIIN Act relates to California water issues and covers a wide range of topics, including funding, infrastructure, research, and potential operational changes to CVP and SWP water management. Section 4001-4003 of the WIIN Act contains the provisions most likely to affect the implementation of CVP and SWP operations in the Delta and, thus, potentially affect migratory and rearing conditions for salmonids.

- Section 4001 ("Operations and reviews") includes provisions related to Delta Cross Channel operations as well as the potential for flexibility in inflow to export ratio (I:E ratio) requirements during water transfers.
- Sections 4002 ("Scientifically supported implementation of OMR flow requirements") and 4003 ("Temporary operational flexibility for storm events") introduced the potential for flexibility in flow requirements in Old and Middle Rivers (OMR flows).

The WIIN Act provisions in Sections 4001-4003 did not govern Delta operations during Water Year 2017 due to the extremely wet hydrology. In May 2018, the CVP and SWP used Section 4001(b)(7) of the WIIN Act to adopt a 1:1 inflow to export ratio (I:E ratio) for a transfer of water from the Stanislaus River to south of the Delta. Additional exports of approximately 50 TAF occurred above the 3:1 required I:E ratio to recover water released on the Stanislaus River by local irrigation districts (Oakdale Irrigation District and South San Joaquin Irrigation District) for transfer south of the Delta (DOSS 2018). No WIIN Act provisions were implemented during WY 2019 since OMR flows were not a controlling regulatory factor when qualifying storms occurred that year. That is, hydrological conditions were such that the physical capacity of the CVP and SWP export facilities was limiting water exports during the time of year that Section 4003 was in effect (DOSS 2019). No WIIN Act provisions were implemented in WY 2020.

The I:E ratio flexibility implemented during May 2018 resulted in higher exports, but also higher San Joaquin River inflow. Compared to operations without the WIIN Act provision, this action was expected to result in improved migratory conditions for salmonids in the mainstem San Joaquin River route in the Delta and degraded migratory conditions for salmonids in the interior channels of the south Delta, in the vicinity of the export facilities. Overall, given the balance of effects in May 2018 and no other uses of WIIN Act operational flexibility, the WIIN Act did not appreciably change the quality of migratory corridor and rearing habitat for Central Valley salmonids.

Implementation of this Act was anticipated to limit the risk that insufficient flows in the south Delta pose to SR winter-run Chinook salmon recovery. And while uses of WIIN Act operational flexibility since the last 5-year review have not appreciably degraded the quality of migratory and rearing habitat for Central Valley salmonids beyond what was considered for the implementation of CVP/ SWP water operations, it remains to be seen whether future applications will provide the protection necessary to address the threats to SR winter-run Chinook salmon recovery in the south Delta. Given this uncertainty, regulatory mechanisms governing instream flow in the south Delta may be inadequate to address the risk posed by insufficient flows on the likelihood of achieving SR winter-run Chinook salmon recovery.

Federal Power Act and Energy Policy Act

The Federal Power Act (FPA) (16 U.S.C. §§ 791 et seq.) is the primary federal statute governing the regulation of hydroelectric power whereas, the Energy Policy Act (42 USC §13201 et seq.) addresses energy production in the United States more broadly. The Federal Energy Regulatory Commission (FERC) and Bureau of Ocean Energy Management (BOEM) interact with NOAA Fisheries over the licensing and re-licensing of non-federal energy projects. In rivers and streams, FERC has jurisdiction over hydroelectric projects. In estuary and marine environments, BOEM has jurisdiction over wind, gas, and oil energy projects and FERC has jurisdiction over tide or current related (hydrokinetic) energy projects. These energy projects affect NOAA trust resources in the Pacific Ocean, offshore of Washington, Oregon, and California. FERC and BOEM have several types of licensing/re-licensing processes that are used to guide the collection of data, development of a license application, and the issuance of a license.

Since the last 5-year review, the California Central Valley Office of NMFS has participated in 28 active (existing and proposed) FERC and Marine Hydrokinetic/Marine Wind Energy (MHK/MWE) projects in California. There are five MHK/MWE projects under consideration, all of which are either proposed or relatively recent, such that their impact to NMFS trust resources is not fully known. Of the remaining 23 FERC projects, none have had any significant changes as they have progressed through the stages of FERC relicensing proceedings. In addition, none of those 23 FERC projects have completed the process for a license. Therefore, none of the potential environmental protection, mitigation, and enhancement conditions, especially those that would enhance, protect, and benefit NMFS trust resources, have been realized. Finally, per their existing licenses, all of the current FERC projects' facilities and operations have continued to negatively impact NMFS' trust species and degrade their habitats.

Because the status of the 23 Central Valley FERC projects has not changed significantly since the last 5-year review, we conclude that the FERC licensing process continues to be inadequate to improve fish passage above/below impassable barriers, and the impacts of hydroelectric power projects continue to threaten the likelihood of achieving SR winter-run Chinook salmon recovery. Because of the very long license duration (30-50 years), it is extremely important for NOAA Fisheries to thoroughly analyze the long-term project effects to species and their habitats.

California State Forest Practice Rules

At the time of salmon and steelhead listings, the State Forest Practice Rules were found to inadequately protect salmonids. Many of the identified inadequacies have been ameliorated through regulation changes by the State Board of Forestry. The most notable rule changes with input from NMFS, CDFW, and other State agencies are the 2010 Anadromous Salmonid Protection Rules and the 2012 Road Rules. These rules have resulted in expanded stream-buffer widths, less damaging road and harvest techniques, and limits on riparian harvesting that will collectively improve instream and riparian habitat and function over the long-term. Additionally, some private timber companies are actively restoring damaged aquatic and upslope habitat by increasing instream large woody debris volume or abating upslope erosion sources. The State Forest Practice Rules have also made additional changes to the cumulative watershed effects analysis of proposed timber harvest practices.

With the continued application of the State Forest Practice Rules, enacted prior to the previous 5-year review, this regulatory mechanism continues to adequately address the potential effects associated with timber harvest in the state of California so as to minimize the risks to SR winter-run Chinook salmon recovery.

California Water Action Plan

Issued by Governor Brown in January 2014, the California Water Action Plan[2] (WAP) sets forth 10 priority actions that guide the state's effort to create more resilient, reliable water systems and to restore critical ecosystems. Action 4 specifically addresses the instream flow needs of imperiled salmonids, stating "the State Water Resources Control Board and the Department of Fish and Wildlife will implement a suite of individual and coordinated administrative efforts to enhance flows statewide in at least five stream systems that support critical habitat for anadromous fish." As part of implementing Action 4, CDFW's Instream Flow Program has supported flow enhancement activities. It is developing flow criteria in five priority streams throughout the state that support critical habitat for threatened and endangered anadromous salmonids: Mark West Creek (Sonoma County), Mill Creek (Tehama County), SF Eel River (Humboldt/Mendocino counties), Shasta River (Siskiyou County), and the Ventura River (Ventura/Santa Barbara counties). To set instream flow prescriptions, CDFW uses the California Environmental Flows Framework (CEFF)[3], a consistent and defensible approach to identifying ecological flow needs for rivers and streams in California. The CEFF utilizes historical flow

[2] https://wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/Action-Plan
[3] https://ceff.ucdavis.edu/

records and site-specific instream habitat analysis to quantify ecologically relevant flow characteristics (flow magnitude, frequency, duration, timing, and rate of change) at the individual stream reach. The identified flow characteristics then inform flow patterns supportive of five identified “functional flow components” (fall pulse flow, wet-season baseflow, wet-season peak flow, spring recession flows, and dry-season baseflow) that inform habitat suitability for various life-stages of anadromous salmonids. However, the CEFF does not specifically consider groundwater-surface flow interactions, or adequately address essential habitat forming or migratory attraction flows; see, for example, Cowan et al. (2021), Maher et al. (2021). The resulting ecological flow recommendations will be used in water management, planning, and decision-making processes, which may include being submitted to the State Water Resources Control Board (SWRCB) pursuant to Public Resources Code §10000-10005[4]. Preliminary instream flow recommendations have been developed for the Ventura River as of November 2020; flow recommendations remain in development for the other four priority streams identified in the WAP.

