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

NOAA's National Marine Fisheries Service's Preferred Alternative for Expenditure of Pacific Salmon Treaty Funds to Increase Prey Availability for Southern Resident Killer Whales

NMFS Consultation Number: WCRO-2024-00664

Action Agencies: The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA)

Affected Species and NMFS' Determinations:

ESA-Listed Species*	**Status**	**Is Action Likely to Adversely Affect Species?**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely to Adversely Affect Critical Habitat?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
Lower Columbia River Chinook Salmon (*Oncorhynchus tshawytscha*)	Threatened	Yes	No	Yes	No
Snake River Fall-run Chinook Salmon (*O. tshawytscha*)	Threatened	Yes	No	Yes	No
Upper Willamette River Chinook Salmon (*O. tshawytscha*)	Threatened	Yes	No	Yes	No
Puget Sound Chinook Salmon (*O. tshawytscha*)	Threatened	Yes	No	Yes	No
Upper Columbia River spring-run Chinook Salmon (*O. tshawytscha*)	Endangered	Yes	No	Yes	No
Snake River spring/summer-run Chinook Salmon (*O. tshawytscha*)	Threatened	Yes	No	Yes	No

ESA-Listed Species*	**Status**	**Is Action Likely to Adversely Affect Species?**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely to Adversely Affect Critical Habitat?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
California Coastal Chinook Salmon (*O. tshawytscha*)	Threatened	Yes	No	No	No
Central Valley spring-run Chinook Salmon (*O. tshawytscha*)	Threatened	Yes	No	No	No
Central California Coast Coho Salmon (*Oncorhynchus kisutch*)	Endangered	No	No	No	No
Southern Oregon/Northern California Coast Coho Salmon (*O. kisutch*)	Threatened	No	No	No	No
Oregon Coast Coho Salmon (*O. kisutch*)	Threatened	No	No	No	No
Lower Columbia River Coho Salmon (*O. kisutch*)	Threatened	Yes	No	Yes	No
Columbia River Chum Salmon (*Oncorhynchus keta*)	Threatened	Yes	No	Yes	No
Hood Canal summer-run Chum salmon (*O. keta*)	Threatened	Yes	No	Yes	No
Snake River Sockeye Salmon (*Oncorhynchus nerka*)	Endangered	Yes	No	Yes	No
Lake Ozette Sockeye Salmon (*O. nerka*)	Threatened	No	No	No	No
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	Yes	No
Upper Columbia River steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Snake River Basin steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No

ESA-Listed Species*	**Status**	**Is Action Likely to Adversely Affect Species?**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely to Adversely Affect Critical Habitat?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
Middle Columbia River steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Upper Willamette River steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Lower Columbia River steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Northern California Coast steelhead (*O. mykiss*)	Threatened	No	No	No	No
California Central Valley steelhead (*O. mykiss*)	Threatened	No	No	No	No
Central California Coast steelhead (*O. mykiss*)	Threatened	No	No	No	No
South Central California Coast steelhead (*O. mykiss*)	Threatened	No	No	No	No
Southern California Coast steelhead (*O. mykiss*)	Endangered	No	No	No	No
Southern Resident killer whales (*Orcinus orca*)	Endangered	No	No	No	No
Sturgeon, green – Southern Distinct Population Segment (*Acipenser medirostris*)	Threatened	No	No	No	No
Eulachon – Southern Distinct Population Segment (*Thaleichthys pacificus*)	Threatened	Yes	No	No	No
Puget Sound/Georgia Basin bocaccio (*Sebastes paucispinis*)	Endangered	Yes	No	No	No

ESA-Listed Species*	**Status**	**Is Action Likely to Adversely Affect Species?**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely to Adversely Affect Critical Habitat?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
Puget Sound/Georgia Basin yelloweye rockfish (*Sebastes ruberrimus*)	Threatened	Yes	No	No	No

*Please refer to section 2.12 for the analysis of species or critical habitat that are not likely to be adversely affected.

Fishery Management Plan That Identifies EFH in the Project Area	**Does Action Have an Adverse Effect on EFH?**	**Are EFH Conservation Recommendations Provided?**
Coastal Pelagic Species	No	No
Highly Migratory Species	No	No
Pacific Coast Salmon	Yes	Yes
Pacific Coast Groundfish	No	No

Consultation Conducted By: National Marine Fisheries Service, West Coast and Alaska Regions

Jennifer Quan
Regional Administrator
NOAA's National Marine Fisheries Service
West Coast Regional Office

Jonathan M. Kurland
Regional Administrator
NOAA's National Marine Fisheries Service
Alaska Regional Office

Date: September 25, 2024

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ACRONYMS AND ABBREVIATIONS

AABM Aggregate Abundance-Based Management
Abs Absolute
ADF&G Alaska Department of Fish and Game
Adj Needs Adjusting
AK Alaska
A/P Abundance and Productivity
APs Alkylphenols
Avg Average
BC British Columbia
BIA Bureau of Indian Affairs
BIAs Biologically Important Areas
BRT Biological Review Team
BSAI Bering Sea/Aleutian Islands
C Core
CA California
CET Critical Escapement Thresholds
CFR Code of Federal Regulations
CI Confidence Interval
CIF Central Incubation Facility
CO_2 Carbon Dioxide
CPS Coastal Pelagic Species
CPUE Catch per Unit Effort
CTC Chinook Technical Committee
CV Coefficient of Variation
CWR Center for Whale Research
CWT Coded-wire Tag
dB Decibels
DDT Dichlorodiphenyltrichloroethane
DEQ Department of Environemental Quality
DFO Fisheries and Oceans Canada
DIP Demographically Independent Population
DNA Deoxyribonucleic acid
DPS Distinct Population Segment
DQA Data Quality Act
E Endangered
EEZ Exclusive Economic Zone
EFH Essential Fish Habitat
EFP Exempted Fishing Permit
ENSO El Niño Southern Oscillation
EPA Environmental Protection Agency
ER Exploitation Rate
ESA Endangered Species Act
ESU Evolutionarily Significant Unit
FA Fall-run
FCRPS Federal Columbia River Power System
FERC Federal Energy Regulatory Commission
FMEP Fishery Management Evaluation Plan
FMP Fishery Management Plan
FR Federal Register
FRAM Fisheries Regulation Assessment Model
Ft Feet
FY Fiscal Year
G Genetic
GOA Gulf of Alaska
GHL Guideline Harvest Level
GSI Genetic Stock Identification
H High
H+ Very High
HGMP Hatchery and Genetic Management Plan
HMS Highly Migratory Species
HO Hatchery Origin
HOB Hatchery Origin Broodstock
HOR Hatchery Origin Recruits
HOS Hatchery Origin Spawners
HR Harvest rate
HV Highly Viable
Hz Hertz
ICTRT Interior Columbia Technical Recovery Team
IDEQ Idaho Department of Environmental Quality
IPCC Independent Panel on Climate Change
IQR Interquartile Range
ISAB Independent Scientific Advisory Board
ISBM Individual Stock-Based Management
ITS Incidental take statement
JF Juan de Fuca
kcal/kg kilocalorie/kilogram
kg kilogram
kHz kilohertz
km kilometers
km^2 square kilometers
Kt knots
L Low
LCREP Lower Columbia River Estuary Partnership
LFH Lyons Ferry Hatchery
LFR Late Fall-run
LOF List of Fisheries
M Moderate
m meters

M/A/G Mill/Abernathy/Germany
MaSa Major Spawning Area
MF Middle Fork
mi miles
mi^2 square miles
MMPA Marine Mammal Protection Act
MPG Major Population Group
MSA Magnuson-Stevens Fishery Conservation and Management Act
M/SI Mortality and Serious Injury
MSY Maximum Sustainable Yield
MU Management Unit
MUP Management Unit Profile
N North
NA Not Available
NAS Naval Air Station
NBC North British Columbia
NCBC North/Central British Columbia
NEPA National Environmental Policy Act
NF North Fork
NFH National Fish Hatchery
NMFS National Marine Fisheries Service
nm Nautical Miles
NOAA National Oceanic and Atmospheric Administration
NO Natural Origin
NOB Natural Origin Broodstock
NOF North of Falcon
NOR Natural Origin Recruits
NOS Natural Origin Spawners
NPDES National Pollutant Discharge Elimination System
NPEAs Natural Production Emphasis Areas
NPFMC North Pacific Fishery Management Council
NPMP Northern Pikeminnow Management Program
NPS National Park Service
NWFSC Northwest Fisheries Science Center
ODFW Oregon Department of Fish and Wildlife
ONI Oceanic Niño Index
Opinion Biological Opinion
OR Oregon
PAHs Polycyclic Aromatic Hydrocarbons
PALs Passive Aquatic Listeners
Parties U.S. and Canada as it pertains to the Pacific Salmon Treaty
PBFs Physical or biological features
PBT Parental Based Tagging
PCE Primary Constituent Element
PDO Pacific Decadal Oscillation
PFAs Polyfluoroalkyl substances
PFMC Pacific Fishery Management Council
pHOS Proportion Hatchery Origin Spawners
PIT Passive Integrated Transponder
PNI Proportion Natural Influence
ppb parts per billion
PRA Population Recovery Approach
PSC/Commission Pacific Salmon Commission
PSIT Puget Sound Indian Tribes
PST/Treaty Pacific Salmon Treaty
PSTRT Puget Sound Technical Recovery Team
PUDs Public Utility Districts
Rel Relative
RER Rebuilding Exploitation Rates
RKM River Kilometer
RMP Resource Management Plan
rms root mean square
ROD Record of Decision
ROV Remotely Operated Vehicle
RPA Reasonable and Prudent Alternative
RPMs Reasonable and Prudent Measures
SAR Stock Assessment Report
SEAK Southeast Alaska
SF South Fork
SP Spring-run
SP/LP Sand Point and La Push
SRFC Snake River Rall-run Chinook
SRFI Snake River Rall-run Chinook Index
SRKW Southern Resident Killer Whale
SS/D Spatial Structure and Diversity
SSPS Shared Strategy for Puget Sound
SUS Southern United States
SWFSC Southwest Fisheries Science Center
SWWCVI Southwest Coast of Vancouver Island
T Threatened
TAC Total Allowable Catch
TBD To Be Determined
TBR Transboundary River
TRT Technical Recovery Team
TTS Temporary Threshold Shifts
UET Rebuilding/Upper Escapement Thresholds
UME Unusual Mortality Event
U.S. United States

USACE United States Army Corps of Engineers
U.S.C. United States Code
USCG United States Coast Guard
USFWS United States Fish and Wildlife Service
USGCRP United States Global Change Research Program
V Viable
VH Very High
VL Very Low
VSP Viable salmonid population
W West
WA Washington
WCR West Coast Region
WCVI West Coast Vancouver Island
WDFW Washington Department of Fish and Wildlife
WLC Willamette-Lower Columbia
WLC TRT Willamette-Lower Columbia Technical Recovery Team

DEFINITIONS

Abundance-based sliding scale gene flow management. This approach allows more hatchery fish on the spawning grounds (higher pHOS), and thus greater hatchery influence (lower PNI), during years when natural population abundance is low. This accepts a greater genetic risk to gain demographic benefits (greater overall number of spawners) and thus lessen the extirpation or extinction risk presented by the low number of natural-origin spawners. During years when the natural population abundance is higher and risk of extirpation or extinction is reduced, genetic risk is curtailed by requiring higher PNI and lower pHOS. This approach attempts to balance the risk of extirpation (low natural-origin abundance) with the risk of hatchery influence.

Genetically linked. Functionally equivalent to the stepping-stone genetic management strategy.

Hatchery-origin (HO). Fish that have been reared and released by a hatchery program, regardless of the origin (hatchery or natural) of their parents.

Hatchery-origin recruits (HOR). Hatchery-origin fish that have returned to freshwater as adults or jacks. Usage varies, but typically the term refers to fish that have escaped fisheries and that will spawn in nature or be collected and used for hatchery broodstock or euthenized.

Hatchery-origin spawners (HOS). Hatchery-origin fish that spawn in nature.

Hatchery-origin broodstock (HOB). Hatchery-origin fish that are spawned in the hatchery (i.e., used as broodstock). This term is rarely used.

Integrated genetic management strategy. One of three primary strategies for managing a hatchery program's genetic relationship with a natural population (the other two are segregated, also known as isolated, and stepping-stone). The integrated strategy intentionally incorporates natural-origin fish into the hatchery broodstock at some level (i.e., pNOB > 0). In an ideal integrated program, natural-origin and hatchery-origin fish represent two components of a single gene pool that is locally adapted to the natural habitat. The integrated strategy is intended to maintain natural population genetics within the hatchery program, and thus maintain genetic continuity between the hatchery and affected natural population(s).

Isolated genetic management strategy. Same as segregated.

Natural-origin (NO). Fish whose parents spawned in nature, regardless of the origin (natural or hatchery) of those parents.

Natural-origin recruits (NOR). Natural-origin fish that have returned to freshwater as adults or jacks. Usage varies, but typically the term refers to fish that have escaped fisheries and that will either spawn in nature or be collected and used for hatchery broodstock.

Natural-origin spawners (NOS). Natural-origin fish that spawn in nature.

Natural-origin broodstock (NOB). natural-origin fish that are spawned in the hatchery (i.e., are used as broodstock). An important derivative term is pNOB, the proportion of a hatchery program's broodstock consisting of NO fish.

pHOS (proportion of hatchery-origin spawners). The proportion of fish on a natural population's spawning grounds that are hatchery origin. pHOS is the expected maximum genetic contribution of HO spawners to the naturally spawning population.

PNI (Proportionate Natural Influence). Proportional influence that natural-origin fish have on a composite hatchery-/natural-origin population. Can also be thought of as the percentage of time the genes of a composite population spend in the natural environment. Calculated as:

$$PNI = \frac{pNOB}{(pNOB + pHOS)}$$

pNOB (proportion of natural-origin brood). The proportion of a hatchery program's broodstock consisting of natural-origin fish.

Predator buffering. Occurs when a mass of hatchery fish in an area overwhelms established predator populations, providing a beneficial, protective effect to co-occurring natural-origin fish. That is, by providing a large abundance of additional prey, hatchery-origin fish may ease predation on natural-origin fish when they occur in the same places at the same times.

Predator swamping. Same as predator buffering.

Segregated genetic management strategy. One of three primary strategies for managing a hatchery program's genetic relationship with a natural population (the other two are integrated and stepping-stone). Segregated programs do not intentionally incorporate natural-origin fish into the broodstock (i.e., pNOB = 0). The intent of a segregated hatchery program is to maintain a genetically distinct hatchery population. This strategy is intended to maintain complete (or near complete) genetic separation of hatchery and natural populations.

Stepping-stone genetic management strategy. One of three primary strategies for managing a hatchery program's genetic relationship with a natural population (the other two are integrated and segregated, also known as isolated). It can be thought of as a combination of or intermediary between the other two, typically used when natural production is too low to support a fully integrated program (or to tolerate a segregated one) of sufficient size to meet program objectives. To increase the integration over time, a percentage of returning fish from the integrated component are used as broodstock in the segregated component. As overall abundance of adult returns from the integrated component increases, the segregated component includes a greater proportion of integrated returns in the broodstock. Initial analysis by NMFS of programs connected this way shows that these linked programs pose considerably less risk of hatchery-influenced selection than solely segregated programs because they maintain a genetic linkage with the naturally spawning population (Busack 2015).

1 INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1 Background

The National Marine Fisheries Service (NMFS) prepared the Biological Opinion (Opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 United States Code (U.S.C.) 1531 et seq.), as amended, and implementing regulations at 50 Code of Federal Regulations (CFR) part 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR part 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available within 2 weeks at the NOAA Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at the Lacey, Washington NMFS office.

This document constitutes the NMFS' Opinion under Section 7 of the ESA and MSA EFH consultation for the federal action proposed by NMFS described in Section 1.3. NMFS proposes to provide annual funding to hatchery operators throughout Washington, Oregon, and Idaho to produce Chinook salmon smolts for the specific purpose of increasing the preferred forage base of the ESA-endangered Southern Resident Killer Whale (SRKW) thereby mitigating for the effects of prey removal in fisheries subject to the Pacific Salmon Treaty (PST). This proposed funding action is referred to as the "federal SRKW prey program" or "federal prey program." This Opinion considers effects, including adverse effects, of the proposed action on ESA-listed species and their critical habitat as catalogued in Table 1. A species of Pacific salmon designated for ESA listing is referred to as an Evolutionarily Significant Unit (ESU). Other ESA-listed species discussed in this Opinion are referred to as Distinct Population Segment(s) (DPS). In addition, Section 2.12 provides information supporting "not likely to adversely affect" determinations for other ESA-listed species and critical habitat that occur in the action area (Table 2).

Table 1. Species and ESUs or DPSs likely to be adversely affected (LAA) by the proposed action considered in this Opinion (Section 1.3), including Federal Register (FR) notices for the final rules that listed the ESUs or DPSs under the ESA, designated critical habitat, and applied protective regulations. An asterisk (*) indicates that designated critical habitat for the species is not likely to be adversely affected.

Species and ESU/DPS	Listing Status[a]	Critical Habitat	Protective Regulations[b]
Chinook salmon *(Oncorhynchus tshawytscha)*			
Lower Columbia River	T: 79 FR 20802, 4/14/14	70 FR 52629, 9/2/05	70 FR 37159, 6/28/05
Puget Sound	T: 79 FR 20802, 4/14/14	70 FR 52629, 9/2/05	70 FR 37159, 6/28/05
Snake River fall-run	T: 79 FR 20802, 4/14/14	58 FR 68543, 12/28/93	70 FR 37159, 6/28/05
Snake River spring/summer-run	T: 79 FR 20802, 4/14/14	64 FR 57399, 10/25/99	70 FR 37160, 6/28/05
Upper Columbia River spring-run	E: 70 FR 20816, 4/14/14	70 FR 52732, 9/02/05	Section 9
Upper Willamette River	T: 79 FR 20802, 4/14/14	70 FR 52629, 9/2/05	70 FR 37159, 6/28/05
California Coastal	T: 79 FR 20802, 4/14/14	70 FR 52488, 9/02/05	70 FR 37160, 6/28/05
Central Valley spring-run	T: 79 FR 20802, 4/14/14	70 FR 52488, 9/02/05	70 FR 37160, 6/28/05
Chum salmon *(O. keta)*			
Columbia River	T: 79 FR 20802, 4/14/14	70 FR 52746, 9/02/05	70 FR 37160, 6/28/05
Hood Canal summer-run	T: 79 FR 20802, 4/14/14	70 FR 52630, 9/02/05	70 FR 37160, 6/28/05
Coho salmon *(O. kisutch)*			
Lower Columbia River	T: 79 FR 20802, 4/14/14	81 FR 9252, 02/24/16	70 FR 37160, 6/28/05
Sockeye salmon *(O. nerka)*			
Snake River	E: 79 FR 20802, 04/14/14	70 FR 52630, 9/02/05	Section 9
Steelhead *(O. mykiss)*			
Puget Sound	T: 79 FR 20802, 4/14/14	81 FR 9252, 02/24/16	73 FR 55451, 9/25/08
Lower Columbia River	T: 79 FR 20802, 4/14/14	70 FR 52833, 9/02/05	70 FR 37160, 6/28/05
Upper Willamette River	T: 79 FR 20802, 4/14/14	70 FR 52848, 9/02/05	70 FR 37160, 6/28/05
Middle Columbia River	T: 79 FR 20802, 4/14/14	70 FR 52808, 9/02/05	70 FR 37160, 6/28/05
Upper Columbia River	T: 79 FR 20802, 4/14/14	70 FR 52630, 9/02/05	71 FR 5178, 2/01/06
Snake River Basin	T: 79 FR 20802, 4/14/14	70 FR 52769, 9/02/05	70 FR 37160, 6/28/05
Other species			
Bocaccio (*S. paucispinis*)*	E: 75 FR 22276; 4/28/10	79 FR 68041; 11/13/14	Section 9
Yelloweye rockfish (*S. ruberrimus*)*	T: 75 FR 22276; 4/28/10	79 FR 68041; 11/13/14	-
Eulachon (*Thaleicthys pacificus*), Southern DPS*	T: 75 FR 13012, 3/18/10	76 FR 6532, 10/2/11	-

[a] T = ESA-listed as threatened; E = ESA-listed as endangered.
[b] Where indicated, "Section 9" means that no additional protective regulations apply beyond ESA Section 9 statutory prohibitions.

Table 2. Species and ESUs or DPSs not likely to be adversely affected (NLAA) by the proposed action considered in this Opinion (Section 1.3). Also shown are FR notices for the final rules that listed the ESUs or DPSs under the ESA, designated critical habitat, and applied protective regulations.

Species and ESU/DPS	Listing Status[a]	Critical Habitat	Protective Regulations[b]
Coho salmon *(O. kisutch)*			
Oregon Coast	T: 79 FR 20802, 4/14/14	73 FR 7816, 02/11/08	73 FR 7816, 02/11/08
Southern Oregon/Northern California Coast	T: 79 FR 20802, 4/14/14	64 FR 24049, 05/05/99	70 FR 37160, 6/28/05
Central California Coast	E: 79 FR 20802, 4/14/14	64 FR 24049, 5/05/99	Section 9
Sockeye salmon *(O. nerka)*			
Ozette Lake	T: 79 FR 20802, 4/14/14	70 FR 52756, 9/02/05	70 FR 37160, 6/28/05
Steelhead *(O. mykiss)*			
Northern California	T: 71 FR 834, 1/05/06	70 FR 52769, 9/02/05	70 FR 37160, 6/28/05
California Central Valley	T: 79 FR 20802, 4/14/14	70 FR 52769, 9/02/05	70 FR 37160, 6/28/05
Central California Coast	T: 79 FR 20802, 4/14/14	70 FR 52769, 9/02/05	70 FR 37160, 6/28/05
South-Central California Coast	T: 79 FR 20802, 4/14/14	70 FR 52769, 9/02/05	70 FR 37160, 6/28/05
Southern California	E: 79 FR 20802, 4/14/14	70 FR 52769, 9/02/05	Section 9
Other fish species (non-salmonids)			
Green sturgeon (*Acipenser medirostis*), Southern DPS	T: 71 FR 17757, 4/7/06	74 FR 52300, 10/9/09	75 FR 30714, 6/22/10
Marine mammals			
Killer Whale, Southern Resident DPS (*Orcinus orca*)	E: 70 FR 69903; 11/18/05	71 FR 69054, 11/29/06; 86 FR 41668; 8/2/21	Section 9

[a] T = ESA-listed as threatened; E = ESA-listed as endangered.
[b] Where indicated, “Section 9” means that no additional protective regulations apply beyond ESA Section 9 statutory prohibitions.

1.2 Consultation History

NMFS first consulted on the federal SRKW prey program in a 2019 Opinion (NMFS 2019j) that also consulted on the following federal actions: delegation of management authority over salmon fisheries in the Exclusive Economic Zone (EEZ) in southeast Alaska (SEAK) to the State of Alaska; grants to the State of Alaska for the State’s management of commercial and sport salmon fisheries and transboundary river enhancement necessary to implement the 2019 PST Agreement; and, federal funding of a conservation program for critical Puget Sound stocks related to the 2019 PST Agreement. NMFS concluded in the 2019 Opinion that the proposed actions were not likely to jeopardize the continued existence of any of the listed species and that the actions were not likely to destroy or adversely modify designated critical habitat for any of the listed species (NMFS 2019j).

In 2020, the Wild Fish Conservancy, a 501(c)3 nonprofit organization, filed a lawsuit in the U.S. District Court for the Western District of Washington alleging that the issuance of the 2019 Opinion violated the ESA and the National Environmental Policy Act (NEPA). On August 8, 2022, the District Court found that NMFS violated both the ESA and NEPA. With respect to the ESA, the Court determined that NMFS failed to adequately evaluate whether the federal SRKW prey program would jeopardize the continued existence of ESA-listed Chinook salmon, and that NMFS improperly relied on uncertain mitigation to reach its conclusion that the federal actions related to the SEAK fisheries were not likely to jeopardize ESA-listed Chinook salmon and SRKW. With respect to NEPA, the Court concluded NMFS failed to conduct necessary NEPA analyses for the issuance of the ITS that exempted take associated with the SEAK salmon fisheries from liability under ESA Section 9, and for the federal prey program. The Court remanded the Opinion to NMFS to remedy the flaws it identified. The Court also vacated the portions of the ITS exempting from Section 9 liability take of SRKW and Chinook salmon resulting from harvest in the winter and summer commercial troll salmon fishery. The vacatur was stayed by the U.S. Court of Appeals for the Ninth Circuit on June 21, 2023. The Court did not vacate the findings of the Opinion with regard to the federal SRKW prey program or enjoin the program. On August 16, 2024, the U.S. Court of Appeals for the Ninth Circuit issued a decision that reversed the district court’s partial vacatur of the ITS. This Opinion responds to the Court’s order in regards to ESA review of the federal SRKW prey program.

Detailed histories of hatchery consultations in general within the action area can be found in the Consultation History sections of the following Opinions: 1) NMFS (2020d) for Puget Sound; and, 2) in NMFS (2017o) and NMFS (2018e) for the Columbia River basin. The Consultation History sections of these Opinions are incorporated here by reference.

In 2020, NMFS consulted on the impact of Puget Sound-area salmon and steelhead hatchery programs to listed species that occur only in marine waters (e.g., listed rockfish) (NMFS 2020d), hereafter referred to as the Puget Sound hatcheries and marine species consultation. The proposed action for that consultation was the ongoing operation of hatcheries to bolster salmon and steelhead populations, mitigate for habitat loss, and offer fishing opportunities, not specifically to increase prey resources for SRKWs. For Chinook salmon, we used a “current (2020) release” number of 51.7 million fish. We then also considered a “high release” scenario to evaluate the upper end of likely/potential Chinook releases for all purposes (e.g., harvest, salmon conservation). The number used for this scenario was 88.1 million Chinook, which the action agency (NMFS Sustainable Fisheries Division [SFD]) provided after considering production capacity should all hatcheries in the region operate at their maximum currently achievable level. At the time, we characterized the high release estimate combined with other precautionary estimates for rockfish as a maximum scenario to bookend potential impacts and assess foreseeable risk potential given theoretical operationalization of all existing hatchery infrastructure.

The 2020 Puget Sound hatcheries and marine species consultation (NMFS 2020d) clearly identifies and evaluates anticipated impacts to listed yelloweye rockfish and bocaccio likely to result from maximal production of Chinook salmon in Puget Sound, and conservation measures to minimize those impacts. All model formulation, analyses, and conservation measures from NMFS (2020d) are incorporated herein by reference as they apply to hatchery program activities and operational capacity that have not changed appreciably since that time. The high release scenario evaluated in 2020 and described in the preceding paragraph exceeds the levels of releases that would occur including the proposed action here, facilitating an abbreviated analysis of the Effects of the Action below.

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 Fed. Reg. 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent measures), were not intended to result in changes to the Services' existing practice in implementing section 7(a)(2) of the Act (89 Fed. Reg. at 24268; 84 Fed. Reg. at 45015). We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this biological opinion and incidental take statement would not have been any different under the 2019 regulations or pre-2019 regulations.

1.3 Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies (50 CFR 402.02). Under the MSA, "Federal action" means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910).

NMFS, through its West Coast Region office, proposes to provide annual funding to hatchery operators throughout Washington, Oregon, and Idaho to produce Chinook salmon smolts for the specific purpose of increasing the preferred forage base of the ESA-endangered SRKW, thereby mitigating for the effects of prey removal in fisheries subject to the PST. Hereafter, we will refer to this proposed funding action as the "federal SRKW prey program", or simply as the "federal prey program."

The purpose of the federal prey program is to mitigate the effects of fisheries managed under the PST with a goal to meaningfully increase adult hatchery-origin Chinook salmon abundance in marine waters at times and in places most beneficial to SRKWs. As described in NMFS's preferred alternative that is detailed in the Final Environmental Impact Statement for Expenditure of Funds to Increase Prey Availability for Southern Resident Killer Whales (NMFS 2024e), the goal of the federal prey program is to increase the abundance of Chinook salmon in marine waters by up to 4–5%. Further, hatchery fish releases should come from the following two regions: 1) Puget Sound; and, 2) the Columbia River basin and the Washington coast. Hatchery production from both of these regions is important for providing prey across the array of times and places needed by SRKWs, indicated as Puget Sound in the summer and coastal areas in the winter (Dygert 2018). Dygert (2018) specified hatchery production goals from each region that would achieve the goal of the federal prey program. However, a new modelling tool—the FRAM-Shelton model (PFMC 2020c)—provides a more sophisticated approach for determining this. This FRAM-Shelton model will be used in determining hatchery production goals from each region to satisfy the goal of the prey program.

The following criteria will be used by NMFS each year when selecting hatchery program operator proposals eligible to receive funding:

1. Prey program-funded hatchery production should be for Chinook salmon stocks that are a high priority for SRKW (NOAA Fisheries and WDFW 2018; PFMC 2020c).
2. Prey program-funded hatchery production should be distributed across an array of priority Chinook salmon stocks from different geographic areas and run timings (i.e., a diverse portfolio).
3. Prey program-funded hatchery production cannot jeopardize the survival and recovery of any ESA-listed species, including salmon or steelhead.
4. Prey program funding proposals should not include or require major capital upgrades to hatchery facilities.
5. All prey program funding proposals should have fisheries co-manager agreement (i.e., agreement among relevant tribal, state, and federal hatchery managers), as applicable.
6. Prey program-funded hatchery programs must have been reviewed under the ESA and NEPA, as applicable, before NMFS funding can be used. That is, a facility- and hatchery program-level (i.e., “site-specific”) ESA and NEPA review must be completed.

In applying criterion 2 each year, NMFS will consider its funding in conjunction with any Washington State-funded SRKW-directed hatchery production. That is, each year’s federal funding decision will be made after taking into consideration any Washington State-funded SRKW-directed hatchery production to be implemented that year, such that the combined federal- and state-funded SRKW-directed production satisfies criterion 2.

In applying criterion 6 each year, prey program funding will be contingent on NMFS determination that the actions, analyses of effects, incidental take limits, and Terms and Conditions described in the NMFS and USFWS site-specific Opinions and associated ITSs, as well as this Opinion and its ITS, remain in force. Site-specific Opinions have associated individual ITSs to specify the amount or extent of resultant incidental take from the proposed action, and to ensure that the impact of such take on ESA-listed species is minimized. As part of these ITSs, NMFS requires hatchery operators to submit annual reports detailing that the programs were implemented as described in the Opinions and operated in accordance with their respective ITSs, including associated Terms and Conditions. NMFS will continue to review and monitor these programs and reports, and make an annual determination that criterion 6 is met, communicating that determination to each Service annually prior to issuing funds to any specific program.

NMFS has been funding the federal prey program through annual Congressional appropriations for the Department of Commerce to implement the U.S. domestic aspects of the 2019–2028 PST agreement. NMFS develops an annual spending plan for allocating the PST appropriation. Beginning with FY 2020, NMFS has annually directed a portion of the PST funding to the federal SRKW prey program. The exact annual dollar amount NMFS allocates to the federal prey program may vary from year to year depending on the Congressional PST appropriation. For example, NMFS allocated $5.6–7.3 million annually for FYs 2020–2023 to the federal prey program out of $35.1–39.5 million. Most recently in FY 2024, per its spend plan report to Congress, NMFS allocated $5.7 million out of $41 million Congressionally appropriated funds for 2019–2028 PST implementation. For this Opinion we expect similar or greater amounts in NMFS allocations for the federal prey program, up to the amount needed to achieve the 4–5% prey increase goal (NMFS 2024e).

The number of hatchery salmon produced each year will likely vary depending on the funding amount and other factors such as hatchery operational expenses and broodstock[1] availability. Typical variables associated with rearing live fish (e.g., individual female salmon fecundity, in-hatchery egg-to-smolt[2] survival) may also cause annual release numbers to fluctuate. In site-specific ESA consultations, NMFS accounts for overages relative to production goals. Such overages are common and arise from the nature of managing for the aforementioned variables. Thus, the number of federal prey program-funded smolts released in a given year will vary, but is expected to be up to approximately 20 million smolts to achieve these specified adult abundances in the ocean, as explained in the NEPA preferred alternative (NMFS 2024e). Up to 22 million smolts may be released in any given year due to the variables described above. However, we expect that the average releases over any 5-year period will not exceed 21 million smolts.

Our expectation of hatchery smolt production is based on a number of factors. Foremost, hatchery operators have identified facilities with available capacity to produce Chinook salmon for SRKW prey that meet criteria 1 and 4. Most of these also meet criterion 6 for site-specific ESA and NEPA review. Those that do not currently meet criterion 6 currently have site-specific ESA and NEPA reviews in informal or formal consultation phases, except for Washington coast facilities[3]. These programs would not be eligible for federal funding for SRKW prey production until they meet criterion 6.

The current estimated production capacity available for SRKW prey production that meet criteria 1 and 4 is 28.3 million Chinook salmon smolts, distributed as follows: 14.4 million smolts for Puget Sound region facilities, and 13.9 million smolts for the region comprising Columbia River

[1] Broodstock are the mature adult hatchery salmon that are used to produce more progeny in the hatchery.
[2] A smolt is a young salmon life stage, after the parr stage, when it becomes silver and migrates from fresh water to the sea.
[3] Washington coast facilities operate in areas currently with no ESA-listed species under NMFS jurisdiction. Thus, there are no effects to listed species in the freshwater areas where these facilities operate. NMFS has issued 90-day findings that petitions to list the following warrant further review: Washington Coast Chinook Salmon ESU (88 FR 85178), the Oregon Coast and Southern Oregon and Northern California Coastal Chinook Salmon ESUs (88 FR 1548), and the Olympic Peninsula Steelhead DPS (88 FR 8774). In instances where an ESA-listed species is affected by Washington coast facilities' operations due to a new listing, the criteria would still need to apply for funding to be awarded, meaning site-specific ESA consultations could be necessary if any of these petitions resulted in a subsequent ESA listing.

(9.8 million smolts) and Washington coast (4.1 million smolts) facilities[4]. These represent approximate upper limits on SRKW prey program production goals from each of these regions, pending satisfaction of criteria 2, 3, 5, and 6. However, assuming all criteria were satisfied, these levels would not be achieved for both regions in the same year because the total available capacity (28.3 million smolts) would exceed the number needed to meet the prey program's goal of up to a 4–5% increase in SRKW prey abundance.

Federal prey program funding is not limited to only those facilities that have currently available capacity. For example, a hatchery currently using all of its production capacity to meet needs unrelated to the federal prey program may experience future budget cuts and downsizing of those programs, thereby freeing-up capacity. Federal prey program funding could be used to produce Chinook salmon smolts with that newly freed-up capacity, assuming all 6 criteria are met. However, such instances are likely to be limited and, therefore, unlikely to cause federal prey program-funded production to exceed the regional production limits noted above.

Current NMFS modelling using the FRAM-Shelton model[5] (Appendix A) shows that releasing smolts at the maximum available capacity from either region would broadly achieve a 4–5% increase in SRKW prey, as intended, though neither scenario would achieve it at all priority times and places (Table 3). That is, maximizing Puget Sound production (i.e., 14.4 million smolts from Puget Sound with an additional 5.6 million smolts from the Columbia River and Washington Coast) can achieve a 4–5% increase in SRKW prey, as can maximizing Columbia River and Washington coast production (i.e., 13.9 million smolts from the Columbia River and Washington coast, with an additional 6.1 million smolts from Puget Sound). Production would not need to be maximized from either region to achieve a 4–5% prey increase, as indicated by calendar year 2023's release distribution from federal and state funding[6] (11.6 million smolts from Puget Sound and 8.3 million smolts from the Columbia River and Washington Coast) (Table 3). Thus, the regional distribution of hatchery releases may vary annually within a range set by the estimated production capacities from each region, as described above and summarized as follows: 31–72% of the 20 million hatchery smolts approximated to achieve a 4–5% prey increase would come from Puget Sound, with the remainder coming from the Columbia River and Washington coast. This was developed using a more current and sophisticated methodology (the FRAM-Shelton model) which NMFS views as the best scientific information available, than

[4] Puget Sound and Columbia River figures are based on WDFW's survey of available hatchery capacity (WDFW 2019), Hatchery and Genetic Management Plans (HGMPs) submitted to NMFS, and, where completed, in site-specific Opinions (see Table 72 in the Environmental Baseline section). The Washington coast estimate is based on WDFW's survey of available hatchery capacity (WDFW 2019) and verbal and written communication from hatchery operators. Actual capacity available for SRKW prey production may vary depending on changes to other salmon and steelhead programs operated at hatcheries (e.g., harvest, harvest management, salmon conservation and recovery programs).
[5] The FRAM-Shelton model has been updated with new information since it was initially proposed in 2020. We used the current, up-to-date version throughout this Opinion.
[6] State funding of hatchery Chinook salmon for SRKW prey increase is not part of the proposed action. It is mentioned here only to provide a real-world example of how releasing approximately 20 million Chinook salmon smolts without maximizing production from either region (Puget Sound or Columbia River and Washington coast) can achieve a 4–5% increase in adult and subadult marine Chinook salmon abundance.

did Dygert (2018), and is therefore more likely to ensure that the goal of the federal prey program (to increase prey abundance in the times and areas most important to SRKW) is met.

NMFS will annually estimate the SRKW prey increase expected to be achieved with federal prey program funding using the FRAM-Shelton modeling methodology[7] described in the Pacific Fishery Management Council's (PFMC) SRKW Risk Assessment Ad Hoc Workgroup Report (PFMC 2020c). This same methodology was employed in our programmatic evaluation of the

Table 3. Modeled increase in marine abundance of adult Chinook salmon under different possible hatchery release scenarios (Appendix A). Not all possible release scenarios were modeled. The percent increase shown is relative to all adult Chinook salmon, hatchery- and natural-origin combined. Bolded entries are the times and places where SRKW are expected to benefit from increased prey abundance (Dygert 2018).

Region	Time period	Modeled increase in Chinook salmon (age 3–5)		
		Puget Sound capacity maximized[a]	Columbia R. and Washington coast capacity maximized[b]	Actual calendar year 2023 releases[c]
Salish Sea	October–April	9.2%	4.3%	8.0%
	May–June	**6.1%**	**3.0%**	**5.0%**
	July–September	**1.6%**	**1.1%**	**1.3%**
Southwest portion of the west coast of Vancouver Island	**October–April**	**6.2%**	**6.4%**	**5.7%**
	May–June	5.9%	4.1%	5.1%
	July–September	5.5%	3.6%	4.9%
Washington coast (north of Cape Falcon, OR)	**October–April**	**4.0%**	**4.6%**	**3.8%**
	May–June	1.5%	1.7%	1.2%
	July–September	2.8%	5.8%	2.8%
Oregon coast (south of Cape Falcon, OR)	**October–April**	**0.7%**	**1.1%**	**0.7%**
	May–June	0.4%	0.5%	0.3%
	July–September	0.3%	0.6%	0.3%
California coast	October–April	0.8%	1.4%	1.2%
	May–June	0.3%	0.2%	0.3%
	July–September	0.2%	0.2%	0.2%

[a] Modeled releases were 14.4 million smolts from Puget Sound hatcheries, and 5.6 million smolts from the Columbia River and Washington Coast hatcheries. See Appendix A for details.
[b] Modeled releases were of 6.1 million smolts from Puget Sound hatcheries, and 13.9 million smolts from the Columbia River and Washington coast hatcheries. See Appendix A for details.
[c] Modeled releases were of 12.5 million smolts from Puget Sound hatcheries, and 7.4 million smolts from the Columbia River and Washington coast hatcheries. Releases funded by the federal prey program and the Washington State program were included. See Appendix A for details.

[7] The FRAM-Shelton model may be updated with new information during the time the federal prey program is operating. The most up-to-date version of the model available at the time will be employed in making these estimations.

program under NEPA (NMFS 2024e) and used for our analysis in this Opinion. Model results will be used to evaluate program benefits to SRKW and ensure that negative effects to listed species are within the range considered in this Opinion. For example, current NMFS modelling (Appendix A) indicates that the prey program may increase adult Chinook salmon abundance by up to 9.2% in some marine areas at some times (Table 3) in order to achieve a 4–5% increase in SRKW prey at the times and places originally identified by NMFS (Dygert 2018)[8]. Proposed releases that would result in greater increases to adult Chinook salmon abundance would not be covered by this Opinion, nor would increases stemming from non-federally-funded hatchery production.

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would not.

[8] For example, releasing Puget Sound's full estimated SRKW prey production capacity of 14.4 million smolts would, based on NMFS modelling, increase abundance by 4.0% along the Washington coast during October–April (Table 3), a time and place that would benefit SRKW identified by NMFS (Dygert 2018). This would result in a larger 9.2% increase in the Salish Sea during October–April, a time not identified by NMFS (Dygert 2018) as benefitting SRKW.

2 ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

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

NMFS determined the proposed action described in Section 1.3 is not likely to adversely affect the following: 1) ESA-listed species and critical habitat shown in Table 2; and, 2) critical habitat only for species noted with an asterisk (*) in Table 1. The basis for these determinations is discussed in the "Not Likely to Adversely Affect" Determinations section (Section 2.12).

2.1 Analytical Approach

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

This Opinion also relies on the regulatory definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designations of critical habitat for the listed species discussed in this Opinion use the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the critical habitat regulations (50 CFR 424.12) replaced this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this Opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The ESA Section 7 implementing regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision does not change the scope of our analysis, and in this Opinion, we use the terms "effects" and "consequences" interchangeably.

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

1. *Identify the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action*
   Section 2.2 describes the current status of each adversely affected listed species and critical habitat relative to the conditions needed for recovery. For listed salmon and steelhead, NMFS has developed specific guidance for analyzing the status of the listed species' component populations in a "viable salmonid populations" (VSP) paper (McElhany et al. 2000). Similar criteria are used to analyze the status of ESA-listed rockfish and eulachon because these parameters are applicable for a wide variety of species. The VSP approach considers the abundance, productivity, spatial structure, and diversity of each population as part of the overall review of a species' status. For listed salmon and steelhead, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the rangewide status of listed species, we rely on viability assessments and criteria in technical recovery team documents and recovery plans, and other information where available, that describe how VSP criteria are applied to specific populations, major population groups (MPGs), and species. We determine the rangewide status of critical habitat by examining the condition of its physical or biological features (also called "primary constituent elements" or PCEs in some designations) which were identified when the critical habitat was designated.

2. *Describe the environmental baseline in the action area*
   The environmental baseline (Section 2.4) includes the past and present impacts of federal, state, or private actions and other human activities in the action area (Section 2.3). It includes the anticipated impacts of proposed federal projects that have already undergone formal or early Section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process.

3. *Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach*
   In this step (Section 2.5), NMFS considers how the proposed action would affect the species' reproduction, numbers, and distribution or, in the case of salmon and steelhead, their VSP and other relevant characteristics. NMFS also evaluates the proposed action's effects on critical habitat features.

4. *Describe any cumulative effects in the action area*
   Cumulative effects, as defined in our implementing regulations (50 CFR 402.02 and 402.17(a)), are the effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area. Future federal actions that are unrelated to the proposed action are not considered because they require separate Section 7 consultation. Cumulative effects are described in Section 2.6.

5. *Integrate and synthesize the above factors*
   This is accomplished by adding the effects of the proposed action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyzing whether the proposed action is likely to: (1) appreciably reduce, either directly or indirectly, the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species, or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species. Integration and synthesis is described in Section 2.7.

6. *Conclude whether species are jeopardized or critical habitat is adversely modified*
   Based on the logic and rationale presented in the integration and synthesis (Section 2.7), we conclude whether species are jeopardized or critical habitat is adversely modified (Section 2.8).

7. *If necessary, suggest a reasonable and prudent alternative (RPA) to the proposed action*
   If, in completing the previous step in the analysis, we determine that the proposed action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, we must identify an RPA to the proposed action. The RPA must not be likely to jeopardize the continued existence of listed species nor adversely modify their designated critical habitat and it must meet other regulatory requirements.

2.2 Rangewide Status of the Species and Critical Habitat

This Opinion examines the status of each species that is likely to be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species’ likelihood of both survival and recovery. The species status section also helps to inform the description of the species’ “reproduction, numbers, or distribution” for the jeopardy analysis. The opinion also examines the condition of designated critical habitat, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated critical habitat, and discusses the function of the PBFs that are essential for the species' conservation.

This section consists of narratives for each of the endangered and threatened species that occur in the action area and that may be adversely affected by the proposed action. In each narrative, we present a summary of information on the population structure and distribution of each species to provide a foundation for the exposure analyses that appear later in this opinion. Then we summarize information on the threats to the species and the species' status given those threats to provide points of reference for the jeopardy determinations we make later in this opinion. That is, we rely on a species' status and trend to determine whether or not an action's direct or indirect effects are likely to increase the species' probability of becoming extinct.

2.2.1 Status of Listed Species

2.2.1.1 Viability Approach

NMFS commonly uses four parameters to assess the viability of the populations that, together, constitute the species: abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). These VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. When these parameters are collectively at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment. These attributes are substantially influenced by habitat and other environmental conditions.

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

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

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

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

2.2.1.2 Listed Salmonids

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

In order to describe a species' status, it is first necessary to define what the term "species" means in this context. In addition to defining "species" as including an entire taxonomic species or subspecies of animals or plants, the ESA also recognizes listing units that are a subset of the species as a whole. As described above, the ESA allows a DPS (or in the case of salmon, an ESU) of a species to be listed as threatened or endangered. In terms of determining the status of a species, the Willamette Lower Columbia TRT (WLC TRT) developed a hierarchical approach for determining ESU-level viability criteria (Figure 1).

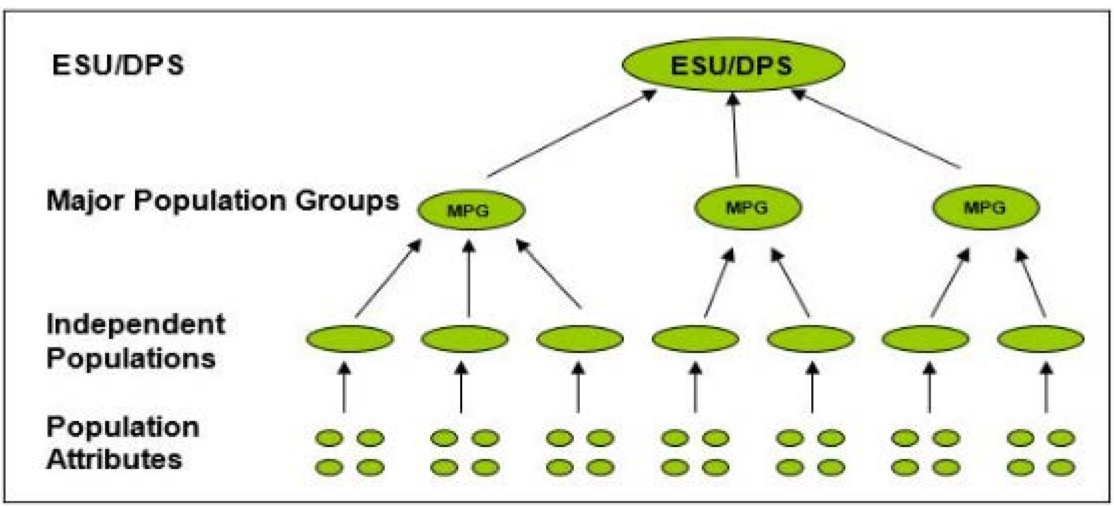

Figure 1. Hierarchical approach to ESU viability criteria.

Briefly, an ESU or DPS is divided into natural populations (McElhany et al. 2000). The risk of extinction of each population is evaluated, taking into account population-specific measures of abundance, productivity, spatial structure, and diversity. Natural populations are then grouped into ecologically and geographically similar *strata*, referred to as MPGs which are evaluated on the basis of population status. In order to be considered viable, an MPG generally must have at least half of its historically present natural populations meeting their population-level viability criteria (McElhany et al. 2006). At the MPG-level each of the ESU's MPGs also must be viable. A viable salmonid ESU or DPS is naturally self-sustaining, with a high probability of persistence over a 100-year time period.

NMFS has used this approach for the various salmon ESUs and steelhead DPSs discussed in this section, except for Puget Sound Chinook, which uses a very similar approach, but there are some differences in the details related to recovery criteria. The NMFS adopted the recovery plan for Puget Sound Chinook on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan prepared by the Shared Strategy for Puget Sound (Puget Sound Salmon Recovery Plan) (SSDC 2007) and Final Supplement to the Puget Sound Salmon Recovery Plan (NMFS 2006a)) The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2002; Ruckelshaus et al. 2006). The PSTRT's Biological Recovery Criteria will be met when the following conditions are achieved:

1. All watersheds improve from current conditions, resulting in improved status for the species;
2. At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a low risk status over the long-term[2];
3. At least one or more populations from major diversity groups historically present in each of the five Puget Sound regions attain a low risk status;
4. Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario; and,
5. Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery.

In assessing status, we start with the information used in its most recent ESA status review for the salmon and steelhead species considered in this opinion, and if applicable consider more recent data, that are relevant to the species' rangewide status. Many times, this information exists in ESA recovery plans or annual performance reports from existing ESA authorizations. Recent information from recovery plans, where they are developed for a species, is often relevant and is used to supplement the overall review of the species' status. This step of the analysis tells us how well the species is doing over its entire range in terms of trends in abundance and productivity, spatial distribution, and diversity. It also identifies the causes for the species' decline.

The status review starts with a description of the general life history characteristics and the population structure of the ESU or DPS including the MPGs where they occur. We review VSP information that is available including abundance, productivity and trends (information on trends supplements the assessment of abundance and productivity parameters), and spatial structure and diversity. We also summarize available estimates of extinction risk that are used to characterize the viability of each natural population leading-up to a risk assessment for the ESU or DPS, and the limiting factors and threats. This section concludes by examining the status of critical habitat. Recovery plans are an important source of information that describe, among other things, the status of the species and its component populations, limiting factors, recovery goals and actions that are recommended to address limiting factors. Recovery plans are not regulatory documents. Consistency of a proposed action with a recovery plan, therefore, does not by itself provide the basis for determining that an action does not jeopardize the species. However, recovery plans do provide a perspective encompassing all human impacts that is important when assessing the effects of an action. Information from existing recovery plans for each respective ESA-listed salmon and steelhead is discussed where it applies in various sections of this Opinion.

Recovery domains are the geographically-based areas within which NMFS prepares recovery plans (Figure 2). The LAA species analyzed in this consultation occur in six recovery domains (Table 4) and NLAA species occur in additional recovery domains as detailed in the NLAA section (see Section 2.12.1).

For each recovery domain, a TRT appointed by NMFS has developed, or is developing, criteria necessary to identify independent populations within each species, recommended viability criteria for those species, and descriptions of factors that limit species survival. Viability criteria are prescriptions of the biological conditions for populations, biogeographic strata, and ESUs and DPSs that, if met, would indicate that an ESU or DPS will have a negligible risk of extinction over a 100-year time frame.[9]

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[9] For Pacific salmon, NMFS uses its 1991 ESU policy, which states that a population or group of populations will be considered a DPS if it is an ESU. An ESU represents a DPS of Pacific salmon under the ESA that: (1) is substantially reproductively isolated from conspecific populations, and (2) represents an important component of the evolutionary legacy of the species. The species *O. mykiss* is under the joint jurisdiction of NMFS and the United States Fish and Wildlife Service (USFWS), so in making its January 2006 listing determinations NMFS elected to use the 1996 joint FWS-NMFS DPS policy for this species.

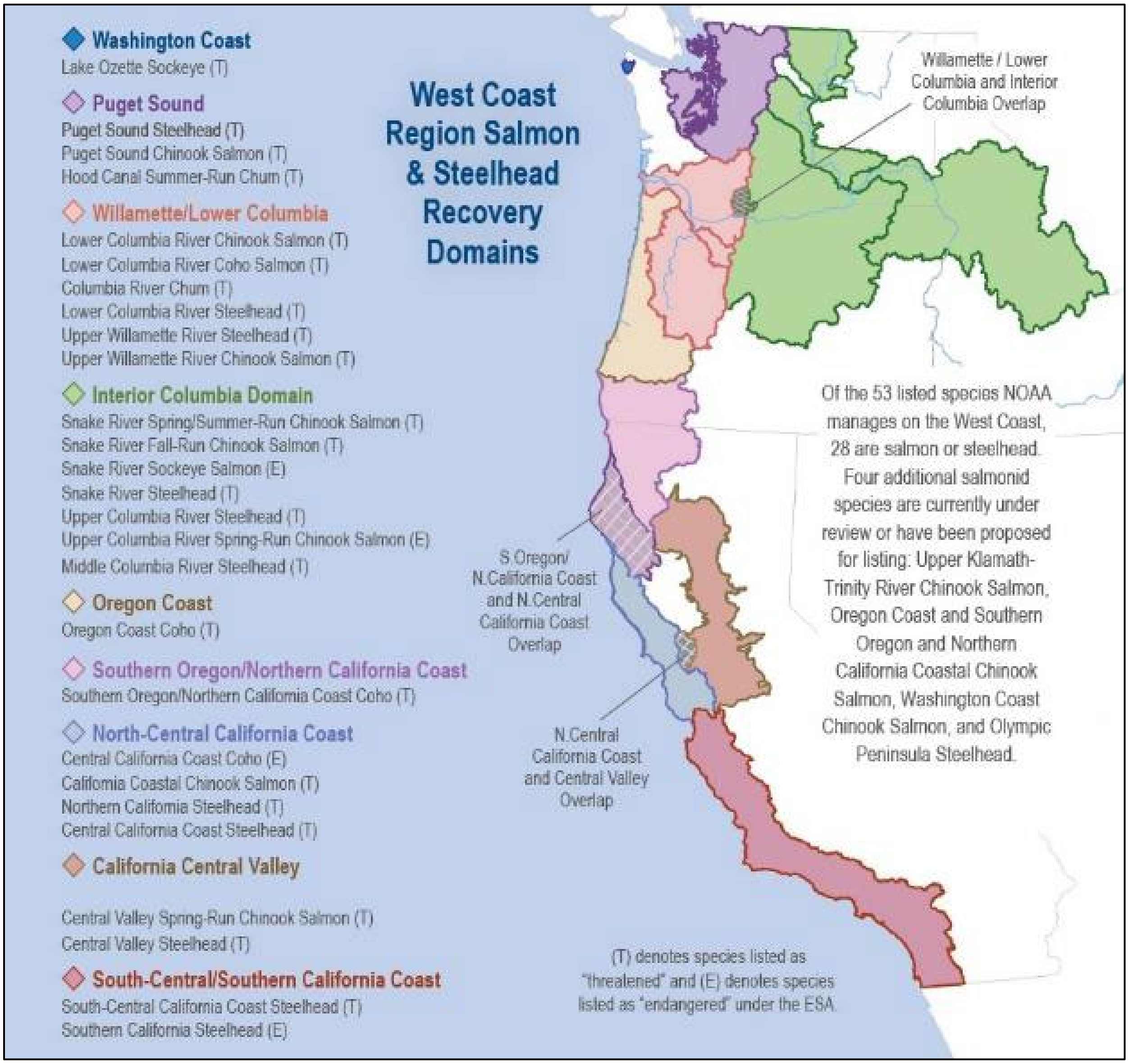


Figure 2. Map showing the range of NMFS' West Coast Region and the encompassed recovery domains for salmon and steelhead listed under the ESA. The ESUs and DPSs of ESA-listed salmon and steelhead addressed in this Opinion (either in the LAA or NLAA sections) are listed on the left side of the figure. T indicates ESUs and DPSs that are listed as Threatened and E indicates an Endangered listing.

Table 4. Recovery planning domains identified by NMFS and their ESA-listed salmon and steelhead species that were identified as LAA for this consultation.

Recovery Domain	Species
Puget Sound	Puget Sound Chinook salmon
	Hood Canal summer-run chum salmon
	Puget Sound steelhead
Willamette/Lower Columbia	Lower Columbia River Chinook salmon
	Upper Willamette River Chinook salmon
	Lower Columbia River coho salmon
	Columbia River chum salmon
	Lower Columbia River steelhead
	Upper Willamette River steelhead
Interior Columbia	Snake River fall-run Chinook salmon
	Snake River spring/summer-run Chinook salmon
	Upper Columbia River spring-run Chinook salmon
	Snake River sockeye salmon
	Middle Columbia River steelhead
	Upper Columbia River steelhead
	Snake River Basin steelhead
North-Central California Coast	California Coastal Chinook salmon
Central Valley	Central Valley spring-run Chinook salmon

Although the TRTs dealing with anadromous fish species operated from the common set of biological principals described in McElhany et al. (2000), they worked semi-independently from each other and developed criteria suitable to the species and conditions found in their specific recovery domains. All of the criteria have qualitative as well as quantitative aspects. The diversity of salmonid species and populations makes it impossible to set narrow quantitative guidelines that will fit all populations in all situations. For this and other reasons, viability criteria vary among species, mainly in the number and type of metrics and the scales at which the metrics apply (*i.e.*, population, MPG, or ESU/DPS) (Busch et al. 2008).

Most TRTs included in their viability criteria a combined risk rating for abundance and productivity (A/P), and an integrated spatial structure and diversity (SS/D) risk rating (*e.g.*, Interior Columbia TRT) or separate risk ratings for spatial structure and diversity (e.g., WLC TRT).

The boundaries of each population were defined using a combination of genetic information, geography, life-history traits, morphological traits, and population dynamics that indicate the extent of reproductive isolation among spawning groups. The overall viability of a species is a function of the VSP attributes of its constituent populations. Until a viability analysis of a species is completed, the VSP guidelines recommend that all populations should be managed to retain the potential to achieve viable status to ensure a rapid start along the road to recovery, and that no significant parts of the species are lost before a full recovery plan is implemented (McElhany et al. 2000).

Viability status or probability or population persistence is described below for each of the populations considered in this opinion. The sections that follow describe the status of the ESA-listed species, and their designated critical habitats, that occur within the geographic area of this proposed action and are considered in this opinion.

2.2.2 Status of the Chinook Salmon ESUs

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

Chinook salmon species evaluated in this consultation are detailed in Table 5. The TRTs identified 93 demographically independent populations of Pacific Chinook salmon (Table 5). These populations were further aggregated into strata or MPGs, groupings above the population level that are connected by some degree of migration, based on ecological subregions.

Table 5. Chinook salmon ESA-listed salmon populations considered in this Opinion.

Recovery Domain	ESU	MPGs[a]	Populations
Puget Sound	Puget Sound Chinook salmon	5	22
Willamette/Lower Columbia	Lower Columbia River Chinook salmon	6	32
	Upper Willamette River Chinook salmon	1	7
Interior Columbia	Snake River fall-run Chinook salmon	1	1
	Snake River spring/summer-run Chinook salmon	5	28
	Upper Columbia River spring-run Chinook salmon	3	3
North-Central California Coast	California Coastal Chinook salmon	4	17
Central Valley	Central Valley spring-run Chinook salmon	4	9
Totals	**8 ESUs**	**29**	**119**

[a] Note that the term MPG is not used for either California ESU. The terms used for the overarching population groups are Diversity Strata and Diversity Groups for California Coastal Chinook salmon and Central Valley spring-run Chinook salmon respectively.

Many Chinook salmon ESUs include hatchery programs as part of the ESU. In general, hatchery programs can provide short-term demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of risk depends on the status of affected populations and on specific practices in the hatchery program (NMFS 2022o). 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 2018e). Genetic resources can be housed in a hatchery program, but for a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS see NMFS (2005b).

2.2.2.1 Puget Sound Recovery Domain

2.2.2.1.1 Puget Sound Chinook Salmon ESU

This ESU was listed as a threatened species on March 24, 1999 (64 FR 14308). Its threatened status was reaffirmed June 28, 2005 (70 FR 37160), and again on April 14, 2014 (79 FR 20802). Critical habitat for Puget Sound Chinook salmon was designated on September 2, 2005 (70 FR

52629). There are 61 watersheds within the range of this ESU. Habitat areas for this ESU include 2,216 mi (3,566 kilometers (km)) of stream and 2,376 mi (3,824 km) of nearshore marine areas, which include the zone from extreme high water out to a depth of 30 meters. The Puget Sound Chinook Salmon ESU includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan de Fuca from the Elwha River, westward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington (64 FR 14208).

The ESU also includes Chinook salmon from certain artificial propagation programs. Artificial propagation (hatchery) programs (26) were added to the listed Puget Sound Chinook Salmon ESU in 2005, as part of the final listing determinations for 16 ESUs of West Coast Salmon and Final 4(d) Protective Regulations for Threatened Salmonid ESUs (70 FR 37160). In October of 2016, NMFS proposed revisions to the hatchery programs included as part of some Pacific salmon ESUs and steelhead DPSs listed under the ESA (81 FR 72759). NMFS issued its final rule in December of 2020 (85 FR 81822). This final rule includes 25 hatchery programs as part of the listed Puget Sound Chinook Salmon ESU (Table 6).

NMFS published a 2016 5-year review for Puget Sound Chinook salmon (NMFS 2016b). The Northwest Fisheries Science Center (NWFSC) finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA (Ford 2022) in January of 2022. NMFS's West Coast Region (WCR) is currently preparing the 5-year status-review document for Puget Sound Chinook salmon.

NMFS's guidance classified Puget Sound Chinook salmon populations into three tiers based on a systematic framework that considers the genetic legacy of the population, the population's life history, and production and watershed characteristics (NMFS 2010b) (Figure 3). This framework, termed the *Population Recovery Approach (PRA)*, carries forward the biological viability and delisting criteria described in the Supplement to the Puget Sound Salmon Recovery Plan (Ruckelshaus et al. 2002; NMFS 2006a). The assigned tier indicates the relative role of each of the 22 populations comprising the ESU with respect to the viability of the ESU and its recovery. Tier 1 populations are most important for preservation, restoration, and ESU recovery. Tier 2 populations play a less important role in recovery of the ESU. Tier 3 populations play the least important role. When we analyze proposed actions, we first evaluate impacts at the individual population scale, then consider how those population-level impacts affect the survival and recovery of the ESU. We expect that impacts to Tier 1 populations would be more likely to affect the survival and recovery of the ESU, as a whole, than similar impacts to Tier 2 or 3 populations, because of the relatively greater importance of Tier 1 populations to overall ESU survival and recovery. NMFS has incorporated this and similar approaches in previous ESA Section 4(d) determinations and opinions on Puget Sound salmon fisheries and regional recovery planning (NMFS 2005e; 2008e; 2008f; 2010a; 2011d; 2013c; 2014h; 2015e; 2016n; 2017y; 2018d; 2019k; 2020b; 2021b).

Table 6. Puget Sound Chinook Salmon ESU description and MPGs (Ford 2022). NMFS has determined that the bolded populations, in particular, are essential to recovery of the Puget Sound Chinook Salmon ESU (Ruckelshaus et al. 2006).

ESU Description	
Threatened	Listed under ESA in 1999; updated in 2014
5 MPGs	31 historical populations, 22 extant
MPG	***Populations***
Strait of Juan de Fuca	**Elwha (fall)**, **Dungeness (summer)**
Hood Canal	**Mid-Hood Canal (fall)**, **Skokomish (fall)**
Central/South Sound	**Nisqually (fall)**, Puyallup (fall), **White (spring)**, Green/Duwamish (fall), Cedar (fall), North Lake Washington/Sammamish (fall)
Whidbey Basin	Skykomish (summer), Snoqualmie (fall), North Fork Stillaguamish (summer), South Fork Stillaguamish (fall), Lower Skagit (fall), Upper Skagit (summer), Lower Sauk (summer), Upper Sauk (spring), **Suiattle (spring)**, Cascade (spring)
Strait of Georgia	**North Fork Nooksack (spring)**, **South Fork Nooksack (spring)**
Artificial production	
Hatchery programs included in ESU (25)	Kendall Creek Hatchery Program, Marblemount Hatchery Program (spring-run), Marblemount Hatchery Program (summer-run), Brenner Creek Hatchery Program (fall-run), Harvey Creek Hatchery Program (summer-run), Whitehorse Springs Hatchery Program (summer-run), Wallace River Hatchery Program (yearlings and subyearlings), Issaquah Creek Hatchery Program, White River Hatchery Program, White River Acclimation Pond Program, Voights Creek Hatchery Program, Clarks Creek Hatchery Program, Clear Creek Hatchery Program, Kalama Creek Hatchery Program, George Adams Hatchery Program, Hamma Hamma Hatchery Program, Dungeness/Hurd Creek Hatchery Program, Elwha Channel Hatchery Program, Skookum Creek Hatchery Spring-run Program, Bernie Kai-Kai Gobin (Tulalip) Hatchery-Cascade Program, North Fork Skokomish River Spring-run Program, Soos Creek Hatchery Program (subyearlings and yearlings), Fish Restoration Facility Program, Bernie Kai-Kai Gobin (Tulalip) Hatchery-Skykomish Program, Hupp Springs Hatchery-Adult Returns to Minter Creek Program
Hatchery programs not included in ESU (9)	Samish River Hatchery Fall Program, Glenwood Springs Hatchery Fall Program, George Adams Fall Program, Hoodsport Fall Program, Gorst Creek Fall Program, Grovers Creek Hatchery Fall Program, Minter Creek Fall Program, Tumwater Falls Program, Chambers Creek Fall Program

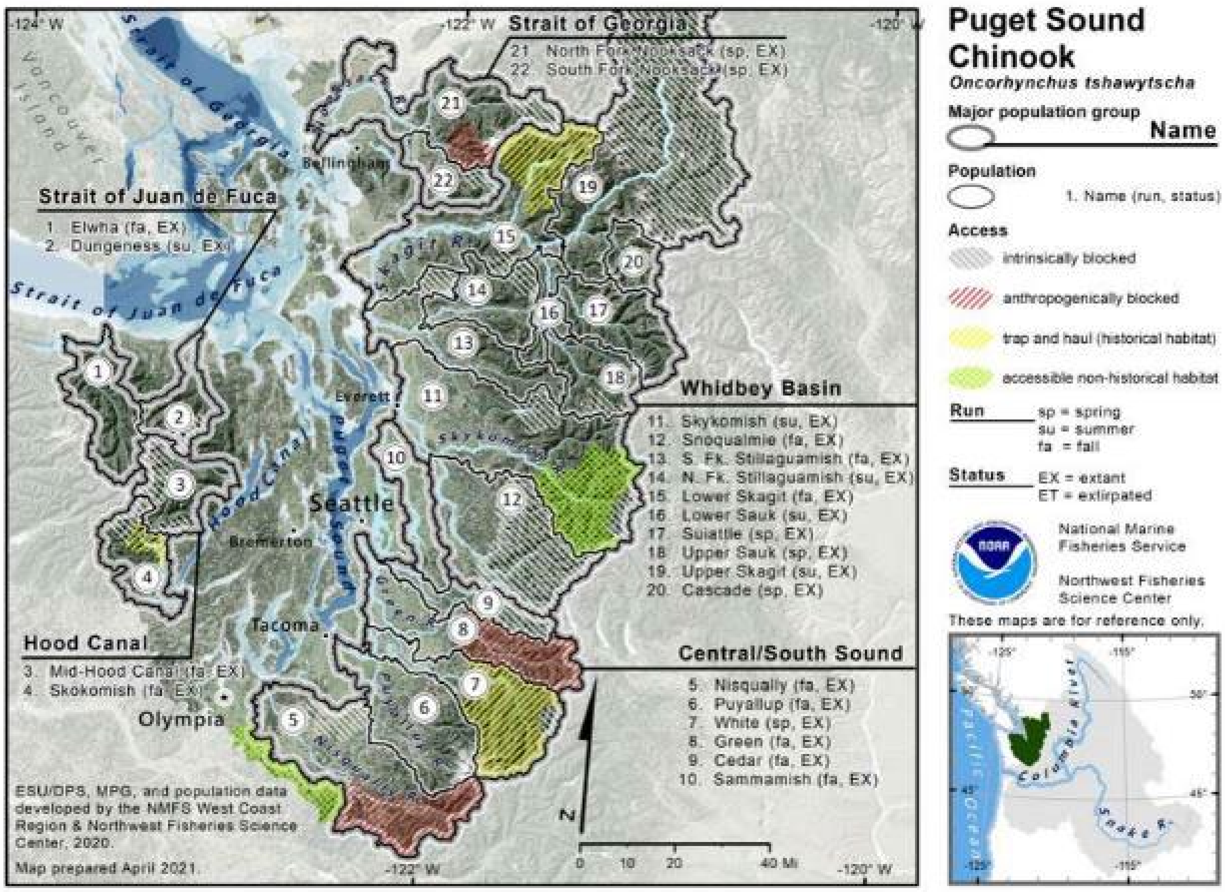


Figure 3. Map of the Puget Sound Chinook Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

NMFS adopted the recovery plan for Puget Sound Chinook on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan (SSDC 2007) and Final Supplement to the Shared Strategy's Puget Sound Salmon Recovery Plan. The recovery plan adopts ESU and population level viability criteria recommended by the PSTRT (Ruckelshaus et al. 2006). The PSTRT's Biological Recovery Criteria will be met when the following conditions are achieved:

1. All watersheds improve from current conditions, resulting in improved status for the species;

2. At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a low risk status over the long-term[10];

3. At least one or more populations from major diversity groups historically present in each of the five Puget Sound regions attain a low risk status;

4. Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario;

5. Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery.

2.2.2.1.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Puget Sound Chinook Salmon ESU, is at moderate risk and remains at threatened status.

2.2.2.1.1.1.1 Abundance and Productivity

Abundance of the 22 extant natural spawning populations in the Puget Sound Chinook Salmon ESU varies considerably between populations (Figure 4). Total abundance in the ESU over the entire time series shows that individual populations have varied in increasing or decreasing abundance. Several populations (North and South Fork Nooksack, Sammamish, Green, White, Puyallup, Nisqually, Skokomish, Dungeness, and Elwha Rivers) are dominated by hatchery returns (Ford 2022). Generally, many populations experienced increases in total abundance during the years 2000–08, and more recently in 2015–17, but general declines during 2009–14, and a downturn again in the two most-recent years, 2017–18 (Figure 4). Abundance across the Puget Sound Chinook Salmon ESU has generally increased since the last status review, with only two of the 22 populations (Cascade River and North and South Fork Stillaguamish Rivers) showing a negative percentage change in the five-year geometric mean natural-origin spawner abundances since the prior status review (Ford 2022). Fifteen of the remaining 20 populations with positive percentage changes since the prior status review have relatively low natural spawning abundances (<1,000 fish), so some of these increases represent small changes in total

[10] The number of populations required to be at low-risk status depends on the number of diversity groups in the region. For example, three of the regions only have two populations generally of one diversity type; the Central Sound Region has two major diversity groups; the Whidbey/Main Region has four major diversity groups.

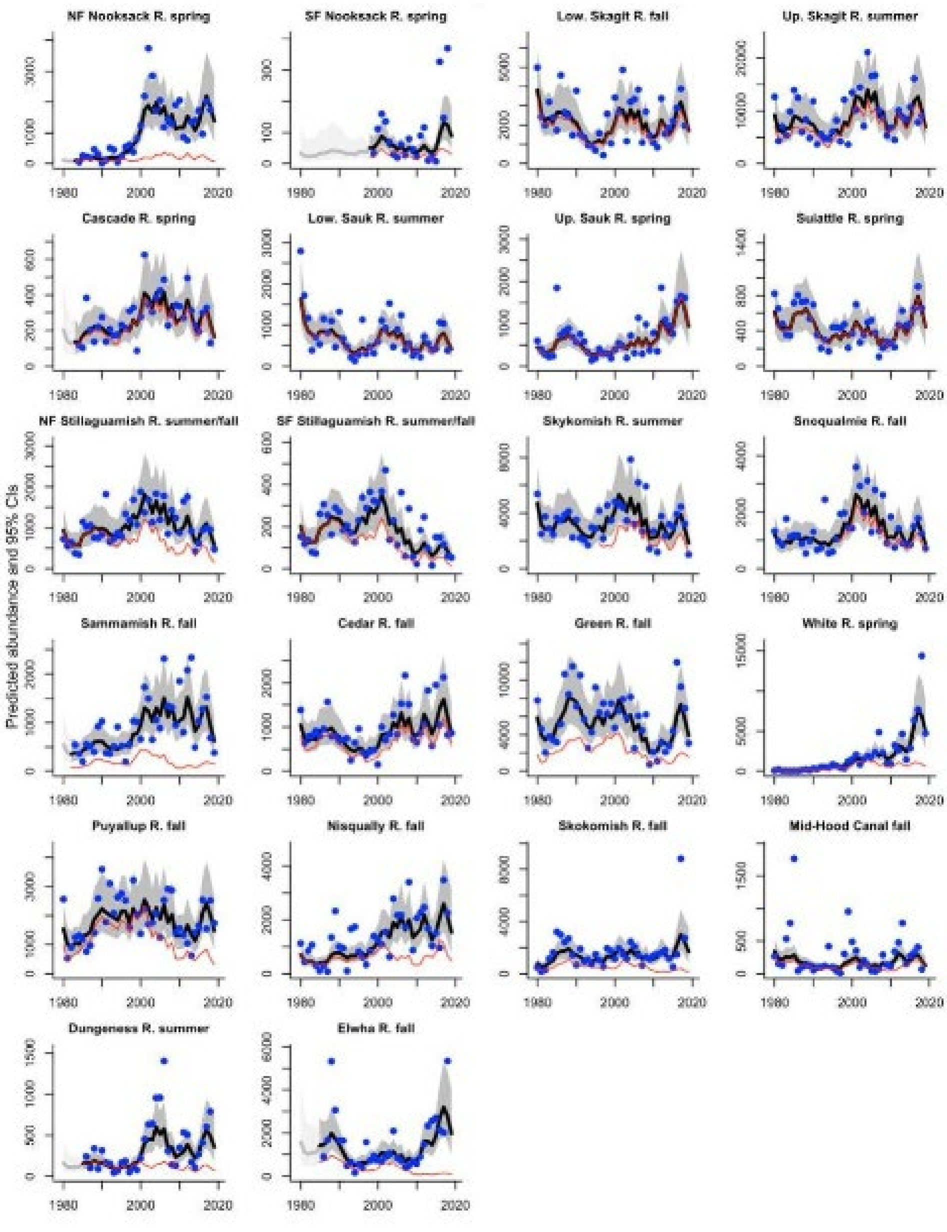


Figure 4. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

abundance (Ford 2022). Given lack of high confidence in survey techniques, particularly with small populations, there remains substantial uncertainty in detecting trends in small populations.

Fifteen-year trends in log natural-origin spawner abundance were computed over two time periods (1990–2005 and 2004–19) for each Puget Sound Chinook salmon population (Ford 2022). Trends were negative for four of the populations in the earlier period, and for 16 of the 22 populations in the later period. Thus, there is a general decline in natural-origin spawner abundance across all MPGs in the most-recent fifteen years (Ford 2022). Upper Sauk and Suiattle Rivers (Whidbey Basin MPG), Nisqually River (Central/South Sound MPG), and Mid-Hood Canal (Hood Canal MPG) are the only populations with positive trends, though Mid-Hood Canal has an extremely low population size. Further, no change in trend between the two time periods was detected in South Fork Nooksack River (Strait of Georgia MPG) or Green and Nisqually Rivers (Central/South MPG). The average trend across the ESU for 1990–2005 was 0.03. The average trends for the MPGs are: Strait of Georgia, 0.03; Whidbey Basin, 0.04; Central/South Sound, 0.04; Hood Canal, 0.03; and Strait of Juan de Fuca, 0.01. The average trend across the ESU for 2004–19 was –0.02. The average trends for the MPGs are: Strait of Georgia, –0.02; Whidbey Basin, –0.02; Central/South Sound, –0.02; Hood Canal, –0.02; and Strait of Juan de Fuca, –0.08. The previous viability status review (NWFSC 2015) concluded that there were widespread negative trends for the total ESU, despite variable escapements and trends for individual populations. The addition of the data to 2018 now shows even more substantially either flat or negative trends for the entire ESU in natural-origin Chinook salmon spawner population abundances (Ford 2022).

Productivity in the Puget Sound Chinook Salmon ESU has been variable across the time period (1980–2018) (Ford 2022). Across the Puget Sound Chinook Salmon ESU, ten of 22 Puget Sound populations show natural productivity below replacement in nearly all years since the mid-1980s (Ford 2022). These include the North and South Fork Nooksack Rivers (Strait of Georgia MPG), North and South Fork Stillaguamish and Skykomish Rivers (Whidbey Basin MPG), Sammamish, Green, and Puyallup Rivers (Central/South Sound MPG), Skokomish River (Hood Canal MPG), and Elwha River (Strait of Juan de Fuca MPG). Productivity in the Whidbey Basin MPG populations was above zero in the mid-to-late 1990s, with the exception of the Skykomish and North and South Fork Stillaguamish River populations. The White River population in the Central/South Sound MPG was above replacement from the early 1980s to 2001, but has dropped in productivity consistently since the late 1980s. In recent years, only five populations have had productivities above zero. These are Lower and Upper Skagit, Lower and Upper Sauk, and Suiattle Rivers in the Whidbey Basin MPG. This is consistent with, and continues the decline reported in, the 2015 status review (NWFSC 2015).

2.2.2.1.1.1.1.1 Harvest

Puget Sound Chinook salmon are harvested in ocean salmon fisheries, in Puget Sound fisheries, and in terminal fisheries in the rivers (Ford 2022). They migrate to the north, so for most Puget Sound Chinook salmon populations, nearly all of the ocean fishery impacts occur in Canada and Alaska, where they are subject to the U.S.–Canada Pacific Salmon Treaty (Ford 2022). Some populations are also harvested at lower rates in the coastal fisheries off Washington and Oregon. Fisheries within Puget Sound are managed by the state and tribal co-managers under a resource management plan. Fishery impact rates vary considerably among MPGs within Puget Sound, primarily due to different terminal-area management and variable exploitation rates in the Canadian and Alaskan fisheries. For populations in the Hood Canal (Skokomish River) and Central/South Sound MPGs (Nisqually, White, Puyallup, and Green Rivers), substantial terminal-area fisheries are directed at hatchery fish that are produced largely to support tribal and recreational fisheries. For populations in the Whidbey Basin (Skokomish, Stillaguamish, and Skagit Rivers) and Strait of Georgia MPGs (Nooksack River), harvest in the northern fisheries accounts for a large portion of the exploitation.

Chinook salmon populations in Puget Sound generally show a similar pattern: declining exploitation rates in the 1990s, and relatively stable-to-increasing exploitation rates since then (Figure 5). This is primarily a result of Canadian interceptions of Puget Sound Chinook salmon off the West Coast Vancouver Island (WCVI) (Ford 2022). During the 1990s, Canada sharply reduced WCVI fisheries in response to depressed domestic stocks. Since then, WCVI stock status has improved somewhat, and Canadian managers have changed the temporal pattern of fishing to avoid WCVI stocks. This has resulted in increased impacts on Puget Sound stocks. A notable exception to this pattern is the North Puget Sound region (Nooksack, Skagit, and Stillaguamish Rivers). These stocks have not seen increased impacts because they migrate through the Strait of Georgia. Canadian stocks in the Strait of Georgia have not recovered, and most fisheries in Canadian inside waters for Chinook and coho salmon have been shut down.

The Chinook salmon agreement under the PST, which took effect in 2009, included 30% reductions in Chinook salmon catch ceilings off WCVI and 15% reductions in southeast Alaska (NMFS 2008f). The PST was revised again in 2018, and a new ten-year agreement (2019–28) now specifies further reductions in these catch ceilings at low abundances (NMFS 2019j). Since the 1999 PST Chinook salmon agreement, an abundance-based Chinook salmon management regime, under which fisheries are classified as either aggregate abundance-based management (AABM) or individual stock-based management (ISBM) regimes, has been in place. AABM fisheries constrain catch to a numerical limit computed from either a pre-season forecast or an in-season estimate of abundance; ISBM fisheries constrain annual impacts, within the fisheries of a jurisdiction, for a naturally spawning Chinook salmon stock or stock group (Pacific Salmon Commission 2020). Goals of the current PST management regime include an abundance-based framework and the ability to respond to significant changes in the productivity of Chinook

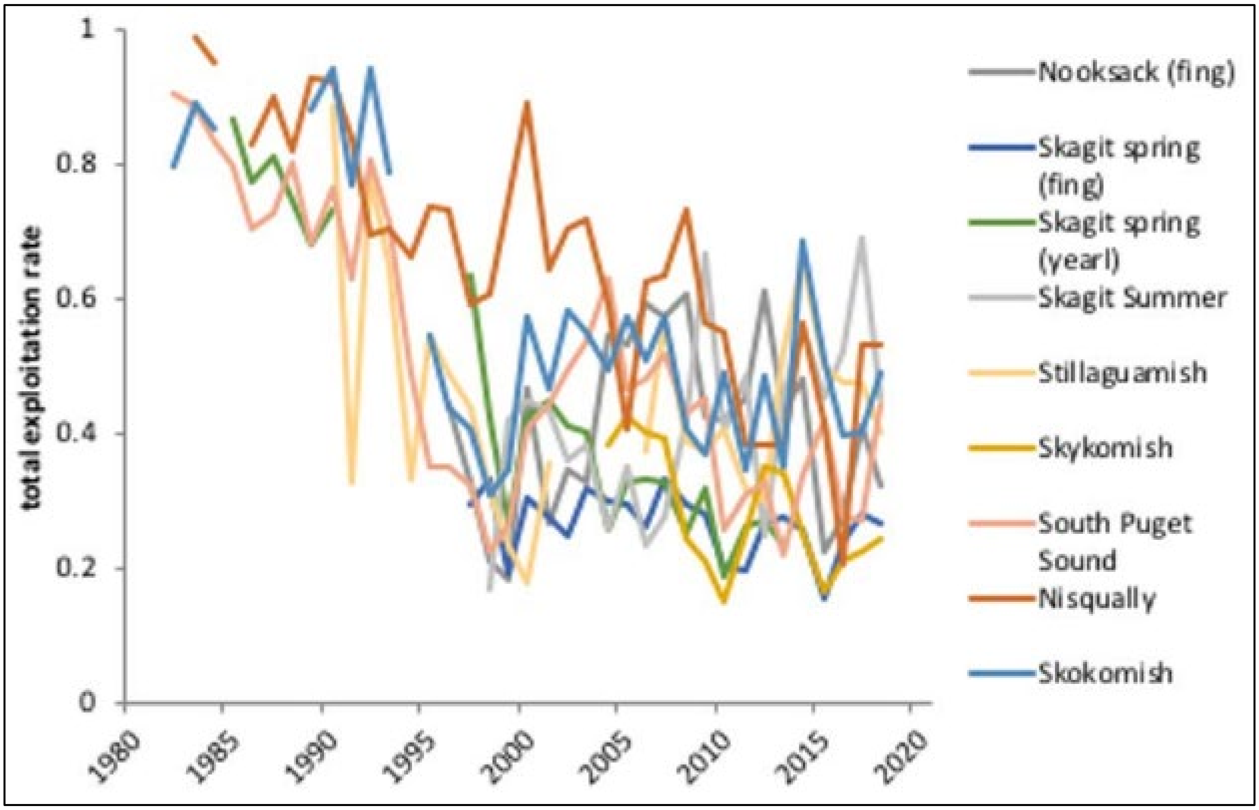


Figure 5. Coded-wire tag-based exploitation rates for Chinook salmon indicator stocks in Puget Sound. Recreated from Ford (2022).

salmon stocks, both to preserve the biological diversity of the Chinook salmon resource and to contribute to the restoration of depressed stocks (Pacific Salmon Commission 2020).

2.2.2.1.1.1.2 Spatial Structure and Diversity

Measures of spatial structure and diversity can give some indication of the resilience of a population to sustain itself. In assessing spatial structure within a population, the TRT recommended that human activities should not change the spatial structure in a way that significantly deviates from the historical pattern (SSDC 2007). The spatial distribution of habitat within a watershed must maintain enough quality, quantity and connectivity of habitat patches to support spawning, rearing, and upstream and downstream migration. The risk of extinction for Puget Sound salmon populations is thus affected by the quality, quantity, and geographic structure of habitat now, and in the future (SSDC 2007). Habitat monitoring and adaptive management planning efforts to develop monitoring plans was undertaken in all individual watersheds of Puget Sound in 2014 (NMFS 2016b). These reports and prior annual three-year workplans document the many habitat actions that were initially identified in the Puget Sound Chinook salmon recovery plan (SSDC 2007). The expected benefits will take years or decades to produce significant improvement in natural population viability parameters (NMFS 2016b). Development of a monitoring and adaptive management program was recommended by NMFS in the 2007 Recovery Plan (SSDC 2007). This program is not yet fully functional for providing assessment of watershed habitat restoration/recovery programs, nor for properly integrating the essentially discrete habitat, harvest and hatchery programs (NMFS 2016b).

Although the spatial distribution of naturally-spawning populations is difficult to determine due to hatchery influence, the remaining populations with significant numbers of natural-origin spawners are concentrated in the region containing the Skagit and Stillaguamish River basins (SSDC 2007). Spatial structure can be measured in various ways, but Ford (2022) analyzed the proportion of natural- vs. hatchery-origin spawners on the spawning grounds, as discussed below. Quantitative viability criteria for spatial structure and diversity are largely unavailable at the population level (SSDC 2007).

2.2.2.1.1.1.2.1 Hatcheries

The proportion of natural-origin spawners across the ESU started declining in approximately 1990, and continued to decline through 2018 (Table 7). The populations with the highest fractions of natural-origin spawners across the entire 1980 to 2018 time period are the six Skagit River populations (Ford 2022). The Skykomish, Snoqualmie, and Cedar River populations had a lower proportion of natural-origin spawners in the late 1990s, but they have rebounded and stayed between 60–90% since the early 2000s (Ford 2022). All other populations vary considerably across the whole time period. A number of populations (North and South Fork Nooksack, North and South Fork Stillaguamish, Skykomish, Snoqualmie, White, Puyallup, Nisqually, Skokomish, Dungeness, and Elwha Rivers) show recent declining trends in the fraction natural-origin estimates (Table 7).

It is important to note that the quality of hatchery contribution data in the earlier time periods (prior to mass marking programs) may be poor, so the long-term trends may lack accuracy in the earlier years (Ford 2022). In the Whidbey Basin MPG, the fraction natural-origin abundance has been consistently high in the six Skagit River populations. With ongoing hatchery programs in the Stillaguamish and Snohomish Rivers, there has been a decrease in five-year mean fraction natural-origin in the last two time periods (2010–14 and 2015–19), particularly in the Stillaguamish River (Table 7). In Ford (2022) the fraction natural-origin estimates prior to mass hatchery marking (pre-1997 and 2002–05) in the Skykomish and Snoqualmie Rivers population data were removed due to concerns by tribal co-managers regarding data quality. Estimates of

Table 7. Five-year mean of fraction natural-origin spawners (sum of all estimates divided by the number of estimates) (Ford 2022). Sp indicates Spring-run, FA indicates Fall-run, and SU indicates Summer-run.

Population	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
North Fork Nooksack River SP	Strait of Georgia	0.28	0.11	0.19	0.14	0.13
South Fork Nooksack River SP	Strait of Georgia	0.26	0.55	0.57	0.42	0.45
Lower Skagit River FA	Whidbey Basin	0.94	0.91	0.86	0.92	0.84
Upper Skagit River SU	Whidbey Basin	0.91	0.87	0.84	0.95	0.91
Cascade River SP	Whidbey Basin	0.98	0.92	0.89	0.94	0.86
Lower Sauk River SU	Whidbey Basin	0.94	0.97	0.95	0.91	0.98
Upper Sauk River SP	Whidbey Basin	0.99	1.00	0.98	0.97	0.99
Suiattle River SP	Whidbey Basin	0.99	0.97	0.99	0.99	0.97
North Fork Stillaguamish River SU/FA	Whidbey Basin	0.59	0.70	0.40	0.43	0.45
South Fork Stillaguamish River SU/FA	Whidbey Basin	0.59	0.70	0.40	0.54	0.46
Skykomish River SU	Whidbey Basin	0.49	0.52	0.76	0.69	0.62
Snoqualmie River FA	Whidbey Basin	0.81	0.89	0.81	0.78	0.75
Sammamish River FA	Central/South Sound	0.29	0.36	0.16	0.07	0.16
Cedar River FA	Central/South Sound	0.61	0.59	0.82	0.78	0.71
Green River FA	Central/South Sound	0.55	0.47	0.43	0.39	0.30
White River SP	Central/South Sound	0.54	0.79	0.43	0.32	0.15
Puyallup River FA	Central/South Sound	0.88	0.79	0.52	0.41	0.32
Nisqually River FA	Central/South Sound	0.80	0.61	0.30	0.30	0.47
Skokomish River FA	Hood Canal	0.40	0.46	0.45	0.10	0.16
Mid-Hood Canal FA	Hood Canal	0.76	0.79	0.61	0.33	0.89
Dungeness River SU	Strait of Juan de Fuca	1.00	0.32	0.43	0.25	0.25
Elwha River FA	Strait of Juan de Fuca	0.41	0.53	0.35	0.06	0.05

hatchery and natural-origin proportions of fish since the implementation of mass marking are considered more robust (NMFS 2022a).

However, the average five-year mean fraction natural-origin estimates for the entire Whidbey Basin MPG remain relatively consistent across all time periods. The Strait of Georgia MPG (North and South Fork Nooksack Rivers) has had increased hatchery influence since the late 1990s and across all time periods. The South Fork Nooksack River population has had extremely small natural fish returns through 2015, but has had increased numbers of natural-origin spawners in the last three years relative to increased supplementation program efforts conducted at Skookum Hatchery (Ford 2022). This population is at high risk of extinction (Ford 2022). The Central/South Sound MPG has had decreasing fraction natural-origin estimates in the Sammamish, Green, White, and Puyallup Rivers populations, and increases in the Cedar population in the three most-recent five-year time periods (2005–09, 2010–14, 2015–19) (Table 7). The Nisqually River population data here represent the total volitional escapement, but in the three most-recent years, a supplementation program has been instituted trucking hatchery fish upstream for release on the spawning grounds. This is an effort to supplement natural spawning.

In the Hood Canal and Strait of Juan de Fuca MPGs, three of four populations had declining five-year mean fraction natural-origin estimates of fish returns to the spawning grounds (Table 7). Skokomish River had a slight increase in the most recent five-year time period, but still a very low fraction natural-origin for the population. This population is heavily impacted by the George Adams Salmon Hatchery program (Ford 2022). The Mid-Hood Canal population had a higher five-year mean fraction natural estimate in the most recent time period (2014–19) because the hatchery supplementation program was ended in the Hamma Hamma River in 2015 (Ford 2022). Some supplementation fish continued to return through 2019; however, the population has not proven to be self-sustaining and viable, and recent returns have been very low (Ford 2022). Genetics data show this population highly correlated to the George Adams Salmon Hatchery and Green River stocks that have been used. State managers conclude from the long-term supplementation program and the genetics composition that if there was an independent population of Chinook salmon that utilized the Mid-Hood Canal streams, then it is most certainly extinct at this point in time. Thus, considering populations by MPG, Whidbey Basin is the only MPG with a consistently high fraction natural-origin spawner abundance, in six of 10 populations (Ford 2022). All other MPGs have either variable or declining spawning populations that have high proportions of hatchery-origin spawners (Ford 2022).

2.2.2.1.1.1.3 Summary

All Puget Sound Chinook salmon populations continue to remain well below the PSTRT planning ranges for recovery escapement levels (Ford 2022). Most populations also remain consistently below the spawner–recruit levels identified by the PSTRT as necessary for recovery. Across the ESU, most populations have increased somewhat in abundance since the last 5-year status review in 2016 (NMFS 2016b), but have small negative trends over the past 15 years. Productivity remains low in most populations. Hatchery-origin spawners are present in high fractions in most populations outside the Skagit River watershed, and in many watersheds, the fraction of spawner abundances that are natural-origin have declined over time (Table 7). Habitat protection, restoration, and rebuilding programs in all watersheds have improved stream and estuary conditions despite record numbers of humans moving into the Puget Sound region in the past two decades. Biannual four-year work plans document the many completed habitat actions that were initially identified in the Puget Sound Chinook salmon recovery plan. The expected benefits will take years or decades to produce significant improvements in natural population viability parameters. Development of a monitoring and adaptive management program was required by NMFS in the supplement to the shared strategy recovery plan (NMFS 2006a), and since the last review, the Puget Sound Partnership has completed this task. However, the program is still not fully functional, neither for providing assessment of watershed habitat restoration/recovery programs, nor for fully integrating the essentially discrete habitat, harvest, and hatchery programs (Ford 2022). A number of watershed groups are in the process of updating their recovery plan chapters, and this includes prioritizing and updating recovery strategies and actions as well as assessing prior accomplishments. Overall, the Puget Sound Chinook Salmon ESU remains at “moderate” risk of extinction, and viability is largely unchanged from the prior (NWFSC 2015) review (Ford 2022).

2.2.2.1.1.2 Limiting Factors

Limiting factors described in SSDC (2007) and reiterated in NMFS (2016b) relate to present or threatened set of conditions within certain habitat parameters that inhibit the viability of salmon as defined by the VSP criteria, including the following:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.
- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, impaired passage conditions and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development. Some improvements have occurred over the last decade for water quality and removal of forest road barriers.

Additional factors affecting Puget Sound Chinook salmon viability include the following:

- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations. The risk to the species' persistence that may be attributable to hatchery-related effects has decreased since the 2015 Status Review (NWFSC 2015), based on hatchery risk reduction measures that have been implemented (Ford 2022). Improvements in hatchery operations associated with on-going ESA review and determination processes are expected to further reduce hatchery-related risks.

- Salmon harvest management: Total fishery exploitation rates (ERs) on most Puget Sound Chinook salmon populations have decreased substantially since the late 1990s when compared to years prior to listing – 1992–1998 (average reduction = -21%, range = -49 to +33%), Fisheries Regulation Assessment Model (FRAM) base period validation results, version 7.1.1) but weak natural-origin Chinook salmon populations in Puget Sound still require protective measures to reduce the risk of overharvest. The risk to the species' persistence because of harvest remains the same since the 2015 status review, meaning that for some of the populations with minimal abundance, even low rates of harvest impact can pose demographic and genetic risks. However, there has been greater uncertainty associated with this threat due to shorter term harvest plans for Puget Sound fisheries (uncertainty about future harvest plans) and exceedance of Rebuilding ERs for many Chinook salmon populations essential to recovery.
- Concerns regarding existing regulatory mechanisms, including: lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans, lack of reporting and enforcement for some regulatory programs, certain state, local, or private land and water use actions continue to occur without protective measures for ESA-listed Chinook salmon. State, local, and private actions can have no Federal nexus to trigger the ESA Section 7 consultation requirement, nor are ESA Section 10 permits sought for those actions, thus ESA measures are not protecting listed species and their habitat from those actions.

2.2.2.2 Willamette/Lower Columbia Recovery Domain

2.2.2.2.1 Lower Columbia River Chinook Salmon ESU

On March 24, 1999, NMFS listed the Lower Columbia River Chinook Salmon ESU as a threatened species (64 FR 14308). The threatened status was reaffirmed on June 28, 2005 (70 FR 37159) and on April 14, 2014 (79 FR 20802). Critical habitat for Lower Columbia River Chinook salmon was designated on September 2, 2005 (70 FR 52706). In 2022, NMFS completed its most recent 5-year review for Lower Columbia River Chinook salmon (NMFS 2022j).

On February 6, 2015, we announced the initiation of five-year reviews for 17 ESUs of salmon and 11 DPSs of steelhead in Oregon, California, Idaho, and Washington (80 FR 6695). We requested that the public submit new information on these species that has become available since our original listing determinations or since the species' status was last updated. In response to our request, we received information from federal and state agencies, Native American Tribes, conservation groups, fishing groups, and individuals. We considered this information, as well as information routinely collected by our agency, to complete these five-year reviews. The most recent five year status review of the Lower Columbia River Chinook Salmon ESU was released October 21, 2022 (NMFS 2022j), and this section summarizes the current findings of that review.

The Lower Columbia River Chinook Salmon ESU includes natural populations in Oregon and Washington from the ocean upstream to, and including, the White Salmon River (river mile 167.5) in Washington and Hood River (river mile 169.5) in Oregon, except for salmon in the Willamette River (which enters the Columbia River at river mile 101). Within the Willamette River Chinook salmon are listed separately as the Upper Willamette River Salmon ESU, and not as part of the Lower Columbia River Chinook Salmon ESU.

Thirty-two historical populations, within six MPGs, comprise the Lower Columbia River Chinook Salmon ESU. These are distributed through three ecological zones[11]. A combination of life-history types, based on run timing and ecological zones, result in six MPGs, some of which are considered extirpated or nearly extirpated (Table 10). The run timing distributions across the 32 historical populations are: nine spring populations, 21 early-fall populations, and two late-fall populations (Table 10, Figure 6).

Within the geographic range of the Lower Columbia River Chinook Salmon ESU, during the interim since the 2015 status review update, there have been a number of changes in both the quality and quantity of hatchery production in the lower Columbia River (Ford 2022). Currently 18 of these hatchery programs are included in the ESU (Table 8), while the remaining programs are excluded (70 FR 37159; (NMFS 2022j)). For a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS, see NMFS (2005b).

[11] There are a number of methods of classifying freshwater, terrestrial, and climatic regions. The WLC TRT used the term ecological zone as a reference, in combination with an understanding of the ecological features relevant to salmon, to designate four ecological areas in the domain: (1) Coast Range zone, (2) Cascade zone, (3) Columbia Gorge zone, and (4) Willamette zone. This concept provides geographic structure to ESUs in the domain. Maintaining each life-history type across the ecological zones reduces the probability of shared catastrophic risks. Additionally, ecological differences among zones reduce the impact of climate events across entire ESUs (Myers et al. 2003).

Table 8. Lower Columbia River Chinook Salmon ESU description and MPGs (Ford 2022; NMFS 2022j). The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively[a].

ESU Description	
Threatened	Listed under ESA in 1999; updated in 2014.
6 MPGs	32 historical populations
MPG	***Populations***
Cascade Spring	Upper Cowlitz (C,G), Cispus (C), Tilton, Toutle, Kalama, NF Lewis (C), Sandy (C,G)
Gorge Spring	(Big) White Salmon (C), Hood
Coast Fall	Grays/Chinook, Elochoman (C), Mill Creek, Youngs Bay, Big Creek (C), Clatskanie, Scappoose
Cascade Fall	Lower Cowlitz (C), Upper Cowlitz, Toutle (C), Coweeman (G), Kalama, EF Lewis (G), Salmon Creek, Washougal, Clackamas (C), Sandy River early
Gorge Fall	Lower Gorge, Upper Gorge (C), (Big) White Salmon (C), Hood
Cascade Late Fall	North Fork Lewis (C,G), Sandy (C,G)
Artificial production	
Hatchery programs included in ESU (18)	Big Creek Tule Fall Chinook; Astoria High School Salmon-Trout Enhancement Program (STEP) Tule Chinook Program; Warrenton High School (STEP) Tule Chinook Program; Cowlitz Tule Chinook Program; North Fork Toutle Tule Chinook Program; Kalama Tule Chinook Program; Washougal River Tule Chinook Program; Spring Creek National Fish Hatchery (NFH) Tule Chinook Program; Cowlitz Spring Chinook Program in the Upper Cowlitz River and in the Cispus River; Friends of the Cowlitz Spring Chinook Program; Kalama River Spring Chinook Program; Lewis River Spring Chinook Program; Fish First Spring Chinook Program; Sandy River Hatchery Program; Deep River Net Pens-Washougal Program; Klaskanine Hatchery Program; Bonneville Hatchery Program; and the Cathlamet Channel Net Pens Program.
Hatchery programs not included in ESU (12)	Clatsop County Fisheries (CCF) Select Area Brights Program Fall Chinook, CCF Spring Chinook salmon Program, Carson NFH Spring Chinook salmon Program, Little White Salmon NFH Tule Fall Chinook salmon Program, Bonneville Hatchery Tule Fall Chinook salmon Program, Hood River Spring Chinook salmon Program[b], Deep River Net Pens Tule Fall Chinook, Klaskanine Hatchery Tule Fall Chinook, Bonneville Hatchery Fall Chinook, Little White Salmon NFH Tule Fall Chinook, Cathlamet Channel Net Pens Spring Chinook, Little White Salmon NFH Spring Chinook

[a] Core populations are defined as those that, historically, represented a substantial portion of the species' abundance. Genetic legacy populations are defined as those that have had minimal influence from nonendemic fish due to artificial propagation activities, or may exhibit important life-history characteristics that are no longer found throughout the ESU (McElhany et al. 2003).

[b] The ongoing Hood River Spring Chinook Salmon Program is currently integrating returning natural-origin spring Chinook salmon into the broodstock. The program had been using only spring Chinook salmon returning to the Hood River for broodstock since the release year 2013 when the last release of out-of-basin Deschutes River spring Chinook salmon occurred (NMFS 2022j). NMFS will continue to monitor the status of the natural-origin population to determine if the Hood River spring Chinook salmon 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).

Lower Columbia River Chinook salmon are classified into three life-history types including spring runs, early-fall runs ("tules", pronounced too-lees), and late-fall runs ("brights") based on when adults return to freshwater (Table 10). Lower Columbia River spring Chinook salmon are stream-type, while Lower Columbia River early-fall and late-fall Chinook salmon are ocean-type. Other life-history differences among run types include the timing of: spawning, incubation, emergence in freshwater, migration to the ocean, maturation, and return to freshwater. This life-history diversity allows different runs of Chinook salmon to use streams as small as 10 feet wide and rivers as large as the mainstem Columbia (NMFS 2013c). Stream characteristics determine the distribution of run types among Lower Columbia River streams. Depending on run type, Chinook salmon may rear anywhere from a few months to a year or more in freshwater streams, rivers, or the estuary before migrating to the ocean in spring, summer, or fall. All runs migrate far into the north Pacific on a multi-year journey along the continental shelf to Alaska before circling back to their river of origin. The spawning run typically includes three or more age classes. Adult Chinook salmon are the largest of the salmon species, and Lower Columbia River Chinook salmon can reach sizes of up to 25 kilograms (55 pounds). Chinook salmon require clean gravels for spawning, and pool and side-channel habitats for rearing. All Chinook salmon die after spawning once (NMFS 2013c).

Fall Chinook salmon (tules and brights) historically were found throughout the entire range, while spring Chinook salmon historically were only found in the upper portions of basins with snowmelt driven flow regimes (western Cascade Crest and Columbia Gorge tributaries) (NMFS 2013c). Bright Chinook salmon were identified in only two basins in the western Cascade Crest tributaries. In general, bright Chinook salmon mature at an older average age than either Lower Columbia River spring or tule Chinook salmon, and have a more northern oceanic distribution. Currently, the abundance of all fall Chinook salmon greatly exceeds that of the spring component (Ford 2022).

Table 9. Lower Columbia River Chinook salmon populations and recommended status under the recovery scenario (NMFS 2013c).

MPG	Population (State)	Contribution[b]	Recovery Scenario[a] Target Persistence Probability	Recovery Scenario[a] Abundance Target[c]
Cascade Spring	Upper Cowlitz (Washington (WA))	Primary	H+	1,800
	Cispus (WA)	Primary	H+	1,800
	Tilton (WA)	Stabilizing	VL	100
	Toutle (WA)	Contributing	M	1,100
	Kalama (WA)	Contributing	L	300
	North Fork Lewis (WA)	Primary	H	1,500
	Sandy (Oregon (OR))	Primary	H	1,230
Gorge Spring	White Salmon (WA)	Contributing	L+	500
	Hood (OR)	Primary[d]	VH[d]	1,493
Coast Fall	Youngs Bay (OR)	Stabilizing	L	505
	Grays/Chinook (WA)	Contributing	M+	1,000
	Big Creek (OR)	Contributing	L	577
	Elochoman/Skamokawa (WA)	Primary	H	1,500
	Clatskanie (OR)	Primary	H	1,277
	Mill/Aber/Germ (WA)	Primary	H	900
	Scappoose (OR)	Primary	H	1,222
Cascade Fall	Lower Cowlitz (WA)	Contributing	M+	3,000
	Upper Cowlitz (WA)	Stabilizing	VL	--
	Toutle (WA)	Primary	H+	4,000
	Coweeman (WA)	Primary	H+	900
	Kalama (WA)	Contributing	M	500
	Lewis (WA)	Primary	H+	1,500
	Salmon (WA)	Stabilizing	VL	--
	Clackamas (OR)	Contributing	M	1,551
	Sandy (OR)	Contributing	M	1,031
	Washougal (WA)	Primary	H+	1,200
Gorge Fall	Lower Gorge (WA/OR)	Contributing	M	1,200
	Upper Gorge (WA/OR)	Contributing	M	1,200
	White Salmon (WA)	Contributing	M	500
	Hood (OR)	Primary[d]	H[d]	1,245
Cascade Late Fall	North Fork Lewis (WA)	Primary	VH	7,300
	Sandy (OR)	Primary	VH	3,561

[a] Overall persistence probability of the population under the delisting scenario to achieve VSP criteria, including abundance target. VL =very low, L = low, M = moderate, H = high, VH = very high. These are adopted in the recovery plan (NMFS 2013c).
[b] Primary, contributing, and stabilizing designations reflect the relative contribution of a population to recovery goals and delisting criteria. Primary populations are targeted for restoration to a high or very high persistence probability. Contributing populations are targeted for medium or medium-plus viability. Stabilizing populations are

those that will be maintained at current levels (generally low to very low viability), which is likely to require substantive recovery actions to avoid further degradation.
[c] Abundance objectives account for related goals for productivity (NMFS 2013c).
[d] Oregon analysis indicates a low probability of meeting the delisting objectives for these populations.

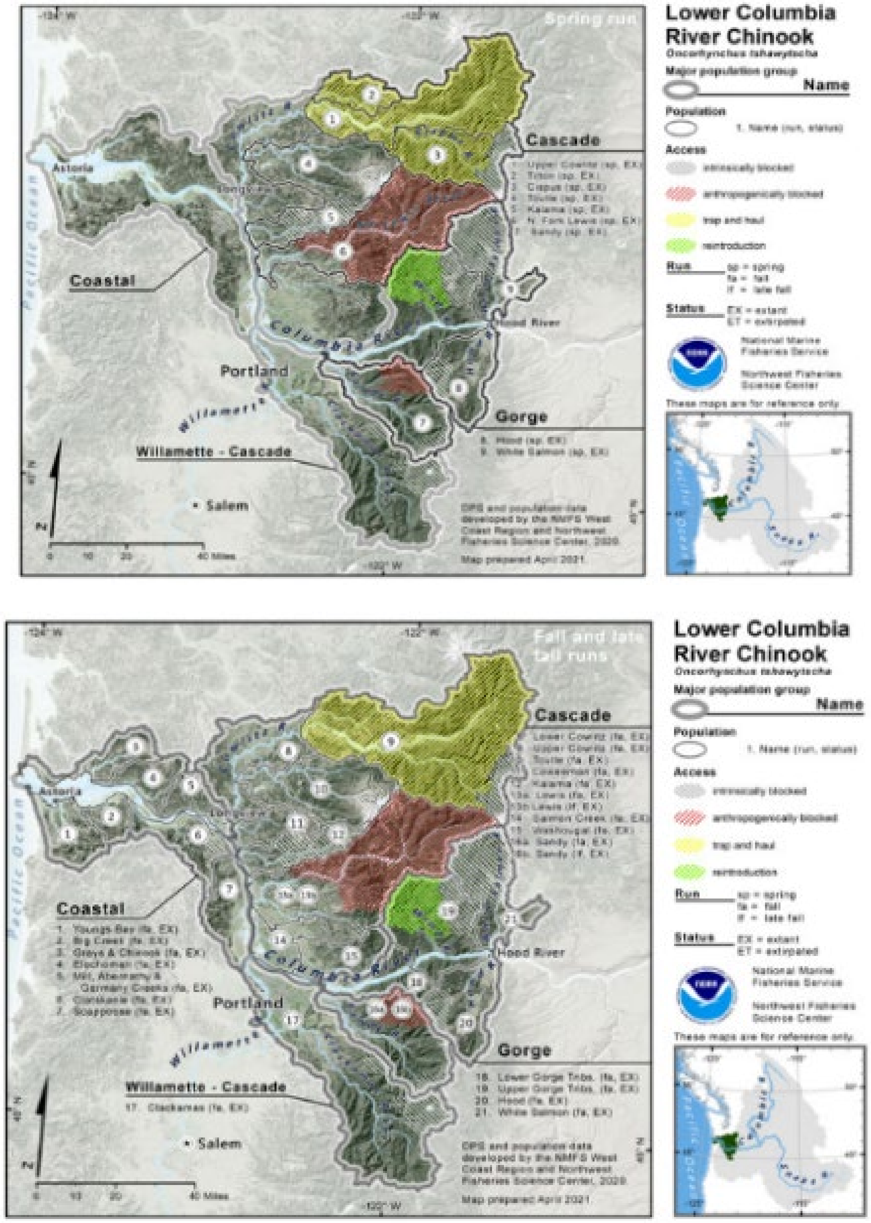


Figure 6. Maps of the Lower Columbia River Chinook Salmon ESU's spawning and rearing areas for Chinook salmon Demographically Independent Populations (DIPs or 'populations'), illustrating populations and MPGs. Several watersheds contain, or historically contained, both fall and spring runs. The upper figure illustrates spring-run populations and the lower figure illustrates fall-run populations (Ford 2022).

Table 10. Life-history and population characteristics of Lower Columbia River Chinook salmon.

Characteristic	Life-History Features		
	Spring	**Early-fall (tule)**	**Late-fall (bright)**
Number of extant populations	9	21	2
Life-history type	Stream	Ocean	Ocean
River entry timing	March–June	August–September	August–October
Spawn timing	August–September	September–November	November–January
Spawning habitat type	Headwater large tributaries	Mainstem large tributaries	Mainstem large tributaries
Emergence timing	December–January	January–April	March–May
Duration in freshwater	Usually 12–14 months	1–4 months, a few up to 12 months	1–4 months, a few up to 12 months
Rearing habitat	Tributaries and mainstem	Mainstem, tributaries, sloughs, estuary	Mainstem, tributaries, sloughs, estuary
Estuarine use	A few days to weeks	Several weeks up to several months	Several weeks up to several months
Ocean migration	As far north as Alaska	As far north as Alaska	As far north as Alaska
Age at return	4–5 years	3–5 years	3–5 years
Recent natural spawners	800	6,500	9,000
Recent hatchery adults	12,600 (1999–2000)	37,000 (1991–1995)	NA

2.2.2.2.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Each Lower Columbia River Chinook salmon natural population target persistence probability level is summarized in Table 9. Additionally, Table 9 provides the target abundance for each population that would be consistent with delisting. Persistence probability is measured over a 100-year time period and ranges from very low (probability < 40%) to very high (probability >99%).

The WLC TRT established recovery criteria as two primary populations with high target persistence probability in each MPG to achieve ESU viability. If the recovery scenario in Table 9 were achieved, it would exceed the WLC TRT's MPG-level viability criteria for the Coast and Cascade fall MPGs, the Cascade spring MPG, and the Cascade late-fall MPG. However, the recovery scenario in Table 9 for the Gorge spring and Gorge MPGs does not meet WLC TRT criteria. Within each of these MPGs, the scenario targets only one population (the Hood) for high persistence probability because Bonneville Dam spans the Gorge fall and spring MPGs affecting passage of fish to these areas. Exceeding the WLC TRT criteria, particularly in the Cascade fall and Cascade spring Chinook salmon MPG, was intentional on the part of recovery planners to compensate for uncertainties about meeting the WLC TRT's criteria in the Gorge fall and spring MPGs. In addition, multiple spring Chinook salmon natural populations are prioritized for aggressive recovery efforts to balance risks associated with the uncertainty of success in reintroducing spring Chinook salmon populations above tributary dams in the Cowlitz and Lewis systems.

NMFS (2013c) commented on the uncertainties and practical limits to achieving high viability for the spring and tule populations in the Gorge MPGs. Recovery opportunities in the Gorge were limited by the small numbers of natural populations and the high uncertainty related to restoration, due to Bonneville Dam passage and inundation of historically productive habitats. NMFS also recognized the uncertainty regarding the TRT's MPG delineations between the Gorge and Cascade MPG populations, and that several Chinook salmon populations downstream from Bonneville Dam may be quite similar to those upstream of Bonneville Dam. As a result, the recovery plan recommends that additional natural populations in the Coast and Cascade MPGs achieve recovery status, as it will help to offset the anticipated shortcomings for the Gorge MPGs. This was considered a more precautionary approach to recovery than merely assuming that efforts related to the Gorge MPG would be successful. The information provided by the WLC TRT and the management unit recovery planners led NMFS to conclude in the recovery plan that the recovery scenario (Table 9) represents one of multiple possible scenarios that would meet biological criteria for delisting. The similarities between the Gorge and Cascade MPG, coupled with compensation in the other strata for not meeting TRT criteria in the Gorge stratum, would provide an ESU no longer likely to become endangered.

Expanded spawner surveys begun after the 2010 review, especially in regard to abundance time series and hatchery contribution to the naturally spawning adults. Presently, there is some level of monitoring for all Chinook salmon populations except those that are functionally extinct (Ford 2022). Table 11 captures the geometric mean of natural spawner counts available, indicating that more recent years have more populations being monitored.

2.2.2.2.1.1.1 Abundance and Productivity

Out of the 32 populations that make up this ESU, only seven populations are at or near the recovery viability goals (Table 11) set in the recovery plan (refer above to Table 9). Six of these seven populations were located in the Cascade stratum; most of the populations in the Coastal and Gorge strata are doing rather poorly (Ford 2022).

Overall, there has been modest change since the 2015 viability review (NWFSC 2015) in the biological status of Chinook salmon populations in the Lower Columbia River Chinook salmon ESU (Ford 2022). Increases in abundance were noted in about half of the fall-run populations, and in 75% of the spring- run populations for which data were available (Figure 7). Decreases in hatchery contribution were also noted for several populations. Relative to baseline VSP levels identified in the recovery plan (NMFS 2013c), there has been an overall improvement in the status of a number of spring and fall-run populations (Table 11), although most are still far from the recovery plan goals.

Many of the populations in this ESU remain at “high risk,” with low natural-origin abundance levels. Although many of the populations in this ESU are at “high” risk, it is important to note that poor ocean and freshwater conditions existed during the 2015–19 period and, despite these conditions, the status of a number of populations improved, some remarkably so from the previous status review (Grays River Tule, Lower Cowlitz River Tule, and Kalama River Tule fall runs) (Ford 2022).

Table 11. Current 5-year geometric mean of raw natural-origin spawner abundances compared to the recovery scenario presented in the recovery plan (NMFS 2013c) for Lower Columbia River Chinook salmon populations (Ford 2022). Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > x < 50%, yellow = 50% > x < 100%, green = >100%.

MPG	Population	Abundance	
		2015–19	Recovery Target
Coastal	Grays River Tule FA (WA)	228	1,000
	Youngs Bay FA (OR)	145	505
	Big Creek FA (OR)	0	577
	Elochoman River/Skamokawa Tule FA (WA)	95	1,500
	Clatskanie River FA (OR)	3	1,277
	Mill/Abernathy/Germany Creeks Tule FA (WA)	28	900
	Scappoose Creek FA (OR)	n/a	1,222
Cascade	Upper Cowlitz/Cispus Rivers SP (WA)	171	1,800
	Kalama River SP (WA)	43	300

MPG	Population	Abundance	
		2015–19	Recovery Target
	North Fork Lewis River SP (WA)	-112	1,500
	Sandy River SP (OR)	3,359	1,230
	Toutle River SP (WA)	n/a	1,100
	Cispus River SP (WA)	n/a	1,800
	Tilton River SP (WA)	n/a	100
	Lower Cowlitz River Tule FA (WA)	3,208	3,000
	Coweeman River Tule FA (WA)	543	900
	Toutle River Tule FA (WA)	280	4,000
	Upper Cowlitz River Tule FA (WA)	1,761	n/a
	Kalama River Tule FA (WA)	2,142	500
	Lewis River Tule FA (WA)	2,003	1,500
	Clackamas River FA (OR)	236	1,551
	Sandy River FA (OR)	-2,074	1,031
	Washougal River Tule FA (WA)	914	1,200
	Salmon Creek FA (WA)	n/a	n/a
	Lewis River Bright LFR (WA)	8,725	7,300
	Sandy River Bright LFR (OR)	n/a	3,561
Gorge	Big White Salmon River SP (WA)	8	500
	Hood River SP (OR)	n/a	1,493
	Lower Gorge Tributaries Tule FA (WA & OR)	4,528	1,200
	Upper Gorge Tributaries Tule FA (WA & OR)	537	1,200
	Big White Salmon River Tule FA (WA)	283	500
	Hood River FA (OR)	n/a	1,245

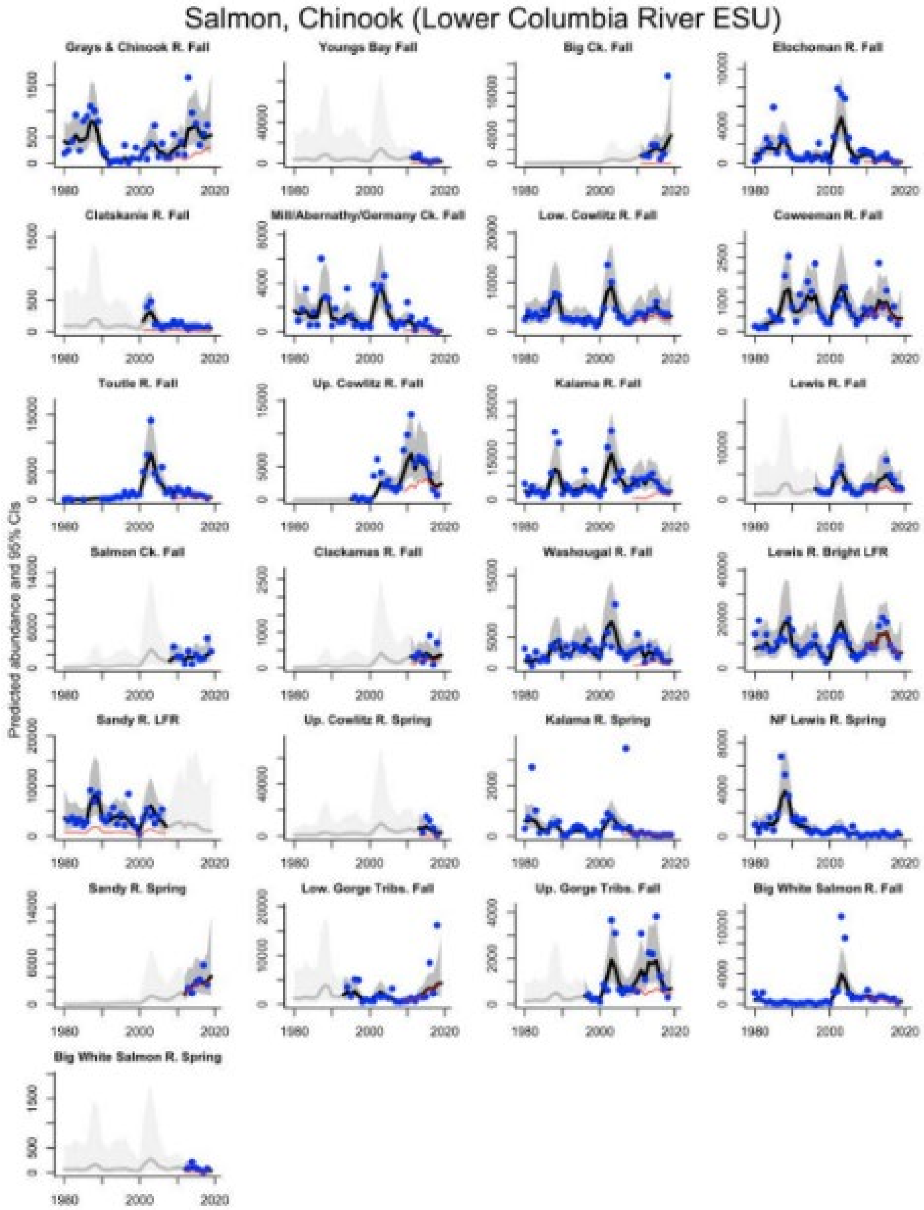


Figure 7. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

2.2.2.2.1.1.1.1 Harvest

Harvest rates for populations with different run timings share similar ER patterns, but differ in absolute harvest rates. With each run timing, tributary-specific harvest rates may differ. All populations saw a drop in ERs in the early 1990s in response to decreases in abundance. There has been a modest increase since then (Figure 8). Ocean fishery impact rates have been relatively stable in the past few years, with the exception of the bright (late fall) component of the ESU. The different MPGs are subject to different in-river fisheries (mainstem and tributary) because of differences in life histories and therefore river entry timing, but share relatively similar ocean distributions.

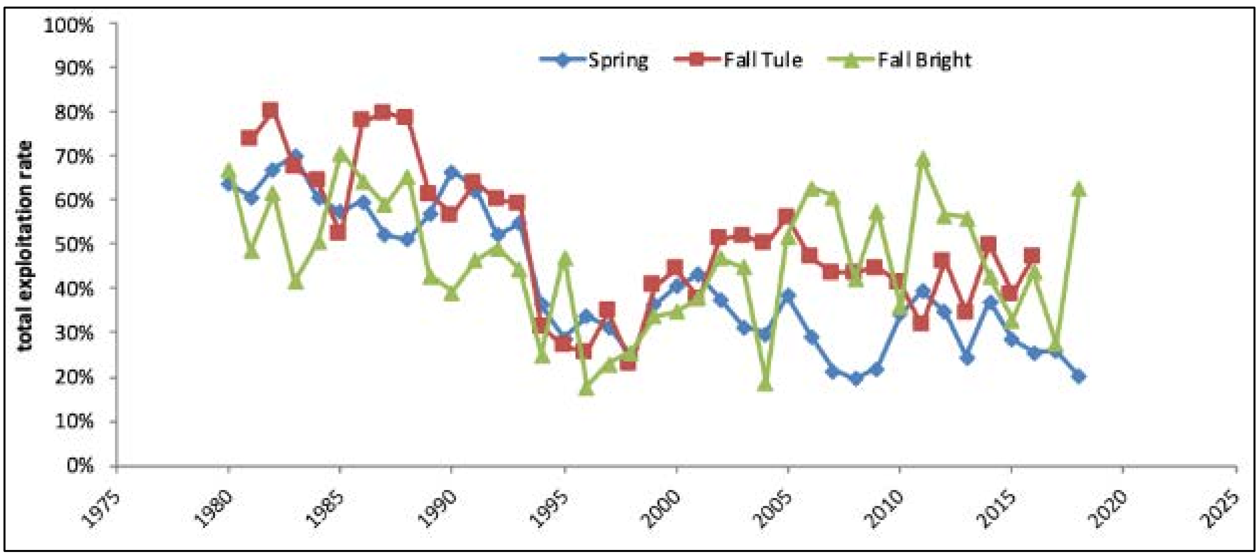


Figure 8. Total ERs on the three components of the Lower Columbia River Chinook salmon ESU (Ford 2022) (see Environmental Baseline for geographic distribution of the ERs).

2.2.2.2.1.1.2 Spatial Structure and Diversity

There have been a number of large-scale efforts to improve accessibility, one of the primary metrics for spatial structure, in this ESU. These include: passage efforts on the Cowlitz River at Cowlitz Falls starting in 1996, collection of juvenile fall-run Chinook salmon from the Tilton

River at Mayfield Dam, removal of the Powerdale Dam on the Hood River in 2010, removal of the Condit Dam on the White Salmon River in 2011, and fish passage operations for spring-run Chinook salmon (trap-and-haul) on the Lewis River beginning in 2012 (Ford 2022). Once passage actions are undertaken, it may still take several years for the benefits to become evident. Still, several programs continue to improve their operations and may achieve fish collection efficiencies suitable to support sustainable populations in previously inaccessible habitat sometime in the near future (5–10 years) (Ford 2022). In addition to these large-scale efforts, there have been a number of recovery actions throughout the ESU to remove or improve thousands of sub-standard culverts and other small-scale passage barriers, as well as breaching dikes to provide access to juvenile habitat (Ford 2022).
Although the spatial structure contribution to Lower Columbia River Chinook salmon ESU viability has improved during the current review period (2015–19), effective access to upstream habitat in the Cowlitz and Lewis River basins remains the major limitation (Ford 2022). Overall, the viability of the Lower Columbia River Chinook salmon ESU has increased since the 2015 viability review (NWFSC 2015), although the ESU remains at "moderate" risk of extinction.

2.2.2.2.1.1.2.1 Hatcheries

In 2017 NMFS adopted a Record of Decision ("Mitchell Act ROD") that would be used to guide NMFS' decision on the distribution of funds for hatchery production under the Mitchell Act (16 U.S.C. §§755-757), which NMFS administers. NMFS' continued funding of Mitchell Act hatchery programs, under the Mitchell Act ROD, was analyzed under the ESA and found not likely to jeopardize the continued existence of any species in the Columbia Basin (NMFS 2017o). The Mitchell Act ROD directs NMFS to strengthen performance goals to all Mitchell Act-funded, Columbia River Basin, hatchery programs that affect ESA-listed primary and contributing salmon and steelhead populations. These stronger performance goals reduced the risks of hatchery programs to natural-origin salmon and steelhead populations, including the Lower Columbia River Chinook Salmon ESU, and primarily to the tule Chinook salmon MPGs. It required integrated hatchery programs to be better integrated and isolated hatchery programs to be better isolated than was the practice at the time. While this action is expected to decrease multiple MPGs high relative dominance of hatchery-origin spawners, this will take some time to occur, and is not likely to show up in the data until the middle of this decade (mid 2020s at the earliest).

Hatchery contributions remain high for a number of populations (Table 12), and it is likely that many returning unmarked adults are the progeny of hatchery-origin parents, especially where large hatchery programs operate (Ford 2022). While overall hatchery production has been reduced slightly, hatchery-produced fish still represent a majority of fish returning to the ESU (Ford 2022). The continuing high proportions of hatchery-origin fish in spawning populations has been purposeful in some areas, e.g. for reintroduction purposes in the Hood, Cowlitz, and Lewis subbasins. The continued release of out-of-ESU stocks, including upriver bright fall-run, Rogue River Basin fall-run, upper Willamette River spring-run, Carson Hatchery spring-run, and Deschutes River spring-run, remains a concern (Ford 2022). Hatchery managers have continued to implement and monitor changes in Lower Columbia River Chinook salmon hatchery management (NMFS 2022j). Although several measures have been implemented to reduce risk, the proportion of hatchery fish on the spawning grounds (pHOS) remains high in the Coastal and Gorge MPGs (NMFS 2022j). NMFS has completed ESA consultations that have resulted in changes to the programs to reduce hatchery effects on natural-origin populations within the ESU (NMFS 2017o). We conclude that hatchery effects continue to present risks to the persistence of the Lower Columbia River Chinook salmon ESU, but they are likely less of a risk than at the time of the previous status review (NMFS 2016g).

Table 12. Five-year mean of fraction natural-origin spawners (sum of all estimates divided by the number of estimates) for Lower Columbia River Chinook salmon ESU populations (Ford 2022). Blanks mean no estimate available in that 5-year range.

Population[a]	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Upper Cowlitz/Cispus Rivers SP	Spring-run Cascade	—	—	—	0.08	0.06
Kalama River SP	Spring-run Cascade	—	—	—	1	1
North Fork Lewis River SP	Spring-run Cascade	—	—	—	—	—
Sandy River SP	Spring-run Cascade	—	—	—	0.89	0.92
Big White Salmon River SP	Spring-run Gorge	—	—	—	0.13	0.18
Grays River Tule FA	Fall-run Coastal	—	—	0.36	0.22	0.43
Youngs Bay FA	Fall-run Coastal	—	—	—	0.04	0.14
Big Creek FA	Fall-run Coastal	—	—	—	0.03	0.04
Elochoman River/ Skamokawa Tule FA	Fall-run Coastal	—	—	—	0.17	0.45
Clatskanie River FA	Fall-run Coastal	—	0.1	0.19	0.09	0.05
Mill/Abernathy/Germany Creeks Tule FA	Fall-run Coastal	—	—	—	0.11	0.22
Lower Cowlitz River Tule FA	Fall-run Cascade	—	—	—	0.7	0.77
Coweeman River Tule FA	Fall-run Cascade	—	—	—	0.82	0.91
Toutle River Tule FA	Fall-run Cascade	—	—	—	0.31	0.55
Upper Cowlitz River Tule FA	Fall-run Cascade	—	—	—	0.35	0.82
Kalama River Tule FA	Fall-run Cascade	—	—	—	0.08	0.57

Population[a]	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Lewis River Tule FA	Fall-run Cascade	—	—	—	0.67	0.56
Clackamas River FA	Fall-run Cascade	—	—	—	0.6	0.68
Sandy River FA	Fall-run Cascade	—	—	—	—	—
Washougal River Tule FA	Fall-run Cascade	—	—	—	0.3	0.58
Lower Gorge Tributaries Tule FA	Fall-run Gorge	—	—	—	0.89	0.96
Upper Gorge Tributaries Tule FA	Fall-run Gorge	—	—	—	0.4	0.58
Big White Salmon River Tule FA	Fall-run Gorge	—	—	—	0.8	0.57
Lewis River Bright LFR	Late fall-run Cascade	—	—	—	1	1
Sandy River Bright LFR	Late fall-run Cascade	0.24	0.24	0.24	—	—

[a] Note that the Tilton (Spring-run Cascade), Toutle (Spring-run Cascade), Hood (Spring-run Gorge), Scapoose (Fall-run Coastal), Salmon (Fall-run Cascade), and Hood (Fall-run Gorge) populations are not included due to low abundances or lack of monitoring and available data, as discussed further in Ford (2022).

2.2.2.2.1.2 Limiting Factors

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Lower Columbia River Chinook Salmon ESU. Lower Columbia River Chinook salmon populations began to decline by the early 1900s because of habitat alterations and harvest rates that were unsustainable, particularly given these changing habitat conditions. Human impacts and limiting factors come from multiple sources, including hydropower development on the Columbia River and its tributaries, habitat degradation, hatchery effects, fishery management and harvest decisions, and ecological factors, including predation and environmental variability. The recovery plan consolidates available information regarding limiting factors and threats for the Lower Columbia River Chinook Salmon ESU (NMFS 2013c).