Since the last 5-year review, the California WAP has improved conditions and protections for CV salmonids through the development of instream flow prescriptions. However, suitable instream flow recommendations have yet to be made for any of the water bodies that comprise SR winter-run Chinook salmon habitat. While the WAP has established a process and regulatory mechanism that could help to address the threat caused by the variable, low flows, affecting SR winter-run Chinook salmon rearing and migratory habitat; since the last 5-year review the WAP has had little effect on the species or on the likelihood of achieving SR winter-run Chinook salmon recovery.

Sustainable Groundwater Management Act

California’s Sustainable Groundwater Management Act (SGMA) was signed into law in January 2015, during the height of the state’s last historic drought. Per SGMA regulations, groundwater basins with currently unsustainable groundwater usage are required to form a local Groundwater Sustainability Agencies (GSA) by 2017, which then must develop a Groundwater Sustainability Plan (GSP) by 2022 that achieves sustainable groundwater conditions no later than 2042. Sustainability under the act is defined as avoiding six “undesirable results” caused by unsustainable groundwater management, one of which is “significant and unreasonable impacts to beneficial uses of surface water.” Since most waterways overlying SGMA basins contain federally designated critical habitat for ESA-listed salmonids, NMFS has actively participated as a stakeholder in many GSP development processes throughout the state by urging GSAs to properly consider streamflow depletion impacts to salmon and steelhead habitat. However, a provision in SGMA legislation allows GSAs to avoid addressing undesirable results occurring before January 1, 2015, and the vast majority of GSAs are interpreting that language as allowing streamflow depletion rates consistent with summer 2014 as an appropriate and legal management objective. Considering that 2014 was the third year in the driest 4-year stretch in California’s

[4] https://wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/Action-Plan

recorded history (Hanak et al. 2016), NMFS has aggressively voiced the concern that streamflow depletion thresholds consistent with 2014 are inappropriate and unlikely to adequately protect ESA-listed salmonids or their habitat. NMFS is currently coordinating with CDFW, other state regulatory agencies, and interested stakeholders to ensure that appropriate streamflow depletion thresholds protective of salmon and steelhead are included in all applicable GSPs developed throughout the state.

While SGMA represents a significant first step in the accounting and management of California's groundwater, several improvements still need to be made. As such, we remain concerned that the protection of ground and surface waters afforded by SGMA remains inadequate to address the potential streamflow depletions that otherwise pose a threat to SR winter-run Chinook salmon recovery.

National Flood Insurance Program (NFIP) and Federal Emergency Management Agency (FEMA)

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.

Nearly 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 have 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 July 10, 2000)"; "Activities affecting this habitat include…wetland and floodplain alteration; (64 FR 50414 Sept. 16, 1999)."

Development proceeding in compliance with NFIP minimum standards ultimately results in impacts to floodplain connectivity, flood storage/inundation, hydrology, and 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 California are NFIP participating communities, applying the NFIP minimum criteria. 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 2008; NMFS 2016c).

In 2011 FEMA was sued by the Coalition for a Sustainable Delta and Kern County Water Agency, challenging that implementation of the NFIP in the Sacramento-San Joaquin Delta requires section 7 consultation, alleging that the NFIP results in development-related impacts to species and habitat that might otherwise not occur. NMFS continues to work with FEMA and NFIP-participating communities in California as FEMA implements the NFIP. In 2019, NMFS and FEMA agreed to pursue a programmatic approach to securing ESA section 7 compliance for the implementation of the NFIP in the state of California.

While the NFIP has not been formally evaluated for its effects on SR winter-run Chinook salmon or on the ESU's designated critical habitat, increases in floodplain connectivity and floodplain quantity are needed for SR winter-run Chinook salmon recovery (NMFS 2014), and the NFIP, as currently implemented, systemically allows a pattern of adverse effects that incrementally and permanently diminish floodplain habitat values (connectivity, complexity, hyporheic connection and streamflow recharge, refugia, and prey base). It is therefore reasonable to conclude that the NFIP does not adequately address floodplain development impacts that continue to limit SR winter-run Chinook salmon recovery.

Clean Water Act

The Federal Clean Water Act addresses the development and implementation of water quality standards, the development of Total Maximum Daily Loads (TMDLs)[5], filling of wetlands, point source permitting, the regulation of stormwater, and other provisions related to the protection of U.S. waters. The Clean Water Act is administered by the State of Oregon and State of California with oversight by the U. S. Environmental Protection Agency (EPA). State water quality standards are set to protect beneficial uses, which include several categories of salmonid use. Together the state and federal clean water acts regulate the level of pollution within streams and rivers in California.

Each state has a water quality section 401 certification program that reviews projects that will discharge dredged or fill materials into waters of the U.S. and issues certifications that the proposed action meets State water quality standards and other aquatic protection regulations, if appropriate. Each state also issues National Pollution Discharge Elimination System (NPDES) permits under section 402 for discharges from industrial point sources, waste-water treatment plants, construction sites, and municipal stormwater conveyances, with established parameters for the allowance of mixing zones if the discharged constituent(s) do(es) not meet existing water quality standards at the 'end of the pipe.' TMDLs set pollution targets and allocate load reductions necessary to meet water quality standards. These constituents may be pesticides, such as dieldrin which is regulated under the Federal Insecticide, Fungicide and Rodenticide Act; industrial chemicals, such as polychlorinated biphenyls (PCBs) regulated under the Toxic

[5] A TMDL is a pollution budget and includes a calculation of the maximum amount of a pollutant that can occur in a waterbody and allocates the necessary reductions to one or more pollutant sources. A TMDL serves as a planning tool and potential starting point for restoration or protection activities with the ultimate goal of attaining or maintaining water quality standards.

Substances Control Act;[6] or physical measures of water, such as temperature for which numeric water quality standards have been developed. Numerous toxicants have yet to be addressed in a TMDL.

Since the 2016 5-year review, overall trends for water quality do not show improvements across the Central Valley. The State's Stream Pollution Trends Monitoring Program showed a significant increase in pyrethroid concentration in the Central Valley. Many surface waters are polluted as water is discharged from agricultural operations, urban/suburban areas, and industrial sites. These discharges transport pollutants such as pesticides, sediment, nutrients, salts, pathogens, and metals into surface waters. Although conditions in most streams, rivers, and estuaries throughout the state are much improved from 40 years ago, the rate of improvement has slowed over time (SFEP 2015). Contaminants such as polybrominated diphenyl ethers have increased over time, and many potentially harmful chemicals and contaminants of emerging concern (e.g., pharmaceuticals) have yet to be addressed (SWRCB, 2020). Legacy pollutants such as mercury and polychlorinated biphenyls directly and indirectly affect endangered fish populations and their designated critical habitat (Wood et al. 2010; Davis et al. 2018).

In particular, recent research has identified stormwater runoff from roadways causing significant mortalities in salmonids due to effluent toxicity (McIntyre et al. 2018). The array of toxicity is variously attributed to metals from motor vehicle brake pads; vulcanizing agents in tire rubber (Tian et al. 2020), Polycyclic Aromatic Hydrocarbons (PAHs) from vehicle emissions of oil, grease, and exhaust; as well as residential pesticide use. Although the tire particle-associated 6PPD-quinone has only recently been identified, it is widely used by tire manufacturers and tire dust has been found where urban and rural roadways drain into waterways (Feist et al. 2017, Sutton et al. 2019). Potential impact levels in a waterbody depend on roadway utilization (traffic density and average speeds) and road density (Feist et al. 2017, Peter et al. 2022) as well as the specific drainage patterns from the roadways.

As of the 2014 and 2016 California Integrated Report (CWA 303(d) list and 305(b) Report), in California, approximately 9,493 miles of rivers/streams and some 513,130 acres of lakes/reservoirs are listed as impaired by irrigated agriculture through section 303(d) of the Clean Water Act (SWRCB 2017). Of these, approximately 2800 miles, or approximately 28 percent, have been identified as impaired by pesticides. In recent years, NOAA scientists have investigated the direct and indirect effects of pesticides on individual ESA-listed species, the food webs on which they depend, and at the population level (Baldwin et al. 2009; Laetz et al. 2009; Macneale et al. 2010). Emphasis on wastewater treatment plant upgrades and new legislative requirements, development and implementation of total maximum daily load programs (i.e., pathogens, selenium, pesticides, pyrethroids, methylmercury, heavy metals, salts,

[6] The Toxic Substances Control Act (TSCA) of 1976 provides EPA with authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures. Certain substances are generally excluded from TSCA, including, among others, food, drugs, cosmetics, and pesticides.

nutrients), and adoption of new water quality standards (i.e., Basin Plans), all aid in protecting beneficial uses for aquatic wildlife.