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

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

Chapter 7 of the recovery plan discusses the limiting factors that pertain to Lower Columbia River Chinook salmon spring, fall, and late fall natural populations and the MPGs in which they reside. The discussion of limiting factors in Chapter 7 (NMFS 2013c) is organized to address:

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

Rather than repeating the extensive discussion from the recovery plan, this discussion in Chapters 4 and 7 is incorporated here by reference.

In our recent five-year status review (NMFS 2022j), based on Section 4(a)(1) of the ESA, we determine if the listed species listing factors have changed. While there have been improvements in the abundance of some populations, we found that the overall viability trends remain low, and well below abundance recovery objectives for Lower Columbia River Chinook Salmon ESU. Some improvements have been made in listing factors, though slight increases in risk in some listing factors are contemporaneous with restoration work and some regulatory improvements, and the recent improvements (particularly habitat restoration work) require time to manifest measurable increases in population viability. The risk from predation and disease to the Lower Columbia River Chinook Salmon ESU remains. For harvest, the risk is increasing for Lower Columbia River Chinook salmon due to modest upward trend in harvest impacts on fall and bright fall-run components of the ESU (NMFS 2022j). Additionally, the risk to the species persistence from climate change is an increasing concern (NMFS 2022j).

Accordingly, when all listing factors and current viability are considered, specific to the Lower Columbia River Chinook Salmon ESU, our recent five-year status review indicates that the collective risk to the persistence of the Lower Columbia River Chinook Salmon ESU has not changed significantly since our listing determination in 2006 and should remain listed as threatened (NMFS 2022j).

2.2.2.2.2 Upper Willamette River Chinook Salmon ESU

On March 24, 1999, NMFS listed the Upper Willamette River Chinook Salmon ESU as a threatened species (64 FR 14308). The threatened status was reaffirmed on June 28, 2005 (70 FR 37160) and again on April 14, 2014 (79 FR 20802). Critical habitat was designated on September 2, 2005 (70 FR 52629). In 2024, NMFS published the most recent 5-year status review for Upper Willamette River Chinook salmon (NMFS 2024d). The NWFSC finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA in 2022 (Ford 2022).

The ESU includes all naturally spawned populations of spring-run Chinook salmon in the Clackamas River, the Willamette River and its tributaries above Willamette Falls, Oregon (Figure 9). Critical habitat encompasses 60 watersheds within the range of this ESU as well as the lower Willamette/Columbia River rearing/migration corridor, occurring in the counties of Benton, Clackamas, Clatsop, Columbia, Lane, Linn, Marion, Multnomah, Polk, and Yamhill, in the State of Oregon, and Clark, Cowlitz, Pacific, and Wahkiakum in the State of Washington (70 FR 52629). The ESU contains seven historical populations, within a single MPG, as well as six artificial propagation programs (western Cascade Range, Table 13).

Table 13. Upper Willamette River Chinook Salmon ESU description and MPG (Jones 2015; NWFSC 2015; Ford 2022; NMFS 2024d).

ESU Description	
Threatened	Listed under ESA in 1999; updated in 2014.
1 MPG	7 historical populations
MPG	***Populations***
Western Cascade Range	Clackamas River, Molalla River, North Santiam River, South Santiam River, Calapooia River, McKenzie River, Middle Fork (MF) Willamette River
Artificial production	
Hatchery programs included in ESU (6)	McKenzie River spring, North Santiam spring, Molalla spring, South Santiam spring, MF Willamette spring, Clackamas spring

The Upper Willamette River Chinook Salmon ESU only has one MPG (Table 13), containing the seven populations listed in Table 13. A recovery plan was finalized for this species on August 5, 2011 (ODFW et al. 2011). The broad sense recovery goal for the ESU is to achieve for all Upper Willamette River salmon populations a “very low” extinction risk, and would therefore lead to a “highly viable” population (i.e. over 100 years throughout their range). In the Lower Columbia River Chinook salmon ESU, this type of population designation is termed “primary”. As no such designation or stratification was done for the Upper Willamette River Chinook Salmon ESU, the adopted approach treats all populations in the ESU as if they were primary populations.

Upper Willamette River Chinook salmon’s genetics have been shown to be strongly differentiated from nearby populations, and are considered one of the most genetically distinct groups of Chinook salmon in the Columbia River Basin (Waples et al. 2004; Beacham et al. 2006). For adult Chinook salmon, Willamette Falls historically acted as an intermittent physical barrier to upstream migration into the Upper Willamette River basin, where adult fish could only ascend the falls at high spring flows. It has been proposed that the falls served as a zoogeographic isolating mechanism for a considerable period of time (Waples et al. 2004). This isolation has led to, among other attributes, the unique early run timing of these populations relative to other Lower Columbia River spring-run populations. Historically, the peak migration of adult salmon over the falls occurred in late May. Low flows during the summer and autumn months prevented fall-run salmon and coho salmon from reaching the Upper Willamette River basin (ODFW et al. 2011).

The generalized life history traits of Upper Willamette River Chinook salmon are summarized in Table 14. Typically, adult Upper Willamette River Chinook salmon begin appearing in the lower Willamette River in January, with fish entering the Clackamas River as early as March. The majority of the run ascends Willamette Falls from late April through May, with the run extending into mid-August (Myers et al. 2006).

Chinook salmon now ascend the falls via a fish ladder at Willamette Falls. Through 2017, ODFW conducted comprehensive spawner surveys (redds and carcasses) both below and above dams in the North Santiam, South Santiam, McKenzie, and Middle Fork Willamette Rivers. Direct adult counts are also made at Willamette Falls, Bennett Dam, and Minto Fish Facility (North Santiam River), Foster Fish Facility (South Santiam River), Leaburg and Cougar Dams and the McKenzie Hatchery (McKenzie River), and Fall Creek Dam and Dexter Fish Facility (Middle Fork Willamette River). Intermittent spawner surveys have been conducted in the Molalla and Calapooia Rivers, but are insufficient to estimate population abundance. Beginning in 2018, there has been a transition in the methodology and extent of adult spawner surveys. In 2018 and 2019, parallel spawner survey efforts were undertaken by ODFW and Environmental Assessment Services (Ford 2022).

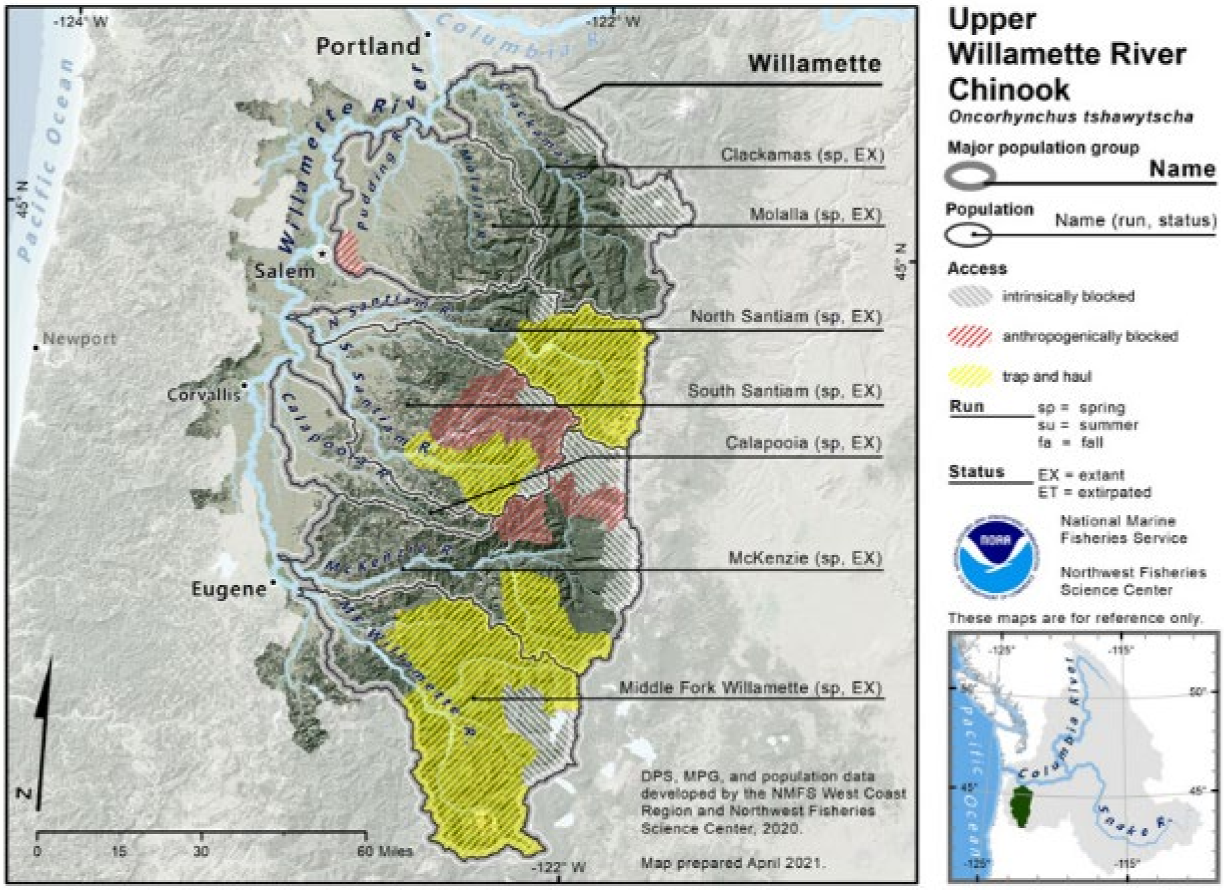


Figure 9. Map of the seven populations within the Upper Willamette River Chinook salmon ESU. Areas that are accessible (green), accessible only via trap-and-haul programs (yellow), or blocked (cross-hatched), are indicated accordingly (Ford 2022).

Table 14. A summary of the general life-history characteristics and timing of Upper Willamette River Chinook salmon[a].

Life-History Trait	Characteristic
Willamette River entry timing	January-April; ascending Willamette Falls April-August
Spawn timing	August-October, peaking in September
Spawning habitat type	Larger headwater streams
Emergence timing	December-March
Rearing habitat	Rears in larger tributaries and mainstem Willamette
Duration in freshwater	12–14 months; rarely 2–5 months
Estuarine use	Days to several weeks
Life-history type	Stream
Ocean migration	Predominantly north, as far as southeast Alaska
Age at return	3–6 years, primarily 4–5 years

[a] Data are from numerous sources (ODFW et al. 2011).

2.2.2.2.2.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. The Willamette Valley was not glaciated during the last epoch (McPhail et al. 1970), and Willamette Falls likely served as a physical barrier for reproductive isolation of Chinook salmon populations. This isolation had the potential to produce local adaptation relative to other Columbia River populations (Myers et al. 2006). Fish ladders were constructed at the falls in 1872 and again in 1971, but it is not clear what role they may have played in reducing localized adaptations in Upper Willamette River fish populations. Little information exists on the life-history characteristics of the historical Upper Willamette River Chinook salmon populations, especially since early fishery exploitation (starting in the mid-1880s), habitat degradation in the lower Willamette Valley (starting in the early 1800s), and pollution in the lower Willamette River (by early 1900s) likely altered life-history diversity before data collection began in the mid-1900s. Nevertheless, there is ample reason to believe that Upper Willamette River Chinook salmon still contain a unique set of genetic resources compared to other Chinook salmon stocks in the WLC Domain (ODFW et al. 2011).

2.2.2.2.2.1.1 Abundance and Productivity

According to the most recent viability assessment (Ford 2022), abundance levels for five of the seven natural-origin populations in this ESU decreased (Figure 10) relative to the 2015 status review (NWFSC 2015). Chinook salmon counts at Willamette Falls have been undertaken since 1946, when 53,000 Chinook salmon were counted; however, not until 2002, with the return of the first cohort of mass-marked hatchery-reared fish, was it possible to inventory naturally produced fish with any accuracy. Cohorts returning from 2015–19 outmigration were strongly influenced by warmer-than-normal and less-productive ocean conditions, in addition to warmer- and drier-than-normal freshwater conditions. The five-year average abundance geomean for 2015–19 was 6,916 natural-origin (unmarked) adults, a 31% decrease from the previous period. Abundances, in terms of adult returns, in the Clackamas and McKenzie Rivers have risen since the 2015 viability review (Ford 2022). Improvements in the status of the Middle Fork Willamette River population is due to the sole return of natural-origin adults to Fall Creek basin. However, the capacity of the Fall Creek basin alone is insufficient to achieve the recovery goals for the Middle Fork Willamette River individual population.

While there was a substantial downward trend in total and natural-origin spring-run abundance at Willamette Falls from 2003 to just before 2010 (Figure 10), there were some indications of improving abundance in 2019 and 2020. Improvements in abundance corresponded with improved ocean and freshwater conditions, as well as changes in pinniped predation. In recent years, counts of spring-run Chinook salmon at Willamette Falls have been impacted by pinniped predation at the base of the falls. For the return years 2014–18, pinnipeds were estimated to consume 6–10% of the unmarked Chinook salmon escapement; however, in 2019, when a pinniped removal program was initiated, the rate dropped to approximately 4% (Ford 2022). Over the last 15 years, the long-term trend for natural-origin returns was negative 4% (Ford 2022), suggesting an overall decline in those populations above Willamette Falls.

Limited data are available for natural-origin spawner abundance for Upper Willamette River Chinook salmon populations. Table 15 includes the most up-to-date available data for natural-origin Chinook salmon spawner estimates from Upper Willamette River subbasins relative to their recovery scenario expectation in the recovery plan.

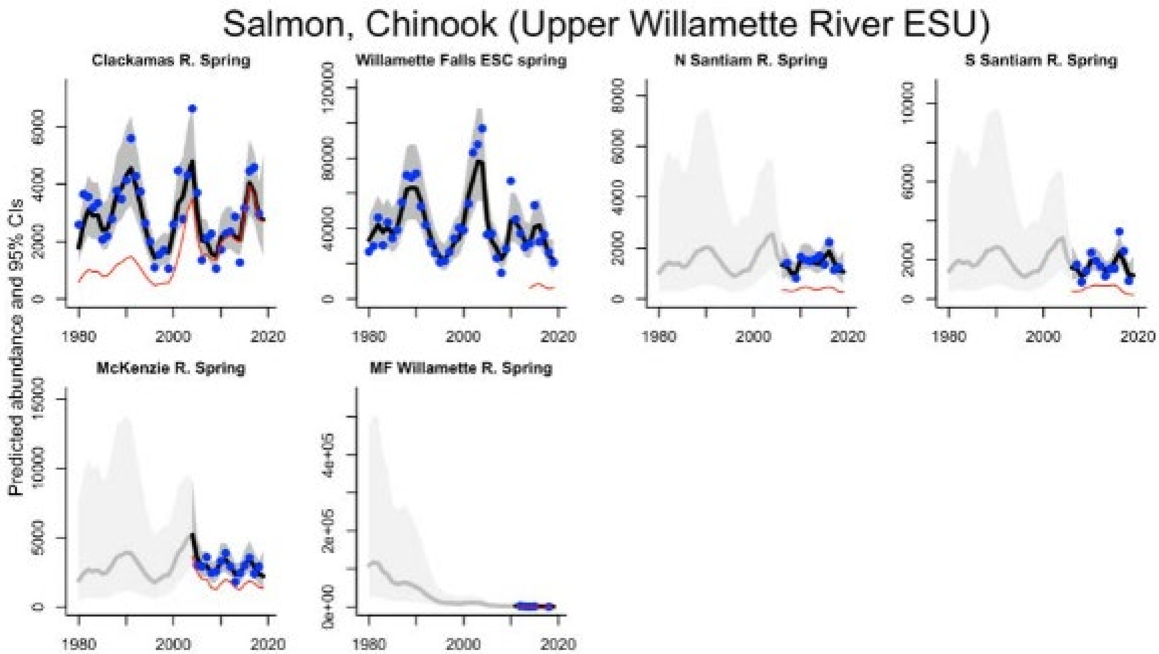


Figure 10. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

Table 15. Current 5-year geometric mean of raw natural-origin spawner abundances compared to the recovery scenario presented in the recovery plan (ODFW et al. 2011) for Upper Willamette River Chinook salmon populations (Ford 2022). Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > x < 50%, yellow = 50% > x < 100%, green = >100%.

MPG	Population	Abundance	
		2015–19	Recovery Target
Willamette	Clackamas River SP	3,617	2,317
	Molalla River SP	n/a	696
	North Santiam River SP	354	5,400
	South Santiam River SP	337	3,100
	Calapooia River SP	n/a	590
	McKenzie River SP	1,664	8,376
	Middle Fork Willamette River SP	20	5,820

2.2.2.2.2.1.1.1 Harvest

Upper Willamette River spring-run Chinook salmon are taken in ocean fisheries primarily in Canada and Alaska. They are also taken in lower mainstem Columbia River commercial gillnet fisheries, and in recreational fisheries in the mainstem Columbia River and the Willamette River. The distribution of mortality accrued in marine fisheries is described in detail in the Environmental Baseline (Section 2.4). The in-river fisheries are directed at hatchery production, but historically could not discriminate between natural and hatchery fish. In the late 1990s, ODFW began mass-marking the hatchery production, and recreational fisheries within the Willamette River switched over to retention of only hatchery fish, with mandatory release of unmarked fish. ERs in ocean fisheries, with the exception of 2016, have been low (Figure 11). The Fishery Management and Evaluation Plan (FMEP) for the Willamette River sets the maximum freshwater mortality rate for naturally produced Chinook salmon at 15% (ODFW et al. 2020). The FMEP proposed to limit the harvest rate on natural-origin fish in all freshwater fisheries to no more than 15%. NMFS concluded in that review that managing Upper Willamette River spring Chinook salmon according to the provisions of the FMEP is not likely to jeopardize the continued existence of the ESU (NMFS 2001a).

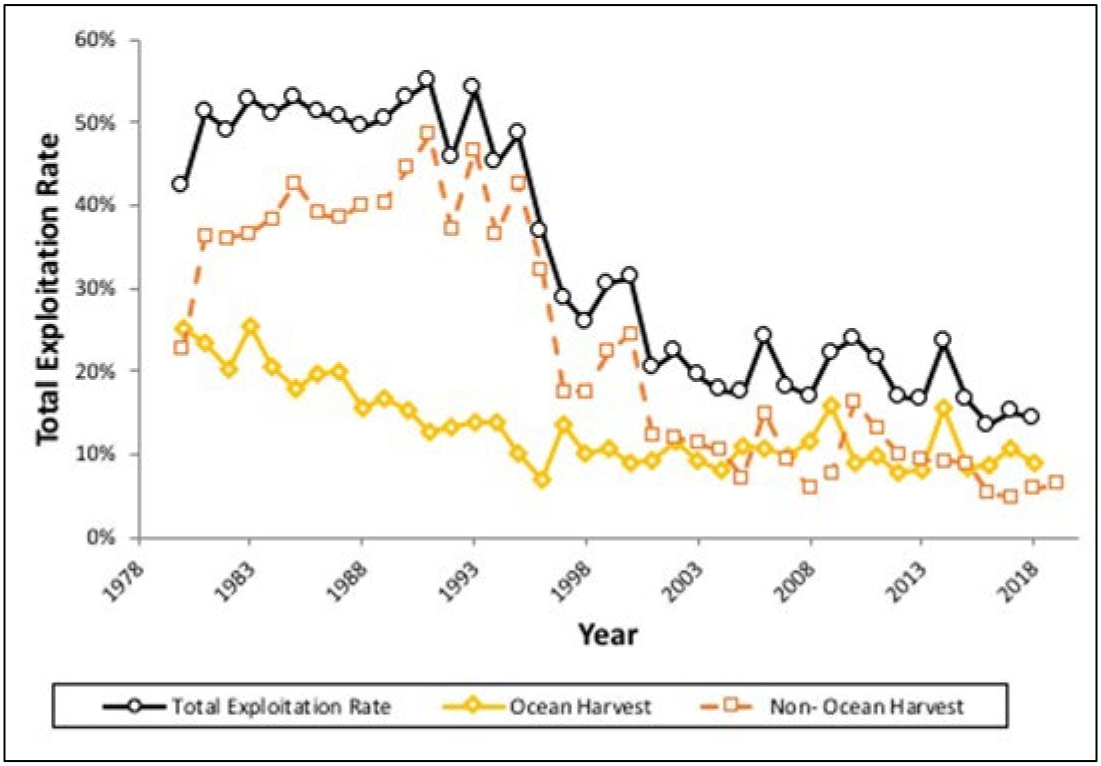


Figure 11. Ocean harvest, terminal harvest, and escapement rates for spring-run Upper Willamette River Chinook salmon, based on coded-wire tag recoveries (Ford 2022). Ocean harvest rates for hatchery and unmarked naturally produced fish are assumed to be comparable; terminal fisheries have been mark-selective since 2001, and unmarked fish mortality rates will be considerably lower: hooking mortality in the Willamette River is assumed to be 12.2% (Ford 2022).

2.2.2.2.2.1.2 Spatial Structure and Diversity

Spatial structure, specifically access to historical spawning habitat, continues to be a concern. Major dams block volitional passage to historical Chinook salmon habitat in five of the seven populations in the ESU. In most cases, effective passage programs are limited by low collection rates for emigrating juveniles. Recovery plans target key limiting factors for future actions. However, there have been no significant actions taken since the 2011 status review to restore access to historical habitat above dams (Ford 2022). Restoration of access to upper watersheds remains a key element in risk reduction for this ESU.

A second spatial structure concern is the availability of juvenile rearing habitat in side-channel or off-channel habitat. River channelization and shoreline development have constrained habitat in the lower tributary reaches and Willamette River mainstem, in turn limiting the potential for fry and subyearling "movers" emigrating to the estuary (Schroeder et al. 2016).

2.2.2.2.2.1.2.1 Hatcheries

For Upper Willamette River Chinook salmon, diversity and productivity concerns include interaction and introgression with hatchery-origin Chinook salmon (Ford 2022). There have been a number of changes in hatchery operations since the initial status review (Myers et al. 1998). In general, production levels are based on mitigation agreements related to the construction of dams in the Willamette River basin. Mass marking of hatchery-origin Chinook salmon began in 1997, with all returning adults being marked by 2002. Off-station releases within some basins have been curtailed in an effort to limit natural spawning by hatchery-origin fish. More recently, NMFS finalized an Opinion on hatchery operations in the Upper Willamette River basin evaluating a number of changes to minimize the potential influence of hatchery-origin fish on natural-origin Chinook salmon and steelhead (NMFS 2019n). Through the provisions of NMFS (2019l) and individual Hatchery and Genetic Management Plans (HGMPs), hatcheries in the Upper Willamette River have reduced releases of spring-run Chinook salmon in the McKenzie and North Santiam Rivers (Figure 12 and Table 16), while shifting production to other basins (Ford 2022). In addition, NMFS (2019l) calls for further action in the McKenzie River to further reduce the number of hatchery fish spawning naturally.

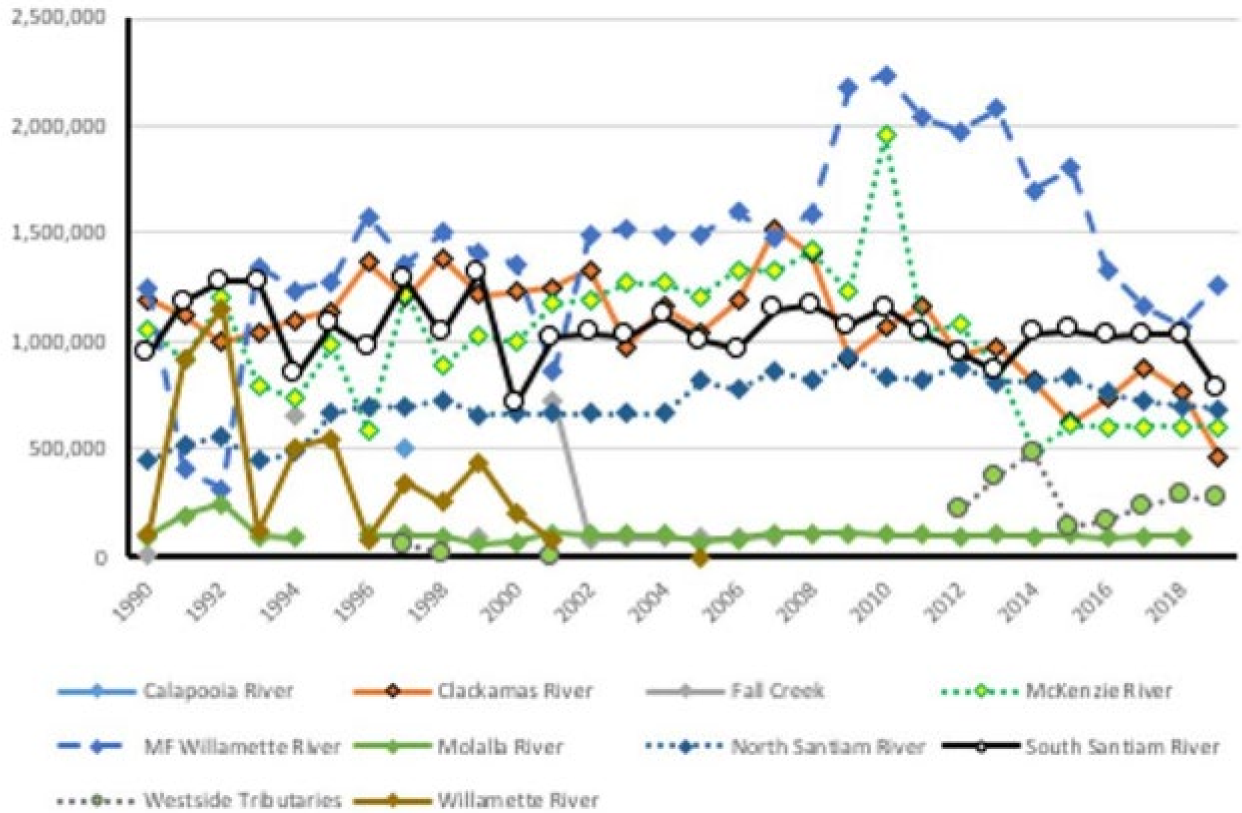


Figure 12. Hatchery releases of juvenile spring-run Chinook salmon into basins of the Upper Willamette River Chinook salmon ESU, 1990–2019. Data for 2019 may be incomplete. Releases of juveniles weighing <2.5 g were not included. Releases into the Row and Coast Fork Rivers were combined under Westside Tributaries (Ford 2022). Data from the Regional Mark Information System (https://www.rmpc.org, June 2020).

In concert with improvements in collection efficiency at various dams throughout the Willamette River basin, the number of hatchery fish released has decreased in most basins where there is natural spawning, with increased releases in westside tributaries (Ford 2022). In general, the influence of hatchery-origin Chinook salmon on the spawning grounds has shown a slight improvement (meaning less influence), with the exception of the South Santiam River, where fish collection at the new facility has been poor leaving more hatchery-origin fish to spawn below Foster Dam (Ford 2022).

Table 16. Five-year mean of fraction natural-origin Chinook salmon spawning naturally in the Upper Willamette River Chinook Salmon ESU (Ford 2022). A dash (“-“) means that no estimate is available in that 5-year range.

Population[a]	MPG	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
Willamette Falls[b]	Willamette	-	0.24	0.30	0.24	0.22
Clackamas River	Willamette	0.33	0.58	0.79	0.94	0.97
North Santiam River	Willamette	-	-	0.33	0.26	0.26
South Santiam River	Willamette	-	-	0.39	0.40	0.21
McKenzie River	Willamette	-	-	0.64	0.55	0.57
Middle Fork Willamette River	Willamette	-	-	-	0.08	0.07

[a] Note that Molalla River and Calapooia River populations are not included due to low abundances or lack of monitoring and available data, as discussed further in Ford (2022).
[b] Willamette Falls is not considered one of the seven populations in this ESU but was included in the above table in Ford (2022) due to many years of available data at that particular location

2.2.2.2.2.1.3 Summary

Access to historical spawning and rearing areas is still restricted by high-head dams in five of the historically most-productive tributaries. Only in the Clackamas River does the current system of adult trap-and-haul and juvenile collection appear to be effective enough to sustain a naturally spawning population (although current juvenile passage efficiencies are still below NMFS criteria). In the McKenzie River, the spring-run Chinook salmon population appears to be relatively stable, having reversed a short-term downward abundance trend that was of concern during the 2015 review. The McKenzie River remains well below its recovery goal, despite having volitional access to much of its historical spawning habitat. The North and South Santiam River DIPs both experienced declines in abundance. The Calapooia and Molalla Rivers are constrained by habitat conditions, and natural reproduction is likely extremely low.

Demographic risks remain “high” or “very high” for most populations, except the Clackamas and McKenzie Rivers, which are at “low” and “low-to-moderate” risk, respectively. The Clackamas River spring-run Chinook salmon population maintains a low pHOS through the removal of all marked hatchery-origin adults at North Fork Dam. Elsewhere, hatchery-origin fish comprise the majority or, in the case of the McKenzie River, nearly half of the naturally spawning population. Diversity risks continue to be a concern (Ford 2022).

Overall, there has likely been a declining trend in the viability of the Upper Willamette River Chinook salmon ESU since the the 2015 viability review (NWFSC 2015). The magnitude of this change is not sufficient to suggest a change in risk category, however, so the Upper Willamette River Chinook salmon ESU remains at “moderate” risk of extinction (Ford 2022).

2.2.2.2.2.2 Limiting Factors

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Upper Willamette River Chinook Salmon ESU. Understanding the limiting factors and threats that affect the Upper Willamette River Chinook Salmon ESU provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. Factors that affect the ESU and its populations have been, and continue to be, dams that block access to major production areas, loss and degradation of accessible spawning and rearing habitat, and degraded water quality and increased water temperatures (Ford 2022). Improvements have been made in operations and fish passage at tributary dams, and numerous habitat restoration projects have been completed in many Upper Willamette River tributaries. These actions eventually will provide benefit to the Upper Willamette River Chinook salmon ESU (Ford 2022). However, the scale of habitat improvements needed is greater than the scale of habitat actions implemented to date, and we remain concerned about impaired passage at multiple dams and degraded habitat through-out the watershed. Most land in the Upper Willamette River is in private ownership, making successful efforts to protect and restore habitat on private lands key to recovery in the upper Willamette, particularly in the face of continuing development. There are also substantial portions of federal land in the upper Willamette, so the protection and restoration of salmon habitat on federal lands is also crucial to recovery.

Additionally, overall ERs reflect changes in fisheries to more conservative management regimes. ERs dropped from a range of 50–60% in the 1980s and early 1990s, to around 30% since 2000, with reductions observed in both ocean and freshwater fisheries. Harvest rates on Upper Willamette River Chinook salmon have remained stable and relatively low since the status review in 2016. Post-release mortality from hooking is generally estimated at 10% in the Willamette River, although river temperatures likely affect this rate. Illegal take of unmarked fish is thought to be low (NWFSC 2015).

The recovery plan for Upper Willamette River Chinook salmon (ODFW et al. 2011) provides a detailed discussion of limiting factors and threats, and describes strategies for addressing each of them (Chapter 5 in ODFW et al. (2011)). Rather than repeating the extensive discussion from the recovery plan, this discussion in Chapter 5 is incorporated here by reference.

Additionally, the Northwest Fisheries Science Center outlines in Ford (2022) additional limiting factors for the Upper Willamette River Chinook Salmon ESU which include the following:

- Significantly reduced access to spawning and rearing habitat because of tributary dams,
- Degraded freshwater habitat, especially floodplain connectivity and function, channel structure and complexity, and riparian areas and large wood recruitment as a result of cumulative impacts of agriculture, forestry, and development,
- Degraded water quality and altered water temperatures as a result of both tributary dams and the cumulative impacts of agriculture, forestry, and urban development,
- Hatchery-related effects,
- Anthropogenic introductions of non-native species and out-of-ESU races of salmon or steelhead have increased predation on, and competition with, native Upper Willamette River Chinook salmon, and
- Historic ocean harvest rates of approximately 30%.

There has likely been an overall decrease in population VSP scores since the 2015 review for the North Santiam, Calapooia, and Middle Fork Willamette rivers populations. However, the magnitude of this change is not sufficient to suggest a change in risk category for the ESU, as the other three populations for which we have data have shown slight improvements in abundance during the last five years (Table 16). Given current climatic conditions, and the prospect of long-term climatic change, the inability of many populations to access historical headwater spawning and rearing areas may put this ESU at greater risk in the near future. The collective risk to the Upper Willamette River salmon persistence has not changed significantly since our previous status review for the Upper Willamette River Chinook salmon ESU, and they remain listed as threatened (Ford 2022).

2.2.2.3 Interior Columbia Recovery Domain

2.2.2.3.1 Snake River Fall-Run Chinook Salmon ESU

On April 22, 1992, NMFS listed the Snake River Fall-Run Chinook Salmon ESU as a threatened species (57 FR 14653). The threatened status was reaffirmed on June 28, 2005 (70 FR 37159) and on May 26, 2016 (81 FR 33468). Critical habitat was designated on December 28, 1993 (58 FR 68543). It includes spawning and rearing areas limited to the Snake River below Hells Canyon Dam, and within the Clearwater, Hells Canyon, Imnaha, Lower Grand Ronde, Lower North Fork Clearwater, Lower Salmon, Lower Snake, Lower Snake-Asotin, Lower Snake-Tucannon, and Palouse hydrologic units. However, this critical habitat designation includes all river reaches presently or historically accessible to this species (except reaches above impassable natural falls, and Dworshak and Hells Canyon Dams). On October 4, 2019 NMFS announced the initiation of a new 5-year status review process including review of the Snake River Fall-Run Chinook Salmon ESU (84 FR 53117), which it completed and published on August 16, 2022 (NMFS 2022p).

The Snake River Fall-Run Chinook Salmon ESU includes naturally spawned fish in the lower mainstem of the Snake River and the lower reaches of several of the associated major tributaries, including the Tucannon, the Grande Ronde, Clearwater, Salmon, and Imnaha Rivers, along with 4 artificial propagation programs (Ford 2022). Table 17 lists the natural and hatchery populations included in the ESU.

Table 17. Snake River Fall-Run Chinook Salmon ESU description and MPGs (Ford 2022).

ESU Description	
Threatened	Listed under ESA in 1992; updated in 2022
1 MPG	2 historical populations (1 extirpated)
MPG	***Population***
Snake River	Lower Mainstem Fall-Run
Artificial production	
Hatchery programs included in ESU (4)	Lyons Ferry National Fish Hatchery (LFH) fall, Acclimation Ponds Program fall, Nez Perce Tribal Hatchery fall, Idaho Power fall

Two historical populations (1 extirpated) within one MPG comprise the Snake River Fall-Run Chinook Salmon ESU. The extant natural population spawns and rears in the mainstem Snake River, and its tributaries, below Hells Canyon Dam. The Interior Columbia River Technical Recovery Team (ICTRT) identified five major spawning areas (MaSAs) which are: Upper Hells Canyon MaSA (Hells Canyon Dam on Snake River downstream to confluence with Salmon River); Lower Hells Canyon MaSA (Snake River from Salmon River confluence downstream to Lower Granite Dam pool); Clearwater River MaSA; Grande Ronde River MaSA; and Tucannon River MaSA (Ford 2022). Figure 1 shows a map of the ESU area. The recovery plan (NMFS 2017x) provides three scenarios that represent a range of potential strategies that can be pursued simultaneously that addresses the entire life cycle of the species that would achieve delisting criteria (Table 18).

Table 18. Potential ESA Viability Scenarios for Snake River Fall-Run Chinook salmon (NMFS 2017x).

Viability Scenarios and Viability Criteria	Abundance and Productivity Metrics	Spatial Structure and Diversity Metrics
Scenario A ─ Two Populations: Achieve highly viable status for the extant Lower Snake River population and viable status for the currently extirpated Middle Snake River population.	a. Lower Snake River population most recent 10-year geometric mean > 3,000 natural origin spawners and 20-year geometric mean intrinsic productivity > 1.5 b. Middle Snake River population most recent 10-year geometric mean > 3,000 natural origin spawners and 20-year geometric mean intrinsic productivity > 1.27	a. Four of five MaSAs in the Lower Snake River population and one or more spawning areas in the Middle Snake River population are occupied. b. Hatchery influence on spawning grounds is low (e.g., pHOS < 30%) for at least one population and hatchery programs are operated to limit genetic risk (e.g., the proportion of natural influence [PNI] > 67% c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing. d. Adult and juvenile run timing patterns are stable or adaptive. e. Indicators of genetic substructure are trending toward patterns expected for a natural origin dominated population.
Scenario B ─ Single Population: Achieve highly viable status for Lower Snake River population (measured in the aggregate).	a. Most recent 10-year geometric mean abundance > 4,200 natural-origin spawners. b. Most recent 20-year geometric mean intrinsic productivity > 1.7	a. Four of five MaSAs in the Lower Snake River population are occupied. b. Recent (2 or more brood cycles) hatchery influence on spawning ground is low (e.g., pHOS < 30%) for the population as a whole and hatchery program is operated to limit genetic risk (e.g., PNI > 67%). c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing. d. Adult and juvenile run timing patterns are stable or adaptive. e. Indicators of genetic substructure are trending toward patterns expected for a natural origin dominated population
Scenario C ─ Single Population: Achieve highly viable status for Lower Snake River population (with Natural	a. Population-level abundance metrics under Scenario C would need to be higher than under Scenario B to accommodate meeting the NPEA requirements. Metrics will vary	a. Four of five MaSAs in the Lower Snake River population are occupied. b. NPEA PNI ≥ 0.67 and NPEA production accounting for at least 40% of the natural production in the population.

Viability Scenarios and Viability Criteria	Abundance and Productivity Metrics	Spatial Structure and Diversity Metrics
Production Emphasis Areas [NPEAs]	depending on the proportion of natural production coming from NPEAs and the level of hatchery influence remaining in the NPEAs. b. Population-level productivity metrics for Scenario B would apply: most recent 20-year geometric mean intrinsic productivity > 1.7	c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing. d. Adult and juvenile run timing patterns are stable or adaptive. e. Indicators of genetic substructure are trending toward patterns expected for a natural origin dominated population.

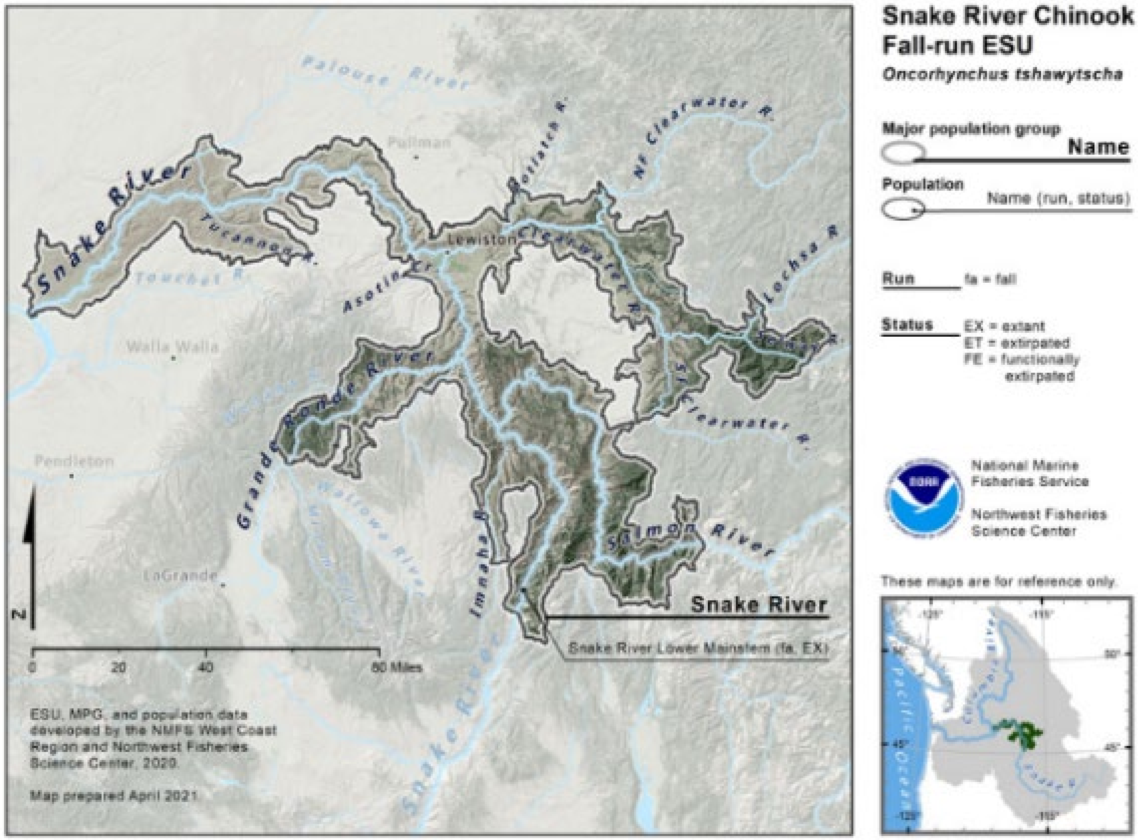


Figure 13. Map of the Snake River Fall-Run Chinook Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

The decline of this ESU was due to heavy fishing pressure beginning in the 1890s and loss of habitat with the construction of Swan Falls Dam in 1901. Additionally, construction of the Hells Canyon Complex from 1958 to 1967 led to the extirpation of one of the historical populations. Hatcheries mitigating for losses caused by the dams have played a major role in the production of Snake River Fall-Run Chinook salmon since the 1980s (NMFS 2022p).

Snake River Fall-Run Chinook salmon spawning and rearing occurs primarily in larger mainstem rivers, such as the Salmon, Snake, and Clearwater Rivers. Historically, the primary fall-run Chinook salmon salmon spawning areas were located on the upper mainstem Snake River (Connor et al. 2005). Now a series of Snake River mainstem dams block access to the Upper Snake River and about 85% of ESU's spawning and rearing habitat (NMFS 2022p). Swan Falls

Dam was the first barrier to upstream migration in the Snake River, followed by the Hells Canyon Complex, composed of Brownlee Dam (completed in 1958), Oxbow Dam (completed in 1961), and Hells Canyon Dam (completed in 1967). Natural spawning is currently limited to the Snake River from the upper end of Lower Granite River to Hells Canyon Dam, the lower reaches of the Imnaha, Grande Ronde, Clearwater, Salmon, and Tucannon rivers, and small areas in the tailraces of the Lower Snake River hydroelectric dams (NMFS 2022p).

Some fall-run Chinook salmon also spawn in smaller streams such as the Potlatch River, and Asotin and Alpowa Creeks, and may spawn elsewhere as well. However, annual redd surveys show that fall Chinook salmon spawning occurs in all five of the historical MaSAs that are accessible within the current range of the population (Ford 2022). Snake River Fall-Run Chinook salmon also spawned historically in the lower mainstem of the Clearwater, Grande Ronde, Salmon, Imnaha, and Tucannon River systems. At least some of these areas probably supported production, but at much lower levels than in the mainstem Snake River. Smaller portions of habitat in the Imnaha and Salmon Rivers have supported Snake River Fall-Run Chinook salmon. Some limited spawning occurs in all of these areas (NMFS 2012b).

As a consequence of losing access to historic spawning and rearing sites (heavily influenced by the influx of ground water in the Upper Snake River), as well as the effects of the dams on downstream water temperatures, Snake River Fall-Run Chinook salmon now reside in waters that may have thermal regimes which differ from historical regimes (Ford 2022). In addition, alteration of the Lower Snake River by hydroelectric dams has created a series of low-velocity pools that did not exist historically. Both of these habitat alterations have created obstacles to Snake River Fall-Run Chinook salmon survival. Before alteration of the Snake River Basin by dams, Snake River Fall-Run Chinook salmon exhibited a largely ocean-type life- history, where they migrated downstream during their first year. Today, fall-run Chinook salmon in the Snake River Basin exhibit one of two life- histories that Connor et al. (2005) have called ocean-type and reservoir-type. Juveniles exhibiting the reservoir-type life-history overwinter in the pools created by the dams before migrating out of the Snake River. The reservoir-type life-history is likely a response to early development in cooler temperatures, which prevents juveniles from reaching a suitable size to migrate out of the Snake River and to the ocean.

2.2.2.3.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations.

Spawner abundance, productivity, and proportion of natural-origin fish abundance estimates for the Lower Mainstem Snake River population are based on counts and sampling at Lower Granite Dam. Separate estimates of the numbers of adult (age 4 and older) and jack (age 3) fall-run Chinook salmon passing over Lower Granite Dam are derived using ladder counts, in addition to the results of sampling a portion of each year's run using a trap associated with the ladder. A portion of the fish sampled at the trap are retained and used as hatchery broodstock. Historically, the data from trap sampling, including coded-wire tag (CWT) recovery results, passive integrated transponder (PIT) tag detections, and the incidence of fish with adipose-fin clips, were used to construct daily estimates of hatchery proportions in the run (Ford 2022). At present, estimates of natural-origin returns are made from a Parental Based Genetic Tagging (PBT)[12] program (Ford 2022), which is a more direct assessment of natural returns and ESU abundance risk (Ford 2022). Sampling methods and statistical procedures used in generating the estimated escapements have improved substantially over the past 10 to 15 years.

2.2.2.3.1.1.1 Abundance and Productivity

In 2013, adult spawner abundance reached over 20,000 fish (Figure 14). From 2012–15, natural-origin returns were over 10,000 adults. Spawner abundance has declined since 2016 to 4,998 adult natural-origin spawners in 2019 (Figure 14). In 2018, natural-origin spawner abundance was 4,916, a quarter of the return in 2013. This appears as a high negative percent change in the five-year geometric mean (Table 19), but, when looking at the trend in longer time frames, across more than one brood cycle, it shows an increase in the ten-year geometric mean relative to the 2015 viability review (NWFSC 2015), and a near-zero population change for the 15-year trend in abundance (Ford 2022). The geometric mean natural adult abundance for the most recent ten years (2010–19) is 9,034 (0.15 standard error), higher than the ten-year geomean reported in the NWFSC (2015) status review (6,418, 0.19 standard error, 2005–14; Ford (2022)). While the population has not been able to maintain the higher returns it achieved in 2010 and 2013–15, abundance has maintained at or above the ICTRT defined Minimum Abundance Threshold (3,000)[13] during climate challenges in the ocean and rivers. Escapements have been increasing since 2020 and have continued through 2022 (WDFW et al. 2022).

[12] PBT is whereby each parent in a hatchery program, both male and female, are genotyped for polymorphic molecular markers. By genotyping each parent all of their offspring are effectively identifiable, and the method requires no juvenile handling. This allows for assignments back to individual parents when the hatchery releases return as adults wherever they are found, so long as they are genetically sampled.

[13] The ICBTRT (2007) incorporated minimum abundance thresholds into population viability curves to "promote achieving the full range of abundance objectives across the recovery scenarios including utilization of multiple spawning areas, avoiding problems associated with low population densities (e.g. Allee effects) and maintaining populations at levels where compensatory processes are functional." The ICTRT recommended using 10-year geometric means of recent natural-origin spawners as a measure of current abundance. It also recommended that current intrinsic productivity should be estimated using spawner-to-spawner return pairs from low-to-moderate escapements over a recent 20-year period. The ICTRT adopted a recommendation from Bevan et al. (1994) as the minimum abundance threshold for the extant Lower Snake River Fall-Run Chinook salmon population.

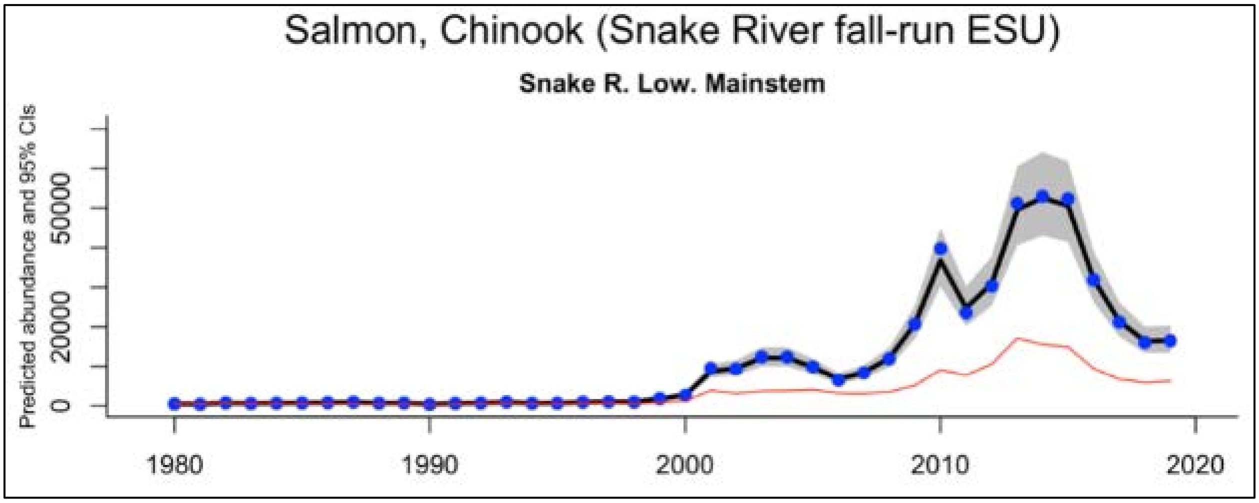


Figure 14. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance (Ford 2022). Points show the annual raw spawning abundance estimates.

Table 19. Five-year mean of fraction natural-origin fish in the population (sum of all estimates divided by the number of estimates) (Ford 2022).

Population	1995–1999	2000–2004	2005–2009	2010–2014	2015-2019
Lower Snake River Fall-run Chinook	0.58	0.34	0.37	0.31	0.33

Productivity, defined in the ICTRT viability criteria as the expected replacement rate at low to moderate abundance relative to a population's minimum abundance threshold, is a key measure of the potential resilience of a natural population to annual environmentally driven fluctuations in survival. The ICTRT Viability Report (ICBTRT 2007) provided a simple method for estimating population productivity based on return-per-spawner estimates for the most recent 20 years. To assure that all sources of mortality are accounted for, the ICTRT recommended that productivities used in interior Columbia River viability assessments be expressed in terms of returns to the spawning grounds. Snake River Fall-Run Chinook salmon have been above the ICTRT defined minimum abundance threshold since 2001 (Ford 2022). Productivity, as seen in broodyear returns-per-spawner, has been below replacement (1:1) in recent years.

2.2.2.3.1.1.1.1 Harvest

Since the species were originally listed in 1992, fishery impacts have been reduced in both ocean and river fisheries. Total ER has been relatively stable in the range of 40% to 50% (Figure 15) since the mid-1990s (Ford 2022). Ocean fisheries are currently managed to achieve a minimum of a 30.0% reduction in the age-3 and age-4 adult equivalent total ER in ocean salmon fisheries relative to the 1988–1993 base period standard; approximately equivalent to an ocean ER limit of 29% on age-3 and age-4 Snake River Fall-Run Chinook salmon. NMFS evaluated this approach under the ESA and found it not likely to jeopardize the continued existence of the Snake River Fall-Run Chinook Salmon ESU or destroy or adversely modify its designated critical habitat (NMFS 1996c). Freshwater harvest rates have averaged 31.8% since 2009 when the current management framework was first implemented under the 2008–2017 *U.S. v. Oregon* Management Agreement (TAC 2022).

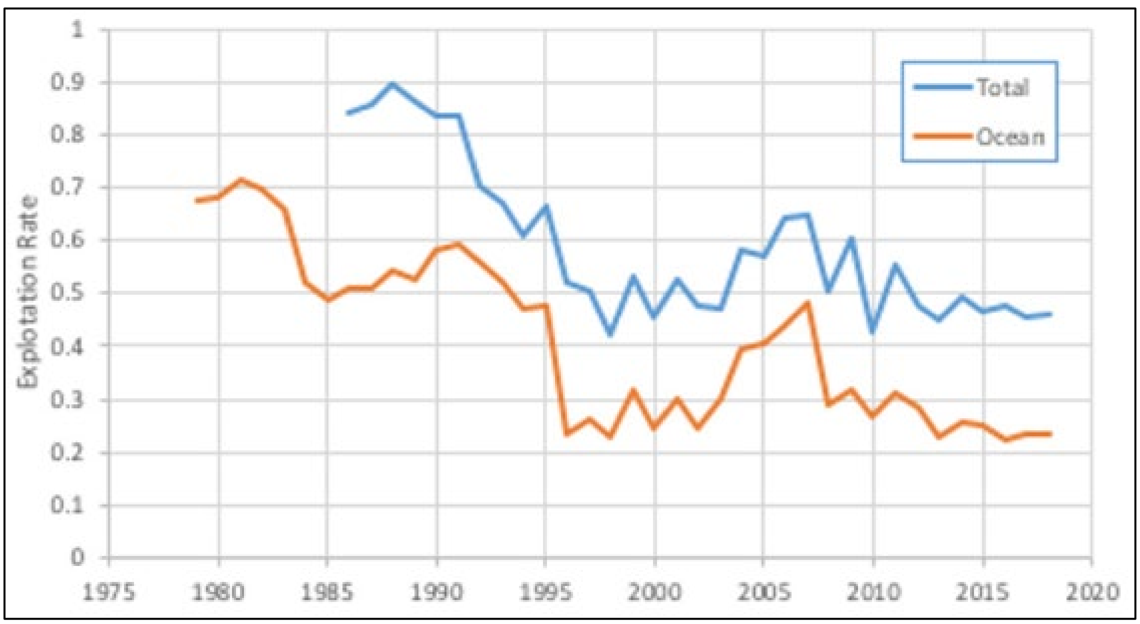


Figure 15. Total ER for Snake River Fall-Run Chinook salmon. Data for marine ERs from the Chinook Technical Committee (CTC) model (Calibration 1503) and for in-river harvest rates from the Columbia River Technical Advisory Committee (Ford 2022).

2.2.2.3.1.1.2 Spatial Structure and Diversity

In terms of spatial structure and diversity, the Lower Mainstem Snake River Fall-Run Chinook salmon population was rated at low risk for recovery Scenario A (allowing natural rates and levels of spatially mediated processes) and moderate risk for recovery Scenario B (maintaining natural levels of variation) in the status review update (Ford 2022), resulting in an overall spatial structure and diversity rating of moderate risk. Annual redd surveys show that fall Chinook salmon spawning occurs in all five of the historical MaSAs, and that the natural origin fraction has remained relatively stable during the last 10 years across the ESU (Figure 16).

2.2.2.3.1.1.2.1 Hatcheries

Parental Based Tagging of hatchery fish has allowed for spawning-ground sampling for parentage analysis. Fidelity studies have indicated there is spawner dispersal within the population from different release sites (Ford 2022). Natural-origin return levels declined substantially following the completion of the three-dam Hells Canyon Complex (1959–67), which completely blocked access to major production areas above Hells Canyon Dam, and the construction of the lower Snake River dams (1962–75). Based on extrapolations from sampling at Ice Harbor Dam (1977–90), the LFH (1987–present), and at Lower Granite Dam (1990–present), hatchery strays made up an increasing proportion of returns at Lower Granite Dam (the uppermost Snake River mainstem dam) through the 1980s (Bugert et al. 1990). Strays from out-planting Priest Rapids hatchery-origin fall-run Chinook salmon (an out-of-ESU stock from the mid-Columbia River) and Snake River Fall-Run Chinook salmon from the LFH program (on-station releases initiated in the mid-1980s) were the dominant contributors. Returns to the Tucannon River are predominantly releases and strays from the LFH program (NMFS 2012b). Estimated natural-origin returns reached a low of less than 100 fish in 1990. The initiation of the supplementation program in 1998 increased returns allowed to naturally spawn. In recent years, naturally spawning fall-run Chinook salmon in the lower Snake River have included returns both originating from naturally spawning parents, and from returning hatchery releases (Ford 2022). The fraction of natural-origin fish on the spawning grounds has remained relatively stable for the last ten years, with five-year means of 31% (2010–14) and 33% (2015–19; Figure 16).

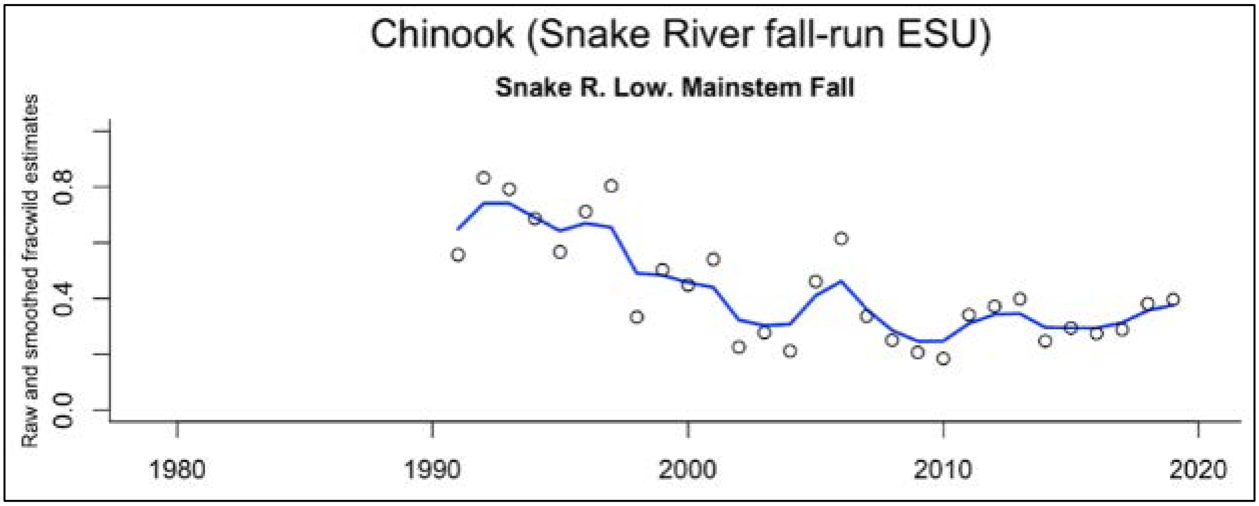


Figure 16. Smoothed trend in the estimated fraction of the natural spawning population consisting of fish of natural origin. Points show the annual raw estimates (Ford 2022).

The NMFS Snake River Fall-run Chinook Recovery Plan (NMFS 2017x) proposes that a single population viability scenario could be possible given the unique spatial complexity of the Lower Mainstem Snake River Fall-Run Chinook salmon population (Table 18). The recovery plan notes that a single population viability scenario could be possible if major spawning areas, supporting the bulk of natural returns, are operating consistently with long-term diversity objectives in the proposed plan. Under this single population scenario, the requirements for a sufficient combination of natural abundance and productivity could be based on a combination of total population natural abundance distributed among the MaSas as described in Table 18 above (while meeting total specific pHOS criteria; see Table 18 above), and relatively high production from one or more major spawning areas with relatively low hatchery contributions to spawning (i.e., low hatchery influence for at least one major natural spawning production area).

2.2.2.3.1.1.3 Summary

The overall current risk rating for the Lower Mainstem Snake River Fall-Run Chinook salmon population is viable, as indicated by the bold outlined cell in Table 20. The single population delisting options provided in the Snake River Fall Chinook Salmon Recovery Plan would require the population to meet or exceed minimum requirements for a risk rating of “Highly Viable with a high degree of certainty”. The current rating of viable is based on evaluating current status against the criteria for the aggregate population. The overall risk rating is based on a low risk rating for A/P and a moderate risk rating for SS/D. To achieve “highly viable” status with a high degree of certainty, the SS/D rating needs to be “low risk.” For abundance/productivity, the rating reflects remaining uncertainty that current increases in abundance can be sustained over the long run. While natural-origin spawning levels are above the highest delisting criteria (the minimum abundance threshold of 4,200 under recovery Scenario B) and estimated productivity is also high, neither measure is high enough to achieve the very low risk rating necessary to buffer against significant remaining uncertainty (Ford 2022).

Table 20. Matrix used to assess natural population viability risk rating across VSP parameters for the Lower Mainstem Snake River Fall-Run Chinook Salmon ESU (NWFSC 2015).[a]

		Spatial Structure/Diversity Risk			
		Very Low	Low	Moderate	High
Abundance/ Productivity Risk[b]	Very Low (<1%)	HV	HV	V	M
	Low (1–5%)	V	V	V Lower Mainstem Snake R.	M
	Moderate (6 – 25%)	M	M	M	HR
	High (>25%)	HR	HR	HR	HR

[a] Viability Key: HV-Highly Viable; V-Viable; M-Maintained; HR-High Risk. The darkest cells indicate combinations of A/P and SS/D at greatest risk (NWFSC 2015).
[b] Percentage represents the probability of extinction in a 100-year time period.

Considering the most recent information available, an increase in estimated productivity (or a decrease in the year-to-year variability associated with the estimate) would be required to achieve delisting status for the ESU, assuming that natural-origin abundance of the single extant Snake River Fall-Run Chinook salmon population remains relatively high.

2.2.2.3.1.2 Limiting Factors

Understanding the limiting factors and threats that affect the Snake River Fall-Run Chinook Salmon ESU provides important information and perspective regarding the status of a species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. This ESU has been reduced to a single remnant population with a narrow range of available habitat. However, the overall adult abundance has been increasing from the mid-1990s, with substantial growth since the year 2000 (NMFS 2017x).

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Snake River Fall-Run Chinook Salmon ESU. Factors that limit the ESU have been, and continue to be, hydropower projects, predation, harvest, degraded estuary habitat, and degraded mainstem and tributary habitat (Ford et al. 2011). Ocean conditions have also affected the status of this ESU. Ocean conditions affecting the survival of Snake River Fall-Run Chinook salmon were generally poor during the early part of the last 20 years (NMFS 2017x).

The recovery plan (NMFS 2017x) provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Section 3.3 of the plan provides criteria for addressing the underlying causes of decline. Furthermore, Section 4.1.2 B.4. of the plan (NMFS 2017x) describes the changes in current impacts on Snake River Fall-Run Chinook salmon. These changes include the following:

- Hydropower systems,
- Juvenile migration timing,
- Adult migration timing,
- Harvest,
- Age-at-return,
- Selection caused by non-random removals of fish for hatchery broodstock, and
- Habitat.

Rather than repeating the extensive discussion from the recovery plan, the discussions in sections 3.3 and 4.1.2.B.4 are incorporated here by reference.

Overall, the single extant population in the ESU is currently meeting the criteria for a rating of “viable” developed by the ICTRT, but the ESU as a whole is not meeting the recovery goals described in the recovery plan for the species, which require the single population to be "highly viable with high certainty" and/or will require reintroduction of a viable population above the Hells Canyon Complex (Ford 2022). The Snake River Fall-Run Chinook Salmon ESU therefore is considered to be at a moderate-to-low risk of extinction, with viability largely unchanged from the prior review.

2.2.2.3.2 Snake River Spring/summer-run Chinook Salmon ESU

On June 3, 1992, NMFS listed the Snake River spring/summer-run Chinook Salmon ESU as a threatened species (57 FR 23458). More recently, the threatened status was reaffirmed on June 28, 2005 (70 FR 37160) and on April 14, 2014 (79 FR 20802). Critical habitat was originally designated on December 28, 1993 (58 FR 68543) but updated most recently on October 25, 1999 (65 FR 57399). In 2022, NMFS completed its most recent 5-year review for Snake river spring/summer-run Chinook salmon (NMFS 2022l).

The Snake River spring/summer-run Chinook Salmon ESU includes all naturally spawned populations of spring/summer-run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins, as well as 13 artificial propagation programs (NMFS 2022l). However, inside the geographic range of the ESU, there are a total of 18 hatchery spring/summer-run Chinook salmon programs currently operational (NMFS 2022l). Table 21 lists the natural and hatchery populations included (or excluded) in the ESU.

Twenty-eight historical populations (four extirpated) within five MPGs comprise the Snake River spring/summer-run Chinook Salmon ESU. The natural populations are aggregated into the five extant MPGs based on genetic, environmental, and life-history characteristics. Figure 17 shows a map of the current ESU and the MPGs within the ESU.

Table 21. Snake River spring/summer-run Chinook Salmon ESU description and MPGs (NMFS 2022l).