Water quality pollution poses important challenges for the conservation and recovery of ESA-listed species and their habitat. Innovative and sustainable solutions such as green infrastructure and low-impact design (LID) are needed to manage pollutants as close to the source as possible. If these solutions can be applied at a broader scale, LID technology, policies, and watershed scale programs have the potential to maintain and/or restore hydrologic and ecological functions in a watershed (Spromberg et al. 2016), thereby improving water quality for ESA-listed species and the ecosystem on which the species depend.

In its current state, the Clean Water Act is inadequate to protect water quality, as demonstrated by the increase in contaminants found by the State's Stream Pollution Trends Monitoring Program. Although the Clean Water Act has been a driver for improving conditions in most streams, rivers, and estuaries in the State relative to 40 years ago, deteriorating water quality trends continue to pose a significant threat to SR winter-run Chinook salmon recovery.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and Toxics

NMFS has performed a series of consultations on the effects to 28 west coast species from commonly applied chemical insecticides, herbicides, and fungicides that are authorized for use per Environmental Protection Agency label criteria. All West Coast salmonids are identified as jeopardized by at least one of the following chemicals; most are identified as being jeopardized by many of the chemicals.

2,4-D – jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Diflubenzuron (NMFS 2015b) – jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Naled (NMFS 2010b) **-** jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Carbaryl and **Carbofuran** (NMFS 2009) - each jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Fenbutatin oxide, and **Propargite** (NMFS 2015b) - each jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Phosmet (NMFS 2010b) - jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Methomyl (NMFS 2009) - jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Pendimethalin and **Trifluralin** (NMFS 2012) - each jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Phorate (NMFS 2010b) - jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Oryzalin (NMFS 2012) – jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Dimethoate (NMFS 2010b) - jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Bensulide (NMFS 2010b) - jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Ethoprop (NMFS 2010b) - jeopardizes and adversely modifies the designated critical habitat for the SR winter-run Chinook salmon.

Chlorothalonil (NMFS 2011) **-** does not jeopardize but does adversely modify critical habitat for the SR winter-run Chinook salmon.

Diuron (NMFS 2011) - does not jeopardize but does adversely modify critical habitat for the SR winter-run Chinook salmon.

The issuance of jeopardy biological opinions on prior proposed FIFRA registrations indicates that FIFRA standards alone would be insufficient to promote species recovery. However, there is a backlog of pesticide ingredients that are in use that have not yet undergone ESA consultation (see EPA, ESA Workplan Update: Nontarget Species Mitigation for Registration Review and Other FIFRA Actions, Nov. 2022, https://www.epa.gov/system/files/documents/2022-11/esa-workplan-update.pdf). Until this backlog is addressed, and until the recommendations of any resulting biological opinions are implemented, the FIFRA standards are likely not sufficient to provide adequate protections for SR winter-run Chinook salmon, which could reduce the likelihood of achieving species recovery.

Harvest

Fishing-related mortality in ocean salmon fisheries is generally lower and management tools were improved since the last 5-year review in 2016. A new SR winter-run Chinook salmon harvest control rule was developed that uses abundance forecasts to set annual impact rates and incorporates information on in-river juvenile survival rates as well as anticipated adult ocean survival. Season and size restrictions have been in place for ocean salmon fisheries south of Point Arena, CA since the late 1990's and have continued since the last 5-year review. ***See Listing Factor B: Overutilization for commercial, recreational, scientific, or educational purposes in this document for details.***

California Inland Harvest Management

The California State Sport Fishing Regulations are promulgated by the California Fish and Game Commission and affirmed, or updated, annually to provide fishing opportunities in the State of California while minimizing fishing impacts to federally listed salmonids. In the Central Valley, regulations focus on the harvest of hatchery-origin salmon and steelhead and include fishing restrictions such as reduced bag limits, limited fishing days, geographic limits, gear restrictions, quick response for degraded habitat conditions due to drought, and other fishing prohibitions to protect federally listed salmonids. Regulations in the Central Valley also include season closures below Keswick Dam to avoid incidental catch where adult SR winter-run Chinook salmon hold and spawn. Development and finalization of Fisheries Management Evaluation Plans for California (FMEP) are recommended to authorize these fisheries under the ESA. CDFW and NMFS are collaborating on the development of FMEPs to ensure proper fisheries management of sensitive stocks by establishing a more formal program to minimize the take of federally listed salmonids.

NMFS encourages the State to continue advocating for accurate species identification and proper handling and release techniques by fishers, when incidental capture of listed salmonids occurs, which are critical to reducing the likelihood of injury and/or death. Improving angling outreach remains a priority to educate anglers on handling techniques, the reporting of poaching and other illegal activities, and their contributions to species population monitoring. Other efforts to improve angler conservation awareness and handling and release skills can be found in NOAA Fisheries Scaling Back Your Impact: Best Practices for Inland Fishing (www.fisheries.noaa.gov/about/west-coast-region) catch and release brochure (NMFS 2020b).

Listing Factor D Conclusion

Based on the relative improvement noted above, we conclude that the risk to the species' persistence because of the inadequacy of existing regulatory mechanisms is decreasing. However, despite the improvement in the adequacy of regulatory mechanisms within the ESU, there remain a number of concerns regarding existing regulatory mechanisms, including:

- The inappropriate use of a baseline streamflow depletion condition that is unlikely to provide adequate species or habitat protection.
- An imbalance in the suite of floodplain development incentives and disincentives that favor continued development, and disconnection of the natural floodplain and riparian habitats.
- An inability to address a slowing positive trend, and sometimes a negative trend, in water quality and associated habitat condition.
- A general lack of documentation, analysis, and synthesis of the adequacy of some regulatory mechanisms and programs.

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

Climate Change

Climate change is a factor that will continue to affect SR winter-run Chinook salmon as observed temperatures have risen steadily over the past century and precipitation remains highly variable. Major ecological realignments are already occurring in response to climate change

(IPCC WGII, 2022). Long-term trends in warming have continued at global, national, and regional scales. Global surface temperatures in the last decade (2010s) were estimated to be 1.09 °C higher than the 1850-1900 baseline period, with larger increases over land ~1.6 °C compared to oceans ~0.88 (IPCC WGI, 2021). The vast majority of this warming has been attributed to anthropogenic releases of greenhouse gases (IPCC WGI, 2021). Globally, 2014-2018 were the 5 warmest years on record both on land and in the ocean (2018 was the 4th warmest) (NOAA NCEI 2022). Events such as the 2013-2016 marine heatwave (Jacox et al. 2018) have been attributed directly to anthropogenic warming in the annual special issue of the Bulletin of the American Meteorological Society on extreme events (Herring et al. 2018). Global warming and anthropogenic loss of biodiversity represent profound threats to ecosystem functionality (IPCC WGII 2022). These two factors are often examined in isolation, but likely have interacting effects on ecosystem function.

Updated projections of climate change are similar to or greater than previous projections (IPCC WGI, 2021). NMFS is increasingly confident in our projections of changes to freshwater and marine systems because every year brings stronger validation of previous predictions in both physical and biological realms. Retaining and restoring habitat complexity, access to climate refuges (flow and temperature), and improving growth opportunity in both freshwater and marine environments are strongly advocated in the recent literature (Siegel and Crozier 2020).

Salmon and Steelhead Habitat Changes

Climate change is systemic, influencing freshwater, estuarine, and marine conditions. Other systems are also being influenced by changing climatic conditions. Literature reviews on the impacts of climate change on Pacific salmon (Crozier 2015, 2016, 2017; Crozier and Siegel 2018; Siegel and Crozier 2019, 2020) have collected hundreds of papers documenting the major themes relevant for salmon. Here we describe habitat changes relevant to Pacific salmon and steelhead, and how these changes result in the varied specific mechanisms impacting these species in subsequent sections.

Forests

Climate change will impact the forests of the western U.S., which dominate the landscape of many watersheds in the region. Forests are already showing evidence of increased drought severity, forest fire, and insect outbreak (Halofsky et al. 2020). Climate change will also affect tree reproduction, growth, and phenology, leading to spatial shifts in vegetation. Halofsky et al. (2018) projects that the largest changes will occur at low- and high-elevation forests, with an expansion of low-elevation dry forests and diminishing high-elevation cold forests and subalpine habitats.

Forest fires affect salmon streams by altering sediment load, channel structure, and stream temperature through the removal of canopy. Holden et al. (2018) examined environmental factors contributing to observed increases in the extent of forest fires throughout the western U.S. They found strong correlations between the number of dry-season rainy days and the annual extent of forest fires, as well as a significant decline in the number of dry-season rainy days over the study period (1984-2015). Consequently, predicted decreases in dry-season precipitation, combined with increases in air temperature, will likely contribute to the existing trend toward more extensive and severe forest fires and the continued expansion of fires into higher elevation and wetter forests (Alizedeh 2021).

Agne et al. (2018) reviewed literature on insect outbreaks and other pathogens affecting coastal Douglas-fir forests in the Pacific Northwest and examined how future climate change may influence disturbance ecology. They suggest that Douglas-fir beetle and black stain root disease could become more prevalent with climate change, while other pathogens will be more affected by management practices. Agne et al. (2018) also suggested that climate impacts will differ by region and forest type due to complex interacting effects of disturbance and disease.

Freshwater Environments

The following is excerpted from Siegel and Crozier (2019), who present a review of recent scientific literature evaluating the effects of climate change, where they describe the projected impacts of climate change on instream flows:

> Cooper et al. (2018) examined whether the magnitude of low river flows in the western U.S., which generally occur in September or October, are driven more by summer conditions or the prior winter's precipitation. They found that while low flows were more sensitive to summer evaporative demand than to winter precipitation, interannual variability in winter precipitation was greater. Malek et al. (2018), predicted that summer evapotranspiration is likely to increase in conjunction with declines in snowpack and increased variability in winter precipitation. Their results suggest that low summer flows are likely to become lower, more variable, and less predictable.

And later describe the projected impacts of climate change on groundwater:

> 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 […] Projections using [Representative Concentration Pathway] 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.

As cited in Siegel and Crozier (2019), Isaak et al. (2018) examined recent trends in stream temperature across the Western U.S. 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, *O. nerka,* and the availability of suitable habitat for brown trout, *Salmo trutta,* and rainbow trout, *O. mykiss*. Isaak et al. (2018) concluded that most stream habitats will likely remain suitable for salmonids in the near future, with some becoming too warm. However, in cases where habitat access is currently restricted by dams and other barriers, salmon and steelhead will be confined to downstream reaches that are typically most at risk of rising temperatures unless passage is restored (FitzGerald et al. 2020; Myers et al. 2018).

Streams with intact riparian corridors that lie in mountainous terrain are likely to be more resilient to changes in air temperature. These areas may provide refuge from climate change for numerous species, including Pacific salmon. Krosby et al. (2018) identified potential stream refugia throughout the Pacific Northwest based on a suite of features thought to reflect the ability of streams to serve as such refuges. Analyzed features include large temperature gradients, high canopy cover, large relative stream width, low exposure to solar radiation, and low levels of human modification. They created an index of refuge potential for all streams in the region, with mountain area streams scoring the highest. Flat lowland areas, which commonly contain migration corridors, were generally scored the lowest, and thus were prioritized for conservation and restoration. However, forest fires can increase stream temperatures dramatically in short time-spans by removing riparian cover (Koontz et al. 2018). Streams that lose their snowpack with climate change may see the largest increases in stream temperature due to the removal of temperature buffering (Yan et al. 2021). These processes may threaten some habitats that are currently considered refugia.

A strong and persistent warming trend and large year-to-year variations in precipitation are among the most notable features of California's climate in recent decades (Figure 6). For both the Pacific Northwest and California, water year 2015 stands out as the warmest year on record, while water year 2018 is the second warmest year on record for California. California's surface air temperatures in water years 2014-2018 were all much warmer than the 1981-2010 average.

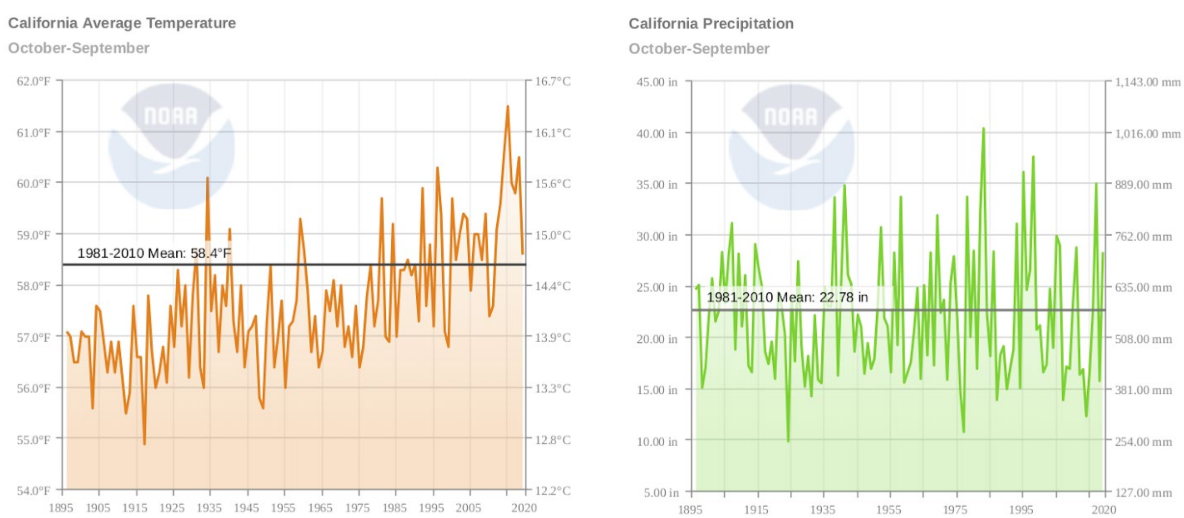

Figure 6. Water year (October-September) surface air temperature (left panels) and precipitation (right panels) for California.
In each panel, the historical average for 1981-2010 is shown with the black horizontal line. These figures show US Climate Division Data and were created at https://www.ncdc.noaa.gov/cag/regional/time-series.

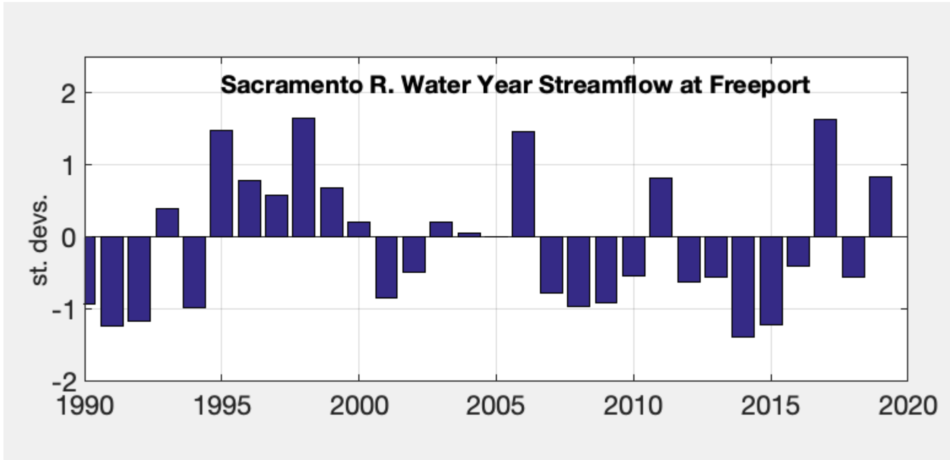

Figure 7. Water year streamflow anomalies (normalized with respect to the 1981-2010 mean and standard deviation) for the Sacramento River.
Data for this figure were downloaded from the USGS (waterdata.usgs.gov).

A broad-brush overview of water year streamflow variations in northern California is provided in Figure 7, where stream gage data indicate substantially more low-flow than high-flow years from 2000-2019. The Sacramento River had above average water years in 2006, 2011, 2017, and 2019; with below average water years from 2001-02, 2007-10, 2012-15 and 2018. In 2016, streamflow was a bit below average in the Sacramento River. California's multiyear drought of 2012-2015 was especially notable for the persistence and magnitude of above-average surface temperatures, below-average precipitation, below-average snow pack, and below-average streamflow throughout the state.