ESU Description	
Threatened	Listed under ESA in 1992; updated in 2014.
5 MPGs	28 historical populations (4 extirpated)
MPG	***Populations***
Lower Snake River	Tucannon River
Grande Ronde/Imnaha River	Wenaha, Lostine/Wallowa, Minam, Catherine Creek, Upper Grande Ronde, Imnaha
South Fork Salmon River	Secesh, East Fork/Johnson Creek, South Fork Salmon River Mainstem, Little Salmon River
Middle Fork	Bear Valley, Marsh Creek, Sulphur Creek, Loon Creek, Camas Creek, Big Creek, Chamberlain Creek, Lower Middle Fork (MF) Salmon, Upper MF Salmon
Upper Salmon	Lower Salmon Mainstem, Lemhi River, Pahsimeroi River, Upper Salmon Mainstem, East Fork Salmon, Valley Creek, Yankee Fork, North Fork Salmon
Artificial production	
Hatchery programs included in ESU (13)	Tucannon River Spr/Sum, Lostine River Spr/Sum, Catherine Creek Spr/Sum, Lookingglass Hatchery Reintroduction Spr/Sum, Upper Grande Ronde Spr/Sum, Imnaha River Spr/Sum, McCall Hatchery summer, Johnson Creek Artificial Propagation Enhancement summer, Pahsimeroi Hatchery summer, Sawtooth Hatchery spring, Yankee Fork Program, South Fork Salmon River Eggbox Program, Panther Creek Program
Hatchery programs not included in ESU (5)	Rapid River Hatchery spring, Dworshak NFH spring, Kooskia spring, Clearwater Hatchery spring, Nez Perce Tribal Hatchery spring

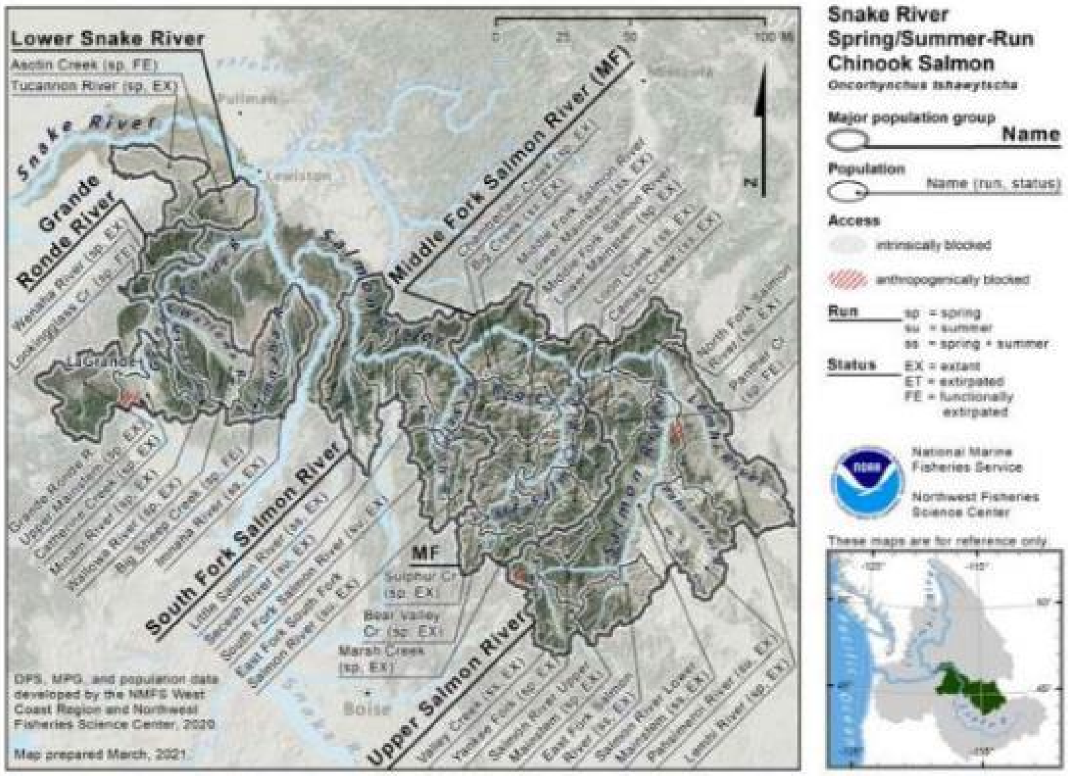


Figure 17. The Snake River spring/summer-run Chinook salmon ESU' spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

The Snake River spring/summer-run Chinook Salmon ESU consists of "stream-type" Chinook salmon, which spend two to three years in ocean waters and exhibit extensive offshore ocean migrations (Myers et al. 1998). For a general review of stream-type Chinook salmon, see the Upper Willamette River Chinook Salmon ESU life-history and status description. In general, Chinook salmon tend to occupy streams with lower gradients than steelhead, but there is considerable overlap between the distributions of the two species (NMFS 2012b).

Historically, the Snake River drainage is thought to have produced more than 1.5 million adult spring/summer-run Chinook salmon in some years during the late 1800s (Matthews et al. 1991). By the 1950s, the abundance of spring/summer-run Chinook salmon had declined to an annual average of 125,000 adults, and continued to decline through the 1970s. In 1995, only 1,797 spring/summer-run Chinook salmon adults returned (hatchery and wild fish combined). Returns at Lower Granite Dam (LGR) (hatchery and wild fish combined) dramatically increased after

2000, with 185,693 adults returning in 2001. The large increase in 2001 was due primarily to hatchery returns, with only 10% of the returns from fish of natural-origin (NMFS 2012b).

The causes of oscillations in abundance are uncertain, but likely are due to a combination of factors. Over the long-term, population size is affected by a variety of factors, including: ocean conditions, harvest, increased predation in riverine and estuarine environments, construction and continued operation of Snake and Columbia River Dams; increased smolt mortality from poor downstream passage conditions; competition with hatchery fish; and widespread alteration of spawning and rearing habits. Spawning and rearing habits are commonly impaired in places from factors such as agricultural tilling, water withdrawals, sediment from unpaved roads, timber harvest, grazing, mining, and alteration of floodplains and riparian vegetation. Climate change is also recognized as a possible factor in Snake River salmon declines (Tolimieri et al. 2004; Scheuerell et al. 2005a; NMFS 2012b).

2.2.2.3.2.1 Abundance, Productivity, Spatial Structure, and Diversity

NMFS has finalized recovery planning for the Snake River drainage, organized around a subset of management unit plans corresponding to state boundaries (NMFS 2017q). A tributary recovery plan for one of the major management units, the Lower Snake River tributaries within Washington state boundaries, was developed under the auspices of the Lower Snake River Recovery Board (LSRB). The LSRB Plan provides recovery criteria, targets, and tributary habitat action plans for the two populations of the spring/summer-run Chinook salmon in the Lower Snake MPG in addition to the populations in the Touchet River (Mid-Columbia Steelhead DPS) and the Washington sections of the Grande Ronde River (NWFSC 2015).

The recovery plan developed by NMFS incorporated viability criteria recommended by the ICTRT (NMFS 2017q). The ICTRT recovery criteria are hierarchical in nature, with ESU/DPS level criteria being based on the status of natural-origin Chinook salmon assessed at the population level. The population level assessments are based on a set of metrics designed to evaluate risk across the four VSP elements – abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). The ICTRT approach calls for comparing estimates of current natural-origin abundance and productivity against predefined viability curves (NWFSC 2015). Achieving recovery (i.e., delisting the species) of each ESU via sufficient improvement in the abundance, productivity, spatial structure, and diversity is the longer-term goal of the recovery plan.

2.2.2.3.2.1.1 Abundance and Productivity

The majority of populations in the Snake River spring/summer Chinook salmon ESU remain at high overall risk, with three populations (Minam River, Bear Valley Creek, and Marsh Creek) improving from the previous status review (NMFS 2016s) to an overall rating of maintained due to an increase in abundance/productivity (Table 22). However, natural-origin abundance has generally decreased from the levels reported in the prior review for most populations in this ESU, in many cases sharply (Figure 18). The most recent 5-year geometric mean abundance estimates for 26 out of the 27 populations are lower than the corresponding estimates for the previous 5-year period by varying degrees; the estimate for the 27th population was a slight increase from a very low abundance in the prior 5-year period (Ford 2022). The entire ESU abundance data shows a consistent and marked pattern of declining population size, with the recent 5-year abundance levels for the 27 populations declining by an average of 55%. Medium-term (15-year) population trends in total spawner abundance were positive over the period 1990 to 2005 for all of the population natural-origin abundance series, but are all declining over the more recent time interval (2004–2019; Table 12 and Figure 21 in Ford (2022)). The consistent and sharp declines for all populations in the ESU are concerning, with the abundance levels for some populations approaching similar levels to those of the early 1990s when the ESU was listed.

No population in the ESU currently meets the Minimum Abundance Threshold designated by the ICTRT, with nine populations under 10% of Minimum Abundance Threshold and three populations under 5% Minimum Abundance Threshold for recent 5-year geometric means. Populations with 5-year geometric mean abundances below 50 fish are at extremely high risk of extinction from chance fluctuations in abundance, depensatory processes, or the long-term consequences of lost genetic variation according to the ICTRT defined quasi-extinction threshold[14] (Waples 1991; ICBTRT 2007; Crozier et al. 2021). These populations include the Tucannon River, Middle Fork Salmon River lower mainstem, Camas Creek, Loon Creek, Sulphur Creek, North Fork Salmon River, Salmon River lower mainstem, and Yankee Fork populations. Productivity remained the lowest for the Grande Ronde and Lower Snake River MPGs. Relatively low ocean survivals in recent years were a major factor in recent abundance patterns.

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

Table 22. Snake River spring/summer-run Chinook salmon population status relative to ICTRT viability criteria, grouped by MPG. Natural spawning abundance: most recent 10-yr geometric mean (range). ICTRT productivity: 20-yr geometric mean for parent escapements below 75% of population threshold. Current abundance and productivity estimates are geometric means. Range in annual abundance, standard error, and number of qualifying estimates for productivities in parentheses. Populations with no abundance and productivity data are given a default High A/P Risk rating (Ford 2022). Note that Panther Creek is considered functionally extirpated (Ford 2022).

	Abundance/productivity (A/P) metrics				Spatial structure/diversity (SS/D) metrics			
Population	ICTRT threshold	Natural spawning	ICTRT productivity	Integrated A/P risk	Natural processes	Diversity risk	Integrated SS/D risk	Overall risk rating
Lower Snake MPG								
Tucannon River	750	116 (SD 205)	1.09 (0.31, 17/20)	High	Low	Moderate	Moderate	High
Grande Ronde/Imnaha MPG								
Wenaha River	750	437 (SD 191)	1.21 (0.16, 15/20)	High	Low	Moderate	Moderate	High
Lostine River	1,000	654 (SD 400)	0.97 (0.21, 18/20)	High	Low	Moderate	Moderate	High
Minam River	750	544 (SD 256)	1.44 (0.15, 15/20)	Moderate	Low	Moderate	Moderate	Maintained
Catherine Creek	1,000	200 (SD 207)	0.76 (0.27, 20/20)	High	Moderate	Moderate	Moderate	High
Grande Ronde River Upper Mainstem	1,000	80 (SD 157)	0.47 (0.25, 20/20)	High	High	Moderate	High	High
Imnaha River Mainstem	750	513 (SD 214)	0.65 (0.27, 14/20)	High	Low	Moderate	Moderate	High
South Fork Salmon River MPG								
South Fork Salmon River Mainstem	1,000	381 (SD 514)	0.96 (0.20, 12/20)	High	Low	Moderate	Moderate	High
Secesh River	750	472 (SD 396)	—	High	Low	Low	Low	High
East Fork South Fork Salmon River	1,000	483 (SD 265)	—	High	Low	Low	Low	High
Little Salmon River	750	*Insufficient data*	—	—	Low	Low	Low	High
Middle Fork Salmon River MPG								
Chamberlain Creek	750	342 (SD 171)	1.36 (0.34, 17/20)	High	Low	Low	Low	High
Middle Fork Salmon R. Lower Mainstem	1,000	163 (SD 114)	1.47 (0.34, 20/20)	High	Very Low	Moderate	Moderate	High
Big Creek	500	45 (SD 37)	1.95 (0.33, 13/20)	High	Low	Moderate	Moderate	High
Camas Creek	500	42 (SD 27)	1.37 (0.42, 17/20)	High	Low	Moderate	Moderate	High
Loon Creek	500	*Insufficient data*	*Insufficient data*	—	Moderate	Moderate	Moderate	High

Population	Abundance/productivity (A/P) metrics			Integrated A/P risk	Spatial structure/diversity (SS/D) metrics			Overall risk rating
	ICTRT threshold	Natural spawning	ICTRT productivity		Natural processes	Diversity risk	Integrated SS/D risk	
Middle Fork Salmon R. Upper Mainstem	750	71 (SD 43)	1.30 (0.34, 17/20)	High	Low	Moderate	Moderate	High
Sulphur Creek	500	67 (SD 65)	1.02 (0.25, 13/20)	High	Low	Moderate	Moderate	High
Marsh Creek	500	333 (SD 262)	2.11 (0.32, 7/20)	Moderate	Low	Low	Low	Maintained
Bear Valley Creek	750	428 (SD 327)	2.22 (0.26, 13/20)	Moderate	Very Low	Low	Low	Maintained
Upper Salmon River MPG								
North Fork Salmon River	2,000	71 (SD 87)	1.30 (0.23, 20/20)	High	Low	Low	Low	High
Lemhi River	1,000	326 (SD 270)	1.13 (0.31, 18/20)	High	Low	Low	Low	High
Salmon River Lower Mainstem	1,000	218 (SD 168)	1.26 (0.20 20/20)	High	Moderate	High	High	High
Pahsimeroi River	2,000	250 (SD 159)	1.63 (0.28, 19/20)	High	High	High	High	High
East Fork Salmon River	500	113 (SD 100)	1.63 (0.26, 17/20)	High	Low	Moderate	Moderate	High
Yankee Fork	1,000	288 (SD 291)	2.00 (0.28, 17/20)	High	Low	High	high	High
Salmon River Upper Mainstem	500	62 (SD 139)	0.99 (0.51, 17/20)	High	Moderate	High	High	High
Valley Creek	500	*Insufficient data*	*Insufficient data*	—	Low	Low	Low	High
Panther Creek	750	*Insufficient data*	*Insufficient data*	—	—	—	—	*See caption*

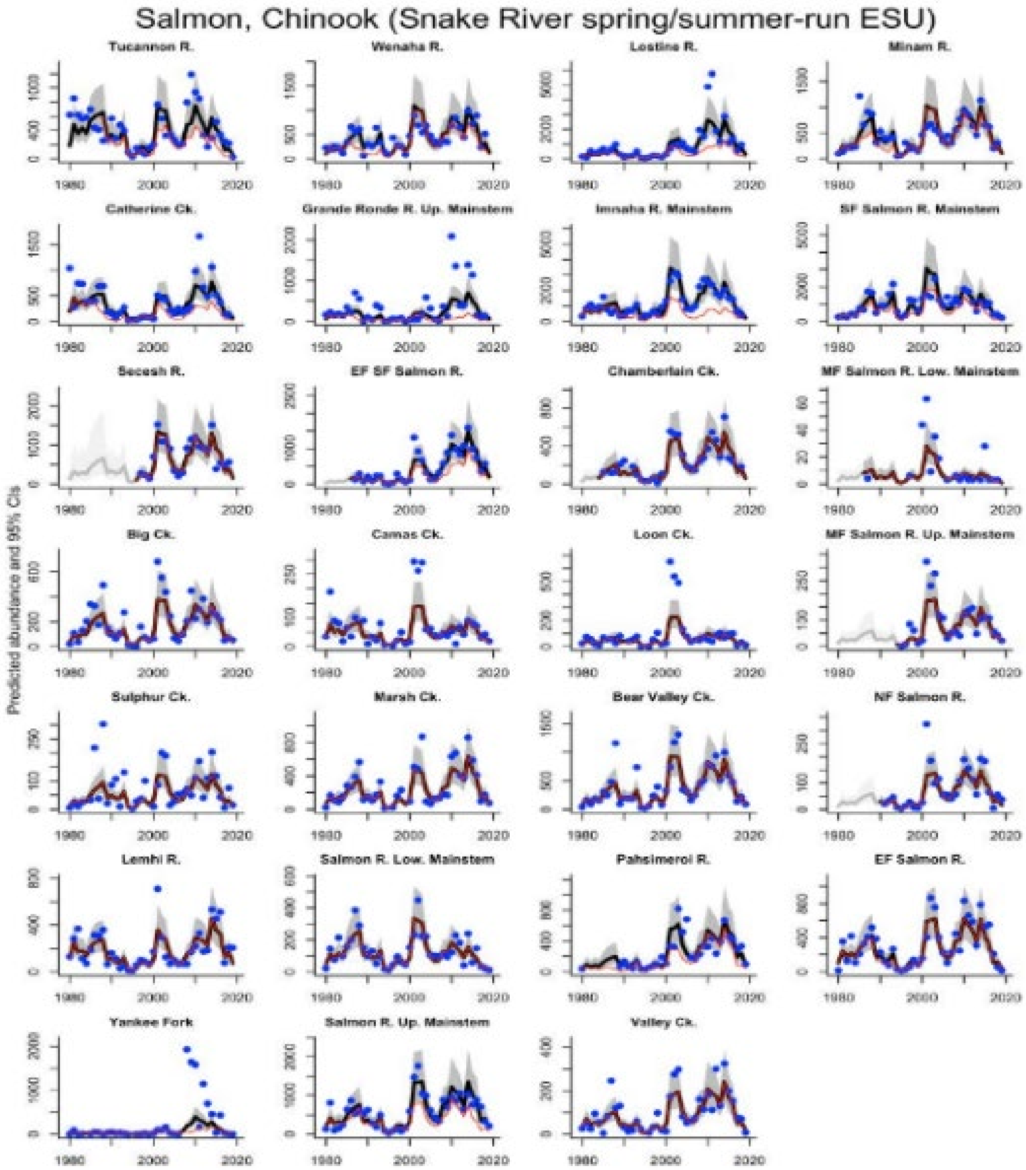


Figure 18. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot.

2.2.2.3.2.1.1.1 Harvest

Harvest impacts on the spring component of this ESU are essentially the same as those on the Upper Columbia River ESU. Harvest occurs in the lower portion of the mainstem Columbia River. Mainstem Columbia River fisheries represent the majority of harvest impacts on this ESU. In some years, additional harvest occurs in the Snake River basin on specific populations within the ESU. Snake River summer Chinook salmon share the ocean distribution patterns of the upper basin spring runs and are only subject to significant harvest in the mainstem Columbia River (Ford 2022). Harvest of summer Chinook salmon has been more constrained than that of spring Chinook salmon, with consequently lower exploitation rates on the summer component of this ESU. However, the overall pattern of exploitation rates calculated by the total allowable catch (TAC) is nearly identical to that of the Upper Columbia River spring-run Chinook salmon ESU.

Systematic improvements in fisheries management since the 2016 5-year review include implementation of a new *U.S. v. Oregon* Management Agreement for years 2018–2027 (NMFS 2018e). This agreement replaces the previous 10-year agreement. It maintains the limits and reductions in harvest impacts for the listed Snake River ESUs/DPSs that were secured in previous agreements (NMFS 2018e).

Contributions of Snake River spring/summer Chinook salmon are considered negligible in fisheries managed by the Pacific Fishery Management Council (PFMC) (PFMC 2016; 2020b), and the fisheries are not likely to jeopardize the ESU (Thom 2020). Snake River spring/summer Chinook salmon are encountered in fisheries in the Columbia River, the Snake River, and some tributaries. The majority of the harvest-related impacts to this ESU occur in mixed stock Columbia River fisheries. These fisheries are limited to an incidental take of 5.5 to 17% (depending on run size) of Snake River spring/summer Chinook salmon returning to the Columbia River mouth (NMFS 2018e). Actual incidental take has remained the same since the 2016 5-year review and averaged 11.0% for the years 2014–2019 (NMFS 2022l). Estimated harvest rates for Snake River spring/summer Chinook salmon over the last four decades are shown in Figure 19.

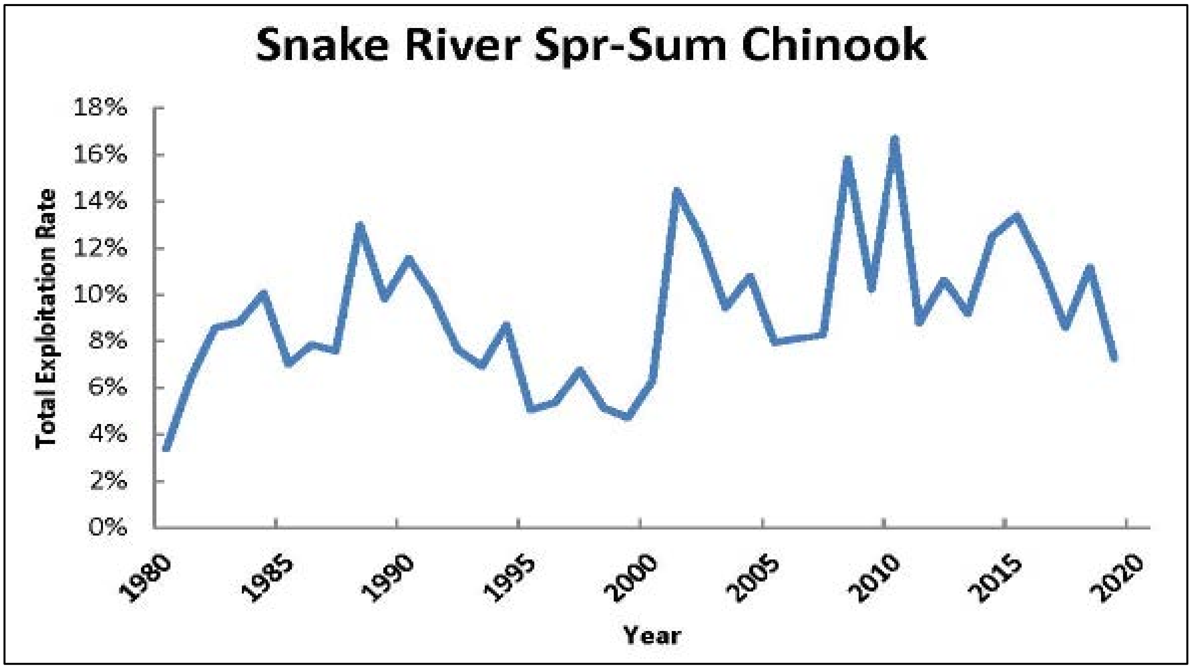


Figure 19. Total exploitation rates for Snake River spring/summer Chinook salmon in the mainstem Columbia River fisheries (NMFS 2022l). Data from the Columbia River Technical Advisory Team, recreated from NMFS (2022l).

2.2.2.3.2.1.2 Spatial Structure and Diversity

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

2.2.2.3.2.1.2.1 Hatcheries

The hatchery programs that affect the Snake River spring-run Chinook salmon ESU have changed over time, and these changes have likely reduced adverse effects on ESA-listed species (NMFS 2022l). The proportion of hatchery-origin spawners within populations varies considerably across MPGs (Table 23). Over the years, hatchery programs that supplement natural-origin populations in the Snake River have improved their hatchery programs. In particular, program managers have better integrated natural-origin fish into their broodstock and limited the number of hatchery-origin spawners, when appropriate. Integration of hatchery programs is typically done using sliding scales sensitive to population abundance. Under the sliding scales, the programs allow some hatchery-origin fish to spawn in the wild at all abundance levels but reduce the proportions of hatchery-origin spawners as natural-origin abundance increases. In addition, the proportion of natural-origin fish used in broodstock increases as abundance increases, as determined by the sliding scales. This strategy attempts to balance the risk of extinction (low natural-origin abundance) with the risk of hatchery influence.

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

Table 23. Five-year mean of fraction natural-origin spawners (sum of all estimates divided by the number of estimates) (Ford 2022).

Population[a]	MPG	1995–99	2000–04	2005–09	2014–2019	2015–19
Tucannon River	Lower Snake	0.64	0.61	0.69	0.68	0.27
Wenaha River	Grande Ronde/Imnaha	0.89	0.96	0.97	0.73	0.74
Lostine River	Grande Ronde/Imnaha	0.97	0.61	0.39	0.40	0.42
Minam River	Grande Ronde/Imnaha	0.97	0.98	0.98	0.89	0.94
Catherine Creek	Grande Ronde/Imnaha	1.00	0.57	0.35	0.49	0.38
Grande Ronde River Upper Mainstem	Grande Ronde/Imnaha	1.00	0.76	0.33	0.22	0.24
Imnaha River Mainstem	Grande Ronde/Imnaha	0.53	0.44	0.23	0.34	0.41
South Fork Salmon River Mainstem	South Fork Salmon River	0.59	0.64	0.56	0.77	0.32
Secesh River	South Fork Salmon River	0.91	0.97	0.95	0.98	0.96
East Fork South Fork Salmon River	South Fork Salmon River	0.99	0.76	0.43	0.62	0.58
Chamberlain Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Middle Fork Salmon River Lower Mainstem	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Big Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Camas Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Loon Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Middle Fork Salmon River Upper Mainstem	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Sulphur Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Marsh Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
Bear Valley Creek	Middle Fork Salmon River	1.00	1.00	1.00	1.00	1.00
North Fork Salmon River	Upper Salmon River	1.00	1.00	1.00	1.00	1.00
Lemhi River	Upper Salmon River	1.00	1.00	1.00	1.00	1.00
Salmon River Lower Mainstem	Upper Salmon River	1.00	1.00	1.00	1.00	1.00

Population[a]	MPG	1995–99	2000–04	2005–09	2014–2019	2015–19
Pahsimeroi River	Upper Salmon River	0.65	0.51	0.79	0.93	0.54
East Fork Salmon River	Upper Salmon River	0.77	1.00	1.00	1.00	1.00
Yankee Fork	Upper Salmon River	1.00	1.00	0.52	0.39	0.93
Salmon River Upper Mainstem	Upper Salmon River	0.80	0.62	0.58	0.71	0.36
Valley Creek	Upper Salmon River	1.00	1.00	1.00	1.00	1.00

[a] Note that the Little Salmon River (South Fork Salmon River) population is not included due lack of available data, as discussed further in Ford (2022)

2.2.2.3.2.1.3 Summary

While there have been improvements in abundance/productivity in several populations relative to the time of listing, the majority of populations experienced sharp declines in abundance in the recent five-year period, primarily due to variation in ocean survival (Ford 2022). If ocean survival rates remain low, the ESU's viability will clearly become much more tenuous. If survivals improve in the near term, however, it is likely the populations could rebound quickly. Overall, at this time the most recent viability review concluded that the Snake River spring/summer-run Chinook salmon ESU continues to be at moderate-to-high risk (Ford 2022).

2.2.2.3.2.2 Limiting Factors

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

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

Based on the information identified above, NMFS (2022l) recommended that the Snake River spring/summer Chinook salmon ESU maintain its classification as a threatened species.

2.2.2.3.3 Upper Columbia River Spring-run Chinook Salmon ESU

On March 24, 1999, NMFS listed the Upper Columbia River Spring-run Chinook Salmon ESU as an endangered species (64 FR 14308). The endangered status was reaffirmed on June 28, 2005 (70 FR 37160) and most recently on April 14, 2014 (70 FR 20816). Critical habitat for the Upper Columbia River spring-run Chinook salmon was designated on September 2, 2005 (70 FR 2732). In 2022, NMFS completed its most recent 5-year review for Upper Columbia River spring-run Chinook salmon (NMFS 2022o).

Inside the geographic range of this ESU, eight natural populations within three MPGs have historically comprised the Upper Columbia River Spring-run Chinook Salmon ESU, but the ESU is currently limited to one MPG (North Cascades MPG) and three extant populations (Wenatchee, Entiat, and Methow populations). Ten hatchery spring-run Chinook salmon programs are currently operational, but only seven are included in the ESU (Table 5 in NMFS (2022o)). Table 24 lists the hatchery and natural populations included (or excluded) in the ESU.

Table 24. Upper Columbia River Spring-run Chinook Salmon ESU description and MPG (updated data from NMFS (2022o)).

ESU Description	
Endangered	Listed under ESA in 1999; updated in 2014.
1 MPG	8 historical populations
MPG	***Populations***
North Cascades	Wenatchee River, Entiat River, Methow River.
Artificial production	
Hatchery programs included in ESU (7)	Twisp River Program, Chief Joseph spring Chinook Hatchery Program (Okanogan River release), Methow Program, Winthrop National Fish Hatchery Program, Chiwawa River Program, White River Program, Nason Creek Program
Hatchery programs not included in ESU (3)	Leavenworth National Fish Hatchery, Okanogan spring (10)(j), Chief Joseph Hatchery (Mainstem Columbia River release)

Approximately half of the area that originally produced spring-run Chinook salmon in this ESU is now blocked by dams. What remains of the ESU includes all naturally spawned fish upstream of Rock Island Dam and downstream of Chief Joseph Dam in Washington State, excluding the Okanogan River (64 FR 14208, March 24, 1999). Figure 20 shows the map of specific basins within the current ESU.

ESA-listed Upper Columbia River spring-run Chinook salmon are known as "stream-type"; they spend 2 to 3 years in coastal ocean waters, whereas "ocean-type" Chinook salmon spend 3 to 4 years at sea and exhibit offshore ocean migrations.

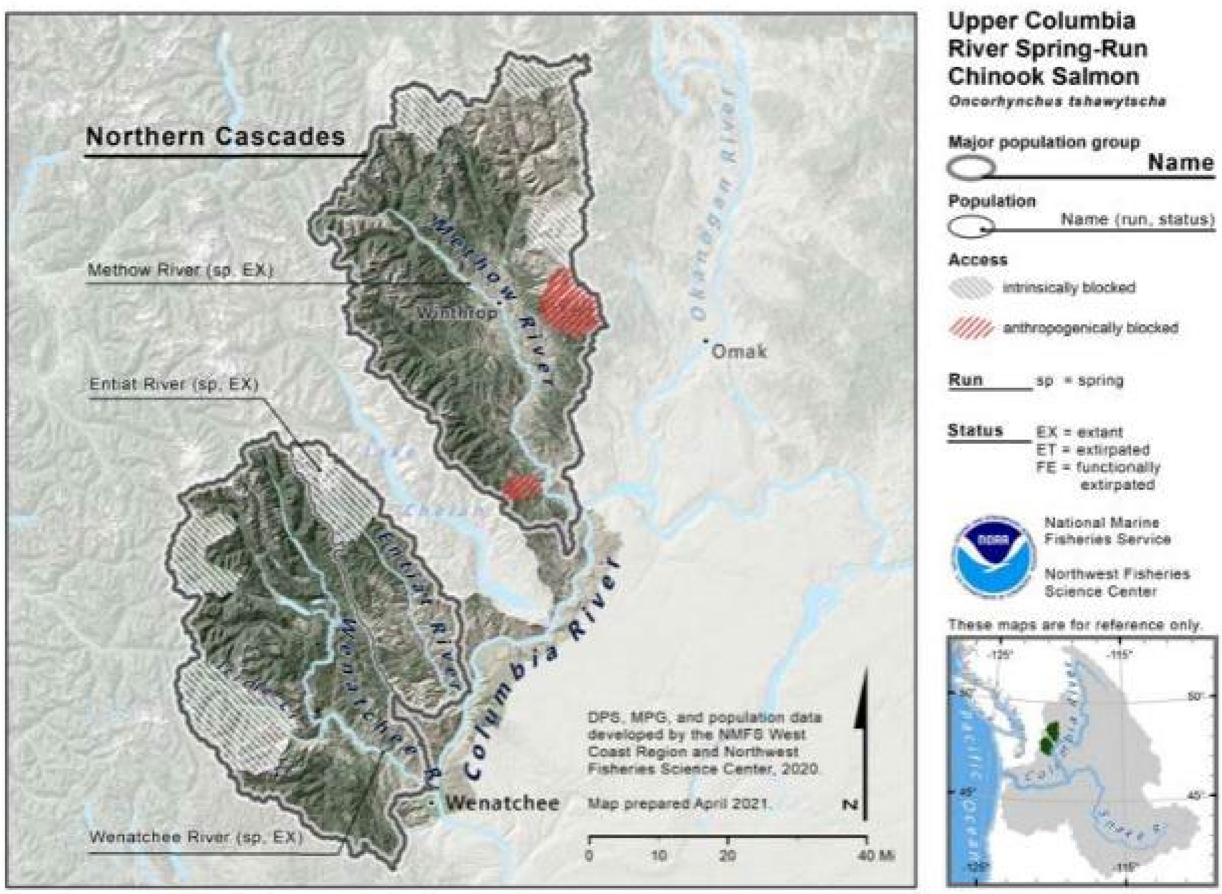


Figure 20. Map of the Upper Columbia River Spring-run Chinook Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

Spring-run Chinook salmon begin returning from the ocean in the early spring, with the run into the Columbia River peaking in mid-May. Spring-run Chinook salmon enter the Upper Columbia tributaries from April through July, and they hold in freshwater tributaries after migration until they spawn in the late summer (peaking in mid to late August) (UCSRB 2007). Juvenile spring-run Chinook salmon spend a year in freshwater before migration to saltwater in the spring of their second year of life.

2.2.2.3.3.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Upper Columbia River Spring-run Chinook Salmon ESU, is at high risk and remains at endangered status (Ford 2022; NMFS 2022o). The ESA Recovery Plan, developed by the Upper Columbia Salmon Recovery Board (UCSRB) (UCSRB 2007) calls for improvement in each of the three extant spring-run Chinook salmon populations (no more than 5% risk of extinction in 100 years) and for a level of spatial structure and diversity that restores the distribution of natural populations to previously occupied areas and that allows natural patterns of genetic and phenotypic diversity to be expressed. This corresponds to a threshold of at least "viable" status for each of the three natural populations. None of the three populations are viable with respect to abundance and productivity, and they all have a greater than 25% chance of extinction in 100 years (Table 25) (UCSRB 2007).

Table 25. Upper Columbia River Spring Chinook Salmon ESU: North Cascades MPG population risk ratings integrated across the four VSP parameters. Viability key: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (Table from NMFS (2022o), data adapted from Table 5 in Ford (2022)).

		Risk Rating for Spatial Structure/Diversity			
		Very Low	Low	Moderate	High
Risk Rating for Abundance/Productivity	Very Low (<1%)	Highly Viable	Highly Viable	Viable	Maintained
	Low (1–5%)	Viable	Viable	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained	Maintained	High Risk
	High (>25%)	High Risk	High Risk	High Risk	High Risk ***Wenatchee Entiat Methow***

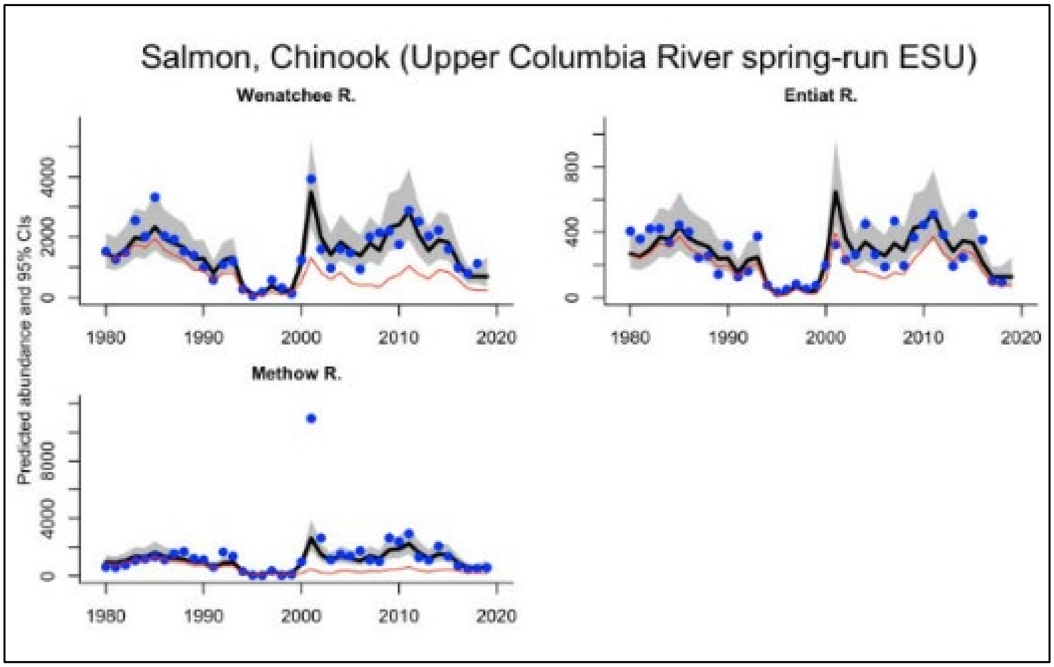


Figure 21. Smoothed trend in estimated total (thick black line, with 95% confidence internal in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

2.2.2.3.3.1.1 Abundance and Productivity

All three populations in the Upper Columbia River Spring-run Chinook Salmon ESU remain at high overall risk (Table 25). Natural origin abundance has decreased over the levels reported in the prior review (NMFS 2016p) for all populations in this ESU, in many cases sharply (Figure 21). The abundance data for the entire ESU show a downward trend over the last 5 years, with the recent 5-year abundance levels for all three populations declining by an average of 48% (NMFS 2022o). The consistent and sharp declines for all populations in the ESU are concerning. Relatively low ocean survivals in recent years were a major factor in recent abundance patterns.

Given the high degree of year-to-year variability in life stage survivals and the time lags resulting from the 5-year life cycle of the populations, it is not possible to detect incremental gains from habitat actions implemented to date in population level measures of adult abundance or productivity (NMFS 2022o). Efforts are underway to develop life stage specific estimates of performance (survival and capacities) and to use a life cycle model framework to evaluate progress (Zabel et al. 2020). Based on the information available for the 2022 review (Ford 2022), the risk category for the Upper Columbia River Spring-run Chinook Salmon ESU remains unchanged from the prior review (NWFSC 2015). Although the recent decline of population abundances is concerning, each population remains well above the abundance levels of when they were listed. All three populations remain at high risk (Table 25).

2.2.2.3.3.1.1.1 Harvest

Spring Chinook salmon from the upper Columbia River basin migrate offshore in marine waters and where impacts in ocean salmon fisheries are too low to be quantified. Contributions of Upper Columbia River spring-run Chinook salmon are considered negligible in PFMC fisheries, and NMFS has determined that these fisheries are not likely to jeopardize the ESU (Thom 2020; PFMC 2022). The only significant harvest in salmon fisheries occurs in the mainstem Columbia River in tribal and non-tribal fisheries directed at hatchery spring-run Chinook salmon from the Columbia and Willamette Rivers (Ford 2022). These fisheries are limited to an incidental take of 5.5 to 17% (depending on run size) of Upper Columbia River spring-run Chinook salmon returning to the Columbia River mouth (NMFS 2018e). Actual incidental take has remained the same since the 2016 5-year review and averaged 11% for the years 2014–2019 (NMFS 2022o). Exploitation rates have remained relatively low for non-treaty harvest, generally below the target rate of 2% (Figure 22).

2.2.2.3.3.1.2 Spatial Structure and Diversity

Spatial structure and diversity ratings remain unchanged from the prior review (NMFS 2016p) and continue to be rated at low to moderate risk for spatial structure but at high risk for diversity criteria (NMFS 2022o). Large-scale supplementation efforts in the Methow and Wenatchee Rivers are ongoing, intended to counter short-term demographic risks given current survival levels (NMFS 2022o). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

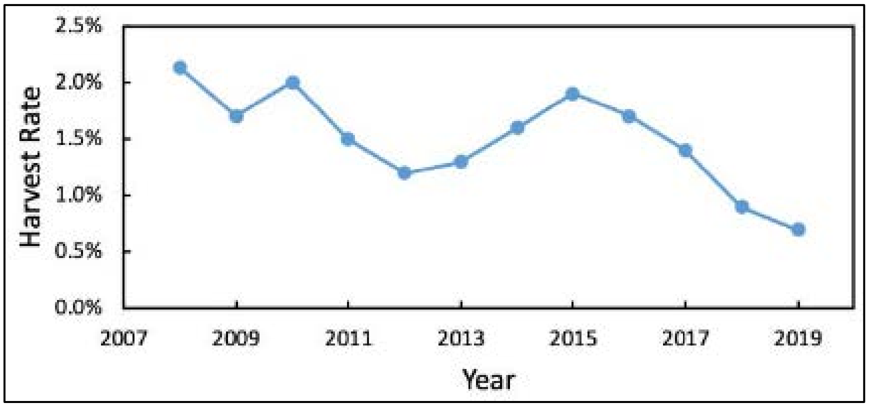


Figure 22. Non-treaty harvest rate for Upper Columbia River spring-run Chinook salmon. Data from the Columbia River Technical Advisory Committee (Figure reproduced from Ford (2022)).

2.2.2.3.3.1.2.1 Hatcheries

Hatchery managers have continued to implement and monitor changes their management actions since the 2016 5-year review for the hatchery programs within this ESU (Table 24). Although several measures have been implemented to reduce risk, the pHOS remains high in the Wenatchee and Methow Basins (Table 26). However, a better measure of hatchery genetic risk is the proportionate natural influence (PNI) within the population, which balances the incorporation of natural-origin fish into the broodstock with pHOS. For example, in the Methow River Basin, specific pHOS goals and genetically linking the two spring Chinook salmon programs in the basin have shown improvement in the estimated PNI for the program (NMFS 2022o). We conclude that hatchery effects continue to present risks to the persistence of the Upper Columbia River Spring-run Chinook Salmon ESU, but they are likely less of a risk compared to the 2016 5-year review (NMFS 2016p) because several additional reform measures have been implemented, such as terminating the Entiat National Fish Hatchery spring Chinook salmon hatchery program and genetically linking the two spring Chinook salmon programs in the Methow River subbasin (NMFS 2022o).

The hatchery programs that affect the Upper Columbia River Spring-run Chinook salmon ESU have also changed over time, and these changes have likely reduced adverse effects on ESA-listed species. Specifically, the hatchery programs funded by the Public Utility Districts (PUDs) were reduced in size starting in 2012 because of a revised calculation of their mitigation

Table 26. Five-year mean of fraction natural-origin (sum of all estimates divided by number of estimates).

Population	1995–99	2000–04	2005–09	2010–14	2015–19
Wenatchee River SP	0.56	0.42	0.23	0.40	0.43
Entiat River SP	0.70	0.56	0.47	0.77	0.70
Methow River SP	0.61	0.16	0.27	0.25	0.37

responsibility, based on increased survival through the PUD dams. Reducing hatchery production has reduced the number of natural-origin fish used for broodstock, as well as the proportion of hatchery fish on the spawning grounds and associated genetic risk (NMFS 2022o).

2.2.2.3.3.1.3 Summary

Current estimates of natural-origin spawner abundance decreased substantially relative to the levels observed in the prior review (NWFSC 2015) for all three extant populations (Ford 2022). Productivities also continued to be very low, and both abundance and productivity remained well below the viable thresholds called for in the UCSRB Recovery Plan (UCSRB 2007) for all three populations. Short-term patterns in those indicators appear to be largely driven by year-to-year fluctuations in survival rates in areas outside of these watersheds—in particular, a recent run of poor ocean condition years. All three populations continued to be rated at low risk for spatial structure, but at high risk for diversity criteria (Ford 2022). Large-scale supplementation efforts in the Methow and Wenatchee Rivers are ongoing, intended to counter demographic risks given current average survival levels and the associated year-to-year variability (Ford 2022). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

2.2.2.3.3.2 Limiting Factors

Understanding the limiting factors and threats that affect the Upper Columbia River Spring-run Chinook Salmon ESU provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting is for all involved parties to ensure that the underlying limiting factors and threats have been addressed. Natural populations of spring-run Chinook salmon within the Upper Columbia River Basin were first affected by intensive commercial fisheries in the Lower Columbia River. These fisheries began in the late 1800s and continued into the 1900s, nearly eliminating many salmon stocks. With time, the construction of dams and diversions, some without passage, blocked salmon migrations and killed upstream and downstream migrating fish. Early hatcheries, constructed to mitigate for fish loss at dams and loss of habitat for spawning and rearing, were operated without a clear understanding of population genetics, where fish were transferred to hatcheries without consideration of their actual origin. Although hatcheries were increasing the total number of fish returning to the basin, there was no evidence that they were increasing the abundance of natural populations and it is considered likely that they were decreasing the diversity and productivity of populations they intended to supplement (UCSRB 2007).Concurrent with these historic activities, human population growth within the basin was increasing, and land uses (in many cases, encouraged and supported by government policy) were in some areas impacting salmon spawning and rearing habitat. In addition, non-native species (for a list of non-native species refer to the recovery plan) were introduced by both public and private interests throughout the region that directly or indirectly affected salmon and trout. These activities acting in concert with natural disturbances decreased the abundance, productivity, spatial structure, and diversity of spring-run Chinook salmon in the Upper Columbia River Basin (UCSRB 2007).

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Upper Columbia River Spring-run Chinook Salmon ESU. According to the recovery plan factors that limit the ESU have been, and continue to be, destruction of habitat, overutilization for commercial/recreational/scientific/educational purposes, disease, predation, inadequacy of existing regulatory mechanisms, and other natural or human-made factors affecting the populations continued existence (UCSRB 2007).

The UCSRB (2007) provides a detailed discussion in Section 5, Strategy for Recovery, of limiting factors and threats and describes strategies for addressing each of them. Rather than repeating this extensive discussion from the recovery board, the discussion in Section 5 of the recovery plan is incorporated here by reference. Section 5 of the recovery plan is organized specifically to discuss threats and limiting factors relative to the following:

- Harvest Actions
- Hatchery Actions
- Hydro Project Actions
- Habitat Actions

The risk category for the Upper Columbia River Spring-run Chinook Salmon ESU remains unchanged from the prior review (NMFS 2016p). Although the status of the ESU is improved relative to measures available at the time of listing, all three populations remain at high risk (NMFS 2022o).

2.2.2.4 North-Central California Coast Recovery Domain

2.2.2.4.1 California Coastal Chinook Salmon ESU

The California Coastal Chinook Salmon ESU was listed as threatened under the ESA on September 16, 1999 (64 FR 50394). Protective regulations were issued in 2002 and 2005 (67 FR 1116; January 9 2002 and 70 FR 37159; August, 29, 2005). Critical habitat for the ESU was designated in 2000 (65 FR 7764; March17, 2000) and reaffirmed in 2005 (70 FR 52487; September 2, 2005) The ESA listing status was reaffirmed in 2014 (79 FR 20802; April 14, 2014).

NMFS reviewed the status of the species in 2005, 2011, and 2016 (Good et al. 2005; Williams et al. 2011; NMFS 2016o). Additionally, viability assessments for the ESU were completed in 2005, 2008, and 2016 (Bjorkstedt et al. 2005; Spence et al. 2008; Williams et al. 2016b). A recovery plan was finalized in 2016 (NMFS 2016q). In the most recent 5-year status review, NMFS (2016o) concluded that no change in the status of the species was warranted. The ESU remains listed as threatened at the time of this Opinion. An updated five-year status review is currently underway but was not finalized before this Opinion was completed. However, information from a recent viability assessment (SWFSC 2022) and draft technical memorandum (O'Farrell et al. 2022) are incorporated into the following status information for this Opinion.

The California Coastal Chinook Salmon ESU includes naturally spawned Chinook salmon originating from rivers and streams south of the Klamath River to (and including) the Russian River in California (Figure 23) (70 FR 37159, June 28, 2005). The ESU historically comprised 38 populations including 32 fall-run populations and 6 spring-run populations (Spence et al. 2008). All six of the spring-run populations are considered extinct (Williams et al. 2011). For recovery planning, the ESU is divided into four diversity strata (North Coastal, North Mountain-Interior, North-Central Coastal, and Central Coastal) comprising 17 populations (Figure 23 and Table 27) (NMFS 2016q). Several hatchery programs were included as part of the ESU when the listing was affirmed in 2005 (70 FR 37159; August, 29, 2005) but those programs are no longer active.

Table 27. California Coastal Chinook Salmon ESU description and MPGs (NMFS 2016o; 2016q).

ESU Description	
Threatened	Listed under ESA in 1999; reaffirmed in 2014
4 diversity strata	38 historical populations, 17 extant
Diversity Strata	***Populations***
North Coastal	Redwood Creek, Little River, Mad River, Humboldt Bay Tributaries, Lower Eel and South Fork Eel[a], Bear River, Mattole River
North-Mountain Interior	Van Duzen River and Larabee Creek[a], Upper Eel River
North-Central Coastal	Ten Mile River, Noyo River, Big River, Albion River
Central Coastal	Navarro River, Garcia River, Gualala River, Russian River
Artificial production	
Hatchery programs included in ESU (0)	No active hatcheries in ESU
Hatchery programs not included in ESU (0)	No active hatcheries in ESU

[a] The Lower Eel River population is divided between the North Coastal Strata (Lower Eel River mainstem and South Fork Eel River) and the North-Mountain Interior Strata (Van Duzen River and Larabee Creek).

2.2.2.4.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Viability is the likelihood that a population will sustain itself over a 100-year time frame (McElhany et al. 2000). We assess the status of the California Coastal Chinook Salmon ESU using criteria based on the VSP concept developed by McElhany et al. (2000). The VSP concept is described above in Section 2.2.1. VSP criteria for California Coastal Chinook salmon are described in NMFS viability assessments, 5-Year Status Reviews, and the Recovery Plan for California Coastal Chinook Salmon (Good et al. 2005; Spence et al. 2008; Williams et al. 2011; NMFS 2016q; 2016o; Williams et al. 2016b; SWFSC 2022). While the VSP criteria were designed to address all of the VSP parameters (abundance, productivity, spatial structure, and diversity), the available metrics for California Coastal Chinook salmon are primarily based on abundance because of the paucity of information (SWFSC 2022). Best available information indicates that the species, in this case the California Coastal Chinook Salmon ESU, is at moderate risk and remains at threatened status.

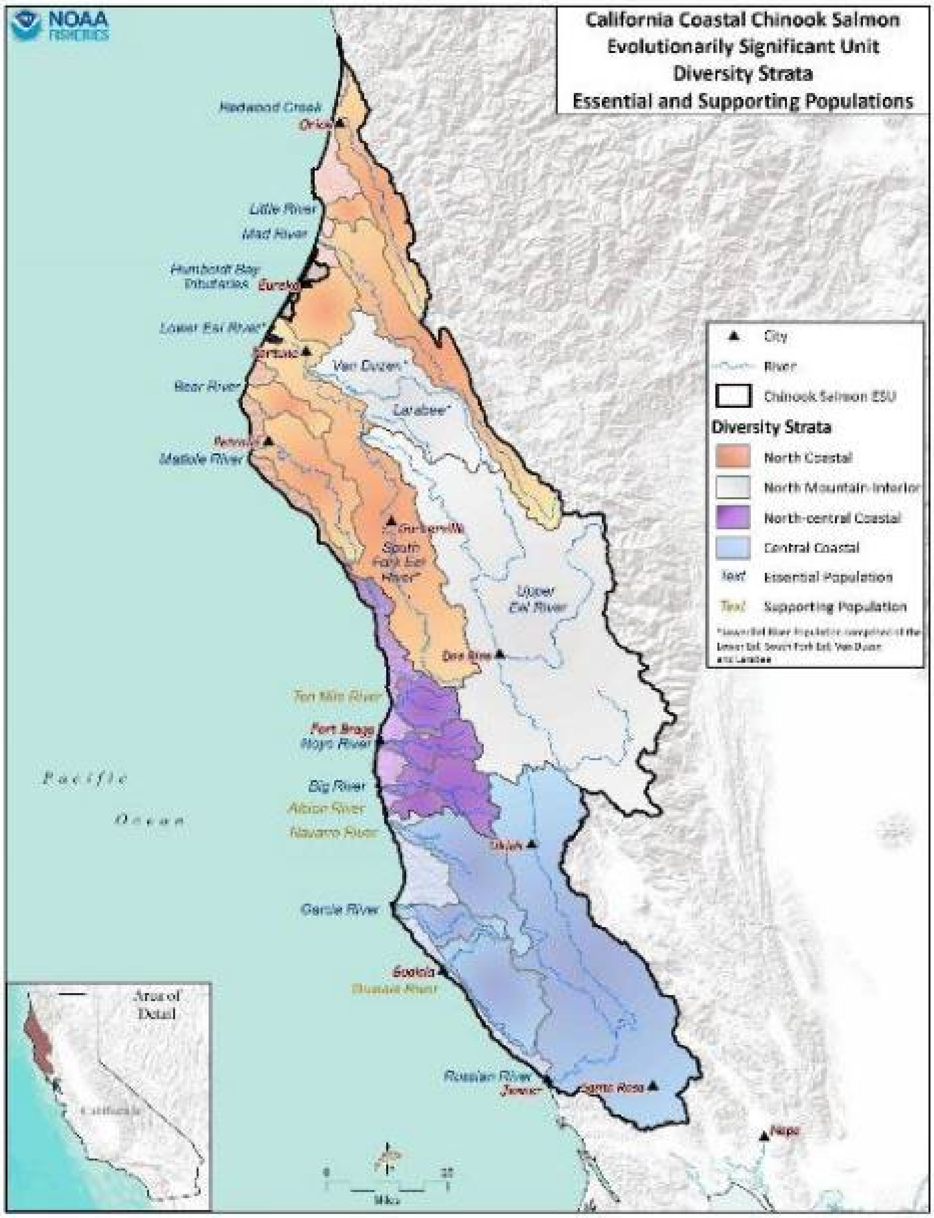


Figure 23. Map of the California Coastal Chinook Salmon ESU's spawning and rearing areas, illustrating populations and diversity strata (NMFS 2016o).

2.2.2.4.1.1.1 Abundance and Productivity

Populations of California Coastal Chinook salmon are categorized as “essential” and “supporting” depending on their role in rebuilding the ESU to recovery (NMFS 2016q). Essential populations must attain low risk of extinction to achieve ESU recovery. Supporting independent populations must attain moderate extinction risk to achieve ESU recovery. Supporting dependent populations will contribute to redundancy and occupancy.

Myers et al. (1998) and Good et al. (2005) concluded that California Coastal Chinook salmon were likely to become endangered in the foreseeable future. Good et al. (2005) cited continued evidence of low population sizes relative to historical abundance, mixed trends in the few available time series of abundance indices available, low abundance and extirpation of populations in the southern part of the ESU, and the apparent loss of the spring-run life-history type throughout the entire ESU as significant concerns. Williams et al. (2011) concluded that there was no evidence to indicate a substantial change in conditions since the previous review of Good et al. (2005), but noted that the lack of population-level estimates of adults continued to hinder assessments of status. They further noted that although independent populations persisted in the North Coastal and North Mountain Interior diversity strata, there was high uncertainty about the current abundance of these populations. They also cited the apparent extirpation of populations in the North-Central Coastal Stratum and the loss of all but one population (Russian River) in the Central Coastal Stratum as significant concerns since this gap reduced connectivity among strata across the ESU (Williams et al. 2011). The 2016 viability assessment (Williams et al. 2016b) concluded there was a lack of compelling evidence to suggest that the viability of these populations has improved or deteriorated since the previous assessment in 2011. The assessment reiterated concerns about the high uncertainty in northern populations such as the Eel and Mad rivers, but noted that improved monitoring indicated that low numbers of Chinook salmon were returning to watersheds (North-Central Coastal and Central Coastal strata) where they were previously believed extirpated (SWFSC 2022).

Prior status reviews and viability assessments for California Coastal Chinook salmon have noted the paucity of long-term population-level estimates of abundance for California Coastal Chinook salmon populations anywhere in the ESU (Myers et al. 1998; Good et al. 2005; Williams et al. 2011). Additionally, there are challenges with the reliability of some data sets throughout all four strata. However, data availability and reliability has improved somewhat since previous status and viability reviews (NMFS 2016o; SWFSC 2022). Adult Chinook salmon abundance estimates include (1) sonar-based estimates on Redwood Creek and the Mad and Eel rivers, (2) weir counts at Freshwater Creek (one tributary of the Humboldt Bay population), (3) trap counts at the Van Arsdale Fish Station[15] (representing a small portion of the upper Eel River population), (4) adult abundance estimates based on spawner surveys for six populations on the Mendocino Coast, and

[15] The Van Arsdale Fish Station is located at the terminus of anadromous access on the mainstem Eel River.

(5) video counts of adult Chinook salmon at Mirabel Dam on the Russian River (SWFSC 2022). A summary of available data from SWFSC (2022) are presented for each diversity stratum in the following subsections. The abundance estimates are for natural-origin fish as hatchery programs within the ESU were discontinued by the early 2000s.

North Coastal Stratum

The North Coastal Stratum includes coastal Chinook salmon populations from Redwood Creek to the Mattole River (Figure 23 and Table 27) except for the interior portions of the Eel River basin. All 7 populations are independent and are considered essential to recovery. Estimates of population-level abundance are currently available for three populations (Redwood Creek, Mad River, and Mattole River) of Chinook salmon in the North Coastal Stratum and shown in Table 28. Estimates of Chinook salmon in Redwood Creek are available beginning in spawning year[16] 2010. Population estimates have averaged 2,896 (range 1,455–4,541) showing a slightly positive, but not significant trend ($p = 0.31$) (Table 28, Figure 24, and Figure 25). The population mean represents 85% of the recovery target of 3,400 spawners. Estimates of Chinook salmon abundance are available for the Mad River since 2014. Estimates have averaged 7,059 fish (range 2,169–12,667) and, though the time series is too short for formal trend analysis, numbers have increased during this brief period (Table 28 and Figure 24). The mean estimated abundance exceeds the recovery target of 3,000 for this population. Spawner surveys have been conducted in the Mattole River since 2013, with results reported as total redd estimates. Redd estimates have averaged 862 (range 331–2,202) with a slightly positive trend (Table 28 and Figure 24).

In addition to the population-level estimates, longer time series of partial abundance estimates are available for two populations. Weir counts have been conducted in Freshwater Creek (part of the Humboldt Bay population) since 2001. Counts have averaged 29 fish (range 0–154) over the period of record, and there has been a negative and significant downward trend ($p = 0.0001$) (Figure 25). This trend was driven by high numbers of returns in the early part of the time series, which likely reflects the legacy of a small hatchery program that was discontinued in the early 2000s. Counts have been very low but relatively stable since the late 2000s. Estimates of Chinook salmon redds are available for the South Fork Eel River (part of the Lower Eel River population) since 2011. The average estimate has been 768 (range 68–1829) during this period and trends appear to be increasing, however the trend is not statistically significant ($p = 0.709$) (Figure 25).

[16] The spawning year (as defined in SWFSC (2022)) is the calendar year at the end of the spawning season (e.g., spawning year 2010 refers to the 2009–2010 spawning season).

Table 28. Average abundance, population trend, and spawner density for independent populations of California Coastal Chinook salmon (SWFSC 2022).

Strata	Population	Number of Years	Average Abundance	Population Trend	Spawner Density
North Coastal	Redwood Creek	8	2,896	0.049	24.9
	Mad River	5	7,059	NA	74.8
	Mattole River	7	862	0.121	4.9
North-Central Coastal	Ten Mile River	11	92	0.351	NA
	Noyo River	11	19	-0.161	0.3
	Big River	10	16	-0.249	0.2
Central Coastal	Navarro River	10	2	-0.174	NA
	Garcia River	10	34	**0.442**	0.6
	Russian River	18	2,947	NA	6.8

NA = Not available or not applicable
Population trends shown only for populations where time series is ≥ 6 years
Bold number indicates significant population trend.

North Mountain Interior Stratum

The North Mountain Interior Stratum includes Chinook salmon populations in the upper Eel River and in two tributaries to the lower Eel River, Van Duzen River, and Larabee Creek (Table 27 and Figure 23). Both populations in this stratum are independent and considered essential to recovery. A long-running time series (since 1947) of adult counts is available from the Van Arsdale Fish Station giving a partial abundance estimate for the Upper Eel River population. An average of 680 Chinook salmon (range 26–3,471) have been counted annually (Figure 25). The trend in abundance appears to be increasing but is not significant ($p = 0.709$) (SWFSC 2022). A new program for estimating abundance of the Upper Eel River Chinook salmon population was initiated in 2019 and produced an estimate of 3,844 fish (36% of the recovery target). This same year, only 94 fish were counted at the Van Arsdale Fish Station. These new data highlight the fact that the Van Arsdale Fish Station count represents only a small (and potentially variable) fraction of the total Upper Eel River population.

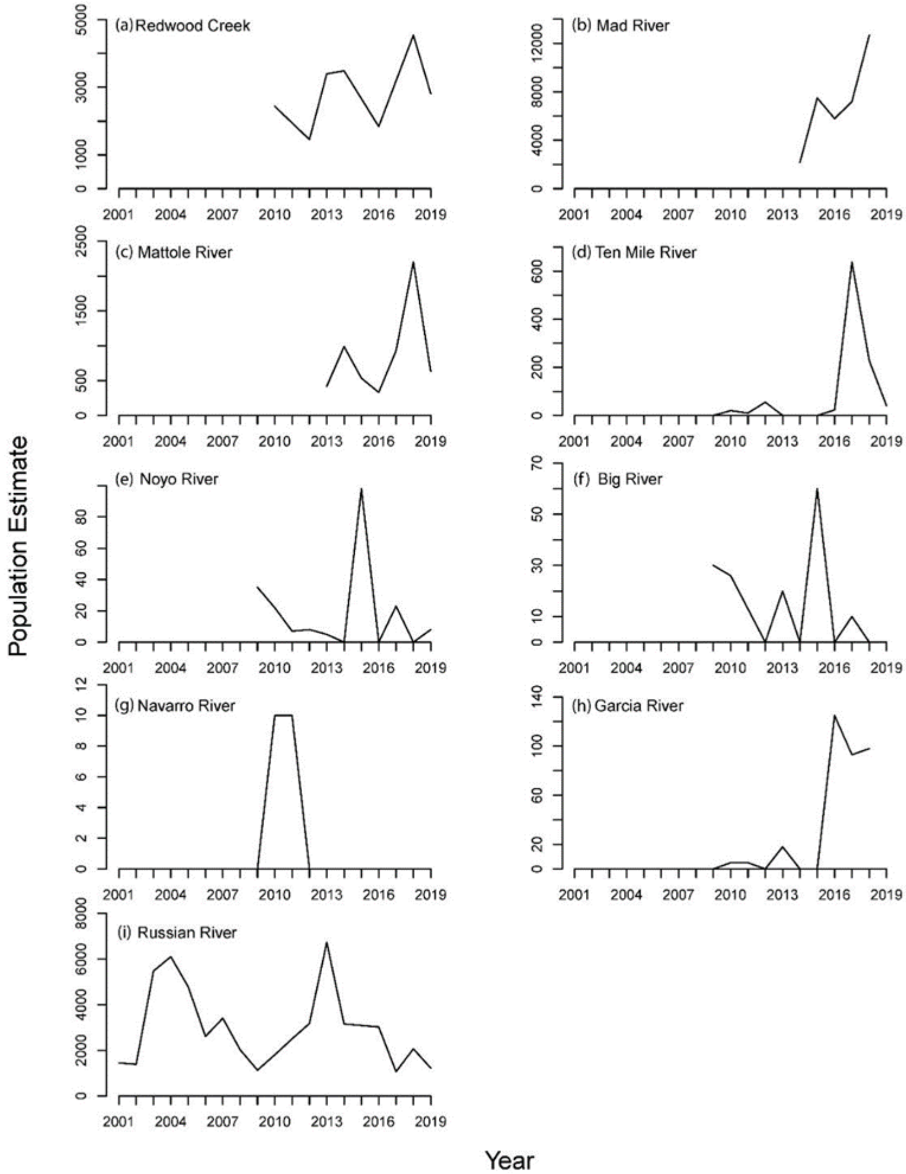


Figure 24. Time series of abundance estimates for independent populations of California Coastal Chinook salmon. (SWFSC 2022).

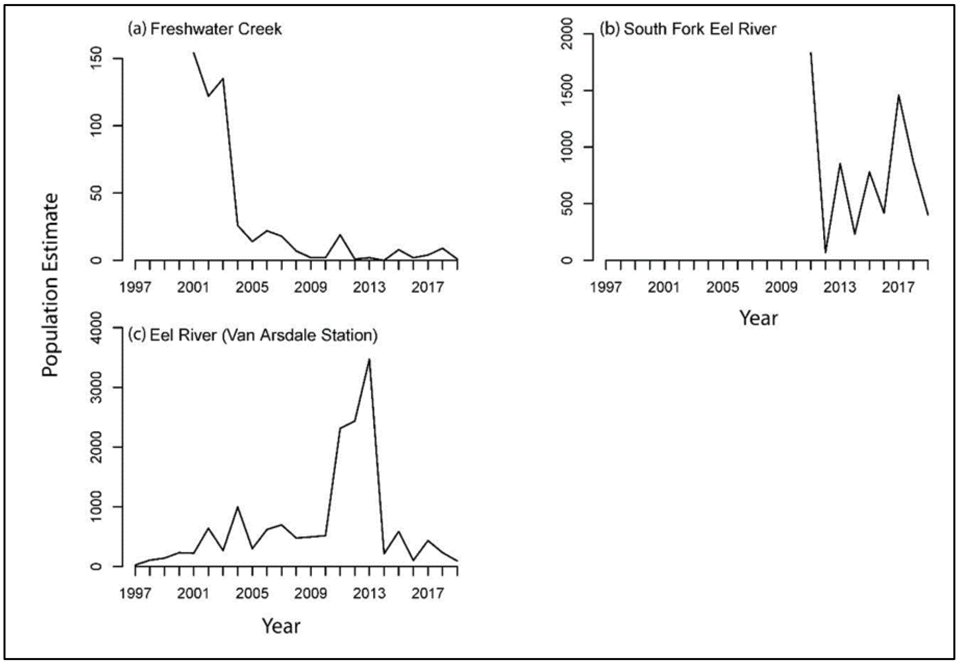


Figure 25. Time series of partial abundance estimates for independent populations of California Coastal Chinook salmon (SWFSC 2022).