Marine and Estuarine Environments

Along with warming stream temperatures and concerns about sufficient groundwater to recharge streams, a recent study projects a nearly complete loss of existing tidal wetlands along the U.S. West Coast, due to sea level rise (Thorne et al. 2018). California and Oregon showed the greatest threat to tidal wetlands (100%), while 68% of Washington tidal wetlands are expected to be submerged. Coastal development and steep topography prevent horizontal migration of most wetlands, causing the net contraction of this crucial habitat.

Rising ocean temperatures, stratification, ocean acidity, hypoxia, algal toxins, and other oceanographic processes will alter the composition and abundance of a vast array of oceanic species. In particular, there will be dramatic changes in both predators and prey of Pacific salmon, salmon life history traits, and relative abundance. Siegel and Crozier (2019) observe that changes in marine temperature are likely to have a number of physiological consequences on fishes themselves. For example, in a study of small planktivorous fish, Gliwicz et al. (2018) found that higher ambient temperatures increased the distance at which fish reacted to prey. Numerous fish species (including many tuna and sharks) demonstrate regional endothermy, which in many cases augments eyesight by warming the retinas. However, Gliwicz et al. (2018) suggest that ambient temperatures can similarly effect 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.

Perhaps the most dramatic change in physical ocean conditions will occur through ocean acidification and deoxygenation. It is unclear how sensitive salmon and steelhead might be to the direct effects of ocean acidification because of their tolerance of a wide pH range in freshwater (although see Ou et al. 2015 and Williams et al. 2019); however, impacts of ocean acidification and hypoxia on sensitive species (e.g., plankton, crabs, rockfish, groundfish) will likely affect salmon indirectly through their interactions as predators and prey. Similarly, increasing frequency and duration of harmful algal blooms may affect salmon directly, depending on the toxin (e.g., saxitoxin vs. domoic acid), but will also affect their predators (seabirds and mammals). The full effects of these ecosystem dynamics are not known but will be complex.

Impacts on Salmon and Steelhead

Currently, more than half of all anadromous Pacific salmon and steelhead DPSs remaining in Oregon, Washington, Idaho and California (as defined in Weitkamp et al. 1995; Busby et al. 1996; Hard et al. 1996; Gustafson et al. 1997; Johnson et al. 1997; Myers et al. 1998) are listed as threatened or endangered under the ESA (Crozier et al. 2019). Climate change threatens salmon throughout their life history in diverse ways in the various habitats on which they depend (Crozier et al. 2021). Anthropogenic factors, especially migration barriers, habitat degradation, and hatchery influence, have reduced the adaptive capacity of most steelhead and salmon populations (Crozier et al. 2019). Nearly all listed ESUs and DPSs are expected to face high exposures to projected increases in stream temperature, sea surface temperature, and ocean acidification. Within the historical range of climate variability, less suitable conditions for salmonids (e.g., warmer temperatures, lower streamflows) have been associated with detectable declines in many of these listed units, highlighting how sensitive they are to climate drivers (Lindley et al. 2009; Williams et al. 2016; Ford 2022). In some cases, the combined and potentially additive effects of poorer climate conditions for fish and intense anthropogenic impacts caused population declines that led to these population groups being listed under the ESA (Crozier et al. 2019).

At the individual scale, climate impacts on salmon in one life stage generally affect body size or timing in the next life stage, and negative impacts can accumulate across multiple life stages (Healey 2011; Wainwright and Weitkamp 2013; Gosselin et al. 2021). Changes in winter precipitation will likely affect the incubation and/or rearing stages of most populations. Changes in the intensity of cool-season precipitation, snow accumulation, and runoff could influence migration cues for fall, winter, and spring adult migrants, such as Coho and steelhead. Egg survival rates may suffer from more intense flooding that scours or buries redds. Changes in hydrological regime, such as a shift from mostly snow to more rain, could drive changes in life history, potentially threatening diversity within an ESU (Beechie et al. 2006). Changes in summer temperature and flow will affect both juvenile and adult stages in some populations, especially those with yearling life histories and summer migration patterns (Crozier and Zabel 2006; Crozier et al. 2010; Crozier et al. 2019).

In freshwater, year-round increases in stream temperature and changes in flow will affect physiological, behavioral, and demographic processes in salmon, and change the species with which they interact. For example, as stream temperatures increase, many native salmonids face increased competition with more warm-water tolerant invasive species. Changing freshwater temperatures are likely to affect incubation and emergence timing for eggs, and in locations where the greatest warming occurs, may affect egg survival, although several factors impact intergravel temperature and oxygen (e.g., groundwater influence) as well as sensitivity of eggs to thermal stress (Crozier et al. 2020). Changes in temperature and flow regimes may alter the amount of habitat and food available for juvenile rearing, which could lead to a restriction in the distribution of juveniles, further decreasing productivity through density dependence. For migrating adults, predicted changes in freshwater flows and temperatures will likely increase exposure to stressful temperatures for many salmon and steelhead populations, alter migration travel times, and increase thermal stress accumulation for ESUs or DPSs with early-returning (i.e., spring- and summer-run) phenotypes associated with longer freshwater holding times (Crozier et al. 2020; FitzGerald et al. 2020). Rising river temperatures increase the energetic cost of migration and the risk of *en route* or pre-spawning mortality of adults with long freshwater migrations. However, some ESA-listed salmon and steelhead populations may be able to use cool-water refuges and run-timing plasticity to reduce thermal exposure (Keefer et al. 2018; Barnett et al. 2020).

Marine survival of salmonids is affected by a complex array of factors, including prey abundance, predator interactions, the physical condition of salmon within the marine environment, and carryover effects from the freshwater experience (Holsman et al. 2012; Burke et al. 2013). Salmon marine survival is generally size-dependent, and thus larger, faster-growing fish are more likely to survive (Gosselin et al. 2021). However, the optimal day of arrival varies across years, depending on the seasonal development of productivity in the California Current, which affects prey available to salmon and the risk of predation (Chasco et al. 2021). Siegel and Crozier (2019) also point out the concern that, for some salmon populations, climate change may drive mismatches between juvenile ocean 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. For example, 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 more than 50 days, with different populations encountering distinct prey fields, and recommended that managers maintain and augment such life-history diversity. Synchrony between terrestrial and marine environmental conditions (e.g., coastal upwelling, precipitation and river discharge) has increased in spatial scale causing the highest levels of synchrony in the last 250 years (Black et al. 2018). A more synchronized climate combined with simplified habitats and reduced genetic diversity may be leading to more synchrony in the productivity of populations across the range of salmon (Braun et al. 2016). For example, salmon productivity (recruits/spawner) has also become more synchronized across Chinook populations from Oregon to the Yukon (Kilduff et al. 2014; Dorner et al. 2018). Other Pacific salmon species (Stachura el al. 2014) and Atlantic salmon (Olmos et al. 2020) also have demonstrated synchrony in productivity across a broad latitudinal range. Salmon historically maintained relatively consistent returns across variation in annual weather through the portfolio effect (Schindler et al. 2015), in which different populations are sensitive to different climate drivers. Applying this concept to climate change, Anderson et al. (2015) emphasized the additional need for populations with different physiological tolerances. Loss of the portfolio increases volatility in fisheries and ecological systems, as demonstrated for Fraser River and Sacramento River stock complexes (Freshwater et al. 2019; Munsch et al. 2022).

At the population level, the ability of organisms to genetically adapt to climate change depends on how much genetic variation currently exists within salmon populations, how selection on multiple traits interact, and whether those traits are linked genetically. While genetic diversity may help populations respond to climate change, the remaining genetic diversity of many populations is highly reduced compared to historic levels. For example, Johnson et al. (2018) compared genetic variation in Chinook salmon from the Columbia River basin between contemporary and ancient samples. A total of 84 samples determined to be Chinook salmon were collected from vertebrae found in ancient middens and compared to 379 contemporary samples. Results suggest a decline in genetic diversity, as demonstrated by a loss of mitochondrial haplotypes as well as reductions in haplotype and nucleotide diversity. Genetic losses in this comparison appeared larger for Chinook from the mid-Columbia than those from the Snake River Basin. In addition to other stressors, modified habitats and flow regimes may create unnatural selection pressures that reduce the diversity of functional behaviors (Sturrock et al. 2020). Managing to conserve and augment existing genetic diversity may be increasingly important with more extreme environmental change (Anderson et al. 2015), though the low levels of remaining diversity present challenges to this effort (Freshwater et al. 2019).

Species-Specific Climate Effects

The following species-specific information on climate vulnerability is summarized from Crozier et al. (2019), which includes Figure 8 below:

Several factors contributed to the ranking of this ESU as very highly vulnerable to climate change. The poor population viability of this single population spawning outside of its historical range was the greatest risk, as the ESU is not thriving under current climate conditions which are expected to worsen. SR winter-run Chinook salmon adults return to freshwater from December through April, and hold in fresh water until spawning from late April through September. Fry emerge from July to mid-October and can rear in tributary habitats and the delta for several months prior to outmigrating. This makes both adult and juvenile life stages vulnerable to hydrologic regime changes, increases in stream temperature, and summer water deficits, and is therefore also vulnerable to cumulative life-cycle impacts over multiple life stages. Juveniles are also vulnerable to changes in flooding, as decreased streamflows and incidents of flooding may limit their ability to use productive floodplain habitat for rearing. Sea level rise may also reduce the availability of tidal marsh habitats for rearing juveniles.

The marine stage of SR winter-run Chinook salmon was ranked moderately vulnerable to climate impacts, with high risk of exposure to changes in upwelling because of the unique migratory behavior of this ESU. These fish enter the ocean somewhat earlier than other Central Valley Chinook, and have a more southerly and nearshore marine distribution than other Chinook salmon ESUs. This contracted range may make the ESU more vulnerable to localized upwelling conditions compared to other Pacific salmon.

SR winter-run Chinook were ranked low in overall adaptive capacity because they are in the southernmost region of the range of Chinook salmon on the West Coast, and the California Central Valley offers the fewest opportunities for adaptive capacity of the Chinook salmon recovery domains. The limited phenotypic and genetic diversity remaining in the extant population is also likely to limit this ESU's ability to adapt to future climate change.

	Sacramento River winter-run Chinook	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Early life history	4	2.8	
	Juvenile freshwater stage	3.7	2.8	
	Estuary stage	3.5	2	
	Marine stage	3.5	2.3	
	Adult freshwater stage	2.9	3	
	Cumulative life-cycle effects	4	2.5	
	Hatchery influence	2	3	
	Other stressors	3.9	1.8	
	Population viability	3.9	3	
	Ocean acidification sensitivity	1.8	1	
	Sensitivity Score	Very High		
Exposure variables	Stream temperature	3.1	2	
	Summer water deficit	2.7	1.8	
	Flooding	3.2	1.3	
	Hydrologic regime	2.6	1.8	
	Sea level rise	3.5	2.3	
	Sea surface temperature	3.4	2	
	Ocean acidification exposure	4	2.5	
	Upwelling	2.9	1	
	Ocean currents	1.9	1	
	Exposure Score	High		
Overall Vulnerability Rank		Very High		

Low
Moderate
High
Very High

Figure 8. SR winter-run Chinook salmon Climate Effects Exposure and Vulnerability (Crozier et al. 2019).

One particularly notable climate impact occurred throughout the 2012-2016 drought in California was that the effects of drought on stream networks accumulated each year rather than reflecting annual precipitation directly. For the SR winter-run Chinook salmon, catastrophically low egg-to-fry survival rates (less than 5%) were not observed until the 3rd and 4th years of drought, in 2014 and 2015 respectively. Observations were based on screw trap collections of outmigrating fry (Voss and Poytress 2017) and the corresponding spawning run size estimate, which was closely aligned with predictions from a model relating embryo survival to thermal and oxygen stress during incubation (Martin et al. 2017; Martin et al. 2020).

Hatchery Impacts

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 can pose risks to natural productivity and diversity. The magnitude and type of the risk depend on the status of affected populations and the specific practices in the hatchery program.

When pre-season temperature modeling predicted the Sacramento River would likely exceed the thermal limit of successful natural SR winter-run Chinook salmon spawning during 2014 and 2015, the fish management agencies (USFWS, NMFS, and CDFW) anticipated the potential of a near-complete failure of natural production. In response, the three agencies enacted emergency measures to temporarily expand the production of winter-run Chinook salmon at LSNFH. Broodstock collection goals at LSNFH were substantially increased in 2014 and 2015, and total hatchery production of winter-run Chinook salmon juveniles reached levels two- and three-fold larger than standard production levels.

Results of spawner escapement surveys support the fish management agencies' expectations that the drought had resulted in the near-complete failure of winter-run Chinook salmon natural production during 2014 and 2015. Spawner escapement surveys estimated 975 adult winter-run Chinook salmon returned to the Upper Sacramento River in 2017 (Azat, 2020), marking the second-lowest annual spawner escapement estimate in the recent 20-year period. An estimated 85 percent of the SR winter-run Chinook salmon spawners in 2017 were hatchery-origin fish from LSNFH (K. Offill, USFWS, Red Bluff, CA, unpublished data), evidence that the emergency measures enacted by the fish management agencies were successful at avoiding a complete year-class failure. The low percentage of natural-origin spawners and high percentage of hatchery-origin spawners in 2017 suggests that the reproductive success of naturally spawning winter-run Chinook salmon in 2014 had been greatly diminished but that the increased propagation efforts enacted at LSNFH substantially benefited the abundance of spawners in 2017. However, because the increased abundance was attributed to hatchery-origin adult returns, hatchery influence also increased, presenting risks such as increased domestication selection. Although the percentage of hatchery-origin spawners was also high during 2018 (82%), it decreased substantially in 2019 (37%) and would be expected to continue to decline so long as hatchery production is sustained at normal hatchery production levels.

As described in the previous 5-year review (NMFS 2016a), the Winter Chinook Captive Broodstock Program was reinstated at LSNFH in 2015. With evidence that the drought had severely reduced the natural reproductive success of adult SR winter-run Chinook salmon for two consecutive year classes, and recognizing the potential conservation values of the captive broodstock at LSNFH, the fish management agencies made the decision to spawn captive broodstock and use their progeny to initiate the reintroduction of winter-run Chinook salmon into their historical spawning habitats of Battle Creek. SR winter-run Chinook salmon from LSNFH's Captive Broodstock Program were spawned during the 2017–2020 spawning seasons. Offspring of captive broodstock were transferred as eyed-eggs or fry to Coleman National Fish Hatchery, where they were reared until their release into North Fork Battle Creek.

Captive broodstock progeny were first released into North Fork Battle Creek during the spring of 2018 (brood year 2017). This action initiated the reintroduction of SR winter-run Chinook salmon to historical spawning and rearing habitats in the watershed. This method of reintroducing winter-run Chinook salmon to Battle Creek differs from the recommendations in the Battle Creek Winter-Run Chinook Salmon Reintroduction Plan (ICF International 2016), which calls for using the progeny of wild-caught broodstock. In order to differentiate this effort from the approach outlined in the Reintroduction Plan, the 'Jumpstart Project' moniker has become the commonly accepted name for referring to this fast-tracked approach to the reintroduction process. The Jumpstart Project is intended to transition into the implementation of the Reintroduction Plan when funding becomes available. Subsequent Jumpstart Project releases of juvenile hatchery-origin winter-run Chinook salmon into Battle Creek occurred during 2019 and 2020. They are expected to continue until efforts shift towards the implementation of the Reintroduction Plan.

It was anticipated that maturing adult winter-run Chinook salmon would begin returning to Battle Creek for spawning during the spring of 2019. Based on the expectation that returns of Jumpstart Project winter-run Chinook salmon would be dominated by 2-year-old males (i.e., jacks) during 2019, the preferred approach was to intercept all Jumpstart Project returns at the Coleman National Fish Hatchery Barrier Weir and transport them to LSNFH for spawning with female captive broodstock. Consistent with expectations, a total of 77 male, age-2 winter-run Chinook salmon were observed attempting to migrate past the Coleman National Fish Hatchery Barrier Weir in Battle Creek from May 1 through July 15, 2019. With the exception of two fish, which were observed migrating through the Barrier Weir fish ladder while the entrance to the hatchery was closed, the remaining 75 fish were diverted into Coleman National Fish Hatchery, where they were held and sampled for genetics. All genetically confirmed Jumpstart Project winter-run Chinook salmon captured at Coleman National Fish Hatchery during the spring of 2019 were transported to LSNFH. A portion died before spawning (pre-spawn mortality) at LSNFH, and some were spawned with female captive broodstock. Juvenile winter-run Chinook salmon produced from Jumpstart Project jacks collected during 2019 contributed to the first multi-generational releases in Battle Creek.