North-Central Coastal Stratum

The North-Central Coastal Stratum includes Chinook salmon populations in Ten Mile River, Noyo River, Big River, and Albion River (Table 27 and Figure 23). The Ten Mile River population is independent and considered supporting to recovery rather than essential. Adult estimates have averaged 92 fish (range 0–638) over the years of record with no significant trend ($p > 0.10$) (Table 28 and Figure 24). The mean represents 11–22% of the recovery target for the Ten Mile River population. The Noyo River and Big River are independent populations and considered essential to recovery. The Noyo River estimate has averaged 19 (range 0–98) and Big River has averaged 16 (range 0–60) (Table 28 and Figure 24) and trends appear to be declining. These mean values are less than 1% of proposed recovery targets and fall below the depensation thresholds for high risk. Likewise, the generational averages fall below the high-risk threshold for effective population size.

Central Coastal Stratum

The Central Coastal Stratum includes Chinook salmon populations from the Navarro River, Garcia River, Gualala River, and the Russian River in the south (Table 27 and Figure 23). All 4 populations are independent, and the Garcia River and Russian River populations are considered essential to recovery. The Gualala and Navarro populations are considered supporting to recovery. Population monitoring has continued for three populations of Chinook salmon in the Central Coastal Stratum. Monitoring of the Navarro and Garcia river populations was initiated in spawn year 2009. In the Navarro River, small numbers (n = 10) of Chinook salmon were reported in 2010 and 2011, but they have not been observed since (Table 28 and Figure 24). In the Garcia River, estimates have averaged 34 (range 0–125) with a significant positive trend (p = 0.04) (Table 28 and Figure 24). However, the population mean is currently less than 2% of the recovery target. Both the Navarro and Garcia river populations are categorized as high risk based on depensation and effective population size criteria (Table 29).

Monitoring of adult Chinook salmon on the Russian River has been conducted since 2001. An average of 2,947 (range 1,062–6,730) Chinook salmon have been counted annually over the 18-year period of record (Table 28 and Figure 24). However, counts for 2015, 2016, and 2017 were derived using alternative methods due to issues with video cameras. Consequently, the statistical significance of this trend cannot be evaluated. However, the trend appears relatively stable over the period of record (SWFSC 2022). The average count represents about 32% of the recovery target for the Russian River and the population is considered low risk based on the effective population size criterion (SWFSC 2022).

2.2.2.4.1.1.1.1 <u>Harvest</u>

Very limited data exists on the harvest of California Coastal Chinook salmon. Instead proxies are used, as for ocean fisheries, the Klamath River fall-run Chinook salmon (KRFC) age-4 ocean harvest rate is used as a fishery management proxy to limit harvest impacts on California Coastal Chinook salmon. The current limit for California Coastal Chinook salmon in the PFMC ocean fishery is a maximum predicted KRFC age-4 ocean harvest rate of 16% (SWFSC 2022).

The KRFC age-4 ocean harvest rate fell sharply from its average value of 44% over the 1981–1990 period (Figure 26). Very low KRFC age-4 ocean harvest rates were observed between 2008 and 2012, partially reflecting the widespread fishery closures in California and Oregon from 2008 to 2010. Since 2013, the KRFC age-4 ocean harvest rate has ranged from 4% to 34%, with annual rates exceeding 16% in five of seven years (SWFSC 2022). The harvest rates were particularly high in 2018 (24%) and 2019 (34%), noting that the 2019 estimate is still

Table 29. Diversity strata, populations, historical status, population's role in recovery, current Intrinsic Potential (IP), recovery criteria, and current extinction risk for California Coastal Chinook salmon (Spence et al. 2008; NMFS 2016q; SWFSC 2022). Recovery target corresponds to the spawner density target multiplied by the IP. Depensation threshold corresponds to 1 spawner per IP-km.

Diversity Strata	Population	Historical Status	Role in Recovery	Intrinsic Potential (IP-km)	Spawner Density Target	Recovery (Low-Risk) Target	Depensation (High-Risk) Threshold	Extinction Risk
North Coastal	Redwood Creek	Independent	Essential	116.1	29.3	3,400	116	Data Deficient
	Little River	Independent	Essential	17.4	40.0	700	17	Data Deficient
	Mad River	Independent	Essential	94.4	31.7	3,000	94	Data Deficient
	Humboldt Bay Tributaries	Independent	Essential	76.6	33.7	2,600	77	Data Deficient
	Lower Eel and South Fork Eel*	Independent	Essential	368.4	20.0	7,400	368	Data Deficient
	Bear River	Independent	Essential	39.4	37.8	1,500	39	Data Deficient
	Mattole River	Independent	Essential	177.5	22.5	4,000	178	Moderate/High
North Mountain-Interior	Van Duzen River and Larabee Creek*	Independent	Essential	144.0	20.0	2,900	144	Data Deficient
	Upper Eel River	Independent	Essential	528.5	20.0	10,600	529	Data Deficient
North-Central Coastal	Ten Mile River	Independent	Supporting	67.2	6-12	401-804	67	High
	Noyo River	Independent	Essential	62.2	35.3	2,200	62	High
	Big River	Independent	Essential	104.3	30.6	3,200	104	High
	Albion River	Dependent	Supporting	17.6	6-12	104-209	18	N / A
Central Coastal	Navarro River	Independent	Supporting	131.5	6-12	787-1,576	132	High
	Garcia River	Independent	Essential	56.2	36.0	2,000	56	High
	Gualala River	Independent	Supporting	175.6	6-12	1,052-2,105	176	High
	Russian River	Independent	Essential	465.2	20.0	9,300	465	Low

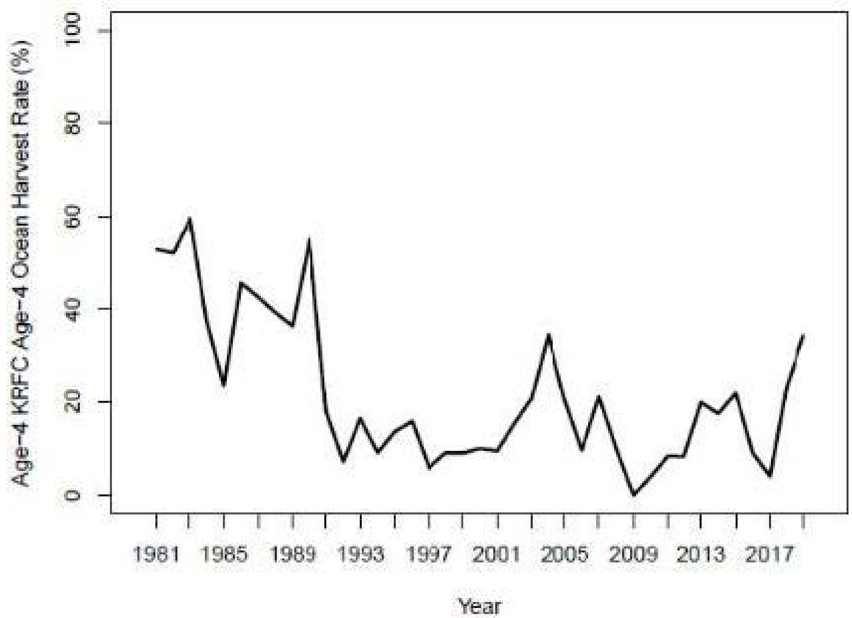


Figure 26. Klamath River fall-run Chinook salmon (KRFC) age-4 ocean harvest rate for years 1981–2019 (PFMC 2020b).

preliminary (PFMC 2020a). The average KRFC age-4 ocean harvest rate estimated over the years since the previous viability assessment update (2015–2019) is 19% (SWFSC 2022). In contrast, the average KRFC age-4 ocean harvest rate estimated for years 2011–2014, as reported in the last viability assessment, was 13% (Williams et al. 2016b).

Freshwater fishery impacts on California Coastal Chinook salmon are likely low because retention of Chinook salmon is prohibited across its range; thus, impacts from freshwater fisheries are limited to incidental handling and mortality from anglers targeting steelhead (SWFSC 2022). Low-flow fishing closure regulations have been adopted in portions of the California Coastal Chinook salmon ESU to better protect both ESA-listed and target species. In 2016, low-flow fishing thresholds in the South Fork Gualala River were established and have been used to trigger closures for streams in Mendocino, Sonoma, and Marin counties (in prior years, flows in the Russian River were used to trigger low-flow fishing closures in these areas, but these were deemed inadequate to protect these populations). A low-flow fishing threshold for the Russian River was also adopted in 2016 to regulate closures in the Russian River. These fishery closures have likely reduced incidental capture and handling of California Coastal Chinook salmon during closure periods; however, the overall effect of these closures is difficult to quantify, as the data needed to evaluate potential temporal shifts in angler effort and encounter rates associated with the closures are not currently available (SWFSC 2022).

In summary, the recent increases in the KRFC age-4 ocean harvest rate suggests that the level of California Coastal Chinook salmon ocean fishery impacts has likely increased since the 2016 salmon and steelhead status review update (NMFS 2016o).

2.2.2.4.1.1.2 Spatial Structure and Diversity

As noted above, the majority of VSP criteria metrics available relate to abundance for the California Coastal Chinook Salmon ESU. Therefore, available information regarding spatial structure and diversity is limited. Concerns remain about maintenance of connectivity across the ESU (SWFSC 2022).

2.2.2.4.1.1.2.1 <u>Hatcheries</u>

There are no current hatcheries within the California Coastal Chinook salmon ESU, but if California Coastal Chinook salmon populations continue to decline, studies are needed to investigate the need and feasibility of a broodstock conservation hatchery, especially along the Mendocino coast (NMFS 2016o).

2.2.2.4.1.1.3 Summary

In the North Coastal Stratum, improved monitoring programs indicate that some populations are doing better than believed in prior 5-year status reviews and viability assessments (Myers et al. 1998; Good et al. 2005; Williams et al. 2011; Williams et al. 2016b) and trends appear to be increasing where population-level estimates are available (NMFS 2016o; SWFSC 2022). All North Coastal populations are considered essential to recovery. The Redwood Creek population is approaching the recovery target in some years with average abundance at 85% of the recovery target. The Mad River population is exceeding the recovery target. The Mattole River population appears to be increasing based on positive trends in redd estimates. Partial abundance estimates exist for Freshwater Creek and the South Fork Eel populations, which are part of the Humboldt Bay and Lower Eel populations, respectively. In Freshwater Creek, long term trends in abundance have declined, but this is heavily influenced by hatchery releases during the early part of the time series. In the South Fork Eel River, estimates of redds have shown an increasing trend.

In the North Mountain Interior Stratum, data are extremely limited, and long-term trends only exist for a portion of the Upper Eel River population (essential to recovery). The partial abundance estimate from data collected at the Van Arsdale Fish Station has shown an increasing trend despite high variability and low reliability. A new monitoring program has been implemented to estimate population-level abundance for the Upper Eel River, and early results indicate significantly higher abundance than the partial abundance estimate.

In the North-Central Coastal Stratum, trends are mixed. Trends in abundance for the Noyo River have been relatively stable while the trends for the Big River have declined. Both the Noyo and Big river populations are essential to recovery and are at high risk of extinction due to depensation. The North Central-Coastal populations are all at low abundance. However, previous viability assessments and status reviews indicated the apparent extirpation of populations in this stratum, so presence even at low levels appears to be an improvement (Myers et al. 1998; Good et al. 2005; Williams et al. 2011; Williams et al. 2016b).

In the Central Coastal Stratum, overall trends appear to be improving. The Garcia River population is essential to recovery and has shown a significant positive trend despite being at high risk due to depensation. The Russian River population is essential to recovery, is at low risk of extinction, and its trends in abundance appear relatively stable. This population has consistently numbered in the low thousands of fish in most years, making it the largest population south of the Eel River. Similar to the North-Central Coastal Stratum, populations in the Central Coastal Stratum (except for the Russian River) were thought to be extirpated in previous viability assessment and status reviews (Myers et al. 1998; Good et al. 2005; Williams et al. 2011; Williams et al. 2016b).

Abundance trends across the California Coastal Chinook Salmon ESU have been mixed but several populations appear to be stable or increasing. Overall extinction risk for the ESU is moderate and has not changed appreciably since the previous (Williams et al. 2016b) viability assessment (SWFSC 2022).

2.2.2.4.1.2 Limiting Factors

The 2016 recovery plan (NMFS 2016q) determined the limiting factors and threats of greatest concern to the ESU. These threats include: channel modification, roads and railroads, logging and wood harvesting, water diversion and impoundments, and severe weather patterns (Table 30). Threat from hatcheries and aquaculture are not applicable within the ESU given the termination of hatchery programs for Chinook salmon. Fishing was identified as a medium threat for most of the populations of California Coastal Chinook salmon because of freshwater fishing. While retention of Chinook salmon is prohibited in the freshwater areas of the ESU, poaching and encounters during steelhead fisheries (especially during low flow conditions) remains a concern (NMFS 2016q). To address this, CDFW has implemented low flow fishing closures, including additional closures in 2022, to reduce the impact on Chinook salmon across the ESU. The specific threats to the California Coastal Chinook Salmon ESU are discussed in detail in the

Threats section of Volume II of the recovery plan (NMFS 2016q) and status reviews (Good et al. 2005; Williams et al. 2011; NMFS 2016o; Williams et al. 2016b; SWFSC 2022).

Table 30. Threats to essential populations of California Coastal Chinook salmon. Cells with [-] were not rated or not applicable (NMFS 2016q).

Threat	Diversity Strata / Population													
	North Coastal							North Mountain Interior			North-Central Coastal		Central Coastal	
	Redwood Creek	Little River	Mad River	Humboldt Bay	Lower Eel / South Fork	Bear River	Mattole River	Van Duzen River	Larabee Creek	Upper Eel River	Noyo River	Big River	Garcia River	Russian River
Agriculture	M	M	M	M	M	M	L	M	M	L	L	-	M	M
Channel Modification	VH	H	H	H	H	M	M	H	M	L	L	L	M	H
Disease, Predation and Competition	H	M	M	M	M	M	M	H	H	M	-	-	M	M
Fire, Fuel Management and Fire Suppression	M	M	M	L	M	M	M	M	M	M	L	L	L	L
Fishing and Collecting	M	M	M	M	M	M	M	M	M	H	M	M	H	M
Hatcheries and Aquaculture	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Livestock Farming and Ranching	M	M	M	M	M	H	M	M	M	L	-	-	M	L
Logging and Wood Harvesting	H	H	M	H	M	H	M	M	M	M	M	M	H	L
Mining	H	-	H	L	M	M	M	M	M	L	-	-	L	M
Recreational Areas and Activities	M	M	M	L	M	M	M	M	M	L	L	L	L	L
Residential and Commercial Development	M	M	M	M	M	M	M	M	M	L	L	L	M	H
Roads and Railroads	H	H	H	M	H	H	M	M	M	H	M	M	H	H
Severe Weather Patterns	H	M	M	H	H	M	H	M	M	M	M	M	M	M
Water Diversion and Impoundments	M	M	M	M	H	M	H	H	M	L	L	L	M	H

Recovery goals objectives and criteria for California Coastal Chinook salmon are outlined in Volume II of the 2016 Recovery Plan in the Recovery Goals section (NMFS 2016q).

Recovery plan objectives are to:

1. Reduce the present or threatened destruction, modification, or curtailment of habitat or range;
2. Ameliorate utilization for commercial, recreational, scientific, or educational purposes;
3. Abate disease and predation;
4. Establish the adequacy of existing regulatory mechanisms for protecting California Coastal Chinook salmon now and into the future (i.e., post-delisting);
5. Address other natural or manmade factors affecting the continued existence of California Coastal Chinook salmon; and,
6. Ensure the status of California Coastal Chinook salmon is at a low risk of extinction based on abundance, growth rate, spatial structure and diversity.

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

2.2.2.5 Central Valley Recovery Domain

2.2.2.5.1 Central Valley Spring-run Chinook Salmon ESU

The Central Valley Spring-run Chinook Salmon ESU was listed as threatened on September 16, 1999 (64 FR 50394). On June 28, 2005 NMFS published the final hatchery listing policy (70 FR 37204) and reaffirmed the threatened status of the ESU (70 FR 37160) (Table 31). The Central Valley Spring-run Chinook Salmon ESU includes spring-run Chinook salmon populations spawning in the Sacramento River and its tributaries and spring-run Chinook salmon in the Feather River Hatchery (Figure 27). Critical habitat was designated on September 2, 2005 (70 FR 52488). The San Joaquin River watershed and Delta are excluded as critical habitat and San Joaquin basin populations are considered extirpated (78 FR 79622). NMFS completed a recovery plan for the ESU in 2014 (NMFS 2014b), and the most recent 5-year status review was completed in 2016 (NMFS 2016t). A viability assessment for the ESU was completed by the Southwest Fisheries Science Center (SWFSC) in 2022 (SWFSC 2022).

Table 31. Central Valley Spring-run Chinook Salmon ESU description and MPGs. "I" indicates independent populations and "D" indicates dependent populations (Lindley et al. 2004; NMFS 2014b; 2016t; SWFSC 2022).

ESU Description	
Threatened	Listed under ESA in 1999; reaffirmed in 2005
4 diversity groups	26 historical populations (18–19 independent), 9 extant (4 independent)
Diversity Group	***Populations***
Basalt and Porous Lava	Battle (I)
Northwestern California	Clear (D), Cottonwood (D)
Northern Sierra Nevada	Mill (I), Deer (I), Butte (I), Yuba (D), Antelope (D), Big Chico (D)
Southern Sierra Nevada	No extant populations
Artificial production	
Hatchery programs included in ESU (1)	Feather River Hatchery Spring-run Chinook Program
Hatchery programs not included in ESU (1)	San Joaquin Experimental Population

2.2.2.5.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. No criteria exist to assess whether this ESU is at moderate or high risk of extinction (SWFSC 2022). Best available information and judgement indicates that the species, in this case the Central Valley Spring-run Chinook Salmon ESU, is likely at either moderate or high risk and remains at threatened status. The process for making this determination is further discussed below.

The Central Valley TRT delineated four diversity groups and 18 or 19 historical independent populations of Central Valley spring-run Chinook salmon (depending on the classification of Mill Creek and Deer Creek populations), along with a number of smaller dependent populations (Lindley et al. 2004). The primary criteria used to identify independent from dependent populations were data on historical accounts of the presence of spring-run Chinook salmon, isolation from other populations that exceeded a critical dispersal distance (>50 km), minimum basin size (500 km2), and genetic information (Lindley et al. 2004).

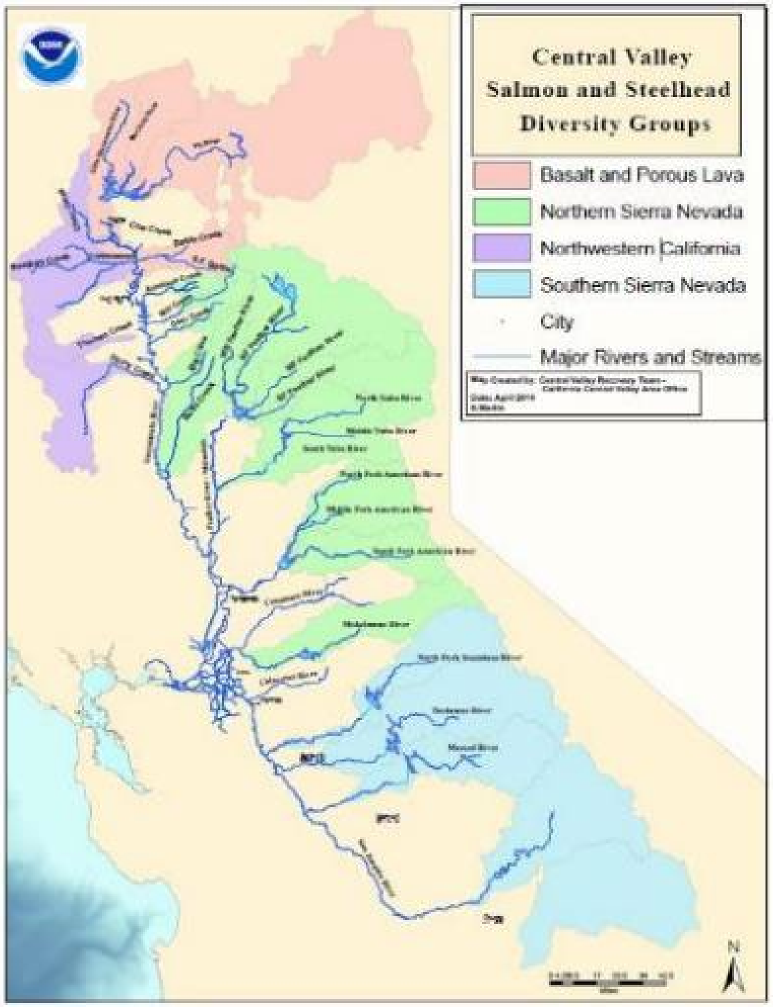


Figure 27. Map of the Central Valley Spring-run Chinook Salmon ESU's spawning and rearing areas, illustrating historical populations and diversity groups (NMFS 2014b).

The TRT considered multiple lines of evidence to evaluate the extent to which Mill and Deer creeks were historically independent from one another or a single panmictic population and reached no definitive conclusion. The TRT did conclude that Central Valley spring-run Chinook salmon in Mill and Deer creeks are currently independent from other Central Valley spring-run

Chinook salmon populations and together with populations on Butte Creek could serve as salmon strongholds in the Northern Sierra Nevada diversity group.

2.2.2.5.1.1.1 Abundance and Productivity

Lindley et al. (2007) provides criteria to assess the level of risk of extinction of Central Valley salmon based on population size, recent population decline, occurrences of catastrophes within the last 10 years that could cause sudden shifts from a low risk state to a higher one, and the impacts of hatchery influence (Table 32). Figure 28 shows the escapement of Central Valley spring-run Chinook salmon to various areas of the Central Valley, and Table 33 shows abundance and trend statistics related to viability criteria. All historically independent populations remaining (Battle, Deer, Mill, and Butte creeks) show substantially lower total population sizes (N) and mean escapement ($\hat{S}$) than the Williams et al. (2016b) viability assessment (SWFSC 2022). The rate of

Table 32. 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 criterion (modified from Lindley et al. (2007)).

Criterion	High	Moderate	Low
Extinction risk and PVA	> 20% within 20 yrs - or any ONE of -	> 5% within 100 yrs - or any ONE of -	< 5% within 100 yrs - or ALL of -
Population size[a]	$Ne \leq 50$ - or - $N \leq 250$	$50 < Ne \leq 500$ - or - $250 < N \leq 2500$	$Ne > 500$ - or - $N > 2500$
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	Not apparent
Hatchery influence[f]	High	Moderate	Low

decline over the past decade coupled with low abundances place Battle, Deer, and Mill creek populations at a high risk of extinction. The Butte Creek population remains at a low risk of extinction despite having a recent decline of 76% in a single generation. All populations experienced recent declines in one generation that exceeded previous year maximums, with the exception of Deer and Antelope creeks whose largest declines in a single generation (84% and 88%), occurred at the beginning of the decadal time series (Table 33). Butte Creek's total

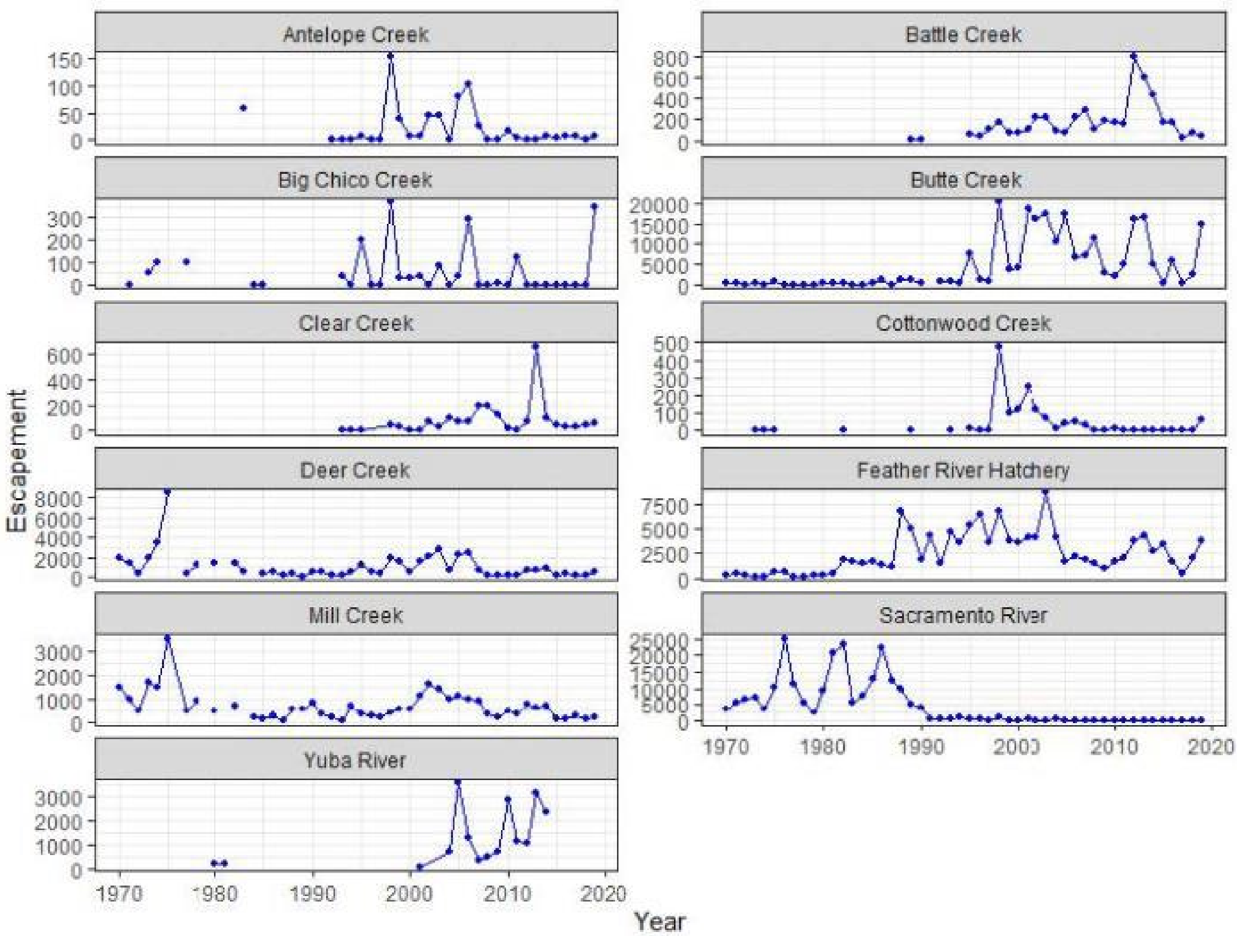


Figure 28. Escapement for Central Valley spring-run Chinook salmon over time. For Butte Creek populations, the mark-recapture estimates are used beginning in 2001. No data were provided for escapement years 2015–2019 for the Yuba River. Figure from SWFSC (2022).

population size is 17,740, which is double what was estimated in 2010 and remains by far the most abundant Central Valley spring-run Chinook salmon population (Table 33). While data for the Yuba River was included in the 2015 viability assessment (Williams et al. 2016b) and showed a low extinction risk based on population size, no data were provided for escapement years 2015–2019 and therefore omitted from the 2022 viability assessment (SWFSC 2022).

All populations of Central Valley spring-run Chinook salmon are still exhibiting declines in population size over time, with the exception of two dependent populations — Antelope and Clear creeks that have positive point estimates of population growth (Table 33). In 2015, Central Valley spring-run Chinook salmon showed strong signs of repopulating Battle Creek, home to a historical independent population in the Basalt and Porous Lava diversity group that had been extirpated for many decades (SWFSC 2022). Current viability metrics show a significant declining trend (23% decline per year) and low population size (N<250) for the Battle Creek spring-run Chinook salmon population placing it at a high extinction risk (SWFSC 2022). Similarly, the Central Valley spring-run Chinook salmon population in Clear Creek, previously identified as increasing in abundance, has experienced recent declines in population size (N=136) down from N=822 in 2015, placing it at a high risk of extinction (SWFSC 2022). Mill Creek and Deer Creek spring-run Chinook salmon populations reached low population sizes (N=590 and N=956, respectively) placing them at a moderate risk of extinction (SWFSC 2022). Yet, the low run sizes in consecutive years for Mill Creek spring-run Chinook salmon following the recent droughts (~150 individuals) and precipitous decline (16% over the decade) places Mill Creek at a high risk of extinction using the criteria in Table 32 (SWFSC 2022). The highest risk score for any criterion determines the overall extinction risk for a given population. Recent declines of population size in all populations have been substantial and almost qualify as catastrophes under the criteria (>90% decline) with the main independent populations of Central Valley spring-run Chinook salmon reaching all-time declines over one generation (Battle Creek = 77%, Butte Creek = 76%, Deer Creek = 84%, and Mill Creek = 68%) (SWFSC 2022).

Beginning in 2009, estimates of spawning escapement of Upper Sacramento River spring-run Chinook salmon were no longer monitored. Historically, this estimate was derived by the total Red Bluff Diversion Dam counts minus the spring-run numbers in the upper Sacramento tributaries. Beginning in 2009, Red Bluff Diversion Dam gates were partially operated in the up position and in 2012 they were entirely removed and thus spring-run estimates were no longer available. Central Valley spring-run Chinook salmon on the mainstem Sacramento River are not thought to be numerous, yet in some years, the majority of fish collected in the spring and summer months in the Keswick trap as adults are genetically assigned as non-winter-run Chinook salmon. Based on when they are sampled, they are likely Central Valley spring-run Chinook salmon. Consideration should be given to the use of genetics to improve viability assessments of Central Valley spring-run Chinook salmon in the Keswick trap sampling as well as the Sacramento River winter- and fall-run carcass survey to quantify Central Valley spring-

Table 33. Viability metrics for the Central Valley Spring-run Chinook Salmon ESU populations through escapement year 2019[a]. Figure from SWFSC (2022).

Population	N	$\hat{S}$	10-year trend (95% CI)	Recent decline (%)
Antelope Creek spring-run	16	5.3	0.181 (-0.949, 1.312)	87.8
Battle Creek spring-run	157	52.3	-0.228 (-0.446, 0.009)	76.5
Big Chico Creek spring-run	350	116.7	-0.411 (-2.404, 1.581)	100.0
Butte Creek spring-run	17740	5913.3	-0.059 (-0.400, 0.283)	76.3
Clear Creek spring-run	136	45.3	0.044 (-0.266, 0.354)	82.9
Cottonwood Creek spring-run[b]	62	20.7	-1.073 (-2.672, 0.527)	100.0
Deer Creek spring-run	956	318.7	-0.037 (-0.191, 0.117)	83.3
Feather River Hatchery spring-run	6509	2169.7	-0.026 (-0.192, 0.140)	45.8
Mill Creek spring-run	590	196.7	-0.158 (-0.288, -0.028)	67.9
Sacramento River spring-run[c]	-	-	-	

[a] Total population size (N) is estimated as the sum of estimated run sizes over the most recent three years for independent populations (bold) and dependent populations. The mean population size ($\hat{S}$) is the average of the estimated run sizes for the most recent 3 years (2017–2019). Population growth rate (or decline; 10-year trend) is estimated from the slope of log-transformed estimated run sizes. In order to log-transform the run data, any ‘0’s’ were replaced with ‘0.00001’. The catastrophic metric (Recent decline) is the largest decline in a single generation over the most recent 10 such ratios (see supplemental for detailed calculations).
[b] Data from 2015–2018
[c] Beginning in 2009, estimates of spawning escapement of Upper Sacramento River spring-run Chinook were no longer monitored. Historically, this estimate was derived by the total Red Bluff Diversion Dam (RBDD) counts minus the spring-run numbers in the upper Sacramento tributaries. Beginning in 2009, RBDD gates were partially operated in the up position and in 2012 they were entirely removed and thus spring-run estimates were no longer available.

*Erratum: Butte Creek and Yuba River viability metrics using data from 2005-2015 reported in the 2015 viability assessment are revised below (see Chapter 5 in Williams et al. (2016b)). These changes do not influence the interpretations of the status or trends provided in the previous viability assessment:

Population	N	Ŝ	10-year trend (95% CI)	Recent decline (%)
Butte Creek spring-run	38182	12727.3	-0.018 (-0.224, 0.187)	51
Yuba River spring-run			0.067 (-0.138, 0.272)	

run Chinook salmon spawning on the mainstem Sacramento River (Prince et al. 2017; Thompson et al. 2019; Meek et al. 2020). In some years, the Sacramento River mainstem population could be more abundant than the other independent Central Valley spring-run Chinook salmon populations.

2.2.2.5.1.1.1.1 Harvest

Attempts have been made to estimate Central Valley spring-run Chinook salmon ocean fishery exploitation rates using CWT recoveries from natural origin Butte Creek fish (Grover et al. 2004), but due to the low number of recoveries the uncertainty of these estimates is too high for them to be reliable (SWFSC 2022). Because Central Valley spring-run Chinook salmon have a relatively broad ocean distribution, generally from central California to Cape Falcon, Oregon, that is similar to that of Sacramento River fall-run Chinook salmon, trends in the Sacramento River fall-run Chinook salmon ocean harvest rate may provide a reasonable proxy for trends in the Central Valley spring-run Chinook salmon ocean harvest rate (SWFSC 2022). While the Sacramento River fall-run Chinook salmon ocean harvest rate can provide information on trends in Central Valley spring-run Chinook salmon fishing mortality, it has been inferred that Central Valley spring-run Chinook salmon likely experiences lower ocean fishing mortality than Sacramento River fall-run Chinook salmon (SWFSC 2022). If maturation rates are similar between Central Valley spring-run Chinook salmon and Sacramento River fall-run Chinook salmon, the ocean exploitation rate on Central Valley spring-run Chinook salmon would be lower than Sacramento River fall-run Chinook salmon in the last year of life because spring-run Chinook salmon escape ocean fisheries in the spring, prior to the most extensive ocean salmon fisheries in summer (SWFSC 2022). Furthermore, Central Valley spring-run Chinook salmon tend to be smaller at age than Sacramento River fall-run Chinook salmon, which would imply lower age-specific ocean fishery mortality for Central Valley spring-run Chinook salmon (Myers et al. 1998; Satterthwaite et al. 2012).

Since the last 5-year status review (NMFS 2016t), Satterthwaite et al. (2018) reviewed available data for Central Valley spring-run Chinook salmon and explored assessment and management options. Included in this paper was the suggestion that until Central Valley spring-run Chinook salmon-specific stock assessments are developed, and exploitation rates can be directly estimated, trends in ocean fishing mortality rates for co-mingling stocks (Sacramento River fall-run Chinook salmon, Klamath River fall-run Chinook salmon, and Sacramento River winter-run Chinook salmon can provide information on how levels of exploitation have changed for Central Valley spring-run Chinook salmon). Figure 29 displays trends in ocean fishery mortality rates for these stocks. Fishing mortality rates generally peaked in the 1980s and 1990s. Very low fishing mortality rates were estimated for 2008–2010, as fishing opportunity was either eliminated or heavily scaled back due to the collapse of the Sacramento River fall-run Chinook salmon stock (SWFSC 2022). Following 2010, fishing mortality rates have returned to levels generally similar

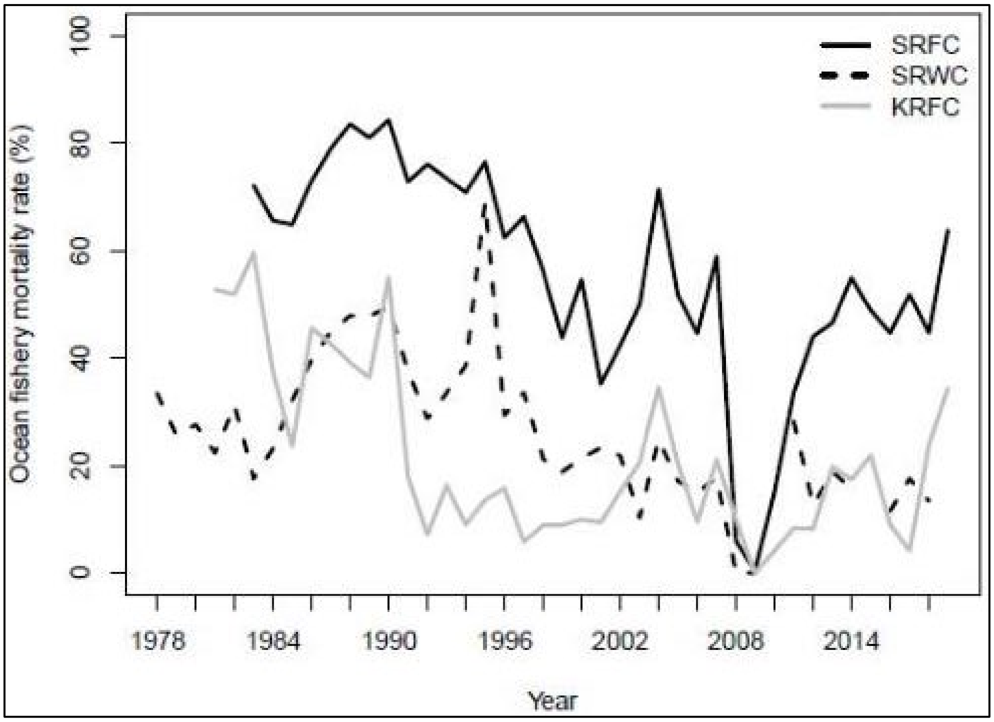


Figure 29. Ocean fishing mortality rates estimated for Sacramento River fall-run Chinook salmon (SRFC), Sacramento River winter-run Chinook salmon (SRWC), and Klamath River fall-run Chinook salmon (KRFC). For SRFC, the fishing mortality rate is the determined by the estimated ocean harvest divided by the Sacramento Index. For SRWC, the fishing mortality rate is represented by the age-3 ocean impact rate. For KRFC, the fishing mortality rate is determined by the age-4 ocean harvest rate. Figure from SWFSC (2022).

to those estimated in the early to mid-2000s, but with notable increases in fishing mortality rates for Sacramento River fall-run Chinook salmon and Klamath River fall-run Chinook salmon in 2019 (SWFSC 2022).

The level of Central Valley spring-run Chinook salmon fishery impacts inferred from patterns in Sacramento River fall-run Chinook salmon, Sacramento River winter-run Chinook salmon, and Klamath River fall-run Chinook salmon mortality rates is mixed, with recent increases in Sacramento River fall-run Chinook salmon and Sacramento River winter-run Chinook salmon, but little change for Sacramento River winter-run Chinook salmon (SWFSC 2022). In summary, the available information suggests that ocean fishery impacts have not changed appreciably since the 2016 5-year status review update (NMFS 2016t).

2.2.2.5.1.1.2 Spatial Structure and Diversity

Spatial structure promotes life-history diversity and phenotypic variation that is critical for the long-term persistence of species and populations, especially in highly variable environments. Central Valley spring-run Chinook salmon express significant diversity in the duration of freshwater rearing (3–15 months) with some juveniles leaving the freshwater as sub-yearlings while others over-summer until they are much larger and migrate as yearlings (SWFSC 2022). Yearlings are difficult to monitor, but have been observed in screw traps on Mill, Deer, and Butte creeks (SWFSC 2022). The extent to which the yearling vs. sub-yearling strategies currently function to create population resilience in Central Valley spring-run Chinook salmon populations is the source of on-going research. Unlike fall-run Chinook salmon that are not occupying the freshwater habitats in the summer, Central Valley spring-run Chinook salmon need cold water as adults and yearlings in the summer. In order to support the yearling life history, cold over-summer temperatures are required, which are lacking on much of the valley floor. This temperature constraint in low elevation habitats likely restricts the expression and/or success of the yearling strategies to tributaries like Mill and Deer creeks that, if adequate flows remain in the streams after water diversions, retain higher elevation access and cooler summer stream temperatures. Further, juvenile smolt outmigration survival in Central Valley spring-run Chinook salmon appears to be linked to higher springtime outmigration flows (Notch et al. 2020) which are regularly suppressed during May to store water in Shasta Reservoir for summer agricultural deliveries, Delta water quality, and Sacramento River temperature management (NMFS 2019a). For example, survival of tagged smolts from Mill Creek had 8-fold higher survival during the high flows in 2017 (42.3% ± 9.1) than during the 2015 drought (4.9% ± 1.6). Further, there is often a mismatch between the ideal timing and outmigration conditions the smolts experience in Mill and Deer creeks and the poorer conditions in the Sacramento River, which is most pronounced near Tisdale Weir. Current efforts are underway to evaluate the extent to which pulse flows in the Sacramento River during May can improve Central Valley spring-run Chinook salmon outmigration survival (NMFS 2019a).

Successful reestablishment of Central Valley spring-run Chinook salmon into multiple populations in the Southern Sierra Nevada Group would significantly increase their spatial diversity and decrease extinction risk of the ESU (SWFSC 2022). Central Valley spring-run Chinook salmon were essentially extirpated from the San Joaquin River after Friant Dam was built in the 1940s, leaving the river dry for 60 miles. For many decades, Central Valley spring-run Chinook salmon were considered extirpated from the Southern Sierra Nevada diversity group in the San Joaquin River Basin, despite their historical numerical dominance in the Basin (Fry

1961; SWFSC 2022). In 2017, the first Central Valley spring-run Chinook salmon redds were observed in the San Joaquin River restoration area and in 2019, 168 Central Valley spring-run Chinook salmon carcasses were detected below Friant Dam for the first time in 65 years (SWFSC 2022). This is a result of a reintroduction program for Central Valley spring-run Chinook salmon was initiated in 2014 as part of the San Joaquin River Restoration Program; 54,000 juvenile spring-run Chinook salmon from Feather River Hatchery broodstock were released into the San Joaquin River. This population of Central Valley spring-run Chinook salmon is designated as an experimental population in accordance with the section 10(j) of the ESA allowing the release of threatened Central Valley spring-run Chinook salmon outside of their current range (78 FR 79622). These fish were confirmed to have originated as juveniles from the Salmon Conservation and Research Facility (SCARF) reintroduction efforts through CWT recoveries (SWFSC 2022). In addition to the active reintroduction of Central Valley spring-run Chinook salmon below Friant Dam, there have been recent reports of adult Chinook salmon exhibiting typical spring-run life-history characteristics including springtime migration, over-summering in deep pools, spawning in the early fall, and the occurrence of yearling sized juveniles to tributaries of the San Joaquin River including Mokelumne, Stanislaus, and Tuolumne rivers (see Chapter 5 in Williams et al. (2016b) and see Franks (2014)).The extent to which these phenotypic spring-run have a similar genetic lineage as other extant spring-run Chinook salmon populations and stray each generation from the Sacramento River Basin remains unknown and is the source of on-going research. It is conceivable that progeny from spring-run adults return to their natal tributaries on the San Joaquin River and thus represent early stages of reestablishing a population and a process trending towards a self-sustaining population (SWFSC 2022).

2.2.2.5.1.1.2.1 Hatcheries

Historical and continued introgression between Feather River spring- and fall-run Chinook salmon ESUs in the breeding program at the Feather River Hatchery compromises the long-term genetic integrity of the spring-run Chinook salmon population on the Feather River and poses a high extinction risk (Hedgecock et al. 2001; California HSRG 2012; Palmer-Zwahlen et al. 2019). Since 2004, spring-run Chinook salmon broodstock have been identified as phenotypic spring run trapped and tagged at the Feather River Hatchery between April 1 and June 30 (SWFSC 2022). As a result of this practice, fall run are very effectively excluded from the spring-run broodstock. Additionally, Feather River Hatchery has been using genetic testing of gametes of their fall-run broodstock to ensure spring-run Chinook salmon are excluded. They have effectively implemented practices to reduce introgression between spring and fall run in the hatchery. In the river, large numbers of fall- and spring-run Chinook salmon individuals from the Feather River Hatchery potentially spawn with natural-origin Feather River spring and fall-run Chinook salmon (Palmer-Zwahlen et al. 2019).

The majority of the Feather River Hatchery spring-run Chinook salmon broodstock and in-river spawning population on the Feather River were produced in the hatchery (Palmer-Zwahlen et al. 2013; SWFSC 2022). The proportion of natural-origin fish in the broodstock is estimated to be 2% in 2015 (Palmer-Zwahlen et al. 2019). The lack of naturally produced fish can disrupt the balance of adaptive gene flow between hatchery and natural-area spawning populations (California HSRG 2012). The proportion of hatchery-origin spring- or fall-run Chinook salmon contributing to the natural area spawning spring-run Chinook salmon population on the Feather River remains unknown due to overlap in the spring- and fall-run spawn timing. However, the hatchery component is likely to be high. For example, 83% of spawners in the 2015 spring-/fall-run carcass survey were estimated to be from the Feather River Hatchery respectively (Palmer-Zwahlen et al. 2019).

Genetic studies suggest that hybridization between Feather River Hatchery spring-run and other Chinook salmon run types (winter-, spring-, and late fall-) in other streams has not occurred, where evaluated. For example, if Feather River Hatchery Central Valley spring-run Chinook salmon have been straying extensively, the effect is not apparent in the genetic structure described by microsatellite markers for Central Valley spring-run Chinook salmon runs in Mill, Deer and Butte creeks, or on winter- and late fall-runs of Chinook salmon that spawn in the mainstem Sacramento River (Banks et al. 2000). These findings are consistent with the generally low stray rates estimated by recovery of CWTs (Palmer-Zwahlen et al. 2013; SWFSC 2022). Yet, there continues to be an increased stray rate associated with hatchery fish that are trucked and released off-site (Huber et al. 2015; Palmer-Zwahlen et al. 2019; Sturrock et al. 2019). Indeed, Feather River Hatchery Central Valley spring-run Chinook salmon adults have been recovered in other Central Valley spring- and fall-run Chinook salmon populations outside of the Feather River. Over 400 Feather River Hatchery spring-run Chinook salmon from fish raised in net pens in the San Francisco Bay strayed as adults and were recovered in the Upper Sacramento River and other natural areas, including Clear Creek, Mill Creek, Deer Creek, and Butte Creek and potentially impacted the genetic integrity of other Central Valley spring-run Chinook salmon populations (Palmer-Zwahlen et al. 2019). In the past, Feather River Hatchery strays to the Yuba River have been significant, yet in 2015 no Feather River Hatchery Central Valley spring-run Chinook salmon were recovered in the Yuba River carcass survey (Palmer-Zwahlen et al. 2019). Research suggests that the practice of trucking hatchery fish downstream to the Delta and Bay for release, rather than on-site releases, increases adult straying (Huber et al. 2015). Prolonged influx of Feather River Hatchery spring-run Chinook salmon strays to other spring-run Chinook salmon populations even at levels $<1\%$ is undesirable and can cause the receiving population to shift to a moderate risk after four generations of such impact (Lindley et al. 2007) (Figure 30). Beginning in 2014, all Feather River Hatchery spring-run Chinook salmon have been released in the Feather River, likely reducing straying to watersheds outside of the Feather River (California HSRG 2012; Huber et al. 2015; Palmer-Zwahlen et al. 2019; Sturrock et al. 2019). Additional information on the incidence of Feather River Hatchery spring-run Chinook salmon straying is desirable to more accurately estimate the extent to which spawning and introgression is occurring between fall- and spring-run Chinook salmon and/or between Feather River Hatchery Central Valley spring-run Chinook salmon and natural-origin spring-run Chinook salmon outside of the Feather River (SWFSC 2022).

2.2.2.5.1.1.3 Summary

The viability of Central Valley spring-run Chinook salmon has declined since the 2015 assessment with an increased risk of extinction for all independent Central Valley spring-run Chinook salmon populations (SWFSC 2022). In fact, Mill, Deer, and Battle creeks changed from low/moderate to a high risk of extinction using one or more viability criteria (Table 34). The total abundance of Central Valley spring-run Chinook salmon for the Sacramento River watershed in 2019 was 26,553, approximately half of the population size in 2014 (N=56,023), and close to the decadal lows of approximately 14,000 which occurred as recently as the last two years (Azat 2020). The Central Valley-wide abundance was driven largely by the annual variation in Butte Creek returns. Butte Creek remains at low extinction risk, yet all viability metrics (except hatchery influence) are trending in a negative direction relative to 2015 (SWFSC 2022). The Butte Creek spring-run Chinook salmon population has become the most abundant population of Central Valley Spring-run Chinook Salmon ESU in part due to extensive habitat restoration and the accessibility of floodplain habitat in the Butte Sink and Sutter Bypass for juvenile rearing in the majority of years (SWFSC 2022). Most of the dependent spring-run populations in the ESU have been experiencing continued and in some cases drastic declines in abundance (SWFSC 2022). For example, while adults were observed in Big Chico Creek between 2014–2018, they likely didn’t survive to spawn due to high summer temperatures resulting in zeros (0) in the escapement estimates (Azat 2020; SWFSC 2022). These results underscore the need for improved passage so that these dependent populations and habitats do not become demographic sinks for Central Valley spring-run Chinook salmon. No adults were observed in Cottonwood Creek in 2015–2018, reflecting total loss of cohorts produced in those drought years (SWFSC 2022). Counteracting these developments, Central Valley spring-run Chinook salmon have repopulated Battle Creek, Clear Creek, and the San Joaquin River where they were once extirpated. These Battle and Clear creeks in 2015 suggest they have the potential to establish a self-sustaining population without significant hatchery supplementation (see Chapter 5 in Williams et al. (2016b)).

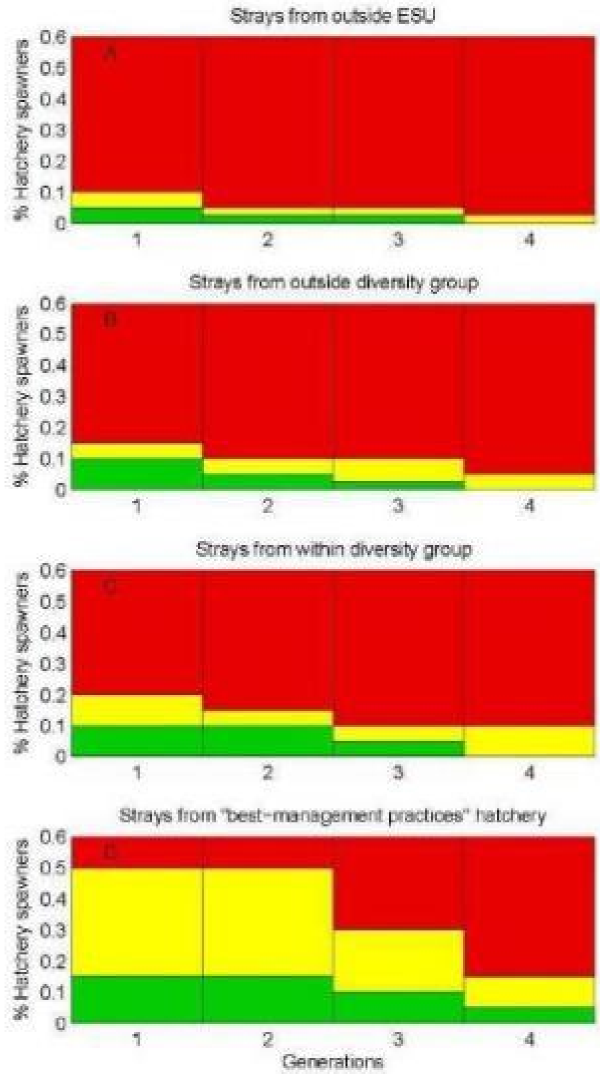


Figure 30. Percentage of hatchery-origin spawners and the resulting risk of extinction due to hatchery introgression from different sources of strays over multiple generations - low (green), moderate (yellow), and high (red). Model using "best-management practices" was used in the winter-run assessment based on the breeding protocols at the Livingston Stone National Fish Hatchery for Sacramento River winter-run Chinook salmon. The parameter "strays from outside ESUs" was used to assess impacts of introgression between Central Valley Spring- and Fall-run Chinook Salmon ESUs at the Feather River Hatchery. Figure reproduced from Lindley et al. (2007).

Table 34. Summary of Central Valley spring-run Chinook salmon extinction risk by population criteria described in Lindley et al. (2007) for the 2010, 2015, and 2020 viability assessment periods. Overall risk is determined by the highest risk score for any criterion. Table from SWFSC (2022).

Population	2010	2015	2020
Mill Creek	High	Moderate	High
Deer Creek	High	Moderate	High
Butte Creek	Low	Low	Low
Battle Creek	High	Moderate	High
Clear Creek	High	Moderate	High
Feather River Hatchery	High	High	High

Central Valley Spring-run Chinook Salmon ESU populations have experienced a series of droughts over the past decade. From 2007–2009 and 2012–2016, the Central Valley experienced drought conditions and low river and stream discharges, which are strongly associated with lower survival of Chinook salmon (Michel et al. 2015). The impacts of the recent drought series, and warm ocean conditions on the juvenile life stage, seems to have manifested in the low run sizes in 2015–2018 for most Central Valley spring-run Chinook salmon populations (SWFSC 2022). For example, the recent drought impacted Central Valley spring-run Chinook salmon adults on Butte Creek, which experienced lethal temperatures in holding habitats during the summer. A large number of adults (903 and 232) were estimated to have died prior to spawning in the 2013 and 2014 drought respectively (NMFS 2016t; SWFSC 2022). Pre-spawn mortality was also observed during the 2007–2009 drought with an estimate of 1,054 adults dying before spawning in 2008 (NMFS 2016t; SWFSC 2022). In 2015, late-arriving adults observed in sections of Butte Creek near the city of Chico experienced exceptionally warm June air temperatures, shutdown of a PG&E flume, and a corresponding fish mortality event (NMFS 2016t; SWFSC 2022). These conditions likely influenced juvenile production and low adult returns in 2015–2018. Fortunately, the favorable hydroclimatic conditions in 2017 appear to have bolstered returns on Butte Creek to pre-drought run sizes of approximately 15,000 adults.

Current introgression between fall- and spring-run Chinook salmon in the Feather River Hatchery breeding program and straying of Feather River Hatchery spring-run Chinook salmon to other spring-run populations where genetic introgression would be possible is unfavorable and reduces population viability. However, beginning in 2014, and expected to continue, the Feather River Hatchery has begun releasing spring-run production into the Feather River rather than releasing in the San Francisco Bay which is expected to reduce straying (California HSRG 2012; Huber et al. 2015; Palmer-Zwahlen et al. 2019; Sturrock et al. 2019).

At the ESU level, the spatial diversity within the Central Valley Spring-run Chinook Salmon ESU is increasing and spring-run Chinook salmon are present (albeit at low numbers in some cases) in all diversity groups (SWFSC 2022). The reestablishment of Central Valley spring-run Chinook salmon to Battle Creek and increasing abundance of Central Valley spring-run Chinook salmon on Clear Creek observed in some years is benefiting the viability of Central Valley spring-run Chinook salmon. Similarly, the reappearance of early migrating Chinook salmon to the San Joaquin River tributaries may be the beginning of natural dispersal processes into rivers where they were once extirpated. On one hand, the Central Valley Spring-run Chinook Salmon ESU is trending in a positive direction towards achieving at least two populations in each of the four historical diversity groups necessary for recovery with the Northern Sierra Nevada region necessitating four populations (NMFS 2014b). On the other hand, Central Valley spring-run Chinook salmon populations have declined sharply in recent years to in most cases worryingly low levels of abundance (SWFSC 2022).

Emerging threats to the Central Valley spring-run Chinook salmon populations may include thiamine deficiency. Thiamine-consistent mortality was seen in both the Feather River Hatchery and in screw trap data, and an increase in juvenile mortality from 2018 to 2019 corresponded with a decrease in juvenile abundance (SWFSC 2022). It is unclear the extent to which this was a basin-wide nutritional deficiency for all Central Valley spring-run Chinook salmon spawning in 2019. Direct mortality or latent effects that would lead to increased mortality in that cohort would not be detected in viability criteria until the dominant age class of 3-year-olds return to spawn in 2022.

The only independent population of Central Valley spring-run Chinook salmon that is not at a high risk of extinction is the population on Butte Creek. Yet, the continued existence of the Butte Creek Central Valley spring-run Chinook salmon population is wholly dependent on the reliable, long-term import of cold water from the West Branch of the Feather River to the anadromous habitat in Butte Creek provided by the operation of the Pacific Gas and Electric Company's (PG&E) DeSabla Centerville Project (SWFSC 2022). Considerable uncertainty remains for the future of the PG&E project and the ability to transfer water from the West Branch Feather River to the anadromous habitat in Butte Creek to support the survival of Central Valley spring-run Chinook salmon.

To conclude, the viability of the Central Valley Spring-run Chinook Salmon ESU has declined since the 2015 viability assessment (Williams et al. 2016b) and the ESU is at greater risk of extinction (SWFSC 2022). The largest impacts are likely due to the freshwater drought conditions and unusually warm ocean conditions experienced by these cohorts, resulting in weakening viability metrics and greater risks of extinction to the majority of the populations since the 2015 viability assessment. The recent declines of many of the dependent populations, high pre-spawn mortality and poor juvenile survival during the 2012–2016 drought, unknown impacts due to warm ocean conditions and reorganization of coastal marine food webs, are all causes for increased concern for the long-term viability of the Central Valley Spring-run Chinook Salmon ESU (SWFSC 2022). Overall, new information on abundance, productivity, rate of population decline, spatial structure, hatchery influence, and diversity, indicate the viability of the majority of populations in the ESU has declined since the 2015 viability assessment (Williams et al. 2016b).

A FEMAT assessment was conducted to rate extinction risk. The specifics of this assessment are detailed in SWFSC (2022). Results of the assessment are summarized in Table 35. It should be noted that the combined weights in the "Low" and "Moderate" categories is greater than the single category of "High" risk of extinction. Unlike ESA-listed Endangered Sacramento River Winter-run Chinook salmon and Central California Coast coho salmon, historically independent populations of Central Valley spring-run Chinook salmon occupy all diversity groups albeit at low numbers; it is at the diversity group spatial scale where catastrophic events are best buffered for the ESU (SWFSC 2022). Extinction risks are of concern due to the low abundance of individuals, the magnitude of the abundance decline observed since the last assessment, and the ESU's pre-existing vulnerability. In the context of the occupied diversity groups yet declining populations and one population disproportionally contributing to the number of fish in the ESU, FEMAT scoring captured the uncertainty of the SWFSC (2022) authors to conclude that the Central Valley Spring-run Chinook Salmon ESU is at moderate to high risk of extinction.

2.2.2.5.1.2 Limiting Factors

The recovery plan (NMFS 2014b) provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Chapters 2 and 4 and Appendix B of the recovery plan (NMFS 2014b) describe the limiting factors and threats, and how they apply to the

Table 35. Tally of the FEMAT vote distribution for extinction risk for Central Valley Spring-run Chinook Salmon ESU. Each of four members allocated 10 points among the three viability categories (low, moderate, high). Table from SWFSC (2022).

Risk category	Number of votes	Percent of total
Low	3	10%
Moderate	13	43%
High	14	47%

four diversity groups in the Central Valley Spring-run Chinook Salmon ESU. Chapters 2 and 4 and Appendix B (NMFS 2014b) include details on threats in three main categories, listed below:

- Loss of historical spawning habitat,
- Degradation of remaining habitat,
- Threats to genetic integrity.

Chapters 2 and 4 and Appendix B of the recovery plan discuss the limiting factors that pertain to Central Valley spring-run Chinook salmon. The discussion of limiting factors and threats in Chapters 2 and 4 and Appendix B (NMFS 2014b) includes details surrounding the following specific threats:

- Agricultural diversions,
- Warm water temperatures,
- Dams and blocked access/passage impediments,
- Entrainment,
- Ocean harvest,
- Loss of rearing habitat,
- Predation,
- Lack of spawning habitat.

Rather than repeating the extensive discussion from the recovery plan (NMFS 2014b), this discussion in Chapters 2 and 4, as well as Appendix B, is incorporated here by reference.

2.2.3 Status of the Coho Salmon ESUs

Only one ESU of coho salmon was evaluated in this Opinion, the Lower Columbia River Coho Salmon ESU. The recovery domain and population information for this ESU is detailed below in Table 36.

Table 36. Coho salmon ESA-listed salmon populations considered in this Opinion.

Recovery Domain	ESU	MPGs	Populations
Willamette/Lower Columbia	Lower Columbia River coho salmon	3	24
Totals	**1 ESU**	**3**	**24**

Although run time variation is considered inherent to overall coho salmon life-history, Lower Columbia River coho salmon typically display one of two major life-history types, either early or late returning freshwater entry. Freshwater entry timing for this ESU is also associated with ocean migration patterns based on the recovery of CWT hatchery fish north or south of the Columbia River (Myers et al. 2006). Early returning (Type-S) coho salmon generally migrate south of the Columbia River once they reach the ocean, returning to freshwater in mid-August and to the spawning tributaries in early September. Spawning peaks from mid-October to early November. Late returning (Type-N) coho salmon have a northern distribution in the ocean, returning to the Lower Columbia River from late September through December and enter the tributaries from October through January. Most of the spawning for Type-N occurs from November through January, but some spawning occurs in February and as late as March (NMFS 2013c). In general, early returning fish (Type-S) spawn further upstream than later migrating fish (Type-N), although Type-N fish enter rivers in a more advanced state of sexual maturity (Table 38) (Sandercock 1991).

Regardless of adult freshwater entry timing, coho salmon fry move to shallow, low velocity rearing areas after emergence, primarily along the stream edges and in side channels. All coho salmon juveniles remain in freshwater rearing areas for a full year after emerging from the gravel. Most juvenile coho salmon migrate seaward as one-year smolts from April to June. Salmon with stream-type life-histories, like coho salmon, typically do not linger for extended periods in the Columbia River estuary, but the estuary is critical habitat used for foraging during the physiological adjustment to the marine environment (NMFS 2013c). Coho salmon typically spend 18 months in the ocean before returning to freshwater to spawn. Jacks (i.e., precocial males) spend five to seven months in the ocean before returning to freshwater to spawn.

2.2.3.1 Willamette/Lower Columbia Recovery Domain

2.2.3.1.1 Lower Columbia River Coho Salmon ESU

On June 28, 2005, NMFS listed the listed the Lower Columbia River Coho Salmon ESU as a threatened species (70 FR 37160). The threatened status was reaffirmed on April 14, 2014 (79 FR 20802). Critical Habitat was originally proposed January 14, 2013 and was finalized on February 24, 2016 (81 FR 9251). In 2022, NMFS completed its most recent 5-year review for Lower Columbia River coho salmon (NMFS 2022j).

Inside the geographic range of the ESU, 23 hatchery coho salmon programs are currently operational (Table 37). Table 37 lists the 21 hatchery programs currently included in the ESU and the two excluded programs (NMFS 2022j). Lower Columbia River coho salmon are primarily limited to the tributaries downstream of Bonneville Dam (Figure 31).

Table 37. Lower Columbia River Coho Salmon ESU description and MPGs (Ford 2022; NMFS 2022j)[a].

ESU Description	
Threatened	Listed under ESA in 2005; updated in 2014.
3 MPGs	24 historical populations
MPG	***Population***
Coastal	Youngs Bay, Grays/Chinook, Big Creek, Elochoman/Skamokawa, Clatskanie, Mill/Abernathy/Germany Creeks, Scappoose
Cascade	Lower Cowlitz, Upper Cowlitz, Cispus, Tilton, South Fork Toutle, North Fork Toutle, Coweeman, Kalama, North Fork Lewis, East Fork Lewis, Salmon Creek, Clackamas, Sandy, Washougal
Gorge	Lower Gorge, Washington Upper Gorge/White Salmon, Oregon Upper Gorge/Hood
Artificial production	
Hatchery programs included in ESU (21)[b]	Grays River Program, Peterson Coho Project, Big Creek Hatchery Program, Astoria High School Salmon-Trout Enhancement Program (STEP) Coho Program, Warrenton High School STEP Coho Program, Cowlitz Type-N Coho Program in the Upper and Lower Cowlitz Rivers, Cowlitz Game and Anglers Coho Program, Friends of the Cowlitz Coho Program, North Fork Toutle River Hatchery Type-S Hatchery Program, Kalama River Type-N Coho Program, Lewis River Type-N Coho Program, Lewis River Type-S Coho Program, Fish First Wild Coho Program, Fish First Type-N Coho Program, Syverson Project Type-N Coho Program, Washougal River Type-N Coho Program, Eagle Creek National Fish Hatchery Program, Sandy Hatchery Program, Bonneville/Cascade/Oxbow Complex Hatchery Program, Clatsop County Fisheries Net Pen Program, Clatsop County Fisheries/Klaskanine Hatchery Program
Hatchery programs not included in ESU (2)[c]	Deep River Net Pens (Elochoman River and Lewis River Type-S), Beaver Creek (Elochoman River Type-N)

[a] Because NMFS had not yet listed this ESU in 2003 when the WLC TRT designated core and genetic legacy populations for other ESUs, there are no such designations for Lower Columbia River coho salmon.
[b] Note that NMFS (2022j) indicates the Fish First Wild Coho Program has been terminated, with the last releases in 2017.
[c] The Deep River Net Pens program is transitioning to using only stocks included in the ESU. The Beaver Creek program includes both an integrated and segregated program.