2020 marked the first year of 3-year-old adult winter-run Chinook salmon returns to Battle Creek resulting from the Jumpstart Project. Jumpstart Project winter-run Chinook salmon began returning to Battle Creek in mid-January and were diverted to the Coleman National Fish Hatchery, similar to the approach taken in 2019. However, due to the statewide mandatory shelter-in-place orders resulting from the COVID-19 pandemic, the Coleman National Fish Hatchery ladder was opened in April 2020, and the returning adult winter-run Chinook salmon were allowed to volitionally pass upstream. At that time, USFWS had observed over 370 Jumpstart Project winter-run Chinook salmon adults return. A video monitoring station was installed within the fish ladder to document adult winter-run Chinook salmon passage into the upstream reaches of Battle Creek. Upon analyzing the video footage, it was determined that over 1,000 winter-run Chinook salmon adults had returned to Battle Creek in 2020. Before opening the fish ladder, approximately 100 adult Jumpstart Project winter-run Chinook salmon were collected for broodstock and transferred to LSNFH.

Although the ability to conduct spawning surveys during 2020 was limited, successful winter-run Chinook salmon spawning was observed in Battle Creek. Both redds and live adult winter-run Chinook salmon were documented, including 12 redds in North Fork Battle Creek and one redd in the mainstem of Battle Creek (Laurie Earley, USFWS Red Bluff, CA, unpublished data). USFWS subsequently deployed a rotary screw trap in Battle Creek to determine whether any winter-run Chinook salmon juveniles were successfully produced. On July 30, 2020, USFWS captured the first winter-run Chinook salmon fry in the upper Battle Creek rotary screw trap, indicating that Battle Creek can successfully support winter-run Chinook salmon adult spawning and juvenile production. The recent success of the Jumpstart Project has proven to be a good sign for the planned transition to the implementation of the Reintroduction Plan (USFWS 2020).

Listing Factor E Conclusion

The risk to the species' persistence because of climate change, drought impacts on water availability and temperature, and hatchery influence is increasing and continues to threaten the single population of the SR winter-run Chinook salmon ESU.

Climate Change

The changing climate over the past century has realized steadily rising temperatures, coupled with highly variable precipitation. In the snow-dominated watersheds, warmer winters and springs reduce snow accumulation and hasten snowmelt. The resulting reduced snowpack has led to a smaller freshet that occurs earlier in spring. The reduced snowpack has also led to lower minimum flows and higher stream temperatures in summer. Specifically, precipitation and streamflow in the Sacramento River watershed since the last 5-year review have remained highly variable, with 2017 and 2019 being above-average water years and 2016 and 2018 being below-average years. Overall, rising atmospheric temperatures have exacerbated an already high evaporative demand. The region is now experiencing a significant moisture deficit, including precipitation deficits of up to 50 inches in some areas since October 1, 2019. Likewise, sea surface temperatures in the northeast Pacific Ocean achieved record highs for much of the period from fall 2013-2019. This temperature shift has produced a dramatic biological response across all trophic levels since 2013 and which continued into 2020.

Hatchery Impacts

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 affected populations' status and the specific hatchery program practices. For example, conservation hatcheries likely pose less risk to salmon and steelhead than production hatcheries that focus on providing fish for harvest. 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).

While hatchery actions taken to address the poor in-river conditions experienced during the recent drought have continued to affect SR winter-run Chinook salmon since the last 5-year review (e.g., increased hatchery influence due to the expansion of hatchery production from LSNFH), the return to normal hatchery operations in 2016 helped to reduce those impacts in subsequent years. The steady reduction in the percentage of hatchery-origin spawners returning to the Sacramento River since 2017 indicates that the impacts associated with increased hatchery production during the drought have been effectively reduced by returning to normal production levels. Furthermore, actions implemented by the fish management agencies, such as restarting the captive broodstock program at LSNFH, have presented new opportunities to improve the status of the ESU. For example, the Battle Creek Jumpstart Project commenced in 2018, using the progeny of captive broodstock at LSNFH. This early implementation of actions related to the reintroduction of SR winter-run Chinook salmon to Battle Creek has and will continue to provide data that can be used to inform the formal reintroduction program, as described in the Reintroduction Plan (ICF International 2016). Furthermore, it is expected that the hatchery programs at LSNFH will contribute to other planned winter-run Chinook salmon reintroduction efforts in the Central Valley.

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's implementing regulations at 50 CFR part 424.

We review the status of the species and evaluate whether any one of the five factors, as identified in ESA section 4(a)(1), suggests that reclassification is warranted: (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; or (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.

2.4.1 Updated Biological Risk Summary

Despite advancements in a pilot reintroduction and habitat improvements, the biological status of the SR winter-run Chinook salmon ESU has declined since the 2016 viability assessment

(Williams et al. 2016), with the single spawning population on the mainstem Sacramento River now at a high risk of extinction (SWFSC 2022). Updated information indicates an increased extinction risk due to the larger influence of the hatchery broodstock and low numbers of natural-origin returns in two consecutive years (SWFSC 2022).

2.4.2 ESA Listing Factor Analysis

Table 8 summarizes our findings on how the five ESA listing factors have changed since the 2016 5-year review.

Table 8. Summary of how each listing factor for SR winter-run Chinook salmon has changed since the 2016 5-year review.

Listing Factor	Change since 2016
A. Present or threatened destruction, modification, or curtailment of its habitat or range	The risk to species persistence posed by the present or threatened destruction, modification or curtailment of its habitat or range continues to be high, but is decreasing. Although much of the historical spawning habitat that once supported the ESU remains inaccessible, recent reintroduction efforts in the Battle Creek watershed have significantly expanded the available spawning habitat. However, despite numerous downstream habitat improvement and restoration actions since the last 5-year review in 2016, the extent of juvenile rearing and migratory habitat supporting this ESU remains greatly diminished, is often found in a highly degraded state, and continues to threaten the SR winter-run Chinook salmon ESU.
B. Overutilization for commercial, recreational, scientific, or educational purposes	The risk to species persistence due to overutilization for commercial, recreational, scientific, or educational purposes continues to be moderate to low. Because the listing factor has not changed appreciably since the 2016 5-year review, harvest and research/monitoring sources of mortality continue to have little impact on the recovery of the SR winter-run Chinook salmon.
C. Disease or predation	The risk to species persistence related to disease and predation is moderate to high and has been increasing since the last 5-year review. Emerging concerns include the advent of a thiamine deficiency complex, which has been observed to cause increased mortality in the early life stages of the ESU, and the recent proliferation of SAV/FAV invasive species in the Delta, which provide habitat conditions that disproportionately favor piscivorous fish that may prey upon SR winter-run Chinook salmon.
D. Inadequacy of existing regulatory mechanisms	The risk to the species' persistence because of the inadequacy of existing regulatory mechanisms is low to moderate, but decreasing since the last 5-year review. Specifically, the seasonal closure of the Upper Sacramento River spawning reach and, more broadly, fishing restrictions like low-flow closures, reduced bag limits, limited fishing days, geographic limits, gear restrictions, and fishing prohibitions established by the California Fish and Game Commission have reduced the potential for direct impact on the ESU. However, despite a number of improved protections for the species, NMFS remains concerned about the adequacy of some existing habitat regulatory mechanisms affecting groundwater sustainability, floodplain development, and regional water quality. These regulatory mechanisms affect the available stream flow volume, limit habitat connectivity and availability, and/or impact habitat conditions.
E. Other natural or man-made factors affecting its continued existence	The risk to the species' persistence as a result of other natural or man-made factors is high and has increased since the last 5-year review due to a changing and warming climate, decreased surface water availability, poor ocean conditions, and an increased genetic influence of hatchery-reared fish on the wild population.

2.4.3 Conclusion

Although conservation efforts for SR winter-run Chinook salmon have reduced the severity of some threats to this ESU, the remaining threats described in the five listing factor discussion above have increased since the 2016 5-year review (NMFS 2016a). While much progress has been made to address the threats to habitat, including increased spawning habitat availability and improved conditions in the migratory corridor habitat, other previously unidentified threats linked to disease and predation have worsened. Most of these threats are exacerbated by the changing climate, epitomized by a prolonged drought in California. In coming years, the climate is expected to alter riverine hydrologic patterns and trend towards warmer winter temperatures with less snowpack storage, more intense runoff events, and lower streamflows during dry periods. Further, although recent federal and state regulatory mechanisms have improved, concern remains regarding the adequacy of the regulations that will be needed to protect SR winter-run Chinook salmon habitat given the changing climate.