Twenty-four historical populations within three MPGs comprise the Lower Columbia River Coho Salmon ESU with generally low baseline persistence probabilities (Ford 2022; NMFS 2022j). The ESU includes all naturally spawned populations of coho salmon in the Columbia River and its tributaries from the mouth of the Columbia River up to and including the White Salmon and Hood Rivers, and including the Willamette River to Willamette Falls, Oregon

(Figure 31). Coho salmon in the Willamette River spawning above Willamette Falls are not considered part of the Lower Columbia River Coho Salmon ESU (70 FR 37160).

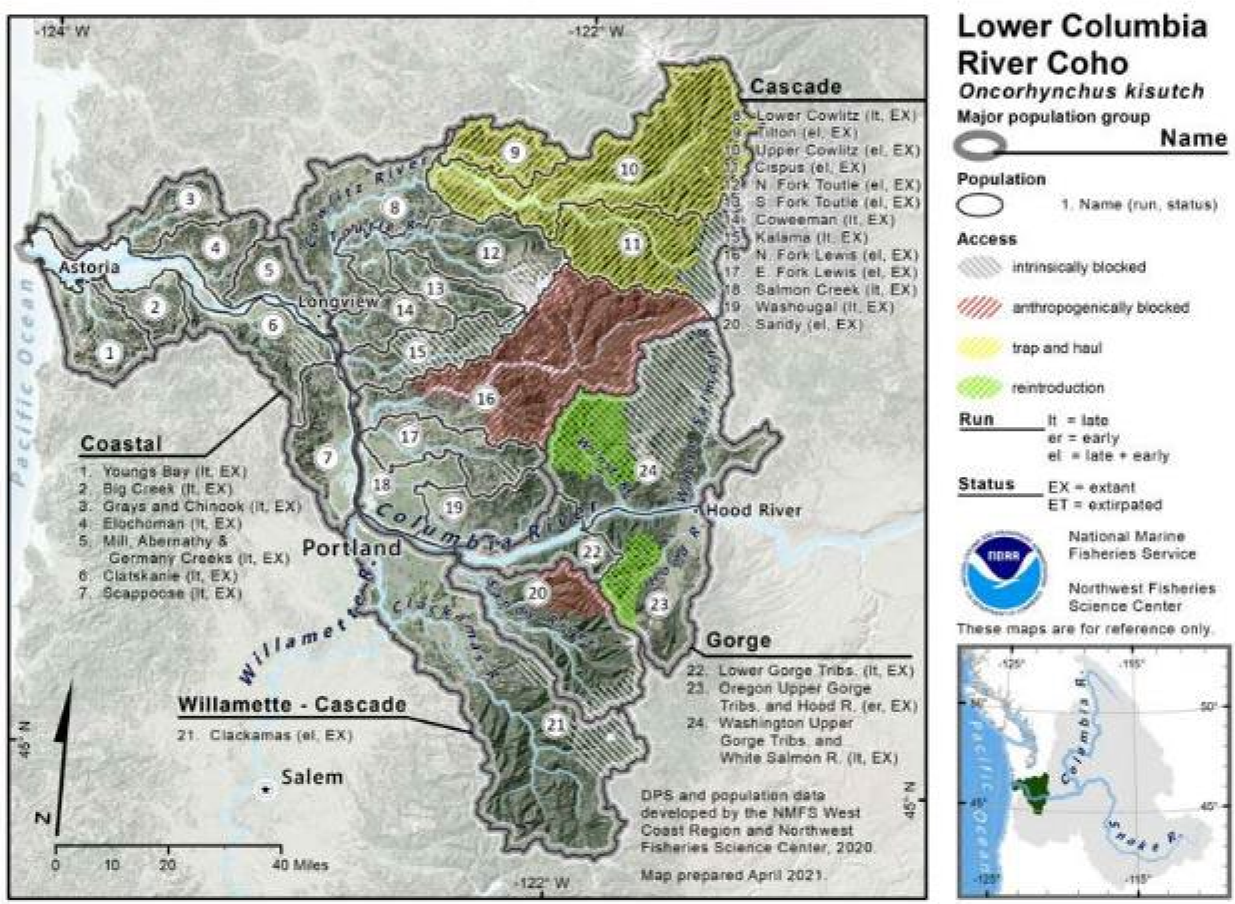


Figure 31. Map of the Lower Columbia River Coho Salmon ESU's spawning and rearing areas, illustrating demographically independent populations and MPGs. Areas that are accessible (green), accessible only via trap-and-haul programs (yellow), or blocked (cross-hatched) are indicated accordingly (Ford 2022).

Table 38. Life-History and population characteristics of Lower Columbia River coho salmon.

Characteristic	Life-History Features	
	Early-returning (Type-S)	**Late-returning (Type-N)**
Number of extant population	10	23
Life-history type	Stream	Stream
River entry timing	August–September	September–December
Spawn timing	October–November	November–January
Spawning habitat type	Higher tributaries	Lower tributaries
Emergence timing	January–April	January–April
Duration in freshwater	Usually 12–15 months	Usually 12–15 months
Rearing habitat	Smaller tributaries, river edges, sloughs, off-channel ponds	Smaller tributaries, river edges, sloughs, off-channel ponds
Estuarine use	A few days to weeks	A few days to weeks
Ocean migration	South of the Columbia River, as far south as northern California	North of the Columbia River, as far north as British Columbia
Age at return	2–3 years	2–3 years

In contrast to Chinook salmon and steelhead, Lower Columbia River coho salmon run timing was not used to establish differences between MPGs. Some tributaries historically supported spawning by both run types; therefore Myers et al. (2006) indicated that, regardless of whether run timing is an element of diversity on a subpopulation or population level, the run timing was a factor that needed consideration in recovery planning for Lower Columbia River coho salmon. NMFS' recovery plan took this into consideration by identifying each Lower Columbia River coho salmon population's proposed life-history component(s).

In 2017 NMFS adopted a Record of Decision ("Mitchell Act ROD") for a policy direction that would be used to guide NMFS' decision on the distribution of funds for hatchery production under the Mitchell Act (16 U.S.C.§§ 755-757), which NMFS administers. NMFS' continued funding of Mitchell Act hatchery programs, under the Mitchell Act ROD was analyzed under the ESA and was found to not likely to jeopardize the continued existence of any species in the Columbia Basin (NMFS 2017o). The Mitchell Act ROD directs NMFS to apply stronger performance goals to all Mitchell Act-funded, Columbia River Basin hatchery programs that affect ESA-listed primary and contributing salmon and steelhead populations. These stronger performance goals reduced the risks of hatchery programs on natural-origin salmon and steelhead populations, including the Lower Columbia River Coho Salmon ESU. It required integrated hatchery programs to be better integrated and isolated hatchery programs to be better isolated. While the following information presented is a review of updated status information available, NMFS expects the prevalence of hatchery-origin coho salmon spawning contribution to decrease over the course of the 2018 Agreement due to the ITS limits and terms and conditions required by the opinion (NMFS 2017o).

2.2.3.1.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Lower Columbia River Coho Salmon ESU, is at high risk and remains at threatened status. Each population's target abundance, consistent with delisting the species, is compared against recent abundance estimates in Table 39. Persistence probability is generally measured over a 100-year time period and ranges from very low (probability of less than 40%) to very high (probability of greater than 99%).

2.2.3.1.1.1.1 Abundance and Productivity

NMFS conducted viability status reviews of the Lower Columbia River Coho Salmon ESU in 1996 (NMFS 1996b), in 2001 (NMFS 2001b), in 2005 (Good et al. 2005), in 2011 (Ford et al. 2011), in 2015 (NWFSC 2015), and most recently in 2022 (Ford 2022). In contrast to the previous 5-year review (NWFSC 2015), which occurred at a time of near record returns for several populations, the ESU abundance has declined during the last five years (Figure 32). Only 6 of the 23 populations for which we have data appear to be above their recovery goals (Ford 2022). This includes the Youngs Bay demographically independent population and Big Creek demographically independent population, which have very low recovery goals, and the Salmon Creek demographically independent population and Tilton River demographically independent population, which were not assigned goals but have relatively high abundances (Ford 2022). Of the remaining demographically independent populations in the ESU, three are at 50–99% of their recovery goals, seven are at 10–50% of their recovery goals, and seven are at less than 10% of their recovery goals (this includes the Lower Gorge demographically independent population for which there are no data, but it is assumed that the abundance is low) (Ford 2022).

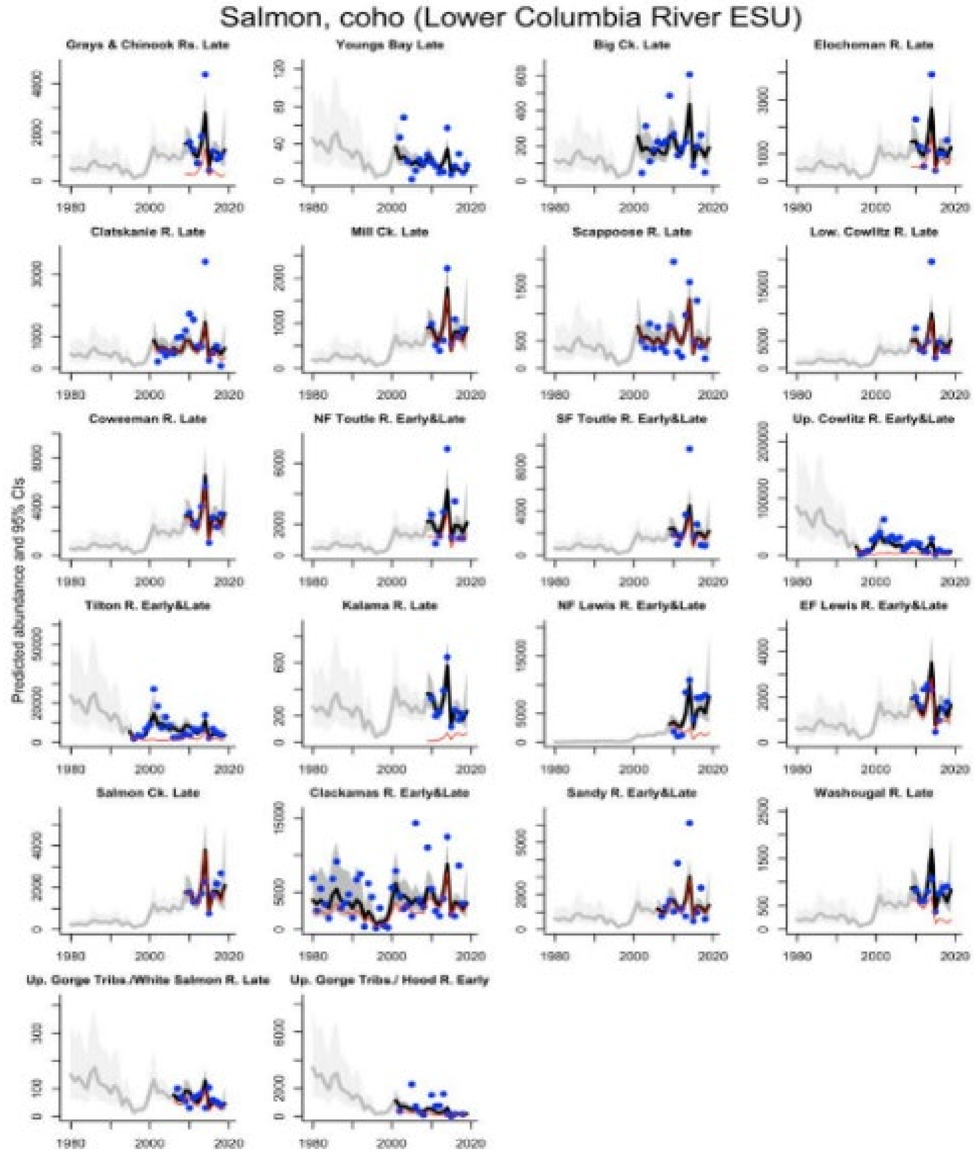


Figure 32. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

Table 39. Current 5-year geometric mean of raw natural-origin spawner abundances and recovery targets for Lower Columbia River coho salmon DIPs. Numbers in parentheses represent total (hatchery- and natural-origin) spawners. Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > *x* < 50%, yellow = 50% > *x* < 100%), green = >100% (Ford 2022).

		Abundance	
Stratum	**Population**	**2015–19**	**Target**
Coastal	Grays/Chinook River (WA)	212	2,400
	Youngs Bay (OR)	(14)	7
	Big Creek (OR)	(122)	12
	Elochoman/Skamokawa (WA)	558	2,400
	Clatskanie River (OR)	199	3,201
	Mill/Abernathy/Germany Creeks (WA)	685	1,800
	Scappoose Creek (OR)	448	3,208
Cascade	Lower Cowlitz River (WA)	2,622	3,700
	Coweeman River (WA)	1,987	1,200
	North Fork Toutle River (WA)	819	1,900
	South Fork Toutle River (WA)	1,075	1,900
	Upper Cowlitz River (WA)	631	2,000
	Cispus River (WA)	n/a	2,000
	Tilton River (WA)	1,932	n/a
	Kalama River (WA)	43	500
	North Fork Lewis River (WA)	1,275	500
	East Fork Lewis River Tule (WA)	686	2,000
	Salmon Creek (WA)	1,546	n/a
	Clackamas River (OR)	2,889	11,232
	Sandy River (OR)	854	5,685
	Washougal River (WA)	174	1,500
Gorge	Lower Gorge (WA & OR)	n/a	1,900
	Upper Gorge/White Salmon River (WA & OR)	45	1,900
	Upper Gorge/Hood River (OR)	29	5,162

2.2.3.1.1.1.1.1 Harvest

Lower Columbia River coho salmon are part of the Oregon Production Index and are harvested in ocean fisheries primarily off the coasts of Oregon and Washington, with some harvest that historically occurred off of the West Coast Vancouver Island (Ford 2022). Canadian coho salmon fisheries were severely restricted in the 1990s to protect upper Fraser River coho salmon and have remained so ever since. Ocean fisheries off California were closed to coho salmon retention in 1993 and have remained closed ever since. Ocean fisheries for coho salmon off of Oregon and Washington were dramatically reduced in 1993 in response to the depressed status of Oregon Coast natural coho salmon and subsequent listing and moved to mark-selective fishing beginning in 1999. Lower Columbia River coho salmon benefitted from the more restrictive management of ocean fisheries. Overall exploitation rates regularly exceeded 80% in the 1980s but have remained below 30% since 1993 (Figure 33). In addition, freshwater fisheries impacts on naturally produced coho salmon have been markedly reduced through the implementation of selective fisheries. The total allowable marine and mainstem Columbia River exploitation rate for Lower Columbia River coho salmon was 23.0% in 2019 (PFMC 2019b; Ford 2022).

2.2.3.1.1.1.2 Spatial Structure and Diversity

There have been a number of large-scale efforts to improve accessibility, one of the primary metrics for spatial structure, in this ESU. On the Hood River, Powerdale Dam was removed in

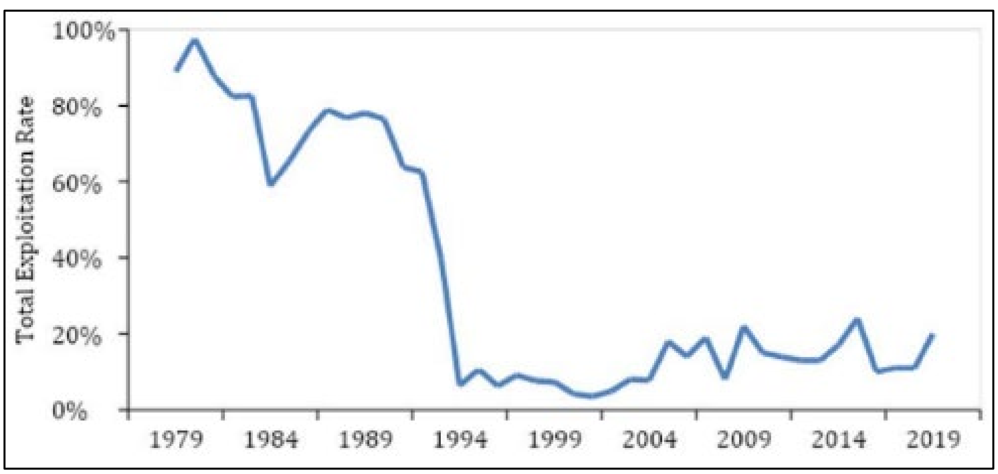


Figure 33. Total exploitation rate on natural Lower Columbia River coho salmon. Data (2005–19) from ODFW et al. (2020). Figure reproduced from Ford (2022).

2010 and, while this dam previously provided fish passage, its removal is thought to eliminate passage delays and injuries. Condit Dam, on the White Salmon River, was removed in 2011, providing access to previously inaccessible habitat. Current monitoring is limited, but screw trap results indicate that coho salmon are successfully spawning in the White Salmon River (Jezorek et al. 2018). Fish passage operations (trap-and-haul) were begun on the Lewis River in 2012, reestablishing access to historically occupied habitat above Swift Dam (river kilometer (RKM) 77.1) (Ford 2022). Juvenile passage efficiencies were initially poor, but have improved considerably, with the 2019 juvenile collection rate estimated at 64% (PacifiCorp and Public Utility District No 1 of Cowlitz County 2020). Nearly 150,000 juvenile coho salmon were produced and collected from the upper North Fork Lewis River (Ford 2022). Similarly, efforts to provide downstream juvenile passage at the Cowlitz Dam complex collection sites began in the 1990s, and since that time there have been a number of modifications in the facilities at Cowlitz Falls Dam. Juvenile collection efficiency for coho salmon at the Cowlitz Falls facility in 2019 was 90.4% (Ford 2022). Coho salmon from the Tilton River are collected separately at Mayfield Dam. A trap-and-haul program also currently maintains access to the North Toutle River above the sediment retention structure, with coho salmon and steelhead being passed above the dam (Liedtke et al. 2013). This sediment retention structure transportation program relocates coho salmon into the North Fork Toutle population; however, there are limited release sites and only a portion of the upper watershed is accessible. Fish access to the upper Clackamas River basin continues to improve, with recent (2019) estimates for fish guidance efficiency of 94.1% at the North Fork Dam (Ford 2022). Improvements in juvenile collection on the Clackamas River at Portland General Electric projects, with nearly 200,000 juvenile coho salmon collected annually, are likely to result in increased abundances in the future under more productive ocean conditions (Ford 2022). On a more general basis, there have been a number of actions throughout the ESU to remove or improve culverts and other small-scale passage barriers.

There have been incremental improvements in spatial structure during this review period, but poor ocean and freshwater conditions have been such as to mask any benefits from these activities (Ford 2022). Similarly, fish passage at culverts has improved, with 132 km (79 mi) of stream habitat being opened up in Washington State alone since 2015, but a large number of small-scale fish barriers still remain to be upgraded or removed (Ford 2022).

2.2.3.1.1.1.2.1 Hatcheries

Hatchery releases have remained relatively steady at 10–17 million since the 2005 biological review team report, with approximately 14 million coho salmon juveniles released in 2019 (Ford 2022). Many of the populations in the ESU contain a substantial number of hatchery-origin spawners (Table 40). Production has been shifted into localized areas (e.g., Youngs Bay, Big Creek, and Deep Creek) in order to reduce the influence of hatchery fish in other nearby populations (Scappoose and Clatskanie Rivers). There were no spawner surveys conducted in the

Youngs Bay or Big Creek demographically independent populations, but it can be assumed that the proportion of natural spawners is very low (Ford 2022). Hatchery influence is also relatively high in the Grays River, with a recent decline in fraction natural origin spawners (Table 40). The influence of hatchery programs on naturally spawning fish has been reduced in a number of basins with the removal of marked adults at weirs, but other basins indicate an increase in the proportion of hatchery fish spawning naturally (Table 40), perhaps as a result of increased hatchery releases (Ford 2022). Mass marking of hatchery-released fish, in conjunction with expanded coho salmon spawning surveys, has provided more accurate estimates of hatchery straying.

Integrated hatchery programs have been developed in a number of basins to limit the loss of genetic diversity. The integrated program in the Cowlitz River was developed for reintroductions into the upper Cowlitz River basin. Large-scale releases of these hatchery-origin coho salmon adults into the upper Cowlitz, Cispus, and Tilton Rivers were used to recolonize stream habitat above the mainstem dams. A segregated program exists for coho salmon releases into the lower Cowlitz River. Overall, juvenile releases into the Cowlitz River basin were reduced some 10 years ago, but have been fairly steady since then (Ford 2022). A large integrated program for Type-N coho salmon has been ongoing in the Lewis River for over a decade, while the Type-S (early) coho salmon program in the Lewis River is operated as a segregated program. Both early- and late-run hatchery-origin coho salmon are transported above Swift Dam in the Lewis River to reestablish production in headwater areas (PacifiCorp and Public Utility District No 1 of Cowlitz County 2020).

Other hatchery programs in the Cascade MPG have releases less than 500,000; most operate as integrated programs, except for the Kalama River Hatchery (Ford 2022). Hatchery-origin spawners contribute to escapement in a number of basins, substantially so in some basins, while the Salmon Creek, Clackamas River, and Sandy River populations have hatchery-origin spawner rates of less than 10% (Table 40).

Releases into the Gorge MPG have remained fairly steady at slightly over 3 million annually (Ford 2022). Natural production in this MPG is limited, and the influence of hatchery-origin fish on the spawning grounds remains higher than in other regions (Table 40).

Table 40. Five-year mean of fraction natural Lower Columbia River coho salmon spawners (sum of all estimates divided by number of estimates). Blanks mean no estimate available in that 5-year range (Ford 2022).

Population[a]	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Grays/Chinook Rivers (late)	Coastal	-	-	-	0.37	0.27
Elochoman River (late)	Coastal	-	-	-	0.53	0.65
Clatskanie River (late)	Coastal	-	0.93	0.97	0.94	0.76
Mill/Abernathy/Germany Creeks (late)	Coastal	-	-	-	0.89	0.89
Scappoose River (late)	Coastal	-	0.94	0.99	1.00	0.99
Lower Cowlitz River (late)	Cascade	-	-	-	0.88	0.85
Coweeman River (late)	Cascade	-	-	-	0.91	0.89
North Fork Toutle River (early & late)	Cascade	-	-	-	0.70	0.56
South Fork Toutle River (early & late)	Cascade	-	-	-	0.84	0.79
Upper Cowlitz/Cispus Rivers (early & late)	Cascade	0.73	0.13	0.26	0.20	0.23
Tilton River (early & late)	Cascade	0.64	0.07	0.29	0.38	0.48
Kalama River (late)	Cascade	-	-	-	0.07	0.27
North Fork Lewis River (early & late)	Cascade	-	-	-	0.60	0.22
East Fork Lewis River (early & late)	Cascade	-	-	-	0.87	0.68
Salmon Creek (late)	Cascade	-	-	-	0.98	0.94
Clackamas River (early & late)	Cascade	0.65	0.67	0.64	0.88	0.90
Sandy River (early & late)	Cascade	-	-	0.94	0.92	0.96
Washougal River (late)	Cascade	-	-	-	0.68	0.25
Hood River (early)	Gorge	-	0.40	0.58	0.25	0.48
Washington Upper Gorge Tributaries/White Salmon River (late)	Gorge	-	-	0.73	0.74	0.76

[a] Note that the Youngs Bay (Coastal), Big Creek (Coastal), Cispus (Cascade), and Lower Gorge (Gorge) populations are not included due to low abundances or lack of monitoring and available data, as discussed further in Ford (2022).

2.2.3.1.1.1.3 Summary

Overall abundance trends for the Lower Columbia River Coho Salmon ESU are generally negative (Ford 2022). Natural spawner and total abundances have decreased in almost all populations (Figure 32), and Coastal and Gorge MPG populations are all at low levels, with significant numbers of hatchery-origin coho salmon on the spawning grounds (Table 40). Improvements in spatial structure and diversity have been slight, and overshadowed by declines in abundance and productivity (Ford 2022). In light of the poor ocean and freshwater conditions that occurred during much of this recent review period, it should be noted that some of the populations exhibited resilience and only experienced relatively small declines in abundance (Figure 32). Some populations were exhibiting positive productivity trends during the last year of review, representing the return of the progeny from the 2016 adult return (Ford 2022; NMFS 2022j). For individual populations, the risk of extinction spans the full range, from "low" to "very high" (Ford 2022). Overall, the Lower Columbia River Coho Salmon ESU remains at "moderate" risk (Ford 2022), and viability is largely unchanged from the prior status review (NWFSC 2015).

2.2.3.1.1.2 Limiting Factors

Understanding the limiting factors and threats that affect the Lower Columbia River Coho Salmon ESU provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. Lower Columbia River coho salmon populations began to decline by the early 1900s because of habitat alterations and harvest rates that were unsustainable given these changing habitat conditions. There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Lower Columbia River Coho Salmon ESU. Factors that limit the ESU have been, and continue to be, hydropower development on the Columbia River and its tributaries, habitat degradation, hatchery operations, fishery management and harvest decisions, and ecological factors including predation and environmental variability. The ESU-level recovery plan consolidates the information regarding limiting factors and threats for the Lower Columbia River Coho Salmon ESU available from various sources (NMFS 2013c).

The Lower Columbia River recovery plan provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Chapter 4 (NMFS 2013c) of the recovery plan describes limiting factors on a regional scale and those factors apply to the four listed species from the Lower Columbia River considered in the plan, including Lower Columbia River coho salmon. Chapter 6 of the recovery plan discusses the limiting factors that pertain to the MPGs that compose the Lower Columbia River Coho Salmon ESU. The discussion of limiting factors in Chapter 6 (NMFS 2013c) is organized to address the following:

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

Chapter 4 (NMFS 2013c) includes additional details on large scale issues including the following:

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

Rather than repeating this extensive discussion from the roll-up recovery plan, these discussions in Chapters 4 and 6 are incorporated here by reference.

Harvest-related mortality is identified as a primary limiting factor for all natural populations within the ESU and occurs as a result of direct and incidental mortality of natural-origin fish in ocean fisheries, Columbia River recreational fisheries, and commercial gillnet fisheries. The Lower Columbia River recovery plan envisions refinements in coho salmon harvest through (1) replacement or refinement of the existing harvest matrix to ensure that it adequately accounts for weaker components of the ESU, (2) continued use of mark-selective recreational fisheries, and (3) management of mainstem commercial fisheries to minimize impacts to natural-origin coho salmon (NMFS 2013c). The refinement of the harvest matrix ensured that harvest management is consistent with maintaining trajectories in populations where increasing natural production is beginning to be observed (e.g., the Clatskanie and Scappoose populations), with the assumption that additional refinements will be evaluated as natural production is documented in additional populations. Managing coho salmon harvest to minimize impacts to natural-origin fish has been complicated by uncertainties regarding annual natural-origin spawner abundance and actual harvest impacts on natural-origin fish (in both ocean and mainstem Columbia fisheries). The recovery plan notes these uncertainties and highlight the need for improved monitoring of harvest mortality and natural-origin spawner abundance.

Closely spaced releases of hatchery fish from all Columbia Basin hatcheries could lead to increased competition with natural-origin fish for food and habitat space in the estuary (NMFS 2013c). NMFS (2011e) and LCFRB (2010) identified quantifying levels of competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. As stream-type fish, coho salmon spend less time in the Columbia River estuary and plume than do ocean-type salmon, such as fall Chinook, yet possible ecological interactions in this geographic area likely play a role. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. NMFS is working to better define and describe the scientific uncertainty associated with ecological interaction between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats (NMFS 2013c).

As mentioned above, high proportions of hatchery-origin fish in spawning populations has been purposeful in some areas, e.g. for reintroduction purposes in the Upper Cowlitz and Lewis subbasins, and will continue, but the recent opinion on the majority of hatchery production affecting this ESU (NMFS 2017o) expects Federal funding guideline requirements to reduce limiting factors relative to hatchery effects over the course of the next decade.

2.2.4 Status of the Chum Salmon ESUs

Two ESUs of chum salmon were evaluated in this Opinion, the Columbia River Chum Salmon ESU and the Hood Canal Summer-run Chum Salmon ESU. The recovery domain and population information for each ESU is detailed below in Table 41.

Table 41. Chum salmon ESA-listed salmon populations considered in this Opinion.

Recovery Domain	ESU	MPGs	Populations
Puget Sound	Hood Canal summer-run chum salmon	1	2
Willamette/Lower Columbia	Columbia River chum salmon	3	17
Totals	**2 ESUs**	**4**	**19**

Historically, chum salmon had the widest distribution of all Pacific salmon species, comprising up to 50% of annual biomass of the seven species, and may have spawned as far up the Columbia River drainage as the Walla Walla River (Nehlsen et al. 1991). Chum salmon fry emerge from March through May (LCFRB 2010), typically at night (ODFW 2010), and are believed to migrate promptly downstream to the estuary for rearing. Chum salmon fry are capable of adapting to seawater soon after emergence from gravel (LCFRB 2010). Their small size at emigration is thought to make chum salmon more susceptible to predation mortality during this life stage (LCFRB 2010).

Given the minimal time juvenile chum salmon spend in their natural streams, the period of estuarine residency appears to be a critical phase in their life history and may play a major role in determining the size of returning adults (NMFS 2013d; 2013c). Chum and ocean-type Chinook salmon usually spend more time in estuaries than do other anadromous salmonids—weeks or months, rather than days or weeks (NMFS 2013d; 2013c). Shallow, protected habitats, such as salt marshes, tidal creeks, and intertidal flats serve as significant rearing areas for juvenile chum salmon during estuarine residency (LCFRB 2010).

Juvenile chum salmon rear in the Columbia River estuary from February through June before beginning long-distance ocean migrations (LCFRB 2010). Hood Canal summer-run chum salmon enter the estuarine areas to rear in late winter and early spring, before continuing their seaward-migration (WDFW et al. 2000). Chum salmon remain in the North Pacific and Bering Sea for 2 to 6 years, with most adults returning to the Columbia River as 4-year-olds (ODFW 2010) and Hood Canal as 3 or 4-year-olds (WDFW et al. 2000). All chum salmon die after spawning once.

2.2.4.1 Puget Sound Recovery Domain

2.2.4.1.1 Hood Canal Summer-run Chum Salmon ESU

This ESU was listed as a threatened species on March 25, 1999 (64 FR 14508). Its threatened status was reaffirmed on June 28, 2005 (70 FR 37159) and April 14, 2014 (79 FR 20802). Critical habitat for Hood Canal summer-run chum salmon was designated on September 2, 2005 (70 FR 52630). NMFS' most recent 5-year status review for Hood Canal summer-run chum salmon was its 2016 5-year review (NMFS 2016b). The NWFSC finalized its updated biological viability assessment for Pacific Northwest salmon and steelhead listed under the ESA (Ford 2022) in January 2022. This ESU includes all naturally spawning populations of summer-run chum salmon in Hood Canal tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington, as well as several artificial propagation programs (Figure 34). The Puget Sound Technical Recovery Team identified two independent populations for Hood Canal summer chum, one which includes the spawning aggregations from rivers and creeks draining into the Strait of Juan de Fuca, and one which includes spawning aggregations within Hood Canal proper (Sands et al. 2009). The ESU also includes chum salmon two artificial propagation programs (Table 42).

2.2.4.1.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Hood Canal Summer-run Chum ESU, is at moderate risk and remains at threatened status.

Table 42. Hood Canal Summer-run Chum Salmon ESU description and MPGs (Ford 2022).

ESU Description	
Threatened	Listed under ESA in 1999; updated in 2005 and 2014
1 MPG	2 historical populations
MPG	***Populations***
Hood Canal	Strait of Juan de Fuca, Hood Canal
Artificial production	
Hatchery programs included in ESU (2) [a]	Lilliwaup Creek Fish Hatchery Program, Tahuya River Program
Hatchery programs not included in ESU (0)	N/A

[a] Note that the last releases from the Lilliwaup Creek Fish Hatchery Program were in 2018 with the last fish returning to the hatchery in 2022. The last releases for the Tahuya River Program were in 2015 with the last fish returning to the hatchery in 2018.

2.2.4.1.1.1.1 Abundance and Productivity

Estimates of total (natural-origin spawners + supplementation-origin spawners) and natural spawning abundances are available from 1974 for both the Strait of Juan de Fuca and the Hood Canal populations, and are shown from 1980 through 2019 in Figure 35. Smoothed trends in estimated total and natural population spawning abundances for both populations have generally increased over the 1980 to 2017 time period (Figure 35). Shorter-term trends, specifically from 2002–16 for the Strait of Juan de Fuca population and from 2003–17 for the Hood Canal population, have coincided with the supplementation programs. The co-managers' 2018 assessment (Lestelle et al. 2018) provides evidence that increased abundances have been sustained at a level higher than during the period of listing. However, since 2016, abundances for both populations have sharply decreased. This began in 2017 for the Strait of Juan de Fuca population and in 2018 for the Hood Canal population (Figure 35). This newest information is important in considering summer-run chum salmon abundance and productivity trends, and the co-managers theorize it to be related to Pacific Decadal Oscillation effects on ocean conditions (Lestelle et al. 2018; Lestelle 2020).

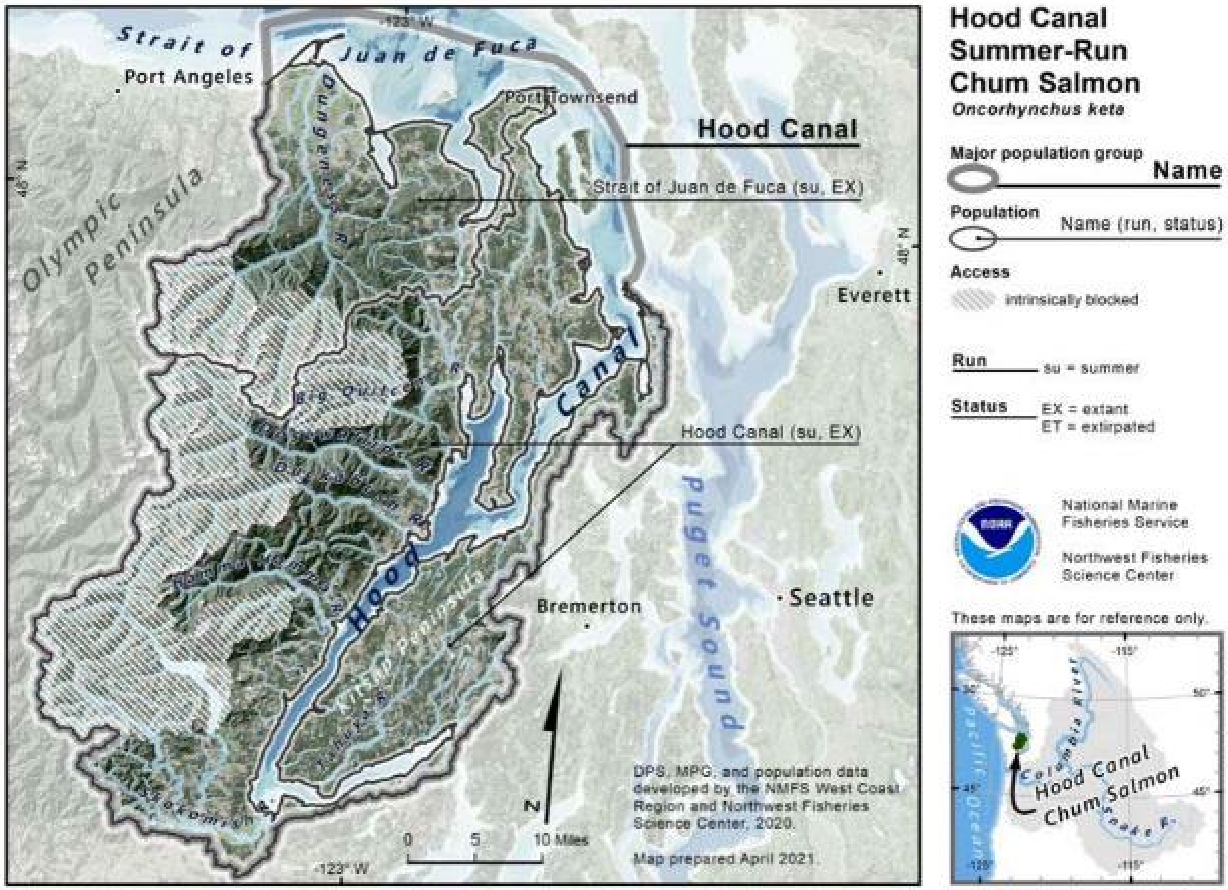


Figure 34. Map of the Hood Canal Summer-run Chum Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

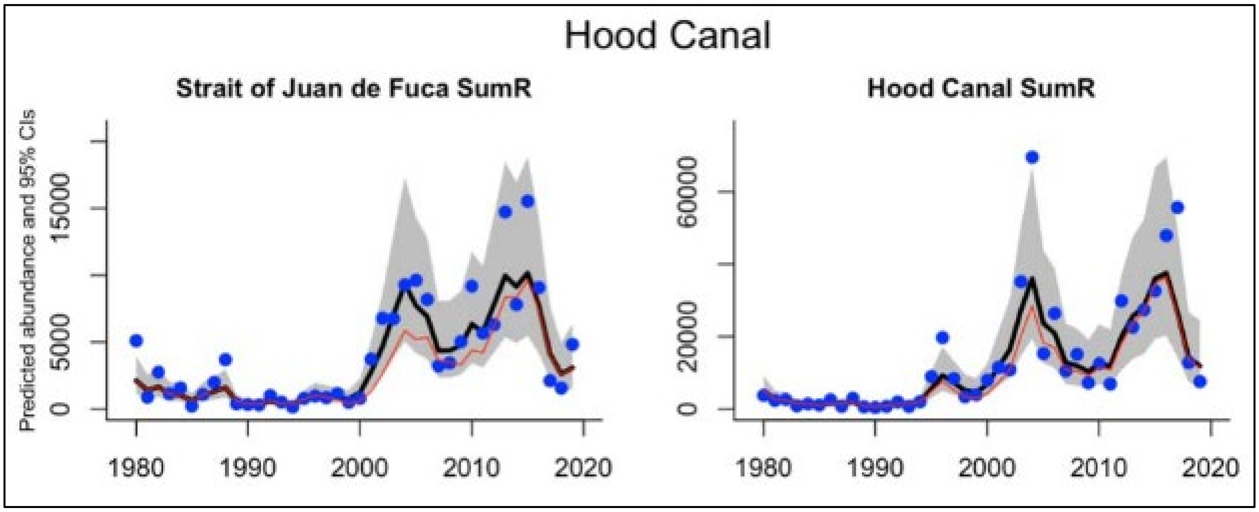


Figure 35. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

Average escapements (geometric means) for five-year intervals beginning in 1990 show estimates of trends over the intervals for both natural-origin spawners and total spawners. The Strait of Juan de Fuca population had a 29% decrease in abundance of natural-origin (43% decrease in total) spawners in the most recent five-year time period (2015–19) vs. the 2010–14 period (Ford 2022). The Hood Canal population had a 46% increase in abundance of natural-origin (40% increase in total) spawners in the same period (Ford 2022). Spawner abundances in both populations were lowest throughout the 1990s, but increased in the early 2000s and had been sustained through 2016 (Figure 35).

2.2.4.1.1.1.1.1 Harvest

There are no directed fisheries on Hood Canal summer-run chum salmon. However, they are taken incidentally in fisheries directed at other species in the Strait of Juan de Fuca, in Hood Canal, and in Canada (Ford 2022). Because the population from the eastern Strait of Juan de Fuca (Dungeness River through Port Townsend Bay) is not subject to the fisheries in Hood

Canal directed at Chinook and coho salmon, they experience lower overall harvest rates in general compared to the Hood Canal population. Historically, the eastern Strait of Juan de Fuca population experienced harvest rates on the order of 10–30%, with rates as high as 50% in individual years (Ford 2022). The Hood Canal population was subject to harvest rates that were typically on the order of 50–70%, with rates in individual years approaching 90% (Point No Point Treaty Tribes and WDFW 2014).

In response to severely depressed runs of summer-run chum salmon in the early 1990s, the State of Washington and the Western Washington Treaty Tribes took measures to curb the incidental harvest of summer chum salmon, and harvest rates fell dramatically (Figure 36). The co-managers implemented a Base Conservation Regime (BCR) and continued to constrain harvest impacts as runs have approached or returned to historic levels, leading to escapements that have exceeded historic levels. Under the BCR, harvest rates have declined to less than 2% for the Strait of Juan de Fuca population and to about 3–15% for Hood Canal summer chum salmon (Lestelle et al. 2018). Harvest rates have been below the BCR harvest rate limits for all years in the Strait of Juan de Fuca fisheries and for all years except 2004 and 2007–09 in Hood Canal fisheries (Ford 2022). From 2000 through 2018, the harvest rate for the ESU has averaged about 7% (Ford 2022).

2.2.4.1.1.1.2 Spatial Structure and Diversity

Spatial structure and diversity measures for the Hood Canal summer-run chum salmon recovery program include the reintroduction and sustaining of natural-origin spawning in multiple small streams where summer chum salmon spawning aggregates had been extirpated. A supplementation program was initiated in 1992 to meet this objective, and supportive habitat protection and restoration projects have been conducted in many of the streams as well. The first supplementation-origin spawners began to return in 1995; however, it wasn't until 2001 that large numbers of Supplementation-origin fish were widely distributed in each population (Point No Point Treaty Tribes and WDFW 2014). Previously extirpated spawning subpopulations were reintroduced and have now rebounded in Chimacum Creek in the Strait of Juan de Fuca population (Ford 2022). Reintroductions in Big Beef Creek and Tahuya River in the Hood Canal population have not been quite as successful, and it does not appear that the rebounding natural-origin production will be sustained (Lestelle et al. 2018). Two other streams, Dewatto and Skokomish Rivers, which had been deemed extirpated by the PSTRT at the time of their analysis, and which have not had reintroduction efforts, have seen subpopulations rebound substantially in recent years (Ford 2022). This follows completion of habitat restoration projects in the lower portion of the Skokomish River and estuary. Habitat on the Dewatto River remains largely intact (Lestelle et al. 2018).

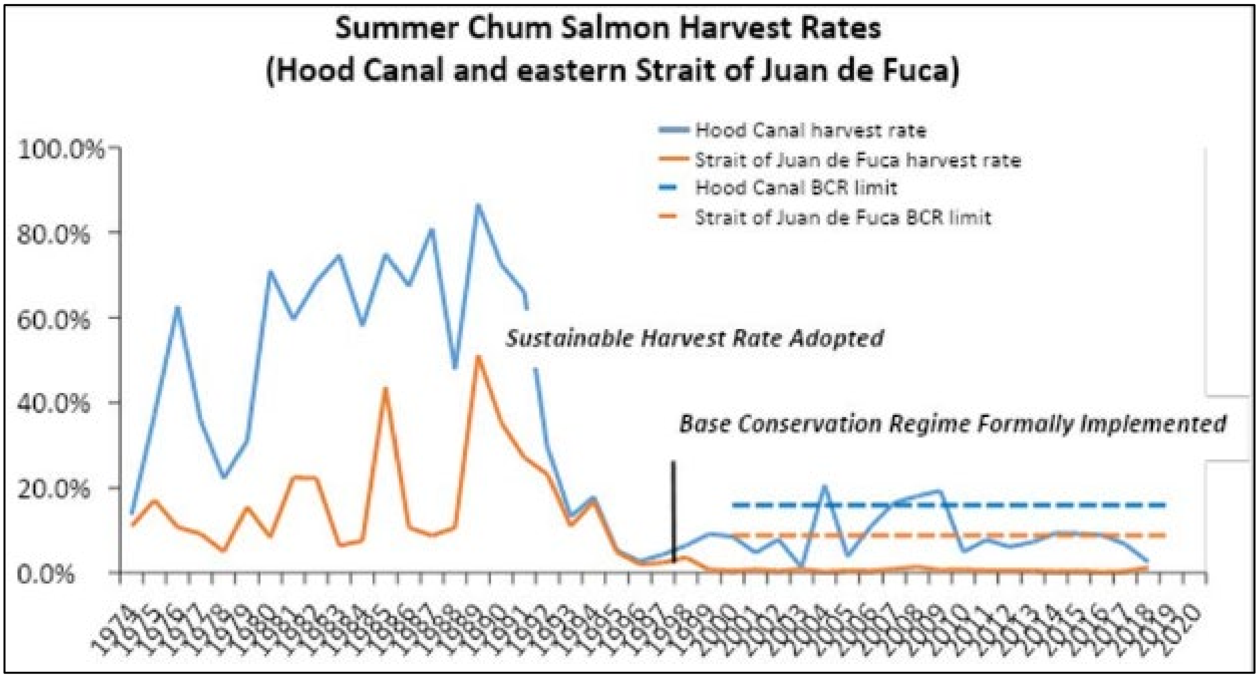


Figure 36. Total exploitation rate on the Hood Canal Summer-run Chum Salmon ESU (Ford 2022).

2.2.4.1.1.1.2.1 Hatcheries

One measure of spatial structure and diversity parameters is related to the proportion of natural-origin spawners vs. supplementation-origin spawners on the spawning grounds. All returning summer-run chum salmon spawners were natural in both populations until fish from the supplementation program began to return to spawn in 1995 (Ford 2022). Supplementation programs were intended to run for a maximum duration of three generations, or 12 years. Programs in the Strait of Juan de Fuca population (Salmon, Jimmycomelately, and Chimacum Creeks) and in the Hood Canal population (Big Quilcene, Hamma Hamma, Lilliwaup, Union, Tahuya, and Big Beef Creeks) were phased in between 1992 and 2003. As program goals were met, all programs have now been terminated (Ford 2022). Lilliwaup Creek did not meet the production targets (e.g., broodstock collections and release numbers) in some earlier years and also had a lack of focused habitat protection/restoration efforts, so supplementation was continued in Lilliwaup Creek through broodyear 2017 (Lestelle et al. 2018). As supplementation-origin fish returns have phased out, there has been a gradual return to predominantly natural-origin spawners for both populations (Table 43). For the Hood Canal population, supplementation-origin fish returned to the Dewatto and Tahuya Rivers and to Lilliwaup Creek through 2018. The Strait of Juan de Fuca population shows estimates of nearly 100% natural-origin spawners since 2015 (Table 43).

Table 43. Five-year mean of fraction natural-origin spawners (sum of all estimates divided by the number of estimates) (Ford 2022).

Population	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Strait of Juan de Fuca	Hood Canal	0.85	0.54	0.76	0.79	0.98
Hood Canal	Hood Canal	0.72	0.70	0.83	0.92	0.97

2.2.4.1.1.1.3 Summary

Natural-origin spawner abundance has increased since ESA listing, and spawning abundance targets in both populations have been met in some years. Productivity had increased at the time of the 2015 viability review (NWFSC 2015), but has been down for the last three years for the Hood Canal population, and for the last four years for the Strait of Juan de Fuca population (Ford 2022). Productivity of individual spawning aggregates shows that only two of eight aggregates have viable performance (Ford 2022). Spatial structure and diversity viability parameters, as originally determined by the TRT, have improved, and nearly meet the viability criteria for both populations (Ford 2022). Despite substantive gains toward meeting viability criteria in the Strait of Juan de Fuca and Hood Canal summer chum salmon populations, the ESU still does not meet all of the recovery criteria for population viability at this time. Overall, the Hood Canal summer-run chum salmon ESU therefore remains at “moderate” risk of extinction (Ford 2022), with viability largely unchanged from the prior review (NWFSC 2015).

2.2.4.1.1.2 Limiting Factors

Limiting factors for this species include (HCCC (Hood Canal Coordinating Council) 2005):

- Reduced floodplain connectivity and function,
- Poor riparian condition,
- Loss of channel complexity (reduced large wood and channel condition, loss of side channels, channel instability),
- Sediment accumulation, and
- Altered flows and water quality

Mantua et al. (2010) suggested that the unique life history of Hood Canal summer-run chum salmon makes this ESU especially vulnerable to the climate change impacts because they spawn in small shallow streams in late summer, eggs incubate in the fall and early winter, and fry migrate to sea in late winter. Sensitivity during the adult freshwater stage and the early life history was ranked moderate. Predicted climate change effects for the low-elevation Hood Canal streams historically used by summer chum salmon include multiple negative impacts stemming from warmer water temperatures and reduced streamflow in summer, and the potential for increased redd-scouring from peak flow magnitudes in fall and winter. Exposure for stream temperature and summer water deficit were both ranked high, largely due to effects on returning adults and hatched fry. Likewise, sensitivity to cumulative life-cycle effects was ranked high.

The 2005 recovery plan for Hood Canal summer-run Chum Salmon currently guides habitat protection and restoration activities for chum Salmon recovery (HCCC (Hood Canal Coordinating Council) 2005; NMFS 2007d). Human-caused degradation of Hood Canal summer-run chum salmon habitat has diminished the natural resiliency of Hood Canal/Strait of Juan de Fuca river deltas and estuarine habitats (HCCC (Hood Canal Coordinating Council) 2005). Despite some improvement in habitat protection and restoration actions and mechanisms, concerns remain that given the pressures of population growth, existing land use management measures through local governments (i.e., shoreline management plans, critical area ordinances, and comprehensive plans) may be compromised or not enforced (SSDC 2007). The widespread loss of estuary and lower floodplain habitat was noted by the BRT as a continuing threat to ESU spatial structure and connectivity. (69 FR 33134).

The Hood Canal summer-run chum Salmon recovery plan includes specific recovery actions for each stream (HCCC (Hood Canal Coordinating Council) 2005). General protection and restoration actions summarized from those streams include:

- Incorporate channel migration zones within the protected areas of the Shoreline Master Plans of local governments,
- Acquire high priority spawning habitat,
- Set back or remove levees in the lower rivers and in river deltas,
- Restore upstream ecosystem processes to facilitate delivery of natural sediment and large wood features to lower river habitats,
- Remove armoring along the Hood Canal shoreline, including private bulkheads, roadways, and railroad grades,
- Restore large wood to river deltas and estuarine habitats, and
- Restore salt marsh habitats

2.2.4.2 Willamette/Lower Columbia Recovery Domain

2.2.4.2.1 Columbia River Chum Salmon ESU

On March 25, 1999, NMFS listed the Columbia River Chum Salmon ESU as a threatened species (64 FR 14508). The threatened status was most recently reaffirmed on April 14, 2014 (79 FR 20802). Critical habitat was designated on September 2, 2005 (70 FR 52746). In 2022, NMFS published its most recent 5-year review for Columbia River chum salmon (NMFS 2022j).

The ESU includes all naturally spawning populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon, along with the hatchery chum salmon described in Table 44. This ESU is comprised of three MPGs and has 17 natural populations (Table 44). Chum salmon are primarily limited to the tributaries downstream of Bonneville Dam and the majority of the fish spawn in Washington tributaries of the Columbia River (Figure 37). Inside the geographic range of the ESU, three hatchery chum salmon programs are currently operational. Table 44 lists these hatchery programs, which are all included in the ESU (NMFS 2022j).

Table 44. Columbia River Chum Salmon ESU description and MPGs. The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively (McElhany et al. 2003; Myers et al. 2006; NMFS 2013c; 2022j).

ESU Description	
Threatened	Listed under ESA in 1999; updated in 2014
3 MPGs	17 historical populations
MPG	***Populations***
Coast	Youngs Bay (C), Grays/Chinook (C,G), Big Creek (C), Elochoman/Skamokawa (C), Clatskanie, Mill/Abernathy/Germany Creeks, Scappoose
Cascade	Cowlitz-fall (C), Cowlitz-summer (C), Kalama, Lewis (C), Salmon Creek, Clackamas (C), Sandy, Washougal
Gorge	Lower Gorge (C,G), Upper Gorge[a]
Artificial production	
Hatchery programs included in ESU (3)	Grays River, Washougal Hatchery/Duncan Creek, Big Creek Hatchery
Hatchery programs not included in ESU (0)	N/A

[a] Includes White Salmon population.

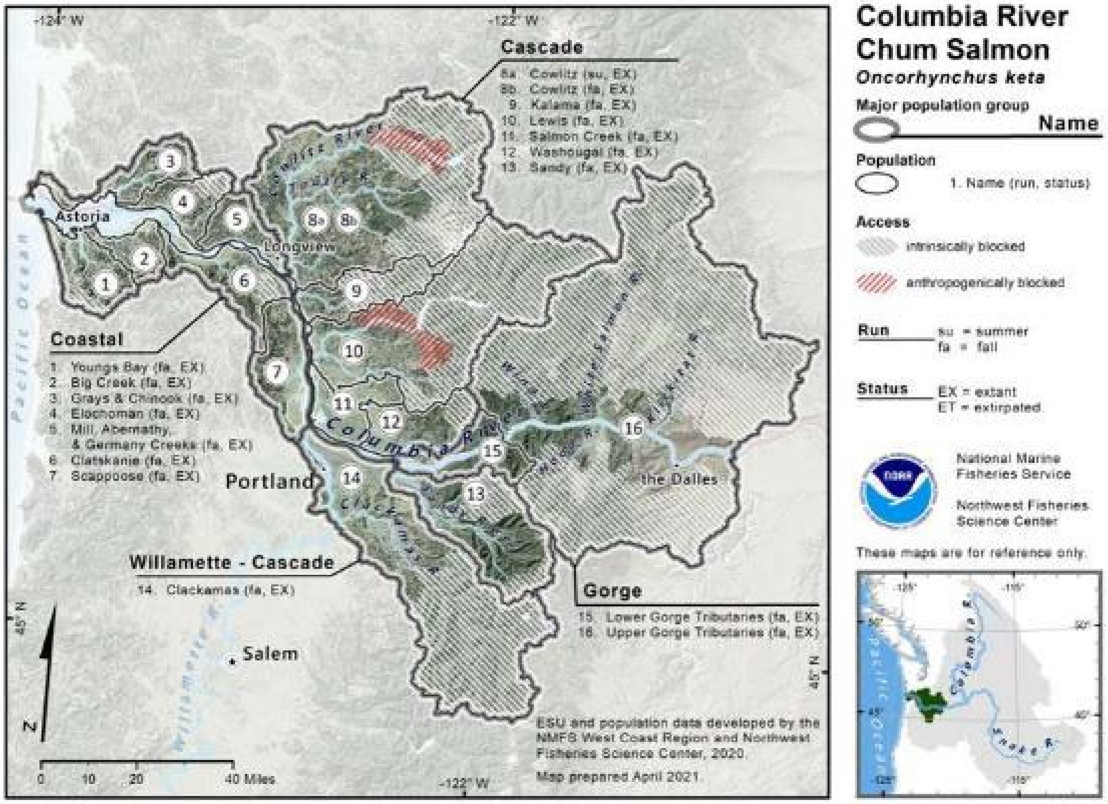


Figure 37. Map of the Columbia River chum salmon ESU's spawning and rearing areas, illustrating all 17 demographically independent populations and the three MPGs. Note that Population 8, Cowlitz River, contains two demographically independent populations, a fall and a summer run (Ford 2022).

Columbia River chum salmon are classified as fall-run fish, entering freshwater from mid-October through November and spawning from early November to late December in the lower mainstems of tributaries and side channels. There is evidence that a summer-run chum salmon population returned historically to the Cowlitz River, and fish displaying this life history are occasionally observed there. The recovery scenario currently includes this as an identified population in the Cascade MPG (Table 44).

2.2.4.2.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Columbia River Chum Salmon ESU, is at high risk and remains at threatened status. Target abundance that would be consistent with delisting criteria for each Columbia River chum salmon natural population is summarized in Table 45, along with the current 5-year mean abundance. Persistence probability is measured over a 100-year time period and ranges from very low (probability of less than 40%) to very high (probability of greater than 99%).

Table 45. Current five-year geometric mean of raw natural-origin spawner abundances and recovery targets for Lower Columbia River chum salmon demographically independent populations. Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > *x* < 50%, yellow = 50% > *x* < 100%, green = >100%. Numbers in parentheses represent total (hatchery and natural-origin) spawners (Ford 2022).

		Abundance	
Stratum	**Population**	**2015–19**	**Target**
Coast	Youngs Bay FA (OR)	n/a	<500
	Grays/Chinook River FA (WA)	10,027	1,600
	Big Creek FA (OR)	n/a	<500
	Elochoman/Skamokawa FA (WA)	n/a	1,300
	Clatskanie River FA (OR)	n/a	1,000
	Mill/Abernathy/Germany Creeks (WA)	n/a	1,300
	Scappoose Creek (OR)	n/a	1,000
Cascade	Cowlitz River SU (WA)	n/a	900
	Cowlitz River FA (WA)	n/a	900
	Kalama River FA (WA)	n/a	900
	Lewis River FA (WA)	n/a	1,300
	Salmon Creek FA (WA)	n/a	n/a
	Clackamas River FA (OR)	n/a	500
	Sandy River FA (OR)	n/a	1,000
	Washougal River (WA)	3,003	1,300
Gorge	Lower Gorge FA (WA & OR)	3,124	2,000
	Upper Gorge FA (WA & OR)	(85)	900

2.2.4.2.1.1.1 Abundance and Productivity

Over the last century, Columbia River chum salmon returns have collapsed from hundreds of thousands to just a few thousand per year (NMFS 2013c). Of the 17 natural populations that historically made up this ESU, 15 of them (six in Oregon and nine in Washington) are so depleted that either their baseline probability of persistence is very low, extirpated, or nearly so (Ford et al. 2011; NMFS 2013c; NWFSC 2015). The Grays River and Lower Gorge populations showed a sharp increase in 2002 for several years, but have since declined back to relatively low abundance levels in the range of variation observed over the last several decades.

It is notable that during this most recent review period, the three populations (Grays River, Washougal, and Lower Gorge demographically independent populations) improved markedly in abundance (Figure 38). Improvements in productivity were observed in almost every year during the 2015–19 interval (Ford 2022). This is somewhat surprising, given that the majority of chum salmon emigrate to the ocean as subyearlings after only a few weeks, and one would expect the poor ocean conditions to have a strong negative influence on the survival of juveniles (as with many of the other ESUs in this region). In contrast to these three demographically independent populations, the remaining populations in this ESU have not exhibited any detectable improvement in status (Ford 2022). Abundances for these populations are assumed to be at or near zero, and straying from nearby healthy populations does not seems sufficient to reestablish self-sustaining populations (Table 45). It may be that the chum salmon life-history strategy of emigrating post-emergence en masse (possibly as a predator swamping mechanism) requires a critical number of spawners to be effective (Ford 2022).

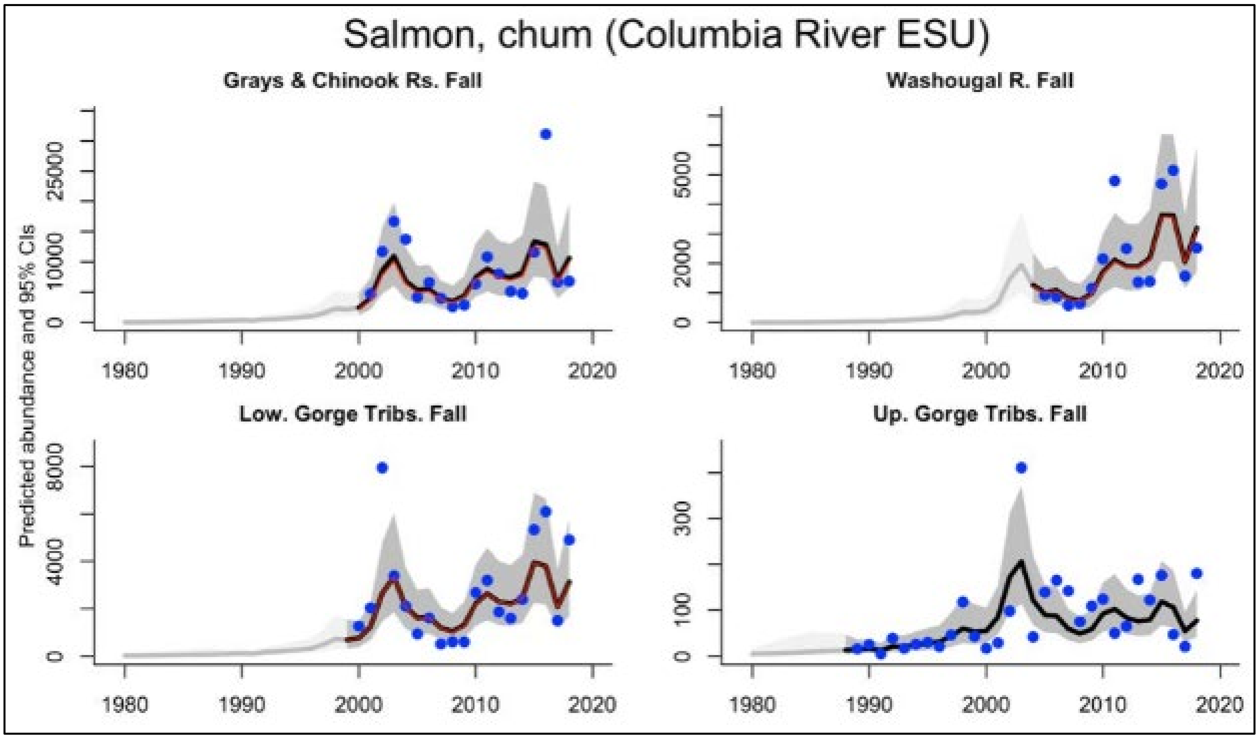


Figure 38. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot. Lower Gorge Tributaries include mainstem Columbia River spawning aggregates (Ives Island, Horsetail Falls, etc.). Upper Gorge Tributaries is based on the Bonneville Dam count, although many chum salmon counted upstream are known to have fallen back and spawned below Bonneville Dam (Ford 2022).

Of the risk factors considered, freshwater habitat conditions may be negatively influencing spawning and early rearing success in some basins, and contributing to the overall low productivity of the ESU. Recent studies also suggest that a freshwater parasite, *Ceratonova shasta*, may be limiting the survival of juvenile chum salmon (WDFW and ODFW 2019). The prevalence of this parasite may increase with warmer water temperatures from flow modification or climatic change. Land development, especially in the low-gradient reaches that chum salmon prefer, will continue to be a threat to most chum populations due to projected increases in the population of the greater Vancouver–Portland area and the lower Columbia River overall (Metro 2014). The viability of this ESU is relatively unchanged since the prior review, and the improvements in some populations do not warrant a change in risk category, especially given the uncertainty regarding climatic effects in the near future. The Lower Columbia River chum salmon ESU therefore remains at "moderate" risk of extinction, and the viability is largely unchanged from the prior review.

2.2.4.2.1.1.1.1 Harvest

Columbia River chum salmon were historically abundant and subject to substantial harvest until the 1950s (Johnson et al. 1997). In recent years, there has been no directed harvest of Columbia River chum salmon (NMFS 2018e). Data on the incidental harvest of chum salmon in lower Columbia River gillnet fisheries exist, but escapement data are inadequate to calculate exploitation rates. Incidental commercial landings have been approximately 100 fish per year since 1993 (except 275 fish in 2010), and all recreational fisheries have been closed since 1995 (Ford 2022). The incidental harvest rate on Columbia River chum salmon was estimated to be 0.3% in 2018 (ODFW et al. 2020). Overall, the exploitation rate has been estimated at below 1% for the last five years (Ford 2022).

2.2.4.2.1.1.2 Spatial Structure and Diversity

Chum salmon generally spawn in the mainstem Columbia River (in areas of groundwater seeps) and the lower reaches of both large and small tributaries, with the exception of the Cowlitz River (Myers et al. 2006). In contrast to other species, mainstem dams have less of an effect on chum salmon distribution; rather, it is smaller, stream-scale blockages that limit chum access to spawning habitat. Upland development can also affect the quality of spawning habitat by disrupting the groundwater upwelling that chum prefer. In addition, juvenile habitat has been curtailed through dikes and revetments that block access to riparian areas that are normally inundated in the spring. Loss of lower river and estuary habitat probably limits the ability of chum salmon to expand and recolonize historical habitat. Presently, detectable numbers of chum salmon persist in only four of the 17 demographically independent populations, a fraction of their historical range (Ford 2022).

2.2.4.2.1.1.2.1 Hatcheries

Hatchery managers have continued to implement and monitor changes in chum hatchery management since the 2016 5-year review (NMFS 2022j). All of the hatchery programs in this ESU use integrated stocks developed to supplement natural production. The goal of these programs for chum salmon is conservation and rebuilding population abundances throughout the ESU, including getting sufficient returns of chum salmon to the Big Creek hatchery. Given the low numbers of hatchery chum salmon released throughout the ESU (approximately 500,000; Figure 39), the vast majority of spawning fish are of natural-origin (>90%; Table 46) (Ford 2022). Existing hatchery programs for chum salmon are important for the conservation and recovery of this ESU (NMFS 2017o). The most recent status review concluded that risk to this ESU from hatchery programs is low (NMFS 2022j).

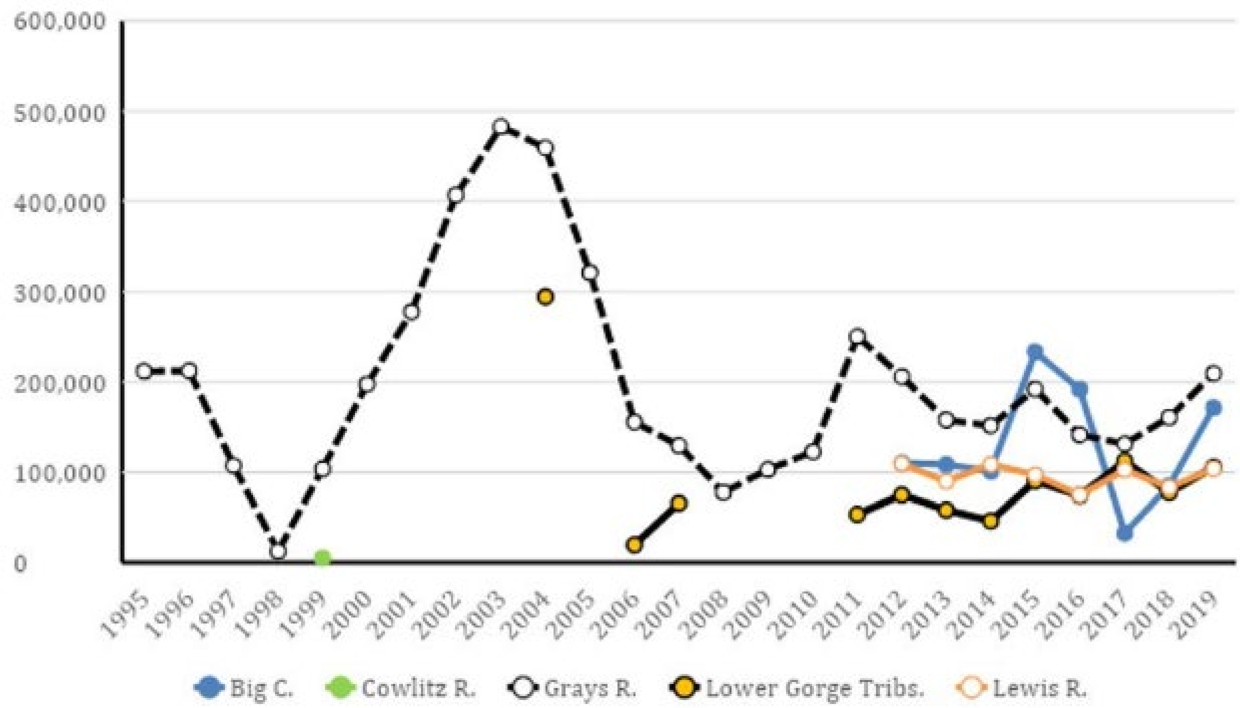


Figure 39. Releases of juvenile chum salmon into the lower Columbia River. All releases were from sources originating from within the ESU. Data from the Regional Mark Information System (https://www.rmpc.org, April 2020). Figure reproduced from Ford (2022).

Table 46. Five-year mean of fraction natural-origin spawner (sum of all estimates divided by the number of estimates) in lower Columbia River chum salmon populations. Blanks (—) indicate that no estimate was available in that 5-year range (Ford 2022).

Population[a]	MPG	1996–2000	2001–05	2006–10	2011–15	2016–20
Grays/Chinook Rivers Fall	Coastal	—	0.92	0.95	0.93	0.95
Washougal River Fall	Cascade	—	0.98	0.97	—	0.99
Lower Gorge Tributaries Fall	Gorge	1	0.99	0.98	1.00	1.00
Upper Gorge Tributaries Fall	Gorge	—	—	—	—	—

[a] Note that the Youngs Bay (Coastal), Big Creek (Coastal), Cispus (Cascade), Elochoman/Skamokawa (Coastal), Clatskanie, Mill/Abernathy/Germany Creeks (Coastal), Scappoose (Coastal), Cowlitz-fall (Cascade), Cowlitz-summer (Cascade), Kalama (Cascade), Lewis (Cascade), Salmon Creek (Cascade), Clackamas (Cascade), and Sandy (Cascade) populations are not included due to low abundances or lack of monitoring and available data, as discussed further in Ford (2022).

2.2.4.2.1.1.3 Summary

Overall, the status of most chum salmon populations is unchanged from the baseline VSP scores estimated in the recovery plan. A total of three of 17 populations exceed the recovery goals established in the recovery plan (NMFS 2013c). The remaining populations have unknown abundances, although it is reasonable to assume that the abundances are very low and unlikely to be more than 10% of the established recovery goals (Ford 2022). Although the Big Creek demographically independent population is currently supported by a hatchery supplementation program, natural-origin returns have been very low (Ford 2022). Even with the improvements observed during the last five years, the majority of demographically independent populations in this ESU remain at a “very high” risk level (Ford 2022). With so many primary demographically independent populations at near-zero abundance, none of the MPGs could be considered viable (Ford 2022). The viability of this ESU is relatively unchanged since the NWFSC (2015) report, and the improvements in some populations do not warrant a change in the “moderate to high risk” category described, especially given the uncertainty regarding climatic effects in the near future (NMFS 2022j)[17].

[17] The NWFSC viability assessment identified risk category as “moderate” (Ford 2022).

2.2.4.2.1.2 Limiting Factors

Understanding the limiting factors and threats that affect the Columbia River Chum Salmon ESU provides important information and perspective regarding the status of a species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Columbia River Chum Salmon ESU. Factors that limit the ESU have been, and continue to be, loss and degradation of spawning and rearing habitat including the estuary, impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the persistence probability of all populations (NMFS 2013c). Columbia River chum salmon were historically abundant and were subject to extensive harvest until the 1950s (Johnson et al. 1997; NWFSC 2015). Other threats to the species include climate change impacts.

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

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

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

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

Rather than repeating this extensive discussion from the recovery plan, the discussions in Chapter 4 and 8 are incorporated here by reference.

2.2.5 Status of the Sockeye Salmon ESU

Only one ESU of sockeye salmon was evaluated in this Opinion, the Snake River Sockeye Salmon ESU. The Snake River Sockeye Salmon ESU contains one MPG and one extant population and is contained within the Interior Columbia Recovery Domain.

While there are very few sockeye salmon currently following an anadromous life cycle in the Snake River, the small remnant run of the historic population migrates 900 miles downstream from the Sawtooth Valley through the Salmon, Snake, and Columbia Rivers to the ocean (Figure 40). After one to three years in the ocean, they return to the Sawtooth Valley as adults, passing once again through these mainstem rivers and through eight major Federal dams, four on the Columbia River and four on the lower Snake River. Anadromous sockeye salmon returning to Redfish Lake in Idaho's Sawtooth Valley travel a greater distance from the sea, 900 miles, to a higher elevation (6,500 ft.) than any other sockeye salmon population. They are the southernmost population of sockeye salmon in the world (NMFS 2015f).

2.2.5.1 Interior Columbia Recovery Domain

2.2.5.1.1 Snake River Sockeye Salmon ESU

On November 20, 1991, NMFS listed the Snake River Sockeye Salmon ESU as an endangered species (56 FR 58619) under the ESA. This listing was affirmed in 2005 (70 FR 37160), and again on April 14, 2014 (79 FR 20802). Critical habitat was designated on December 28, 1993 (58 FR 68543). In 2022, NMFS published the most recent 5-year status review for Snake River sockeye salmon (NMFS 2022m). The ESU includes naturally spawned anadromous and residual sockeye salmon originating from the Snake River Basin in Idaho, as well as two artificially propagated sockeye salmon programs (Table 47).

The ICTRT treats Sawtooth Valley sockeye salmon as the single MPG within the Snake River Sockeye Salmon ESU. The MPG contains one extant population (Redfish Lake) and two to four historical populations (NMFS 2015f) (Figure 40). At the time of listing in 1991, the only confirmed extant population included in this ESU was the beach-spawning population of sockeye salmon from Redfish Lake, with about 10 fish returning per year (NMFS 2015f). Historical records indicate that sockeye salmon once occurred in several other lakes in the Stanley Basin, but no adults were observed in these lakes for many decades; once residual sockeye salmon were observed, their relationship to the Redfish Lake population was uncertain (McClure et al. 2005). Since ESA-listing, progeny of the Redfish Lake sockeye salmon population have been outplanted to Pettit and Alturas lakes within the Sawtooth Valley for recolonization purposes (NMFS 2011b).

Table 47. Snake River Sockeye Salmon ESU description and MPG (Ford 2022; NMFS 2022m).

ESU Description	
Endangered	Listed under ESA in 1991; updated in 2005 and 2014
1 MPG	3-5 historical populations (2-4 extirpated)
MPG	***Population***
Sawtooth Valley	Redfish Lake
Artificial production	
Hatchery programs included in ESU (2)	Redfish Lake Captive Broodstock Program, Snake River Sockeye Salmon Hatchery Program
Hatchery programs not included in ESU (0)	Not applicable

Lakes in the Stanley Basin and Sawtooth Valley are relatively small compared to the other lake systems that historically supported sockeye salmon production in the Columbia Basin. The average abundance targets recommended by the Snake River Recovery Team (Bevan et al. 1994) were incorporated as minimum abundance thresholds into a sockeye salmon viability curve. The viability curve was generated using historical age structure estimates from Redfish Lake sampling in the 1950s to the 1960s, and year-to-year variations in brood-year replacement rates generated from abundance series for Lake Wenatchee sockeye salmon. The minimum spawning abundance threshold is set at 1,000 for the Redfish and Alturas Lake populations (intermediate category for lake size), and at 500 for populations in the smallest historical size category for lakes (i.e., Alturas and Pettit Lakes). Because space in the lakes is limited, the available spawning capacity may also be limited based on available habitat. The ICTRT recommended that long-term recovery objectives should include restoring at least three of the lake populations in this ESU to viable or highly viable status.

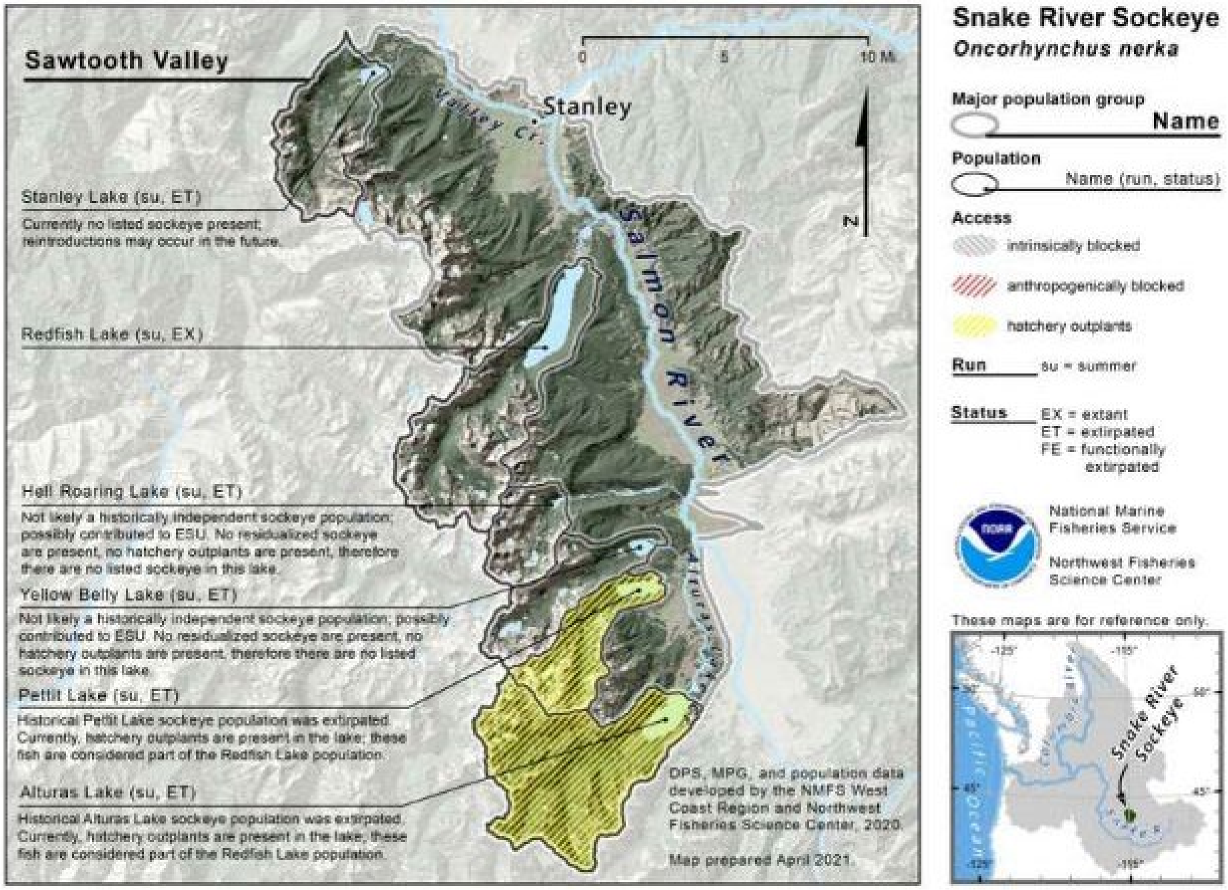


Figure 40. Map of the Snake River Sockeye Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

2.2.5.1.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Snake River Sockeye Salmon ESU, is at high risk and remains at endangered status (Ford 2022).

2.2.5.1.1.1.1 Abundance and Productivity

Prior to the turn of the 20th century (ca. 1880), around 150,000 sockeye salmon ascended the Snake River to the Wallowa, Payette, and Salmon River basins to spawn in natural lakes

(Evermann 1896, as cited in Chapman et al. (1990)). The Wallowa River sockeye salmon run was considered extinct by 1905, the Payette River run was blocked by Black Canyon Dam on the Payette River in 1924, and anadromous Warm Lake sockeye salmon in the South Fork Salmon River basin may have been trapped in Warm Lake by a land upheaval in the early 20th century (ICTRT 2003). In the Sawtooth Valley, the Idaho Department of Fish and Game eradicated sockeye salmon from Yellowbelly, Pettit, and Stanley Lakes in favor of other species in the 1950s and 1960s, and irrigation diversions led to the extirpation of sockeye salmon in Alturas Lake in the early 1900s (ICTRT 2003), leaving only the Redfish Lake sockeye salmon population. From 1991 to 1998, a total of just 16 wild adult anadromous sockeye salmon returned to Redfish Lake. These 16 wild fish were incorporated into a captive broodstock program that began in 1992 and has since expanded. The program currently releases hundreds of thousands of juvenile fish each year in the Sawtooth Valley (Ford et al. 2011).

The increased abundance of hatchery reared Snake River sockeye salmon reduces the risk of extinction over the short-term, but levels of naturally produced sockeye salmon returns are variable and remain extremely low (Ford 2022). The ICTRT’s viability target is at least 1,000 naturally produced spawners per year in each of Redfish and Alturas Lakes and at least 500 in Pettit Lake (ICBTRT 2007). The highest adult returns since the captive broodstock program began were in 2014, with a total of 1,579 counted in the Stanley Basin (Ford 2022). The general increases observed in the number of adult returns during 2008–2014 (Figure 41) were likely due to a number of factors, including increases in hatchery production and favorable marine conditions. The 5-year geometric mean of natural-origin adult returns was 137 for 2010–2014. Since then, natural-origin adult returns have declined (Figure 41) with a 2015–2019 5-year geometric mean of 16 (Ford 2022). Adult returns crashed in 2015 (Figure 41) due to a combination of low flows and warm water temperatures in the migration corridor. There was also high in-basin mortality of smolts released in 2015–2017 due to water chemistry shock between hatchery waters and the water of Redfish Lake (Ford 2022). Poor survival and growth in the ocean also play a role in low returns. The total number of returning adults documented in the Sawtooth Valley in 2020, 2021 and 2022 was 152, 55, and 749, respectively (Johnson et al. 2021a)[18].

[18] https://idfg.idaho.gov/press/july-sockeye-counts-lower-granite-dam-could-signal-larger-return-recent-years and https://idfg.idaho.gov/conservation/sockeye

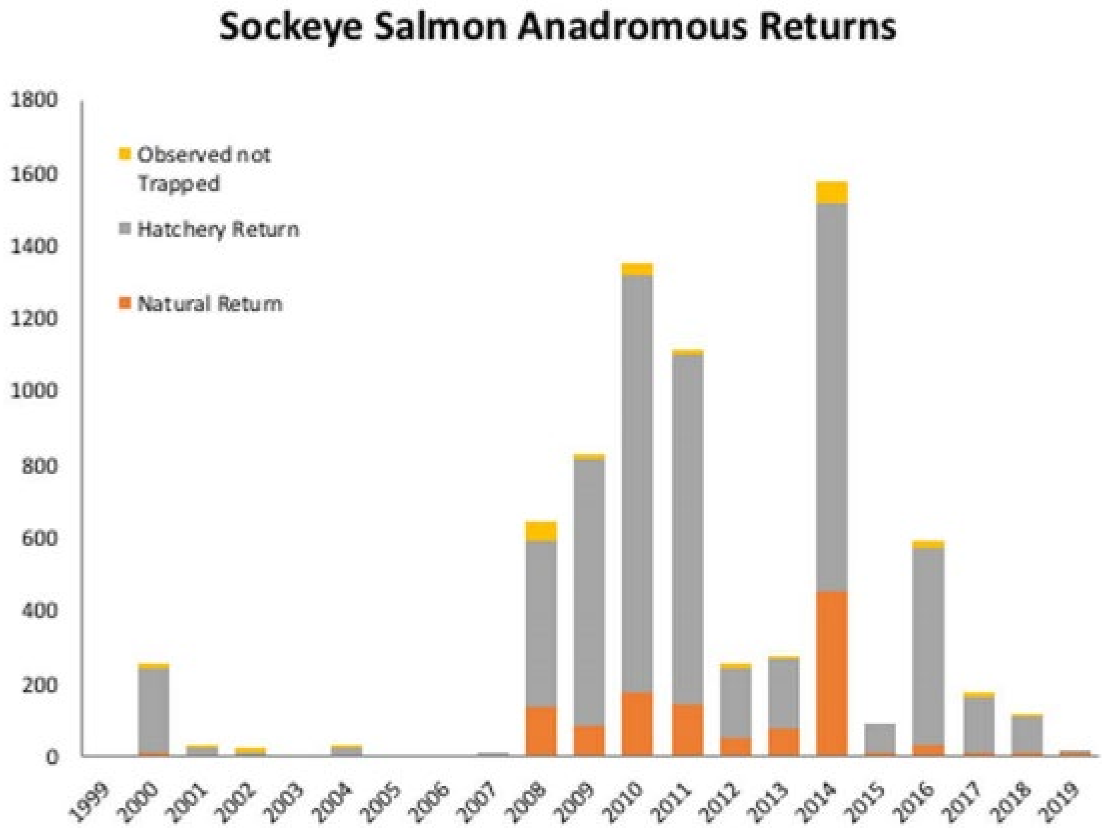


Figure 41. Snake River sockeye salmon anadromous returns, 1999–2019 (figure from Johnson et al. (2020a).

2.2.5.1.1.1.1.1 Harvest

Ocean fisheries do not significantly impact Snake River sockeye salmon (Ford 2022). Within the mainstem Columbia River, treaty tribal net fisheries and non-tribal fisheries directed at Chinook salmon do incidentally take small numbers of sockeye salmon (Ford 2022). Most of the sockeye salmon harvested are from the upper Columbia River (Canada and Lake Wenatchee), but very small numbers of Snake River sockeye salmon are taken incidental to summer fisheries directed at Chinook salmon (Ford 2022). In the 1980s, fishery impact rates increased briefly due to directed sockeye salmon fisheries on large runs of upper Columbia River stocks (Figure 42).

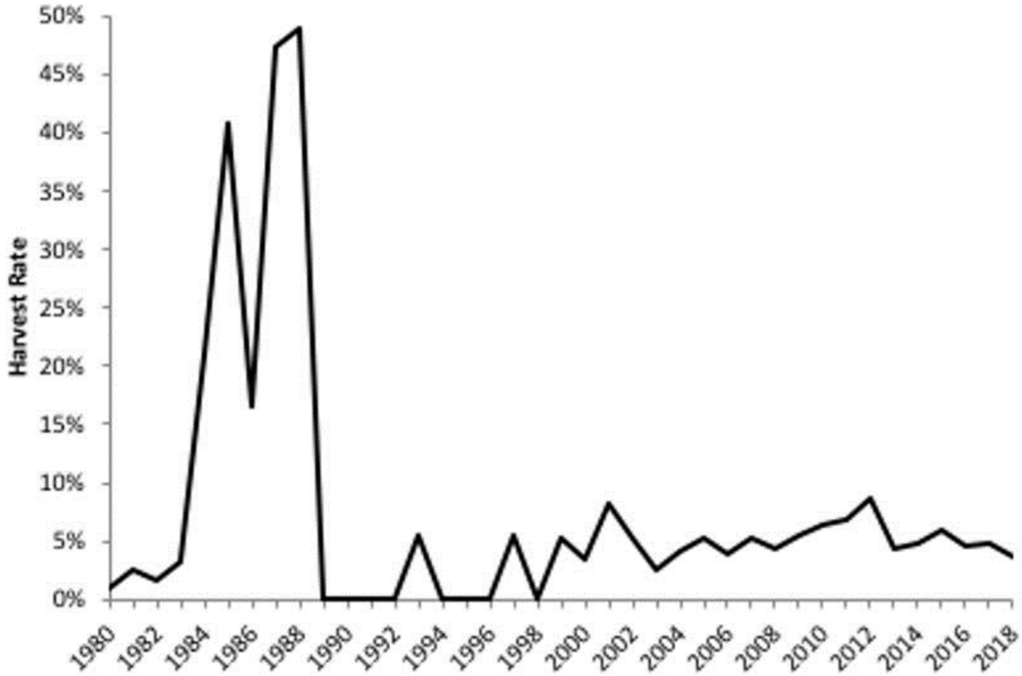


Figure 42. Exploitation rates on Snake River sockeye salmon. Figure reproduced from Ford (2022).

2.2.5.1.1.1.2 Spatial Structure and Diversity

There is evidence that the historical Snake River Sockeye Salmon ESU supported a range of life-history patterns, with spawning populations present in several of the small lakes in the Stanley Basin (NMFS 2015f). Historical production from Redfish Lake was likely associated with a lake shoal spawning life-history pattern, although there may have also been some level of spawning in Fishhook Creek (NMFS 2015f). Historical accounts indicate that Alturas Lake Creek supported an early timed riverine, and may have also contained lake shoal spawners (NMFS 2015f).

At present, anadromous returns are dominated by production from the captive spawning component. The ongoing reintroduction program is still in the phase of building sufficient returns to allow for large-scale reintroduction into Redfish Lake, the initial target for restoring natural production (NMFS 2015f). Initial releases of adult returns directly into Redfish Lake have been observed spawning in multiple locations along the lake shore, as well as in Fishhook Creek (NMFS 2015f). There is some evidence of very low levels of early timed returns in some recent years from outmigrating, naturally produced Alturas Lake smolts. At this stage of the recovery efforts, the ESU remains rated at "high risk" for both spatial structure and diversity.

2.2.5.1.1.1.2.1 Hatcheries

Currently, there are two ESA-listed sockeye salmon hatchery programs in the Snake River basin (Table 47). The hatchery programs' priorities are genetic conservation and building sufficient returns to support sustained outplanting (NMFS 2013e; 2015f). While 318 returning anadromous adults have been released into Redfish and Pettit Lakes since the most recent 5-year review, the captive broodstock program provides the majority of the volitional spawners outplanted into Redfish and Pettit lakes.

The number of Snake River sockeye salmon outmigrants continued to increase through 2019 (Johnson et al. 2020a). After a dip in survival was detected due to disparities in water hardness, stepwise acclimation from high to medium-hardness water and then from medium to low-hardness water was implemented (NMFS 2022m). Fish acclimated in this manner survived to Lower Granite Dam at a rate of 69 to 75%, while smolts directly released into Redfish Lake Creek survived at only 18% (Trushenski et al. 2019). In addition to poor transition survival, poor ocean conditions also contributed to low adult returns from these releases (Johnson et al. 2020b).

In 2020, there were only 26 adult hatchery returns (NMFS 2022m) out of 785,000 hatchery smolt/presmolts released (Johnson et al. 2019). For the same brood year, natural-origin smolt-to-adult survival was higher with 34,009 emigrants producing 126 adult returns to the Sawtooth Valley. Despite improved survival of outmigrants, the cause of poor returns remains uncertain but may be tied to unintentional changes to smolt release size. This may suggest room for improvement with current hatchery practices and/or poor ocean conditions.

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

2.2.5.1.1.1.3 Summary

In terms of natural production, the Snake River Sockeye Salmon ESU remains at “extremely high risk,” although there has been substantial progress on the first phase of the proposed recovery approach—developing a hatchery-based program to amplify and conserve the stock to facilitate reintroductions (Ford 2022). Current climate change modeling supports the “extremely high risk” rating with the potential for extirpation in the near future (Crozier et al. 2020). The viability of the Snake River Sockeye Salmon ESU therefore has likely declined since the time of the prior review (NWFSC 2015), and the extinction risk category remains “high” (Ford 2022).

2.2.5.1.1.2 Limiting Factors

Understanding the limiting factors and threats that affect the Snake River Sockeye Salmon ESU provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. In the 1980s, fishery impact rates increased briefly due to directed sockeye salmon fisheries on large runs of Upper Columbia River stocks. By the 1990s, very small numbers of this species remained in the Snake River Basin (Ford 2022).

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Snake River Sockeye Salmon ESU. Factors that limit the ESU have been, and continue to be the result of impaired mainstream and tributary passage, historical commercial fisheries, chemical treatment of Sawtooth Valley lakes in the 1950s and 1960s, poor ocean conditions, Snake and Columbia River hydropower system, and reduced tributary stream flows and high temperatures (NMFS 2015f). These combined factors reduced the number of sockeye salmon that make it back to spawning areas in the Sawtooth Valley to the single digits, and in some years, zero. The decline in abundance itself has become a major limiting factor, making the remaining population vulnerable to catastrophic loss and posing significant risks to genetic diversity (NMFS 2015f; Ford 2022).

Today, some threats that contributed to the original listing of Snake River sockeye salmon now present little harm to the ESU, while others continue to threaten viability. Fisheries are now better regulated through ESA constraints and management agreements, significantly reducing harvest-related mortality. Potential habitat-related threats to the fish, especially in the Sawtooth Valley, pose limited concern since most passage barriers have been removed and much of the natal lake area and headwaters remain protected. Hatchery-related concerns have also been reduced through improved management actions (NMFS 2015f).

The recovery plan (NMFS 2015f) provides a detailed discussion in Chapters 5-7 of limiting factors and threats, and describes strategies and actions for addressing each of them. These limiting factors and threats include the following:

- Water quality (i.e. sedimentation and pollutants)
- Invasive species
- Blocked access to lakes
- Historical land use effects
- Current recreational use and development
- Irrigation water withdrawals
- FCRPS flow management
- Hydropower
- Fisheries
- Predation and disease
- Competition
- Climate change

Rather than repeating this extensive discussion from the recovery plan, the discussions in Chapters 5-7 are incorporated here by reference. Overall, the recovery strategy aims to reintroduce and support adaptation of naturally self-sustaining sockeye salmon populations in the Sawtooth Valley lakes. An important first step towards that objective has been the successful establishment of anadromous returns from natural-origin Redfish Lake resident stock gained through a captive broodstock program. The long-term strategy is for the naturally produced population to achieve escapement goals in a manner that is self-sustaining and without the reproductive contribution of hatchery spawners (NMFS 2015f).

In terms of natural production, the Snake River Sockeye Salmon ESU remains at extremely high risk although there has been substantial progress on the first phase of the proposed recovery approach – developing a hatchery-based program to amplify and conserve the stock to facilitate reintroductions. At this stage of the recovery program there is no basis for changing the ESU ratings assigned in prior reviews (Ford 2022).

2.2.6 Status of the Steelhead DPSs

Steelhead spawn in a wide range of conditions ranging from large streams and rivers to small streams and side channels (Myers et al. 2006). Steelhead are rainbow trout (*O. mykiss*) that migrate to and from the ocean (i.e., anadromous). Resident and anadromous life-history patterns are often represented in the same populations, with either life-history pattern yielding offspring of the opposite form. Steelhead are iteroparous, meaning they can spawn more than once. Repeat spawners are called “kelts” (NMFS 2013c).

Productive steelhead habitat is characterized by suitable gravel size, depth, and water velocity, and also by complexity that is primarily added in the form of large and small wood (Barnhart 1986). Steelhead may enter streams and arrive at spawning grounds weeks or even months before spawning and therefore are vulnerable to disturbance and predation. They need cover in the form of overhanging vegetation, undercut banks, submerged vegetation, submerged objects (e.g., logs, rocks), floating debris, deep water, turbulence, and turbidity (Geiger 1973). Their spawn timing must optimize avoiding risks from gravel-bed scour during high stream flows and increasing water temperatures that can become lethal to eggs. Spawning generally occurs earlier in areas of lower elevation, where water temperature is warmer, than in areas of higher elevation, with cooler water temperature.

Depending on water temperature, steelhead eggs may incubate for 35 to 50 days before hatching, and the alevins remain in the gravel 2 to 3 weeks thereafter, until the yolk-sac is absorbed. Generally, fry emergence occurs from March into July, with peak emergence time in April and May. Emergence timing is principally determined by the time of egg deposition and the water temperature during the incubation period. In the Lower Columbia River, emergence timing differs slightly between winter and summer life-history types and among subbasins (NMFS 2013c). These differences may be a function of spawning location (and hence water temperature) or of genetic differences between life-history types.

Following emergence, fry usually move into shallow and slow-moving margins of the stream. As they grow, they inhabit areas with deeper water, with a wider range of velocities, and larger substrate, and they may move downstream to rear in large tributaries or mainstem rivers. Young steelhead typically rear in streams for some time before migrating to the ocean as smolts. Steelhead smolts generally migrate at ages ranging from 1 to 4 years with most smolting after 2 years in freshwater (Busby et al. 1996). Smoltification for steelhead has been described by Thorpe (1994) as a ‘‘developmental conflict’’ whereby juvenile steelhead are faced with three distinct possibilities every year: 1) undergo smoltification, followed by migration to the ocean; 2) begin maturation and attempt to spawn as a resident fish in the following winter (precocial residuals); and 3) remain in freshwater (natal streams, other tributaries, or the main channel of large rivers such as the Columbia River, etc.) and revisit these options in the following year (residuals, collectively). These possibilities represent a case of developmental plasticity where adoption of one of these three life-history strategies is initiated through the interplay of phenotypic expression with environmental and biological cues. In the Lower Columbia River, outmigration of steelhead smolts (of both summer and winter life-history types) generally occurs from March to June, with peak migration usually in April or May (NMFS 2013c).

Both summer and winter steelhead occur in British Columbia, Washington and Oregon; Idaho only has summer steelhead; California is thought to have only winter steelhead (Busby et al. 1996). In the Pacific Northwest, summer steelhead enter freshwater between May and October, and winter steelhead enter freshwater between November and April (NMFS 2011f).

Sampling data suggest that juvenile steelhead migrate directly offshore during their first summer, rather than migrating nearer to the coast. Maturing Columbia River steelhead are found off the coast of Northern British Columbia and west into the North Pacific Ocean (Busby et al. 1996). Fin-mark and CWT data suggest that winter steelhead tend to migrate farther offshore but not as far north into the Gulf of Alaska as summer steelhead (Burgner et al. 1992). Most steelhead spend 2 years in the ocean (ranging from 1 to 4 years) before migrating back to their natal streams (Shapovalov et al. 1954; Narver 1969; Ward et al. 1988). Once in the river, adult steelhead rarely eat and grow little, if at all. Unlike spring-run Chinook salmon, most steelhead do not move upstream quickly to tributary spawning streams.

Steelhead can residualize (i.e., lose the ability to smolt) in tributaries and never migrate to sea, thereby becoming resident rainbow trout. Conversely, progeny of resident rainbow trout can migrate to the sea and thereby become steelhead. Despite the apparent reproductive exchange between resident and anadromous *O. mykiss*, the two life forms remain separated physically, physiologically, ecologically, and behaviorally. Steelhead differ from resident rainbow trout physically in adult size and fecundity, physiologically by undergoing smoltification, ecologically in their preferred prey and principal predators, and behaviorally in their migratory strategy. Given these differences, NMFS believes that the anadromous steelhead populations are discrete from the resident rainbow trout populations (UCSRB 2007).

Steelhead species evaluated in this consultation include Puget Sound steelhead, Lower Columbia River steelhead, Middle Columbia River steelhead, Upper Columbia River steelhead, Upper Willamette River steelhead, and Snake River Basin steelhead. Within these steelhead DPSs 104 demographically independent populations were identified (Table 48). These populations were further aggregated into strata or MPGs, groupings above the population level that are connected by some degree of migration, based on ecological subregions.

Table 48. Steelhead ESA-listed salmon populations considered in this Opinion.

Recovery Domain	DPS	MPGs	Populations
Puget Sound	Puget Sound steelhead	3	32
Willamette/Lower Columbia	Lower Columbia River steelhead	4	23
	Upper Willamette River steelhead	1	4
Interior Columbia	Middle Columbia River steelhead	4	17
	Upper Columbia River steelhead	3	4
	Snake River Basin steelhead	6	24
Totals	**Six DPSs**	**21**	**104**

2.2.6.1 Puget Sound Recovery Domain

2.2.6.1.1 Puget Sound Steelhead DPS

This DPS was listed as a threatened species on May 11, 2007 (72 FR 26722). Its threatened status was reaffirmed on April 14, 2014 (79 FR 20802). Critical habitat for Puget Sound steelhead was designated on February 24, 2016 (81 FR 9251). NMFS' most recent 5-year review for Puget Sound Steelhead was the 2016 5-year review (NMFS 2016b). The NWFSC finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA (Ford 2022) in January 2022. This DPS includes rivers, below natural barriers to migration, in northwestern Washington State that drain to Puget Sound, Hood Canal, and the Strait of Juan de Fuca between the U.S.–Canada border and the Elwha River, inclusive (Figure 43). The PSTRT considered genetic and life-history information from steelhead on the Olympic Peninsula and Washington coast and concluded that there was no compelling evidence to alter the DPS boundary described above. The DPS also includes steelhead from five artificial propagation programs (Table 49).

The Puget Sound Steelhead Recovery Team was established by NMFS and convened in March 2014 to develop a recovery plan for the Puget Sound steelhead DPS. This recovery plan was finalized in December 2019 (NMFS 2019b).

2.2.6.1.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Abundance and productivity are demographic characteristics of a population that determine its ability to persist into the foreseeable future. Spatial structure and diversity, the other two VSP parameters (McElhany et al. 2000), are characteristics that influence a population's ability to persist and evolve over a much longer time course. Spatial structure and diversity consider a population's identifying characteristics—such as utilization of habitat, distribution of spawning aggregations, genetic and phenotypic traits, life-history characteristics such as growth rate, frequency and phenology of reproduction (seasonal run and spawn timing), and age structure. Demographic risks due to low abundance and productivity are typically shorter-term considerations for viability. Spatial structure and diversity buffer a population against short-term environmental fluctuations and long-term climatic change. Compromised spatial structure and diversity are ultimately expressed as longer-term declines in abundance and productivity.

Diversity can be measured through a variety of life-history trait metrics, for example: age structure, run timing, spawning. It is difficult, however, to interpret the significance of changes in life-history traits under changing environmental conditions. Indeed, the responsiveness of life-history traits to environmental change may be a measure of adequate diversity. It is also unclear if the apparent loss of a phenotype is merely an example of plasticity, rather than the loss of the underlying genetic diversity. One of the few quantifiable risks to diversity is the loss of locally adapted traits through introgression by non-native or domesticated hatchery-origin fish (Ford 2022).

Table 49. Puget Sound Steelhead DPS description and MPGs (Ford 2022).

DPS Description	
Threatened	Listed under ESA in 2007; updated in 2014
3 MPGs	32 historical populations
MPG	***Populations***
Hood Canal & Strait of Juan de Fuca	Elwha (winter), Strait of Juan de Fuca Tributaries (winter), Dungeness (summer, winter), Sequim and Discovery Bays Tributaries (winter), West Hood Canal Tributaries (winter), Skokomish (winter), East Hood Canal Tributaries (winter), South Hood Canal Tributaries (winter)
Central/South Sound	East Kitsap Peninsula Tributaries (winter), South Puget Sound Tributaries (winter), Nisqually (winter), Puyallup/Carbon (winter), White (winter), Green (winter), Cedar (winter), North Lake Washington and Lake Sammamish (winter)
Northern Cascades	Snohomish/Skykomish (winter), Pilchuck (winter), Snoqualmie (winter), Tolt (summer), North Fork Skykomish (summer), Stillaguamish (winter), Canyon Creek (summer), Deer Creek (summer), Skagit (summer, winter), Nookachamps Creek (winter), Baker (summer, winter), Sauk (summer, winter), Samish River and Bellingham Bay Tributaries (winter), Nooksack (winter), South Fork Nooksack (summer), Drayton Harbor Tributaries (winter)
Artificial production	
Hatchery programs included in ESU (5)	Green River Natural Program, White River Winter Steelhead Supplementation Program, Hood Canal Supplementation Program, Lower Elwha Fish Hatchery Wild Steelhead Recovery Program, Fish Restoration Facility Program
Hatchery programs not included in ESU (10)	Kendall Creek Hatchery, Whitehorse Pond (Chambers Creek), Tokul Creek Hatchery, Reiter Ponds Hatchery, Dungeness Hatchery, Soos Creek Hatchery, Whitehorse Ponds (Skamania), Reiter Ponds Summer (Skamania), North Fork Skokomish River Winter Steelhead, South Fork Skokomish River Summer Steelhead

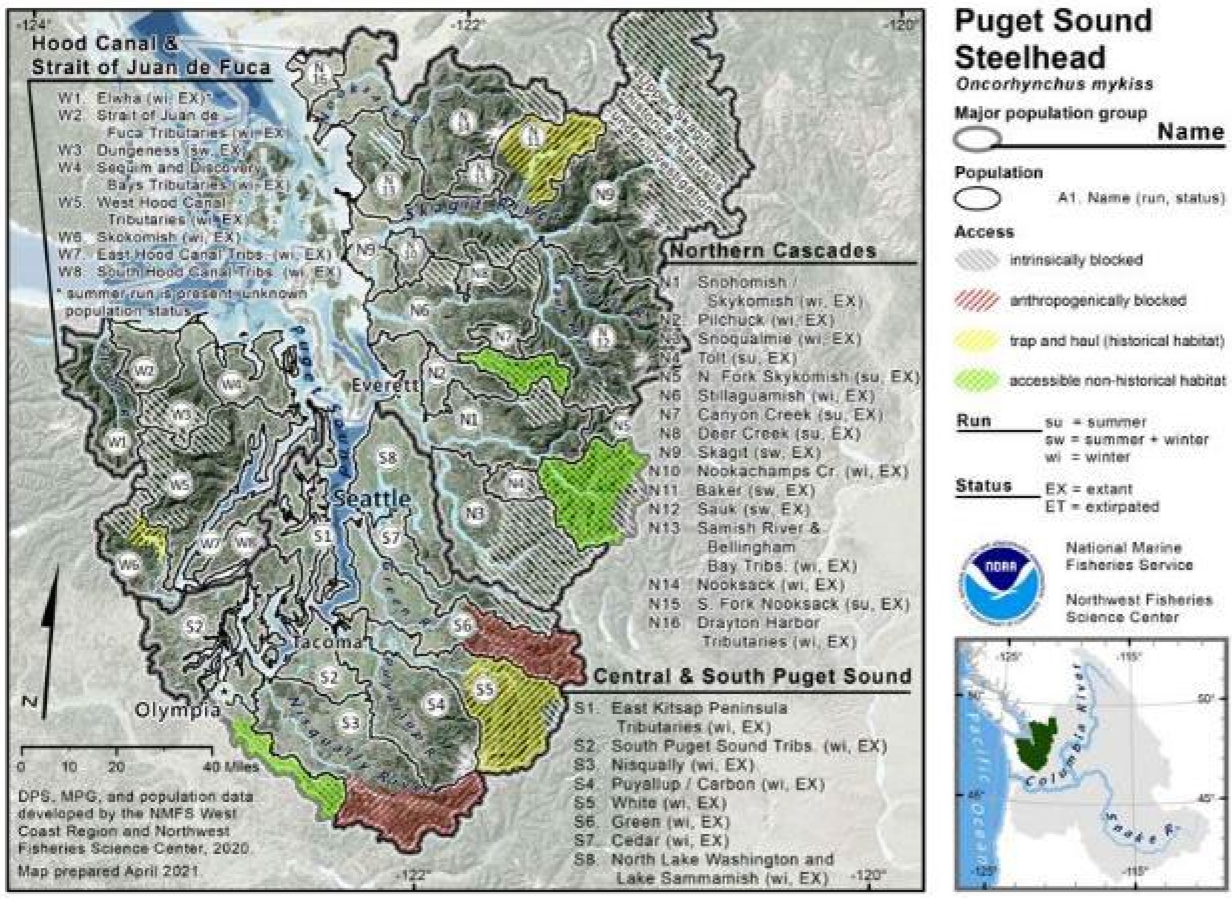


Figure 43. Map of the Puget Sound Steelhead DPS's spawning and rearing areas, identifying 32 demographically independent populations within 3 MPGs. The 3 steelhead MPGs are Northern Cascades, Central & South Puget Sound, and Hood Canal & Strait of Juan de Fuca. Areas where dams block anadromous access to historical habitat is marked in red cross-hatching; and areas where historical habitat is accessible via trap and haul programs is marked in yellow cross-hatching. Areas where the laddering of falls has provided access to non-historical habitat is marked in green cross-hatching. Finally, historically inaccessible portions of watersheds are marked in grey and white cross-hatching (Ford 2022).

2.2.6.1.1.1.1 Abundance and Productivity

The long-term abundance of adult steelhead returning to many Puget Sound rivers has fallen substantially since estimates began for many populations in the late 1970s and early 1980s; however, in the nearer term, there has been a relative improvement in abundance and productivity (Figure 44). Of the 20 datasets analyzed, abundance trends were available for seven of the eight winter-run populations in the Hood Canal & Strait of Juan de Fuca MPG; for five of the eight winter-run populations in the Central & South Puget Sound MPG; and for seven of the 11 winter-run populations, but only one of the five summer-run populations, in the Northern Cascades MPG (Ford 2022). One-third of the populations lack monitoring and abundance data; in most cases it is likely that abundances are very low (Ford 2022). The data submitted only included natural-origin spawners, therefore statistical analyses in Ford (2022) for natural spawners and total spawners were identical.

Recovery targets were calculated in the recovery plan, using a two-tiered approach adjusting for years of low and high productivity (NMFS 2019b). As mentioned above, abundance information is unavailable for approximately one-third of the demographically independent populations, disproportionately so for summer-run populations (Ford 2022). Some population abundance estimates are only representative of part of the population (index reaches, etc.). Where recent five-year abundance information is available, 30% (6/20) are at less than 10% of their high productivity recovery targets (lower abundance target); 65% (13/20) are between 10% and 50% of their targets; and 5% (1/20) are between 50% and 100% (Table 50). Although most populations for which data are available experienced an improvement in abundance during the last five years (Figure 44), significant increases in abundance are necessary for all populations to reach even the high productivity (low abundance) recovery targets (Ford 2022). A key element to achieving recovery is recovering a representative number of both winter- and summer-run steelhead populations, and the restoration of viable summer-run populations would appear to be a long-term endeavor (NMFS 2019b).

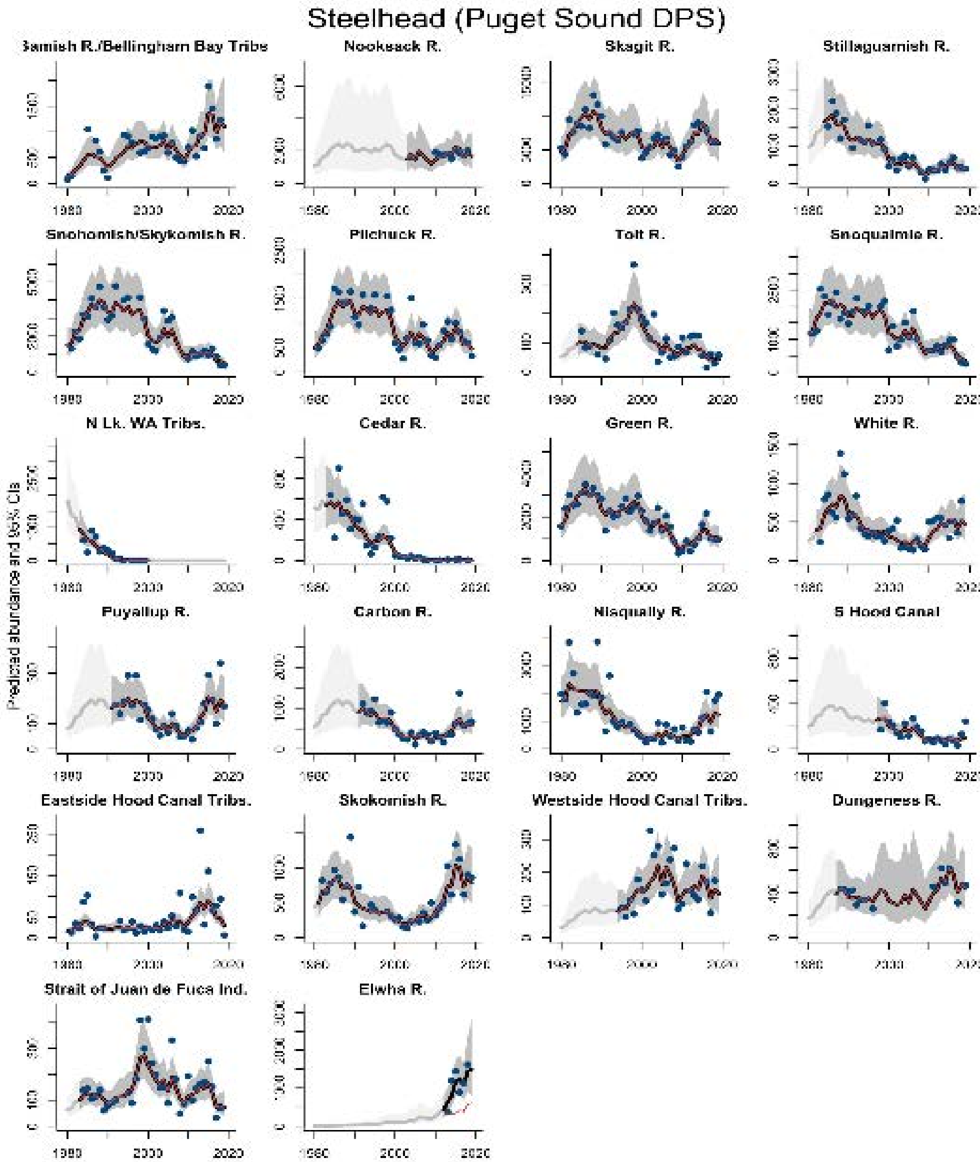


Figure 44. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot. *Note*: For this DPS, all abundance data, except for Elwha River, are only for natural-origin spawners (Ford 2022).

Table 50. Recent (2015–19) 5-year geometric mean of raw natural spawner counts for Puget Sound steelhead populations and population groups compared with Puget Sound steelhead recovery plan high and low productivity recovery targets (NMFS 2019b). Asterisks indicate that the abundance is only a partial population estimate. Superscript *1*s indicate that these populations have a combined target. Abundance is compared to the high-productivity individual population targets. Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > *x* < 50%, yellow = 50% > *x* < 100%, green = >100% (Ford 2022).

Abundance				
			Target	
MPG	Population	2015–19	High productivity	Low productivity
HCSJF	South Hood Canal	91	2,100	7,100
HCSJF	Eastside Hood Canal Tributaries	93	1,800	6,200
HCSJF	Skokomish River	958	2,200	7,300
HCSJF	Westside Hood Canal Tributaries	150	2,500	8,400
HCSJF	Dungeness River	408	1,200	4,100
HCSJF	Strait of Juan de Fuca Independent Tributaries	95	1,000	3,300
HCSJF	Elwha River	358	2,619	2,619
HCSJF	Sequim and Discovery Bay Tributaries	n/a	500	1,700
NC	Samish River/Bellingham Bay Tributaries	1,305*	1,800	6,100
NC	Nooksack River	1,906	6,500	21,700
NC	Skagit River	7,181*.1	15,000	15,000
NC	Stillaguamish River	487	7,000	23,400
NC	Snohomish/Skykomish Rivers	690	6,100	20,600
NC	Pilchuck River	638	2,500	8,200
NC	Snoqualmie River	500	3,400	11,400
NC	Tolt River (SU)	40	300	1,200
NC	Drayton Harbor Tributaries	n/a	1,100	3,700
NC	South Fork Nooksack River (SU)	n/a	400	1,300
NC	Sauk River	1	15,000	15,000
NC	Nookachamps River	1	15,000	15,000
NC	Baker River	1	15,000	15,000
NC	Canyon Creek (SU)	n/a	100	400
NC	Deer Creek (SU)	n/a	700	2,300
NC	North Fork Skykomish River (SU)	n/a	200	500
CSPS	North Lake Washington Tributaries	n/a	4,800	16,000

Abundance				
			Target	
MPG	Population	2015–19	High productivity	Low productivity
CSPS	Cedar River	n/a	1,200	4,000
CSPS	Green River	1,28 2	5,600	18,700
CSPS	White River	130	3,600	12,000
CSPS	Puyallup/Carbon Rivers	136	4,500	15,100
CSPS	Nisqually River	1,36 8	6,100	20,500
CSPS	East Kitsap Tributaries	n/a	2,600	8,700
CSPS	South Sound Tributaries	n/a	6,300	21,200

2.2.6.1.1.1.1.1 Harvest

Harvest of Puget Sound steelhead is limited to terminal tribal net fisheries and recreational fisheries. In response to declining abundance throughout the 1990s, harvest rates were curtailed in 2003, with "wild" harvest rates reduced to below 10% (Ford 2022). Recreational fisheries are mark-selective for hatchery stocks, but some natural-origin steelhead are encountered, with a proportion of those fish subject to hooking mortality and noncompliance. Hatchery steelhead production for harvest is primarily of Chambers Creek winter-run stock (South Puget Sound) and Skamania Hatchery summer-run stock, both of which have been selected for an earlier run timing than natural stocks to minimize fishery interactions (Ford 2022). In tribal net fisheries, most indirect fishery impacts occur in fisheries directed at salmon and hatchery steelhead (Ford 2022). Some additional impacts occur in pre-terminal fisheries, but these are negligible and data are insufficient to attribute them to individual populations. Consequently, harvest impacts are reported as terminal harvest rates.

Harvest rates differ widely among the different rivers, but all have declined since the 1970s and 1980s. Harvest rates on natural steelhead during the earlier period averaged between 10–40%, with some populations in the central and south parts of Puget Sound, such as the Green and Nisqually River populations, experiencing harvest rates over 60%. In recent years, terminal harvest rates have continued to decline, averaging less than 2% over the last five years (Figure 45). In 2018, NMFS approved a resource management plan for the Skagit Basin that allowed for the directed take of ESA-listed steelhead through both net fisheries and the catch-and-release recreational fishery (NMFS 2018b). Under this plan, harvest rates would be based on overall escapement.

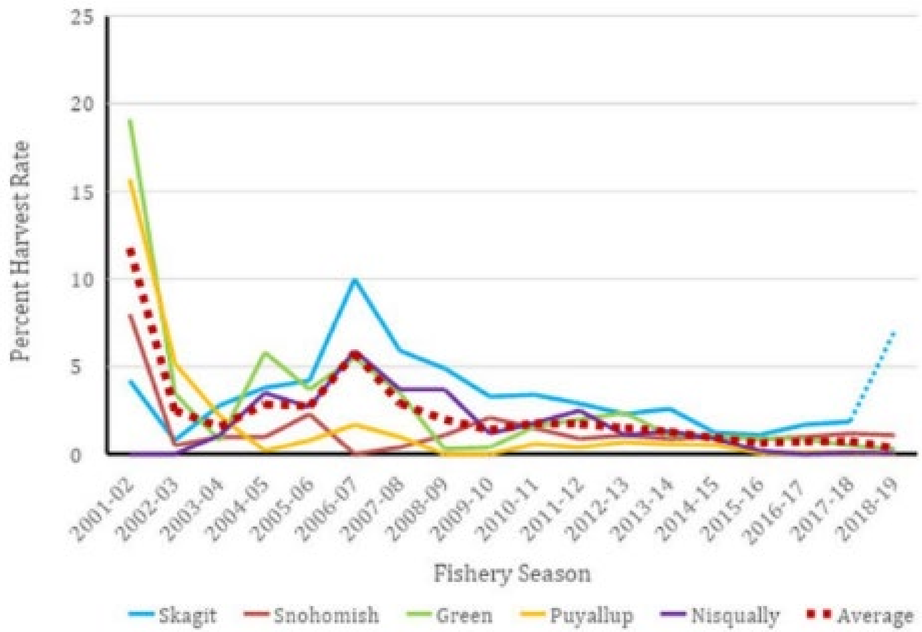


Figure 45. Tribal and non-tribal terminal harvest rate percentages on natural-origin steelhead for five index steelhead populations in Puget Sound, 2001–19. Dotted blue line = post-Skagit Resource Management Plan (RMP) harvest rates, a sliding scale regime based on pre-season terminal escapement estimates to the Skagit River. Dotted red line = average harvest rates across the five populations through 2017, and excludes Skagit River for 2018 and 2019 (Ford 2022).

2.2.6.1.1.1.2 Spatial Structure and Diversity

For spatial structure, the factors the TRT considered for influence on viability included fraction of suitable rearing and spawning habitat occupied by steelhead in the DPS (as measured by intrinsic potential, a measure of historical production or capacity based on the relationship between suitable habitat area and estimates of historical steelhead density). There were a number of events that occurred in Puget Sound during the last review period that affected steelhead habitat. While the 2014 completion of the Elwha and Glines Canyon Dam removals occurred during the previous period, the response of steelhead to this action is still being evaluated. It is clear, however, that steelhead are accessing much of this newly available habitat (Ford 2022). Passage operations have begun on the North Fork Skokomish River to reintroduce steelhead above Cushman Dam; although juvenile collection efficiency is still relatively low, further improvements are anticipated. Similarly, improvements in the adult fish collection facility at

Mud Mountain Dam (White River) are near completion, with the expectation that improvements in adult survival will facilitate better utilization of habitat above the dam (NMFS 2014f). The July 2020 removal of the diversion dam on the Middle Fork Nooksack Dam and of the Pilchuck River Diversion Dam will provide access to important headwater spawning and rearing habitats. Similarly, the proposed modification of Howard Hanson Dam for upstream fish passage and downstream juvenile collection (NMFS 2019c) in the longer term will allow winter steelhead to return to historical headwater habitat in the Green River. It has been hypothesized that summer-run steelhead may have been residualized above Howard Hanson Dam (Myers et al. 2015); restoring access could restore such a run. The effects of these two projects on abundances will not be evident for some time (Ford 2022). Four of the top six steelhead populations identified by Cram et al. (2018) as having habitat blocked by major dams are in the process of having passage restored or improved. While fish passage/collection operations are currently underway in the Baker River for sockeye, coho, and Chinook salmon, returning steelhead are not currently transferred above the Baker River dams. In addition, projects focusing on smaller-scale improvements in habitat quality and accessibility are ongoing. Some 8,000 culverts that block steelhead habitat have been identified in Puget Sound (NMFS 2019b), with plans to address these blockages being extended over many years. Small-scale improvements in habitat, restoration of riparian habitat, and reconnecting side- or off-channel habitats will allow better access to habitat types and niche diversification (Ford 2022). While there have been some significant improvements in spatial structure, it is recognized that land development, loss of riparian and forest habitat, loss of wetlands, and demands on water allocation all continue to degrade the quantity and quality of available fish habitat. In the basins where hatchery production continues, the magnitude and origin of hatchery releases provides one indicator of the potential risks to diversity (Ford 2022).

2.2.6.1.1.1.2.1 Hatcheries

Abundance information provided for the Ford (2022) viability update only included natural-origin spawners, so they were unable to calculate the contribution of hatchery-origin fish on the spawning grounds. Moreover, information on pHOS is rarely obtained in steelhead spawning surveys due to the near absence of carcasses (to identify hatchery marks) (Ford 2022). The recovery plan for Puget Sound steelhead (NMFS 2019b) recognizes that production of hatchery fish of both run types—winter- and summer-run—has posed a considerable risk to diversity in natural steelhead in the Puget Sound Steelhead DPS. Because of the origin and aspects of the propagation history of these fish in Puget Sound, the TRT (Hard et al. 2015) considered continued hatchery production of steelhead to represent a major threat to the diversity VSP component for the DPS. Historically, the majority of winter-run broodstocks produced in hatcheries in the DPS were derived from the Chambers Creek stock (southern Puget Sound), which is considered highly domesticated and has been selected repeatedly for early spawn timing for decades, a trait known to be heritable in salmonids (the natural population is now extinct). Alternatively, summer-run hatchery broodstock are derived from the long-running Skamania

Hatchery stock from the lower Columbia River basin (i.e., out-of-DPS-origin). In response to the risk of introgression between native steelhead populations and hatchery-origin, there has been a general decrease in the overall production from several hatcheries (Ford 2022). In addition, Chambers Creek releases were discontinued in the Elwha and Skagit River basins during the prior viability review period. Chambers Creek programs continue in the Dungeness, Nooksack, Stillaguamish, Snohomish, and Skykomish River basins. Integrated hatchery programs have emerged in place of many of the Chambers Creek programs; these programs incorporate naturally produced returning adults as broodstocks. Programs are currently underway in the Elwha, Green, and White Rivers. It is planned to discontinue the release of Skamania Hatchery-origin summer-run steelhead in the near future from the three programs currently operating (Ford 2022). Additionally, there are plans to develop an integrated hatchery broodstock using local summer-run steelhead; currently the plan is to use unmarked summer-run fish returning to the South Fork Skykomish River. The genetic status of naturally returning summer-run fish to the Skykomish River is currently being studied, and there will likely be new information forthcoming to better understand the level of legacy introgression by Skamania Hatchery summer-run steelhead.

Overall, the risk posed by hatchery programs to naturally spawning populations has decreased during the last five years with reductions in production (especially with non-local programs) and the establishment of locally sourced broodstock (Ford 2022). Unfortunately, whereas competition and predation by hatchery-origin fish can be readily diminished, it is unclear how long it will take to remove the genetic legacy of introgression by natural selection (Ford 2022).

2.2.6.1.1.1.3 Summary

Consideration of the above analyses indicates that the viability of the Puget Sound Steelhead DPS has improved somewhat since the PSTRT concluded that the DPS was at very low viability, as were all three of its constituent MPGs, and many of its 32 demographically independent populations (Hard et al. 2015). Increases in spawner abundance were observed in a number of populations over the prior five years viability review period (Figure 44). These improvements were disproportionately found within the Central & South Puget Sound and the Hood Canal & Strait of Juan de Fuca MPGs, primarily among smaller populations (Ford 2022). The apparent reversal of strongly negative trends among winter-run populations in the White, Nisqually, and Skokomish Rivers abated somewhat the demographic risks facing those populations. Certainly, improvement in the status of the Elwha River steelhead (both winter- and summer-run) following the removal of the Elwha dams reduced the demographic and diversity risk for the demographically independent population and the MPG. Improvements in abundance were not as widely observed in the Northern Cascades MPG. Foremost among the declines were summer- and winter-run populations in the Snohomish River basin. These populations figure prominently as sources of abundance for the MPG and DPS. Additionally, the decline in the Tolt River summer-run steelhead population was especially of concern given that it is the only population for which we have abundance estimates. The demographic and diversity risks to the Tolt River summer-run population are very high. In fact, all summer-run steelhead populations in the Northern Cascades MPG are likely at a very high demographic risk. In spite of improvements in some areas, most populations are still at relatively low abundance levels, with about a third of the populations unmonitored and presumably at very low levels (Ford 2022).

Continued limits on harvest will facilitate population rebuilding during “good” (high escapement) years and buffer against demographic risks under “bad” (low escapement) years. Artificial propagation programs have undergone major changes in both the quantity and quality of hatchery fish produced. Risks to diversity from hatchery programs continue, but at a reduced level. Furthermore, self-sustaining natural populations of winter-run steelhead persist throughout the DPS, albeit at low abundances, and with a very limited risk of interaction with hatchery-origin steelhead (Ford 2022). Overall, the status of summer-run steelhead populations, or the summer-run component of summer/winter populations, remains somewhat precarious (Ford 2022). Information is absent for many populations, and, with the possible exception of the Elwha River, the remaining populations have critically low abundances and/or varying levels of genetic introgression by out-of-DPS sources.

There are a number of planned, ongoing, and completed events that will likely benefit steelhead populations in the future, but have not yet effected changes in adult abundance (Ford 2022). Among these are the removal of the diversion dam on the Middle Fork Nooksack River, passage improvements at Mud Mountain Dam, the ongoing passage program in the North Fork Skokomish River, and the planned passage program at Howard Hansen Dam. Dam removal in the Elwha River and the resurgence of the endemic winter and summer steelhead runs have underscored the benefits of restoring passage. The Elwha River scenario is perhaps somewhat unique in that upstream habitat is in pristine condition, and smolts emigrate into the Strait of Juan de Fuca, not Puget Sound or Hood Canal. Improvements in spatial structure can only be effective if done in concert with necessary improvements in habitat. Habitat restoration efforts are ongoing, but land development and habitat degradation, concurrent with increasing human population in the Puget Sound corridor, may result in a continuing net loss of habitat. Overall, recovery efforts in conjunction with improved ocean and climatic conditions have resulted in an increasing viability trend for the Puget Sound Steelhead DPS, although the extinction risk remains “moderate” (Ford 2022).

2.2.6.1.1.2 Limiting Factors

NMFS, in its listing document and designation of critical habitat (77 FR 26722, May 11, 2007; 76 FR 1392, January 10, 2011), noted that the factors for decline for Puget Sound steelhead also persist as limiting factors. Limiting factors are defined as impaired physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) and associated ecological processes and interactions experienced by the fish that result in reductions in VSP parameters (abundance, productivity, spatial structure, and diversity). This analysis, combined with and the Puget Sound Steelhead Recovery Plan (NMFS 2019b), identified the following factors, as well as ten primary pressures associated with the listing decision for Puget Sound steelhead, and subsequent affirmations of the listing, as those limiting steelhead recovery:

- In addition to being a factor that contributed to the present decline of Puget Sound steelhead populations, the continued destruction and modification of steelhead habitat is the principal factor limiting the viability of the Puget Sound Steelhead DPS into the foreseeable future. This includes agriculture, residential, commercial and industrial development (including impervious surface runoff), timber management activities, water withdrawals and altered flows.
- Fish passage barriers at road crossings and dams.
- Reduced spatial structure for steelhead in the DPS.
- Reduced habitat quality through changes in river hydrology and temperature profile, which are expected to increase with continuing climate change.
- Reduced downstream gravel recruitment, and reduced movement of large woody debris.
- In the lower reaches of many rivers and their tributaries in Puget Sound, urbanization has caused increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows. Altered stream hydrology has resulted in gravel scour, bank erosion, and sediment deposition.
- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, have increased the likelihood of gravel scour and dislocation of rearing juveniles.
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest over the last 25 years. Harvest is not considered a significant limiting factor for PS steelhead due to low harvest rates.
- Threats to genetic diversity and of ecological interactions posed by use of two hatchery steelhead stocks (Chambers Creek and Skamania) inconsistent with wild stock recovery throughout the DPS. However, the risk to the species' persistence that may be attributable to hatchery-related effects has declined since the 2015 status review, based on hatchery risk reduction measures that have been implemented. Improvements in hatchery operations associated with on-going ESA review and determination processes are expected to reduce hatchery-related risks. Further, hatchery releases of steelhead founded from non-native or out of DPS stocks have declined, and are expected to decrease further or cease as a term of recent 4(d) authorizations.
- Declining diversity in the DPS, including the uncertain, but likely weak, status of summer run fish in the DPS.
- High rates of juvenile mortality in estuarine and marine waters of Puget Sound, attributed to marine mammal predation, parasite prevalence, and contaminant loads.

- Concerns regarding existing regulatory mechanisms, including: lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans, lack of reporting and enforcement for some regulatory programs, certain state, local, and private land and water use decisions continue to occur without the benefit of ESA review. State, local, and private decisions can lack a Federal nexus to trigger the ESA Section 7 consultation requirement nor is a ESA Section 10 permit sought for those actions, and thus certain actions allow direct and indirect species take and/or adverse habitat effects.

2.2.6.2 Willamette/Lower Columbia Recovery Domain

2.2.6.2.1 Lower Columbia River Steelhead DPS

On March 19, 1998, NMFS listed the Lower Columbia River Steelhead DPS as a threatened species (63 FR 13347). The threatened status was reaffirmed on January 5, 2006 (71 FR 834) and most recently on April 14, 2014 (79 FR 20802). Critical habitat for Lower Columbia River steelhead was designated on September 2, 2005 (70 FR 52833). The most recent 5-year review for Lower Columbia River steelhead was released in 2022 (NMFS 2022j). The DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between the Cowlitz and Wind Rivers, Washington (inclusive), and the Willamette and Hood Rivers, Oregon (inclusive), as well as multiple artificial propagation programs (Ford 2022; NMFS 2022j).