2.4.4 ESU delineation and hatchery membership

The Southwest Fisheries Science Center's review (SWFSC 2022) found that no new information had become available to justify a change in the delineation of the SR winter-run Chinook salmon ESU. However, the existing ESU delineation will need to be reexamined if the Battle Creek reintroduction is successful or if the species is reintroduced above Shasta Dam. Our review of new information since the 2016 5-year review regarding the ESU membership status of hatchery programs indicates that no changes in the SR winter-run Chinook salmon ESU membership are warranted.

2.4.5 ESU viability and statutory listing factors

- The information presented in the Southwest Fisheries Science Center's review of updated information (SWFSC 2022) indicates that a change in the biological risk category of SR winter-run Chinook salmon since the time of the last 5-year review is warranted, increasing the risk from medium to high.
- Our analysis of ESA section 4(a)(1) factors indicates that the collective risk to the SR winter-run Chinook salmon's persistence has remained the same (high) since our last 5-year review in 2016 (NMFS 2016a).

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3. Results

3.1 Classification

3.1.1 Listing Status

Based on the information identified above, we determine that no reclassification for the SR winter-run Chinook salmon ESU is appropriate, and therefore:

- The SR winter-run Chinook salmon should remain listed as endangered.

3.1.2 ESU Delineation

The Southwest Fisheries Science Center's review (SWFSC 2022) found that no new information has become available that would justify a change in the delineation of the SR winter-run Chinook salmon ESU.

3.1.3 Hatchery Membership

For the SR winter-run Chinook salmon ESU, we do not recommend any changes to the hatchery program membership.

3.2 New Recovery Priority Number

Since the 2016 5-year review, NMFS revised the recovery priority number guidelines and twice evaluated the numbers (NMFS 2019a, NMFS 2022). Table 4 indicates the numbers in place at the beginning of the current review. In January 2022, the recovery priority number of 1C for the SR winter-run Chinook salmon ESU remained unchanged in the FY 2019–2020 Report to Congress (NMFS 2022).

As part of this 5-year review, we reevaluated the recovery priority number based on the best available information, including the new viability assessment (SWFSC 2022). We concluded that the current recovery priority number remains 1C.

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4. Recommendations for Future Actions

Implementation of the action items identified in our current 2024 5-year review of the listing factors and in the Species in the Spotlight 2021-2025 Priority Action Plan for SR winter-run Chinook salmon represent the most important actions to pursue over the next 5 years toward achieving population viability (NMFS 2021). These actions include:

- Improve management of Shasta Reservoir cold-water storage to reduce water temperatures and provide flows to improve SR winter-run Chinook salmon productivity;
- Restore Battle Creek habitat and reintroduce SR winter-run Chinook salmon to historical spawning areas;
- Reintroduce SR winter-run Chinook salmon into historical habitats above Shasta Dam;
- Improve Yolo Bypass fish habitat and passage to increase juvenile survival and rearing opportunities;
- Improve management of winter and early spring Delta conditions to improve juvenile survival; and,
- Continue collaboration on science and fostering partnerships to build greater capacity to address recovery challenges.

Perhaps the greatest opportunity to advance recovery over the next 5 years is to support SR winter-run Chinook salmon reintroduction efforts above Shasta Dam and within Battle Creek. This includes actions that evaluate the opportunities and provide the means to implement reintroductions, such as assessing the feasibility and efficacy of a juvenile salmonid collection system above Shasta Dam, completing the Battle Creek Restoration Project, and implementing the Battle Creek Winter-Run Chinook Salmon Reintroduction Plan (ICF 2016). Successful completion of these actions will lead to the reestablishment of a second, independent population of SR winter-run Chinook salmon. This will increase the spatial structure of the species and reduce the risk of extinction faced by a species that is otherwise limited to a single population vulnerable to catastrophic events.

4.1 Additional recommended actions

- Conduct an independent review of the Livingston Stone National Fish Hatchery genetic management plan that considers the long-term influence of increased production during years with poor environmental conditions. This review should also consider actions that could increase the genetic diversity of hatchery production (e.g., additional downstream collection sites) and/or provide mitigation for the decrease in the proportion of natural influence that results from increased hatchery production. As part of USBR’s proposed operation of the CVP/SWP, there is already a commitment to the chartering of a 4-year independent panel to review the effectiveness of habitat restoration, facility improvements, intervention, and research measures which would include a review of hatchery infrastructure modernization and increased production (USBR 2019).

- Evaluate non-natal rearing habitats and their contribution to SR winter-run Chinook salmon life-history diversity for possible inclusion in designated critical habitat.
- Consider project operations and habitat restoration that accommodate ecologically functional flow regimes. Support those actions that return the Sacramento River and Delta to an ecosystem more conducive for native fish populations and reduce the presence of exotic species.
- Enhance SR winter-run Chinook salmon monitoring to reduce uncertainty in life-stage impacts and assist in management. Specific recommendations include analyzing otolith microchemistry from returning adults to provide information on successful life history variants and non-natal rearing; incorporating genetic run identification at monitoring locations to support real-time operations management and improve the accuracy of juvenile abundance estimates; integrating fish telemetry data on migration behavior and survival with environmental conditions and water quality monitoring; and collecting data on life history diversity, fish condition, and fish passage to understand habitat utilization.

4.2 Research, Monitoring, and Evaluation Recommendations

- Assess the feasibility and efficacy of a juvenile salmonid collection system above Shasta Dam. Additional research and monitoring are needed to improve our understanding of the facilities necessary for the reintroduction of SR winter-run Chinook salmon above Shasta and Keswick dams. This information will inform a reintroduction plan and increase the likelihood of success when reintroduction does occur.
- Assess the feasibility of an additional adult collection facility at the Anderson-Cottonwood Irrigation District Dam as a potential location for hatchery collection and thiamine treatment.
- Implement the monitoring actions identified in the Battle Creek Restoration Project - Adaptive Management Plan (Terraqua 2004) and the Battle Creek Winter-Run Chinook Salmon Reintroduction Plan (ICF 2016).
- Establish a second captive broodstock program to maintain an alternate source of genetic diversity.
- Support collaborative efforts to investigate sources of early life-stage mortality in addition to temperature-related effects. Primary among those sources of mortality that should be studied are:

  - The role of thiamine in egg maturation and juvenile development, including the consideration of potential in-river and hatchery treatments to mitigate those effects,
  - The magnitude and extent of predation in the Upper Sacramento River and Middle Sacramento River, and
  - The potential effects related to habitat availability, capacity and condition.

- Investigate ocean age-1 survival and potential sources of mortality in the marine environment including a synthesis of migration timing in the Bay-Delta and marine conditions at the time of ocean entry.
- Coordinate with the USBR and other Sacramento River recovery partners to improve the monitoring, modeling, and management of Shasta Reservoir cold water releases to provide temperatures suitable for SR winter-run Chinook salmon spawning, egg incubation, fry emergence and juvenile rearing in the Upper Sacramento River. Consider the development and application of appropriate decision support tools like the SWFSC's Winter-run Life Cycle Model to identify and iterate on annual management approaches.
- Evaluate the influence and potential management applications of spring water temperatures below Keswick Dam on SR winter-run Chinook salmon spawn timing.
- Monitor and evaluate juvenile rearing opportunities on floodplains and the flood control bypasses of the Middle Sacramento River. Particular attention should focus on the condition of juveniles entering and exiting the rearing habitats, as well as metrics or indices of variation related to behavioral diversity.
- Implement monitoring actions (e.g., DNA sampling at rotary screw traps and otolith microchemistry of returning adults) that provide information to identify successful life history variants and to understand non-natal rearing.

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5.1 Federal Register Notices

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NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Sacramento River Winter Chinook Salmon

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 Sacramento River Winter-run Chinook ESU Evaluation Team

REGIONAL OFFICE APPROVAL:

for **Lead Regional Administrator, NOAA Fisheries**

Approve Scott Rumsey Digitally signed by RUMSEY.SCOTT.MATHEW.1365888341 Date: 2024.01.12 10:00:47 -08'00' Date: 1/12/24

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.DEAN.1365850948 Digitally signed by RAUCH.SAMUEL.DEAN.1365850948 Date: 2024.01.24 10:42:41 -05'00' Date: _______