Inside the geographic range of the DPS, 25 hatchery programs are currently operational, of which only 9 are considered part of the ESA-listed DPS description (Table 51). The Lower Columbia River Steelhead DPS is composed of 23 historical populations, split by summer or winter life history, resulting in four MPGs (Table 51). There are six summer populations and seventeen winter populations (Figure 46).

Lower Columbia River steelhead exhibit a complex life history. Lower Columbia River basin populations include summer and winter steelhead (Ford 2022; NMFS 2022j). The two life-history types differ in degree of sexual maturity at freshwater entry, spawning time, and frequency of repeat spawning (NMFS 2013c). Iteroparity (repeat spawning) rates for Columbia Basin steelhead have been reported as high as 2% to 6% for summer steelhead and 8% to 17% for winter steelhead (Leider et al. 1986; Busby et al. 1996; Hulett et al. 1996).

Historically, winter steelhead were likely excluded from Interior Columbia River subbasins by Celilo Falls. Winter steelhead favor lower elevation and coastal streams. Winter steelhead were historically present in all Lower Columbia River subbasins and also return to other Columbia River tributaries as far upriver as Oregon’s Fifteenmile Creek.

Table 51. Lower Columbia River Steelhead DPS description and MPGs (Ford 2022; NMFS 2022j). The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively (NMFS 2013c).

DPS Description	
Threatened	Listed under ESA in 1998; updated in 2014.
4 MPGs	23 historical populations
MPG	***Populations***
Cascade summer	Kalama (C), North Fork Lewis, East Fork Lewis (G), Washougal (C)
Gorge summer	Wind (C), Hood
Cascade winter	Lower Cowlitz, Upper Cowlitz (C, G), Cispus (C, G), Tilton, South Fork Toutle, North Fork Toutle (C), Coweeman, Kalama, North Fork Lewis (C), East Fork Lewis, Salmon Creek, Washougal, Clackamas (C), Sandy (C)
Gorge winter	Lower Gorge, Upper Gorge, Hood (C, G)
Artificial production	
Hatchery programs included in DPS (9)	Kalama River Wild Winter, Kalama River Wild Summer, Hood River Winter, Cowlitz Trout Hatchery Late Winter, Upper Cowlitz Wild Late, Tilton River Wild Late, Clackamas Hatchery Late Winter, Sandy Hatchery Late Winter, Lewis River Wild Late
Hatchery programs not included in ESU (16)	South Toutle Summer, Washougal Summer, Echo Net Pens Summer, Lewis Summer, Kalama River Skamania Summer, Kalama River Winter, Washougal Winter, Rock Creek Winter, Cowlitz River Summer, Coweeman Winter, Lewis River Winter, Klineline Winter, Eagle Creek National Fish Hatchery Winter, Eagle Creek National Fish Hatchery Early, Clackamas Summer, Sandy River Summer

2.2.6.2.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Lower Columbia River Steelhead DPS, is at moderate risk and remains at threatened status. Each natural population's baseline and target persistence probabilities are summarized in the section below, along with target abundance for each population that would be consistent with delisting. Persistence probability is measured over a 100-year time period and ranges from very low (probability < 40%) to very high (probability >99%).

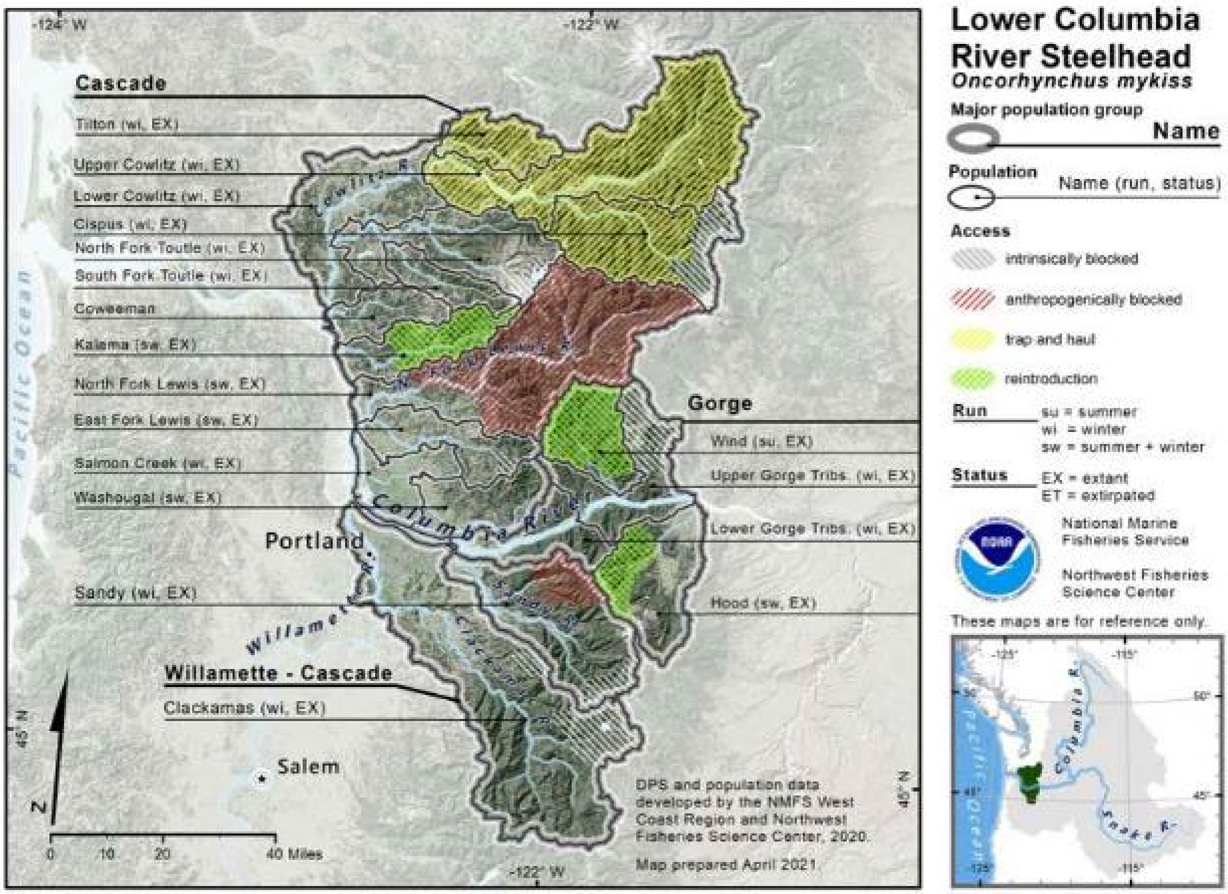


Figure 46. Map of 23 winter and summer-run steelhead demographically independent populations in the Lower Columbia River steelhead DPS. The DPS is separated into two MPGs: Cascade and Gorge. Areas that are accessible (green), accessible only via trap-and-haul programs (yellow), or blocked (cross-hatched), are indicated accordingly (Ford 2022).

2.2.6.2.1.1.1 Abundance and Productivity

The majority of winter-run steelhead demographically independent populations in this DPS continue to persist at low abundance levels (hundreds of fish), with the exception of the Clackamas and Sandy River populations, which have abundances in the low 1,000s (Figure 47, Table 52). Although the five-year geometric abundance means are near recovery plan goals for many populations (Table 52), the recent trends are negative (Ford 2022). Summer-run steelhead demographically independent populations were similarly stable, but also at low abundance levels (Ford 2022). Summer-run demographically independent populations in the Kalama, East Fork Lewis, and Washougal River demographically independent populations are near their recovery plan goals (Table 52); however, it is unclear how hatchery-origin fish contribute to this abundance. The decline in the Wind River summer-run demographically independent population is a source of concern, given that this population has been considered one of the healthiest of the summer runs (Ford 2022). It is not clear whether the declines observed represent a short-term oceanic cycle, longer-term climatic change, or other systematic issue. While other species in the Lower Columbia River steelhead DPS have a coastal-oriented distribution, steelhead are wide-ranging, and it is more difficult to predict the effects of changes in ocean productivity. Alternatively, most steelhead juveniles remain in freshwater for two years prior to emigration, making them more susceptible to climatic changes in temperature and precipitation (Ford 2022).

Spatial structure and abundances are limited due to migrational blockages in the Cowlitz and Lewis River basins (Ford 2022). The efficiency of adult passage and juvenile collection programs remain an issue. Recent studies indicate that there have been improvements in juvenile collection efficiency in the Cowlitz River, but these have not been reflected yet in adult abundance (Ford 2022).

The juvenile collection facilities at North Fork Dam in the Clackamas River appear to be successful enough to support increases in abundance. It is not possible to determine the risk status of this DPS given the uncertainty in abundance estimates for nearly half of the demographically independent populations (Ford 2022). Additionally, nearly all of the demographically independent populations for which there are abundance data exhibited negative abundance trends in 2018 and 2019 (Figure 47).

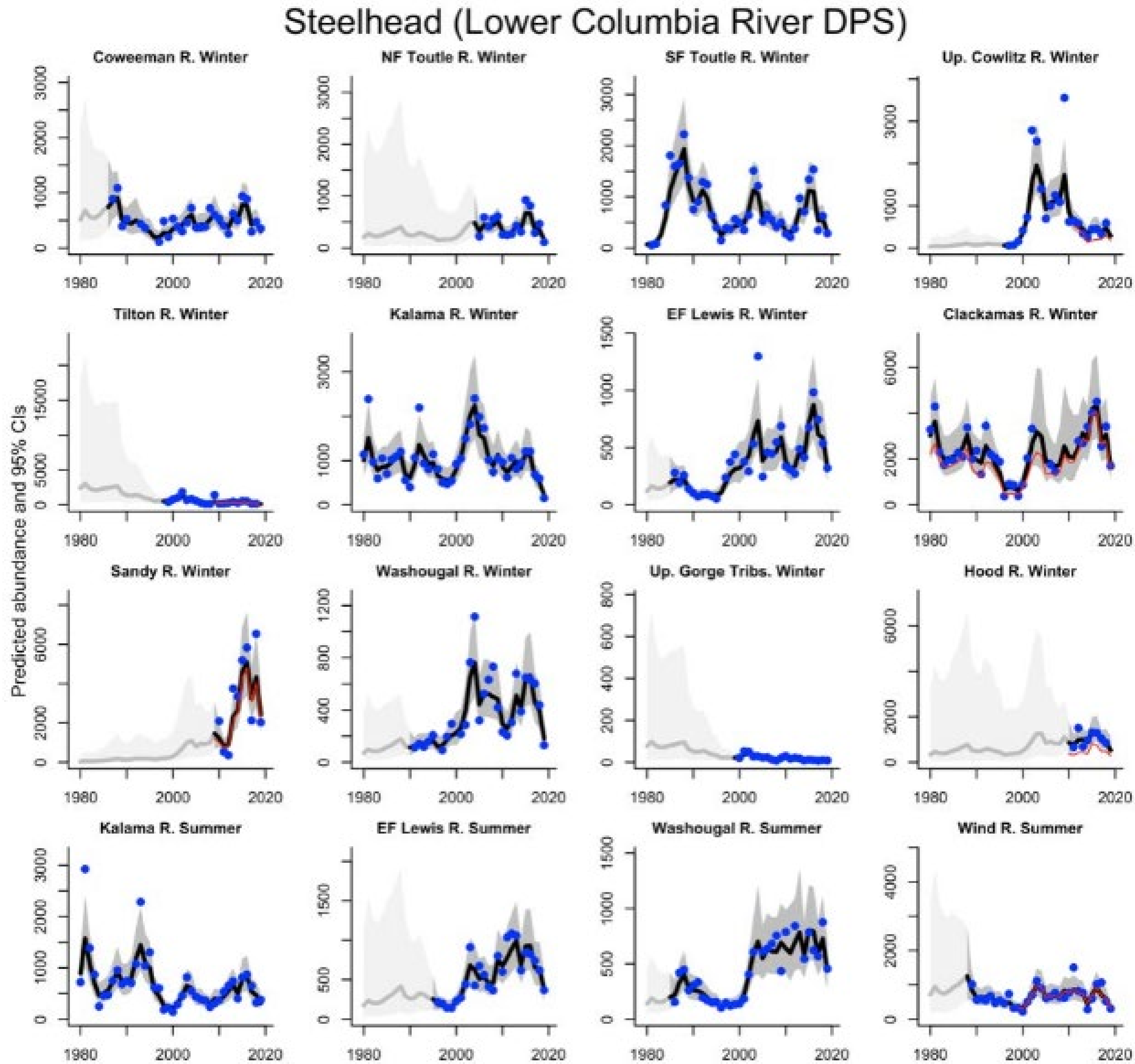


Figure 47. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

Table 52. Current 5-year geometric mean of raw natural-origin spawner abundances and recovery targets for Lower Columbia River steelhead demographically independent populations. Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > *x* < 50%, yellow = 50% > *x* < 100%, green = >100%. Numbers in parentheses represent total (hatchery and natural-origin) spawners; * = high uncertainty about whether they are meeting their recovery targets (Ford 2022). W and Su indicate winter and summer populations.

		Abundance	
Stratum	**Population**	**2015–19**	**Target**
Cascade	Coweeman River (WA) W	(528)*	500
	North Fork Toutle River (WA) W	(409)*	600
	South Fork Toutle River (WA) W	(660)*	600
	Upper Cowlitz River (WA) W	199	500
	Lower Cowlitz River (WA) W	n/a	400
	Cispus River (WA) W	n/a	500
	Tilton River (WA) W	241	200
	Kalama River (WA) W	(618)*	600
	North Fork Lewis River (WA) W	n/a	400
	East Fork Lewis River (WA) W	(613)*	500
	Salmon Cr (WA) W	n/a	n/a
	Clackamas River (OR) W	2,819	10,671
	Sandy River (OR) W	3,615	1,519
	Washougal River (WA) W	(427)*	350
	Kalama River (WA) Su	(560)*	500
	North Fork Lewis River (WA) Su	n/a	500
	East Fork Lewis River (WA) Su	(650)*	500
	Washougal River (WA) Su	(644)*	500
Gorge	Upper Gorge (Wind R) (WA) W	(9)	n/a
	Lower Gorge (WA & OR) W	n/a	300
	Hood River (OR) W	650	2,079
	Wind River (WA) Su	627	1,000
	Hood River (OR) Su	n/a	2,008

2.2.6.2.1.1.1.1 Harvest

Steelhead from this DPS are incidentally intercepted in mainstem treaty, and non-treaty commercial and recreational fisheries targeting non-listed hatchery and naturally produced Chinook salmon, and non-listed steelhead (Ford 2022). Mark-selective net fisheries in the mainstem Columbia River can result in post-release mortality rates of 10% to over 30%, although there is considerable disagreement on the overall rate (NMFS 2022j). Recreational fisheries targeting marked hatchery-origin steelhead encounter natural-origin fish at a relatively high rate, but hooking mortalities are generally lower than those in the net fisheries (NMFS 2022j). Estimated mortality for naturally produced winter-run steelhead has averaged 0.3% (Ford 2022). The current *U.S. v. Oregon* Management Agreement (2018–2027) has, on average, maintained reduced harvest impacts for Lower Columbia River steelhead fisheries with 2018 harvest rates for winter-run steelhead in mainstem fisheries at 0.3% (NMFS 2018e), and with harvest rates for unclipped summer-run steelhead of 0.5% in fisheries below Bonneville Dam and 0.01% in the Bonneville Pool (Ford 2022).

2.2.6.2.1.1.2 Spatial Structure and Diversity

There have been a number of large-scale efforts to improve accessibility (one of the primary metrics for spatial structure) in this DPS. This includes providing access to the upper Cowlitz River basin (Upper Cowlitz, Cispus, and Tilton Rivers) beginning in 1996 with the initiation of juvenile collection at Cowlitz Falls Dam (Ford 2022) and structural and operational changes at the Cowlitz Falls Dam, most recently in 2017, to improve collection efficiency (Ford 2022). The collection of steelhead kelts remains another area where further improvement is needed, with trap-and-haul operations occurring on the Lewis River since 2012 for winter-run steelhead, reestablishing access to historically occupied habitat above Swift Dam (RKM 77.1).

Environmental variability may make it difficult to assess the effects of changes in spatial structure, except through longer-term datasets (Ford 2022). These changes include the removal of Marmot Dam in 2007 and the Little Sandy River diversion dam in 2008, and Hemlock Dam on Trout Creek (Wind River) in 2009. Additionally, beginning in 2010, unmarked steelhead have been passed above the hatchery weir on Cedar Creek, a tributary to the Sandy River. Powerdale Dam was removed in 2010, and while this dam previously provided for fish passage, removal of the dam is thought to eliminate passage delays and injuries. Finally, there has been a trap-and-haul operation at the sediment retention structure on the North Fork Toutle River since 1989. Transportation above the sediment retention structure is limited to two small tributaries, and only a small proportion of the upper basin is utilized (Ford 2022). In addition, there have been numerous recovery actions throughout the DPS to remove or improve the thousands of culverts and other small-scale passage barriers (Ford 2022).

2.2.6.2.1.1.2.1 Hatcheries

Total steelhead hatchery releases in the Lower Columbia River steelhead DPS have decreased slightly since the 2015 viability review (NWFSC 2015), declining from an average annual release (summer- and winter-run) of 3 million smolts annually to 2.75 million (Ford 2022). Some populations continue to have relatively high fractions of hatchery-origin spawners while others have relatively few (Table 53), though data for many populations is not available. Washington Department of Fish and Wildlife (WDFW) is currently developing a new methodology to assess the hatchery contribution to naturally spawning steelhead. In addition, the North Fork Toutle River, East Fork Lewis River, and Wind River have been established by WDFW as natural gene banks. Where hatcheries maintain multiple stocks of steelhead, there continues to be some risk of hybridization between different run times or native and out-of-DPS stocks (Ford 2022).

Hatchery managers have continued to implement and monitor changes in Lower Columbia River steelhead hatchery management since the 2016 5-year review (NMFS 2022j). One of the major changes in hatchery operations was the elimination of the out-of-DPS steelhead broodstock programs in the Kalama River (Ford 2022). Previously, out-of-DPS releases were terminated in the Cowlitz and East Fork Lewis Rivers (NWFSC 2015). Out-of-DPS releases continue in the Clackamas River, Sandy River, South Fork Toutle River, and Washougal River with the release of Skamania Hatchery summer-run steelhead (Ford 2022).

Table 53. Five-year mean of fraction natural Lower Columbia River steelhead spawners (sum of all estimates divided by the number of estimates), 1995–2019. Blanks (—) indicate that no estimate was available in that 5-year range (Ford 2022).

Population[a]	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Upper Cowlitz River (winter)	Cascade	—	—	—	0.70	0.49
Tilton River (winter)	Cascade	—	—	—	1.00	0.79
Clackamas River (winter)	Cascade	0.67	0.76	0.75	0.96	0.92
Sandy River (winter)	Cascade	—	—	—	0.92	0.94
Hood River (winter)	Gorge	—	—	—	0.37	0.61
Wind River (summer)	Gorge	—	—	—	—	—

[a] Note that the Kalama (Cascade Summer), North Fork Lewis (Cascade Summer), East Fork Lewis (Cascade Summer), Washougal (Cascade Summer), Hood (Gorge Summer), Lower Cowlitz (Cascade Winter), Cispus (Cascade Winter), South Fork Toutle (Cascade Winter), North Fork Toutle (Cascade Winter), Coweeman (Cascade Winter), Kalama (Cascade Winter), North Fork Lewis (Cascade Winter), East Fork Lewis (Cascade Winter), Salmon Creek (Cascade Winter), Washougal (Cascade Winter), Sandy (Cascade Winter), Lower Gorge (Gorge Winter), and Upper Gorge (Gorge Winter) populations are not included due to low abundances or lack of monitoring and available data, as discussed further in Ford (2022).

2.2.6.2.1.1.3 Summary

Although a number of demographically independent populations exhibited increases in their five-year geometric means, others still remain depressed, and neither the winter- nor summer-run MPGs are near viability in the Gorge (Ford 2022). There have been improvements in diversity through hatchery reform, especially the elimination of non-native Chambers Creek winter-run broodstock and some Skamania Hatchery-origin broodstock (Ford 2022). Population-specific data on hatchery contribution to the naturally spawning populations is not available for most demographically independent populations, and diversity criteria cannot be properly evaluated without them (Ford 2022). Spatial structure remains a concern, especially for those populations that rely on adult trap-and-haul programs and juvenile downstream passage structures for sustainability. Overall, the Lower Columbia River steelhead DPS is therefore considered to be at “moderate” risk (Ford 2022), and the viability is largely unchanged from the prior review (NWFSC 2015).

2.2.6.2.1.2 Limiting Factors

Understanding the limiting factors and threats that affect the Lower Columbia River Steelhead DPS provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting is to ensure that the underlying limiting factors and threats have been addressed. There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Lower Columbia River Steelhead DPS. Factors that limit the DPS have been, and continue to be, hydropower development on the Columbia River and its tributaries, habitat degradation, hatchery effects, fishery management and harvest decisions, and ecological factors including predation and environmental variability. The recovery plan consolidates the information regarding limiting factors and threats for the Lower Columbia River Steelhead DPS available from various sources (NMFS 2013c).

The recovery plan provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Chapter 4 of the plan describes limiting factors on a regional scale and how they apply to the four listed species from the Lower Columbia River considered in the plan. Chapter 9 of the plan discusses the limiting factors that pertain specifically to Lower Columbia River steelhead with details that apply to the winter and summer populations and MPGs in which they reside. The discussion of limiting factors in Chapter 9 is organized to address the following:

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

- Predation.

Chapter 4 includes additional details on large scale issues including:

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

Rather than repeating this extensive discussion from the recovery plan, these discussions in Chapters 4 and 9 are incorporated here by reference. However, summarizing the recovery plan's discussion of the threat hatchery induced selection poses to Lower Columbia River steelhead indicates population-level effects of hatchery fish interbreeding with natural-origin fish was a primary limiting factor that we expect to reduce greatly in the near future by NMFS adopting and WDFW implementing terms and conditions from its opinion evaluating Mitchell Act funding criteria (NMFS 2017o) which terminated out-of-DPS releases of hatchery steelhead inside this DPS's geographic range. While the low to very low baseline persistence probabilities of most Lower Columbia River steelhead populations reflect low productivity, abundance is improving, and it's likely that genetic and life-history diversity have been reduced as a result of pervasive hatchery effects and population bottlenecks (NMFS 2013c), but this will be alleviated by switching to hatchery broodstocks whose genetic origins are from those in the Lower Columbia River (NMFS 2017o).

2.2.6.2.2 Upper Willamette River Steelhead DPS

On March 25, 1999, NMFS listed the Upper Willamette River Steelhead DPS as a threatened species (64 FR 14517). The threatened status was reaffirmed in 2006 and most recently on April 14, 2014 (79 FR 20802). Critical habitat for the DPS was designated on September 2, 2005 (70 FR 52848). NMFS' most recent five-year review for Upper Willamette River Steelhead was completed in 2024 (NMFS 2024d). The NWFSC finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA in January 2022 (Ford 2022).

The Upper Willamette River Steelhead DPS includes all naturally spawned anadromous winter-run steelhead originating below natural and manmade impassable barriers in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River (Ford 2022). One MPG, composed of four historical populations, comprises the Upper Willamette River Steelhead DPS (Figure 48). Inside the geographic range of the DPS, 1 hatchery program is currently operational, though it is not included in the DPS (Table 54)(Ford 2022; NMFS 2024d). Hatchery summer-run steelhead also occur in the Willamette River Basin but are an out-of-basin stock that is not included as part of this DPS (Ford 2022). As explained above NMFS (2005b), genetic resources can be housed in a hatchery program but for a detailed description of how

NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS see NMFS (2005b).

Table 54. Upper Willamette River Steelhead DPS description and MPGs. The designations "(C)" and "(G)" identify core and genetic legacy populations, respectively (McElhany et al. 2003; Jones 2015; NWFSC 2015; Ford 2022; NMFS 2024d).

DPS Description	
Threatened	Listed under ESA as threatened in 1999; updated in 2014.
1 MPG	4 historical populations
MPG	***Populations***
Willamette	South Santiam River (C,G), North Santiam River (C,G), Molalla River, Calapooia River
Artificial production	
Hatchery programs included in DPS (0)	n/a
Hatchery programs not included in DPS (1)	Upper Willamette summer (in South Santiam River, North Santiam, McKenzie, MF Willamette)

Before the construction of a fish ladder at Willamette Falls in the early 1900s, flow conditions allowed steelhead to ascend Willamette Falls only during the late winter and spring. Presently, the majority of the Upper Willamette River winter steelhead run return to freshwater from January through April, pass Willamette Falls from mid-February to mid-May, and spawn from March through June (with peak spawning in late April and early May). Upper Willamette River steelhead currently exhibit a stream-type life-history with individuals exhibiting yearling life-history strategy. Juvenile steelhead rear in headwater tributaries and upper portions of the subbasins from one to four years (average of two years), then as smoltification occurs in April through May, they migrate downstream through the mainstem Willamette and Columbia River estuaries and into the ocean. The downstream migration speed depends on factors including river flow, temperature, turbidity, and others, with the quickest migration occurring with high river flows. Upper Willamette River steelhead can forage in the ocean for one to two years (average of two years) and during this time period, are thought to migrate north to waters off Canada and Alaska and into the North Pacific including the Alaska Gyre (Myers et al. 2006; ODFW et al. 2011). This species may spawn more than once; however, the frequency of repeat spawning is relatively low. The repeat spawners are typically females that spend more than one year post spawning in the ocean and spawn again the following spring (ODFW et al. 2011).

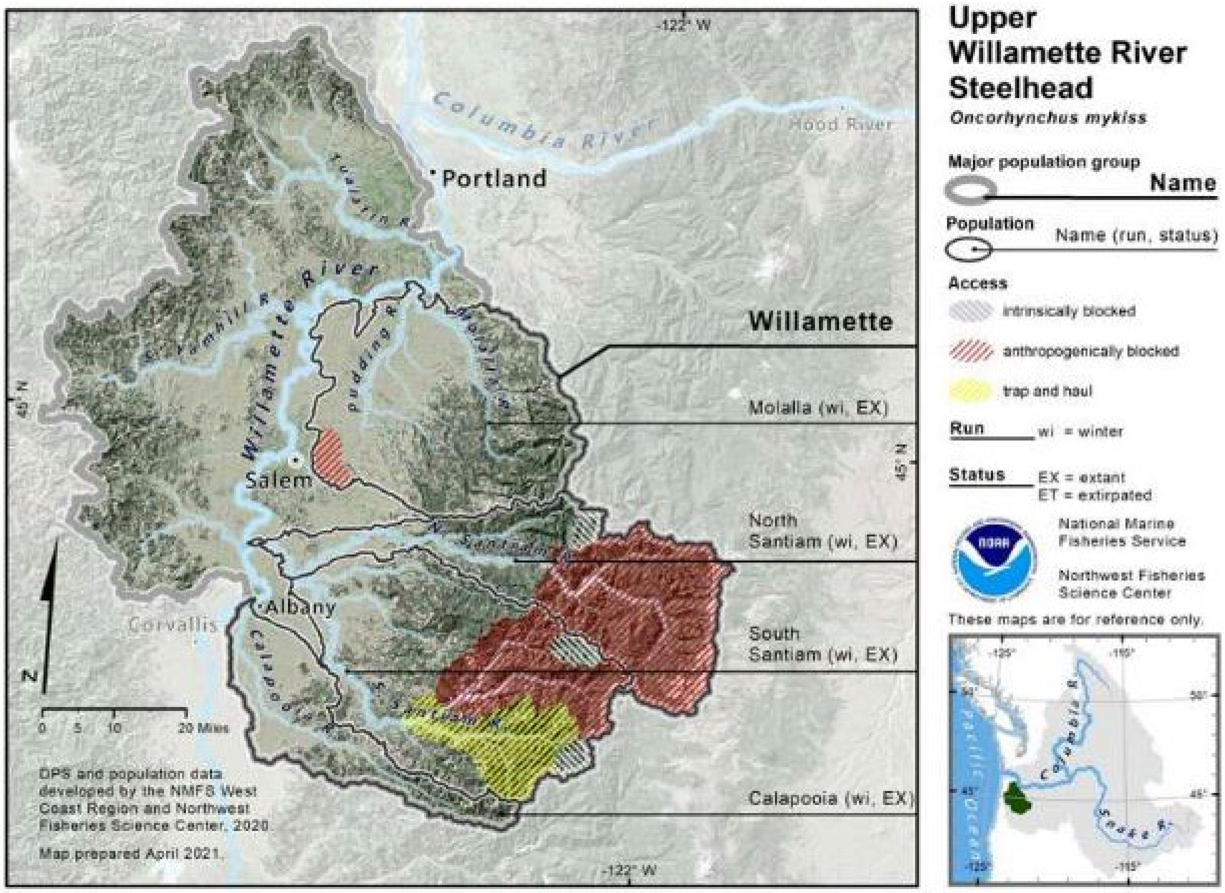


Figure 48. Map of the four demographically independent populations in the Upper Willamette River steelhead DPS (Ford 2022).

2.2.6.2.2.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Upper Willamette River Steelhead DPS, is at moderate risk and remains at threatened status. The most recent viability status update (Ford 2022) determined that there has been no change in the biological risk category since the prior reviews of these populations (NWFSC 2015). There is still uncertainty in the underlying causes of the long-term declines in spawner abundances that these populations have experienced. Although the recent magnitude of these declines is relatively moderate, continued declines would be a cause for concern (Ford 2022).

2.2.6.2.2.1.1 Abundance and Productivity

Abundance and life history data for steelhead in the Upper Willamette River steelhead DPS are very limited. Consistent redd counts are available for some index reaches, primarily in Thomas and Crabtree Creeks, but these do not provide population-level indicators of abundance (Ford 2022). Specific research projects have been undertaken to estimate steelhead spawning abundance and distribution (Mapes et al. 2017), but only in specific basins and for a limited number of years (Ford 2022). Adult counts were also available from observations at Willamette Falls, Bennett Dam, the Minto Dam fish facility (North Santiam River), and Foster Dam (South Santiam River). While steelhead counts at Willamette Falls provide a DPS-wide estimate of abundance, there is some uncertainty in distinguishing native late-winter steelhead from non-native early-winter steelhead and unmarked non-native summer steelhead (Johnson et al. 2018b; Weigel et al. 2019). Counts of steelhead in eastside tributaries provide more population-specific information on abundance (Ford 2022). Winter steelhead counts at Willamette Falls provide a complete count of fish returning to the DPS (Ford 2022).

Populations in this DPS have experienced long-term declines in spawner abundance (Figure 49, Table 55). The underlying cause(s) of these declines is not well understood. Returning adult winter steelhead do not experience the same deleterious water temperatures as the spring-run Chinook salmon, and prespawn mortalities are not likely to be significant (Ford 2022). Although the recent magnitude of these declines is relatively moderate, continued declines would be a cause for concern. Improvements to Bennett Dam fish passage and operational temperature control at Detroit Dam may be providing some stability in abundance in the North Santiam River demographically independent population (Ford 2022). It is unclear if sufficient high-quality habitat is available below Detroit Dam to support the population reaching its VSP recovery goal (Table 56), or if some form of access to the upper watershed is necessary to sustain a "recovered" population (Ford 2022). Similarly, the South Santiam River basin may not be able to achieve its recovery goal status without access to historical spawning and rearing habitat above Green Peter Dam (Quartzville Creek and the Middle Santiam River) and/or improved juvenile downstream passage at Foster Dam (Ford 2022).

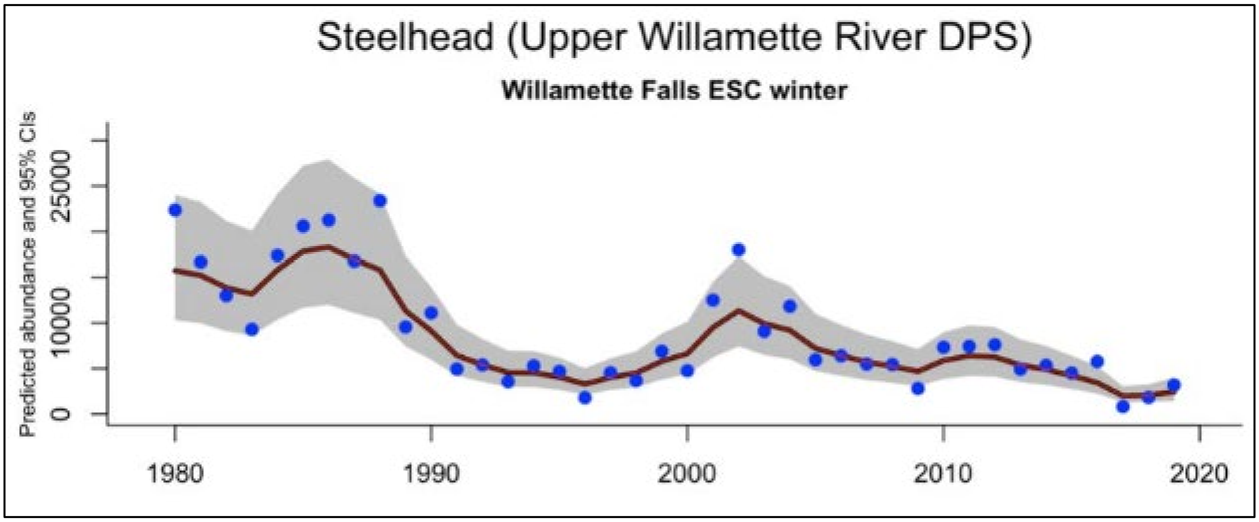


Figure 49. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

Table 55. Five-year geometric mean of raw natural spawner counts for the Upper Willamette River steelhead DPS. Willamette Falls counts represent counts of prespawning winter steelhead, and include an unknown number of non-native early-winter-run steelhead. Population estimates (1990–2009) were calculated using proportional assignment of Willamette Falls counts. In parentheses, 5-year geometric mean of raw total spawner counts is shown. A value only in parentheses means that a total spawner count was available but no or only one estimate of wild spawners available. The geometric mean was computed as the product of counts raised to the power 1 over the number of counts available (2 to 5). A minimum of 2 values were used to compute the geometric mean. Percent change between the 2 most recent 5-year periods is shown on the far right (Ford 2022).

Population	MPG	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019	% change
Willamette Falls W	Cascade	(5,619)	(3,961)	(10,293)	(5,028)	(6,431)	(2,628)	(–59)
Calapooia River W	Cascade	149 (149)	219 (219)	406 (406)	214 (214)	—	—	—
Molalla River W	Cascade	1,182 (1,462)	726 (798)	1,924 (1,924)	1,357 (1,357)	—	—	—
North Santiam River W	Cascade	2,495 (2,928)	1,953 (2,388)	3,333 (3,423)	2,500 (2,500)	—	—	—
South Santiam River W	Cascade	1,940 (1,940)	1,277 (1,277)	2,440 (2,440)	1,594 (1,594)	—	—	—

Table 56. Current 5-year geometric mean of raw natural-origin abundances and recovery scenario targets presented in the recovery plan (ODFW et al. 2011) for Upper Willamette River steelhead demographically independent populations. Willamette Falls count includes non-native early-winter-run steelhead, and therefore represents an upper limit to total abundance. No tributary abundance estimates are available and the approximate total DPS abundance is represented by the Willamette Falls count. This total abundance is compared to the sum of the individual demographically independent population targets. Colors indicate the relative proportion of the recovery target currently obtained: red = <10%, orange = 10% > *x* < 50%, yellow = 50% > *x* < 100%, green = >100% (Ford 2022).

		Abundance	
MPG	**Population**	**2015–19**	**Target**
Cascade	Willamette Falls Winter Count	2,628	n/a
	Molalla River Winter	n/a	3,000
	North Santiam River Winter	n/a	8,358
	South Santiam River Winter	n/a	3,913
	Calapooia River Winter	n/a	498
	Total:	2,628	15,769

2.2.6.2.2.1.1.1 Harvest

There is no consumptive fishery for winter steelhead in the Upper Willamette River (Ford 2022). Winter-run steelhead in the Columbia River fishery are intercepted at a low rate, 0.2% (ODFW et al. 2020; Ford 2022). Similarly, due to differences in return timing between native winter-run steelhead, introduced hatchery summer-run steelhead, and hatchery spring-run Chinook salmon, the encounter rates for winter-run fish in the Willamette River recreational fishery are thought to be low (Ford 2022). Tribal fisheries occurring above Bonneville Dam have not been shown to impact Upper Willamette River steelhead (Ford 2022).

2.2.6.2.2.1.2 Spatial Structure and Diversity

The exclusion of steelhead from headwater reaches in the North and South Santiam Rivers continues to be the primary spatial structure concern (Ford 2022). Although the historical distribution of steelhead is not precisely known, indications are that the majority of steelhead and salmon spawning occurred above the current site of Detroit Dam in the North Santiam River (Mattson 1948; Ford 2022). Similarly, in the South Santiam River, while steelhead have access to habitat above Foster Dam, the Middle Santiam River is blocked by Green Peter Dam. Conditions in the South Santiam River above Foster Reservoir may be limiting, due to high

(>20°C) summer prespawning holding temperatures, and poor incubation and rearing habitat conditions (the river is prone to scour during flood episodes) (Ford 2022). Alternatively, historical habitat (Quartzville Creek and the Middle Santiam River) above Green Peter Dam may provide better spawning and rearing habitat than the upper South Santiam River (Ford 2022). Efforts to provide passage for steelhead in the North Santiam River are still at the planning stage, and little effort has been allocated to providing passage at Green Peter Dam. Foster Dam provides volitional downstream passage, but juvenile and kelt survivals need to improve further to meet passage criteria. Smaller-scale upstream and downstream passage issues exist throughout the DPS, related in part to water withdrawal structures. While some of these have been addressed, others remain (Ford 2022).

2.2.6.2.2.1.2.1 Hatcheries

Winter-run steelhead hatchery programs were terminated in the late 1990s (Ford 2022). Currently, the only steelhead programs in the upper Willamette River release Skamania Hatchery-origin summer-run steelhead. Annual total releases for the entire Upper Willamette River DPS (including the McKenzie and Middle Fork Willamette Rivers) have decreased slightly, to 500,000 (2015–19; Figure 50). Still, the legacy of previous hatchery-origin releases persists in the upper Willamette River.

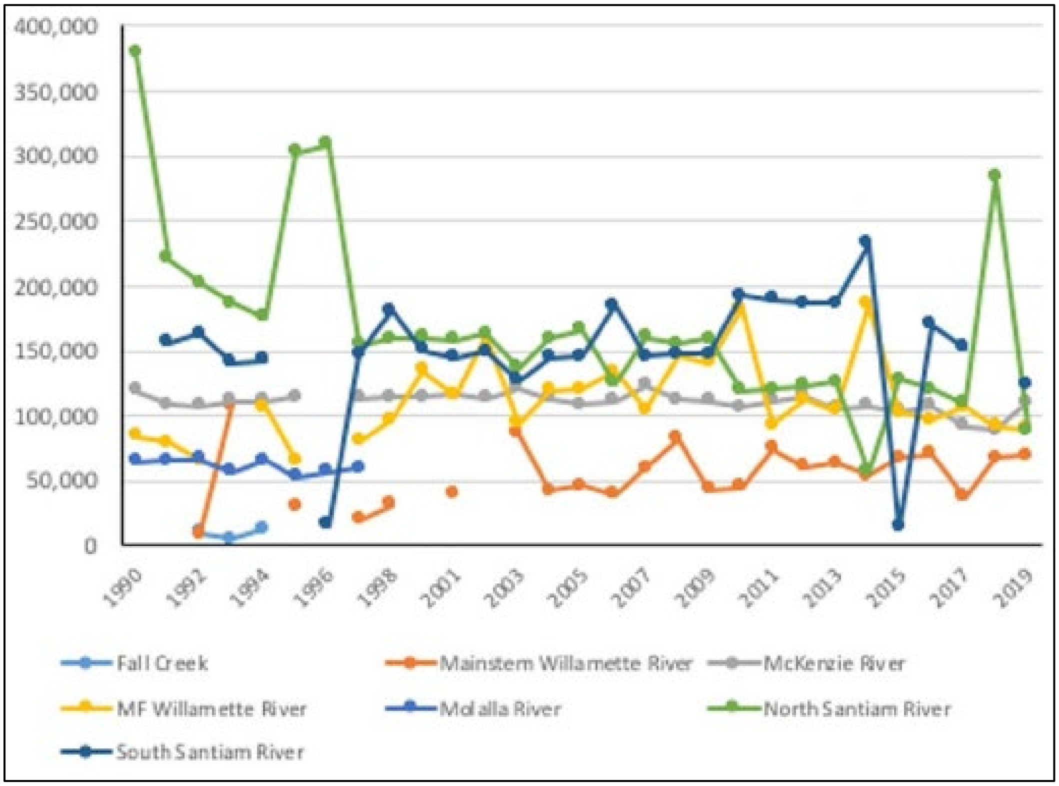


Figure 50. Annual releases of hatchery-origin (Skamania stock) summer-run steelhead into Willamette River tributaries, by sub-basin. Releases of fish <2.5 g are not included. All releases are considered to be out-of-DPS in origin. Data from the Regional Mark Information System (https://www.rmpc.org, April 2020)(Figure reproduced from Ford (2022)).

A recent genetic study by Johnson et al. (2021b) evaluated the level of colonization by non-native stocks and introgression between non-native summer-run steelhead and non-native early-winter-run steelhead with native late-winter-run steelhead. This work identified westside tributaries as being largely occupied by non-native early-winter-run steelhead originating from releases by Big Creek Hatchery (Lower Columbia River, Southwest Washington steelhead DPS) beginning in the 1920s. With the exception of the lower North Santiam River, native late-winter steelhead are still predominant in eastside tributaries that drain the Cascades north of the McKenzie River (Ford 2022). Areas above dams in the North and South Santiam Rivers and in the Calapooia River appear to have little influence from non-native introductions. Below dams in the North Santiam River, pure non-native summer-run and a non-native Big Creek winter-run steelhead were detected, as were hybrids between non-native and native steelhead (Ford 2022). Below dams of the South Santiam River, introgression from introduced steelhead was higher than in the North Santiam. In the Molalla River, the predominant genotype was native winter-run steelhead (40%), but a substantial number of hybrids between the native and non-native steelhead were detected. The presence of pure and hybrid summer-run steelhead in the Molalla River is surprising, because summer run steelhead have not been released in this basin since 1998 (Ford 2022). The establishment of feral non-native summer and winter runs of steelhead poses a genetic risk to the native populations (Ford 2022). In addition, the presence of hatchery-reared and feral hatchery-origin fish may affect the growth and survival of juvenile late-winter steelhead (Ford 2022).

While the diversity goals are partially achieved through the closure of winter-run steelhead hatchery programs in the upper Willamette River, there is some concern that the summer-run steelhead releases in the North and South Santiam Rivers may be influencing the viability of native steelhead (Ford 2022). Overall, none of the populations in the DPS are meeting their recovery goals (Table 56).

2.2.6.2.2.1.3 Summary

Overall, the Upper Willamette River steelhead DPS continued to decline in abundance (Table 55, Figure 49). Although the most recent counts at Willamette Falls and the Bennett Dams in 2019 and 2020 suggest a rebound from the record 2017 lows, it should be noted that current "highs" are equivalent to past lows (Ford 2022). Uncertainty in adult counts at Willamette Falls are a concern, given that the counts represent an upper bound on DPS abundance. Radio-tagging studies suggest that a considerable proportion of "winter" steelhead ascending Willamette Falls do not enter the tributaries that are considered part of this DPS; these fish may be non-native early-winter steelhead that appear to have colonized the western tributaries, misidentified summer steelhead, late-winter steelhead that have colonized tributaries not historically part of the DPS, or hybrids between native and non-native steelhead (Ford 2022).

Introgression by non-native summer-run steelhead continues to be a concern. Genetic analysis suggests that there is introgression among native late-winter steelhead and summer-run steelhead (Van Doornik et al. 2015; Johnson et al. 2018b; Johnson et al. 2021b). Accessibility to historical spawning habitat is still limited, especially in the North Santiam River (Ford 2022). Efforts to provide juvenile downstream passage at Detroit Dam are well behind the proscribed timetable (NMFS 2008i), and passage at Green Peter Dam has not yet entered the planning stage. Much of the accessible habitat in the Molalla, Calapooia, and the lower reaches of the North and South Santiam Rivers is degraded and under continued development pressure (Ford 2022). Although habitat restoration efforts are underway, the time scale for restoring functional habitat is considerable. While the viability of the DPS appears to be declining, the recent uptick in abundance may provide a short-term demographic buffer (Ford 2022). Furthermore, increased monitoring is necessary to provide quantitative verification of sustainability for most of the populations. In the absence of substantial changes in accessibility to high-quality habitat, the DPS will remain at "moderate-to-high" risk (Ford 2022). Overall, the Upper Willamette River steelhead DPS is therefore at "moderate-to-high" risk, with a declining viability trend (Ford 2022).

2.2.6.2.2.2 Limiting Factors

Understanding the limiting factors and threats that affect the Upper Willamette River Steelhead DPS provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting the species is to ensure that the underlying limiting factors and threats have been addressed. The populations in this DPS have experienced long-term declines in spawner abundances, but the underlying cause(s) of these declines is not well understood (Ford 2022). There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Upper Willamette River Steelhead DPS. Factors that limit the DPS have been, and continue to be, loss and degradation of spawning and rearing habitat, impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the abundance, productivity, spatial structure, and diversity of the populations in this DPS (Ford 2022).

The recovery plan (ODFW et al. 2011) provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Chapter 5 of the recovery plan describes the limiting factors on a regional scale and how those factors affect the populations of the Upper Willamette River Steelhead DPS (ODFW et al. 2011). Chapter 7 of the recovery plan addresses the recovery strategy and actions for the entire DPS. The recovery plan addresses the topics of:

- Flood control/hydropower management,
- Land management,
- Harvest-related effects,
- Hatchery-related effects,
- Habitat access,
- Impaired productivity and diversity,
- Effects of predation, competition, and disease,
- Impaired growth and survival,
- Physical habitat quality, and
- Water quality.

Rather than repeating this extensive discussion from the recovery plan, is the discussion in Chapters 5 and 7 are incorporated here by reference.

In summary, the new information in the 2022 viability assessment (Ford 2022) does not indicate a change in the biological risk category of this DPS since the previous review (NWFSC 2015). Although direct biological performance measures for this DPS indicate some progress to date toward meeting its recovery criteria, there is no new information to indicate that its extinction risk has been reduced significantly. The DPS continues to demonstrate a stable overall low abundance pattern. More definitive genetic monitoring of steelhead ascending Willamette Falls in tandem with radio tagging work needs to be undertaken to estimate the total abundance of this DPS (NMFS 2011b; NWFSC 2015; Ford 2022).

The release of non-native summer steelhead continues to be a concern. Genetic analysis suggests that there is some level of introgression among native late-winter steelhead and summer steelhead (Friesen et al. 1999). Accessibility to historical spawning habitat is still limited, especially in the North Santiam River. Much of the accessible habitat in the Molalla River, Calapooia River, and lower reaches of North and South Santiam Rivers is degraded and under continued development pressure. Although habitat restoration efforts are underway, the time scale for restoring functional habitat is considerable (NWFSC 2015; Ford 2022).

2.2.6.3 Interior Columbia Recovery Domain

2.2.6.3.1 Middle Columbia River Steelhead DPS

On March 25, 1999, NMFS listed the Middle Columbia River Steelhead DPS as a threatened species (64 FR 14517). The threatened status was reaffirmed in 2006 and most recently on April 14, 2014 (79 FR 20802). Critical habitat for the Middle Columbia River steelhead was designated on September 2, 2005 (70 FR 52808). The most recent 5-year review for Middle Columbia River steelhead was released in 2022 (NMFS 2022g).

The Middle Columbia River Steelhead DPS includes naturally spawned anadromous *O. mykiss* originating from below natural and manmade impassable barriers from the Columbia River and its tributaries upstream of the Wind River (Washington) and Hood River (Oregon) to and including the Yakima River, excluding the Upper Columbia River tributaries (upstream of Priest Rapids Dam) and the Snake River. Four MPGs, composed of 19 historical populations (2 extirpated), comprise the Middle Columbia River Steelhead DPS (Figure 51). Inside the geographic range of the DPS, six hatchery steelhead programs are currently operational. Four of these artificial programs are included in the DPS (Table 57). As explained by NMFS (2005b), genetic resources can be housed in a hatchery program, but for a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS see NMFS (2005b).

Table 57. Middle Columbia River Steelhead DPS description and MPGs (Ford 2022; NMFS 2022g). Winter steelhead populations are denoted by an asterisk.

DPS Description	
Threatened	Listed under ESA as threatened in 1999; updated in 2014.
4 MPGs	19 historical populations (2 extirpated, 17 extant)
MPG	***Populations***
Cascades Eastern Slope Tributaries	Deschutes River Eastside, Deschutes River Westside, Fifteenmile Creek*, Klickitat River*, Rock Creek*
John Day River	John Day River Lower Mainstem Tributaries, John Day River Upper Mainstem Tributaries, Middle Fork John Day River, North Fork John Day River, South Fork John Day River
Yakima River	Naches River, Satus Creek, Toppenish Creek, Yakima River Upstream Mainstem
Umatilla/Walla Walla Rivers	Touchet River, Umatilla River, Walla Walla River
Artificial production	
Hatchery programs included in DPS (4)	Touchet River Endemic summer, Yakima River Kelt Reconditioning summer (in Satus Creek, Toppenish Creek, Naches River, and Upper Yakima River), Umatilla River summer, Deschutes River summer
Hatchery programs not included in DPS (2)	Walla Walla River Release summer, Skamania Stock Release summer

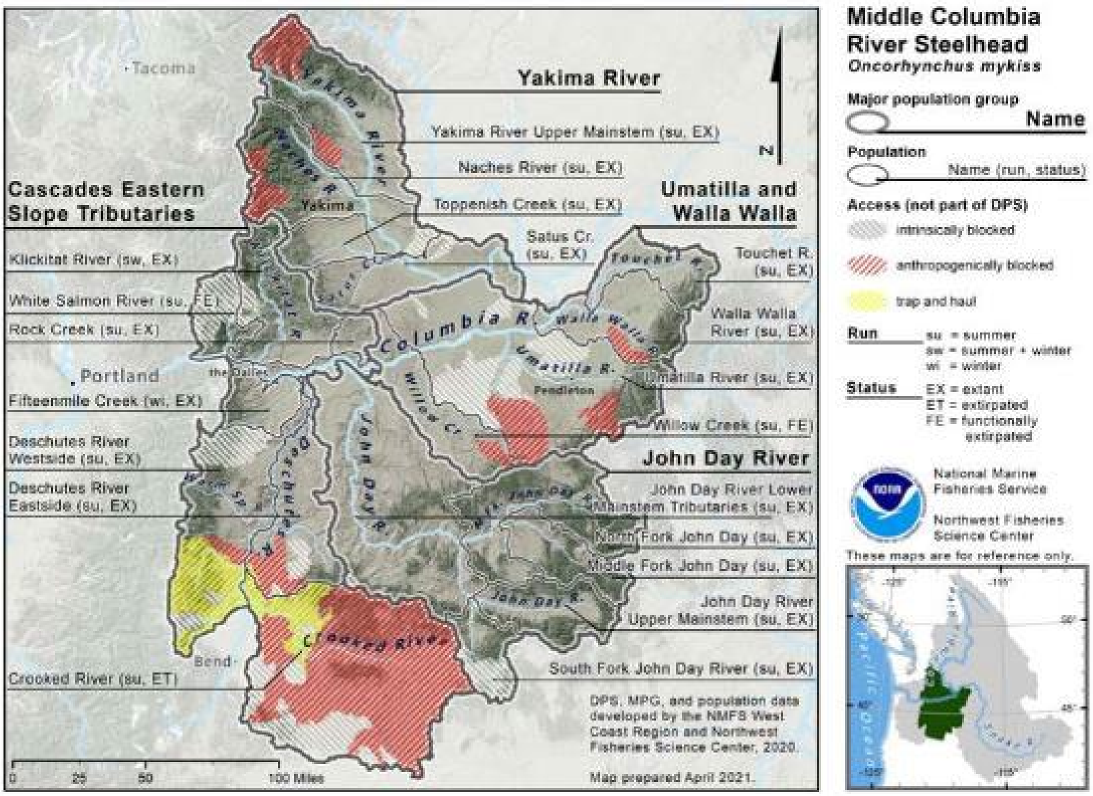


Figure 51. Map of the Middle Columbia River steelhead DPS's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

Steelhead exhibit more complex life history traits than other Pacific salmonid species as discussed in previous steelhead specific DPS sections above. While Middle Columbia River steelhead share these general life history traits, it is worth noting they typically reside in marine waters for two to three years before returning to their natal stream to spawn at four or five years of age (NMFS 2011f).

The Middle Columbia River Steelhead DPS includes the only populations of inland winter steelhead in the Columbia River (those populations in the Lower Columbia River Steelhead DPS and Upper Willamette River Steelhead DPS that are classified as "winter" are geographically close enough to the Pacific Ocean so as not to be considered inland steelhead). Variations in the migration timing exist between populations.

Most fish in this DPS smolt at two years and spend one to two years in salt water before re-entering freshwater, where they may remain up to a year before spawning (Howell et al. 1985; Olsen et al. 1992). Age-2-ocean steelhead dominate the steelhead run in the Klickitat River, whereas most other rivers with summer steelhead produce about equal numbers of age 1- and 2-ocean fish. Juvenile life stages (i.e., eggs, alevins, fry, and parr) inhabit freshwater/riverine areas throughout the range of the DPS. Parr usually undergo a smolt transformation as 2-year-olds, at which time they migrate to the ocean. A non-anadromous form of *O. mykiss* (i.e., rainbow or redband trout) co-occurs with the DPS, which only consists of the anadromous form and its residuals, and juvenile life stages of the two forms can be very difficult to differentiate. In addition, hatchery steelhead are also distributed throughout the range of this DPS (NMFS 2011f).

2.2.6.3.1.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Middle Columbia River Steelhead DPS, is at moderate risk and remains at threatened status. The most recent viability assessment (Ford 2022) used updated abundance and hatchery contribution estimates provided by regional fishery managers to inform the analysis on this DPS. However, this DPS has been noted as difficult to evaluate in several of the reviews for reasons such as: the wide variation in abundance for individual natural populations across the DPS, chronically high levels of hatchery strays into the Deschutes River, and a lack of consistent information on annual spawning escapements in some tributaries (Ford 2022).

Many steelhead populations along the West Coast can co-occur with conspecific populations of resident rainbow trout. Previous status reviews (Ford et al. 2011) have recognized that there may be situations where reproductive contributions from resident rainbow trout could mitigate short-term extinction risk for some steelhead DPS populations (Good et al. 2005). In the Middle Columbia River Steelhead DPS, a study in the Deschutes River Basin found no evidence of a significant contribution from the very abundant resident form to anadromous returns (Zimmerman et al. 2000). A study of natural-origin steelhead kelts in the Yakima Basin, comparing chemical patterns in otoliths (i.e., inner ear bones) with water chemistry sampling, found evidence for variable maternal resident contribution rates to anadromous returns, with a high degree of variation among natal areas and across years (Courter et al. 2013; NWFSC 2015).

2.2.6.3.1.1.1 Abundance and Productivity

Abundance data series are available for all five extant populations in the Cascades Eastern Slope Tributaries MPG (Ford 2022). Spawner abundance estimates for the most recent five years decreased relative to the prior review for all five populations (Figure 52). The 15-year trend in natural-origin spawners was strongly negative for the Deschutes River Eastside population, and essentially zero for the Fifteenmile Creek and Deschutes River Westside runs (Figure 52).

Preliminary estimates of escapements into Rock Creek were recently developed, and a high proportion of the observed steelhead in that system were out-of-basin strays (Ford 2022).

Total escapement and natural-origin escapements declined relative to the prior five-year review (NWFSC 2015) for all five of the John Day MPG populations (Ford 2022). Only two of the five populations in this group had a positive 15-year trend in natural-origin abundance (Figure 52), driven largely by peak returns in the early 2000s, despite the strong declines over the most recent five-year period (Figure 52).

Five-year geometric mean natural-origin and total abundance (Figure 52) estimates for each of the four populations in the Yakima MPG also decreased sharply relative to the previous review (NWFSC 2015). All four populations in this group have exhibited increases since the early 1990s, with similar peak return years as other DPS populations, but, given recent declines, the 15-year trend for all populations was essentially zero (Figure 52).

Total spawning escapements have decreased in the most recent brood cycle for all three populations in the Umatilla/Walla Walla MPG as well (Figure 52). The 15-year trend in natural-origin abundance was positive for the Umatilla River population and slightly negative for Touchet River (Figure 52), though the trends are shallow (Ford 2022). Population productivity was cyclical, with most populations following a similar pattern of growth and decline (Ford 2022).

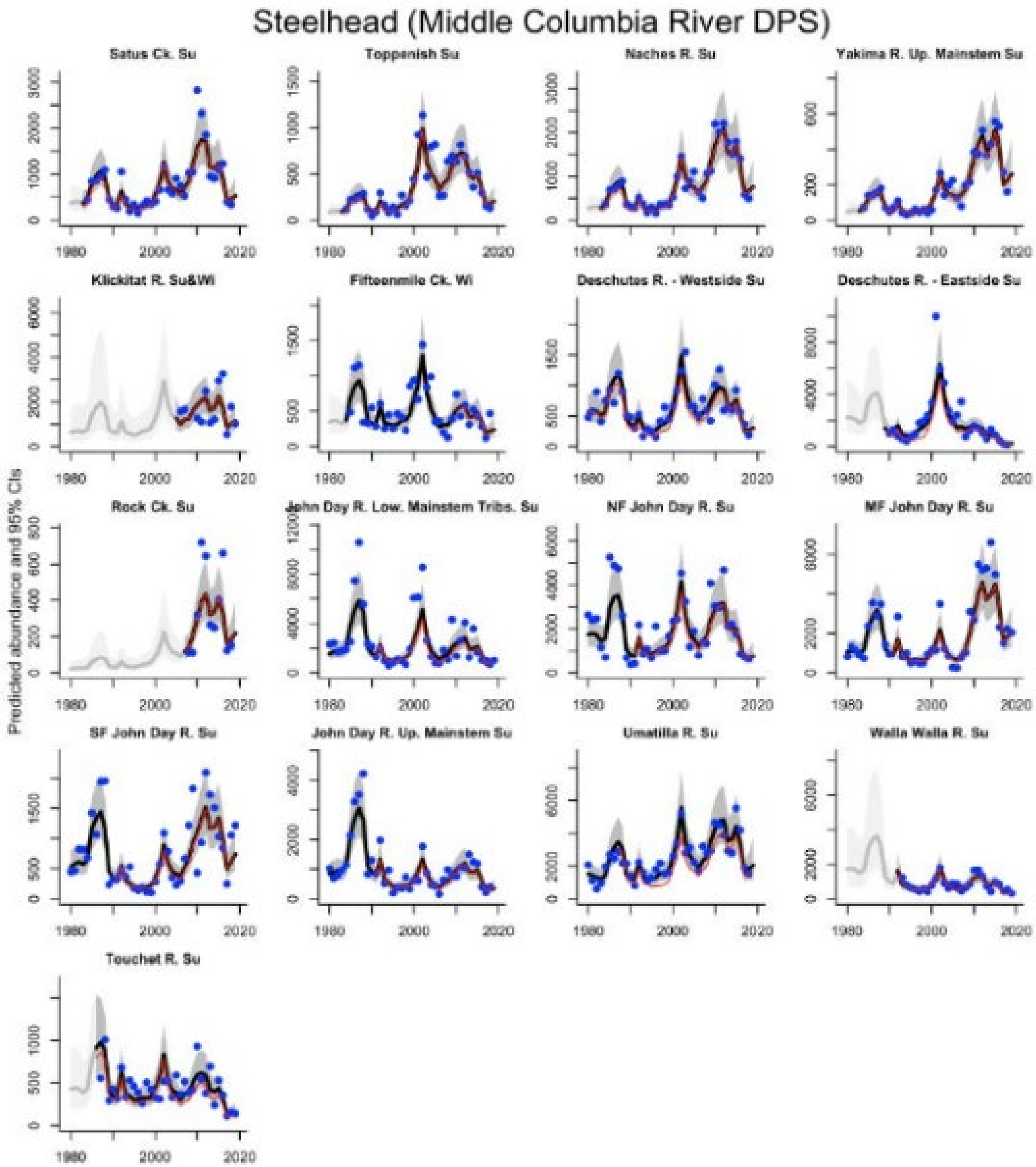


Figure 52. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022).

Table 58. Summary of Middle Columbia River steelhead DPS viability relative to the ICTRT viability criteria, grouped by MPG. Natural spawning = most-recent 10-yr geometric mean (range). ICTRT productivity = 20-yr geometric mean for parent escapements below 75% of population threshold. Current A/P estimates are geometric means. Range in annual abundance, standard error, and number of qualifying estimates for productivities in parentheses (Ford 2022).

	Abundance/productivity (A/P) metrics				Spatial structure/diversity (SS/D) metrics			
Population	**ICTRT threshold**	**Natural spawning**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes**	**Diversity risk**	**Integrated SS/D risk**	**Overall risk rating**
Klickitat River	1,000	1,462 (SD 919)	1.07 (0.12 8/20)	Moderate	Low	Moderate	Moderate	Maintained
Fifteenmile Creek	500	378 (SD 170)	2.12 (0.19 8/20)	Moderate	Very Low	Low	Low	Maintained
Deschutes River Westside	1,500 (1,000)	538 (SD 306)	1.10 (0.15 18/20)	High	Low	Moderate	Moderate	High
Deschutes River Eastside	1,000	604 (SD 453)	1.75 (0.29 7/20)	Moderate	Low	Moderate	Moderate	Maintained
Rock Creek	500	298 (SD 232)	—	High	Moderate	Moderate	Moderate	High
Crooked River (extirpated)	2,000	—	—	—	—	—	—	Extirpated
White Salmon River (extirpated)	500	—	—	—	—	—	—	Extirpated (recolonizing)
John Day River Lower Mainstem Tributaries	2,250	1,424 (SD 1,026)	2.72 (0.19 12/20)	Moderate	Very Low	Moderate	Moderate	Maintained
North Fork John Day River	1,000	1,852 (SD 1,343)	3.31 (0.16 2/20)	Very Low	Very Low	Low	Low	Highly Viable
Middle Fork John Day River	1,000	3,371 (SD 1,811)	4.49 (0.27 8/20)	Very Low	Low	Moderate	Moderate	Viable
South Fork John Day River	500	943 (SD 552)	2.45 (0.29 10/20)	Very-Low	Very Low	Moderate	Moderate	Viable
John Day River Upper Mainstem	1,000	738 (SD 418)	1.56 (0.16 14/20)	Moderate	Very Low	Moderate	Moderate	Maintained
Satus Creek	1,000 (500)	1,064 (SD 777)	1.92 (0.30 3/20)	Low	Low	Moderate	Moderate	Viable
Toppenish Creek	500	407 (SD 231)	3.35 (0.23 9/20)	Moderate	Low	Moderate	Moderate	Maintained
Naches River	1,500	1,340 (SD 601)	2.00 (0.23 6/20)	Moderate	Low	Moderate	Moderate	Maintained
Yakima River Upper Mainstem	1,500	346 (SD 129)	1.73 (0.15 20/20)	Moderate	Moderate	High	High	High

	Abundance/productivity (A/P) metrics				Spatial structure/diversity (SS/D) metrics			
Population	**ICTRT threshold**	**Natural spawning**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes**	**Diversity risk**	**Integrated SS/D risk**	**Overall risk rating**
Umatilla River	1,500	2,747 (SD 1,108)	0.98 (0.27 6/20)	Moderate	Moderate	Moderate	Moderate	Maintained
Walla Walla River	1,000	713 (SD 511)	1.79 (0.18 8/20)	Moderate	Moderate	Moderate	Moderate	Maintained
Touchet River	1,000	253 (SD 222)	0.91 (0.09 19/20)	High	Low	Moderate	Moderate	High

2.2.6.3.1.1.1.1 Harvest

Encounters of steelhead in the ocean fisheries are rare and incidental impacts to steelhead in ocean fisheries targeting other species are inconsequential to very rare (PFMC 2023d). The majority of harvest related impacts on Middle Columbia River steelhead occurs in the mainstem Columbia River. Fisheries that impact Middle Columbia River steelhead are subject to fisheries management provisions of the *U.S. v. Oregon* Management Agreement. A new 10-year agreement (2018–2027) was adopted since the 2016 5-year review (NMFS 2016m) and limits on incidental harvest rates for Middle Columbia River steelhead have remained the same (NMFS 2018e). Pursuant to the Agreement, non-treaty fisheries (Figure 53) are managed subject to limits on the winter and summer components of the Middle Columbia River steelhead DPS of 2% and 4%, respectively (NMFS 2018e). Over the past six years (run year 2014 through 2019), harvest rates of Middle Columbia River steelhead have remained relatively constant. In non-treaty fisheries (Figure 53), harvest rates on the winter and summer components of the DPS have averaged 0.4% and 1.8%, respectively (NMFS 2022g). There are no specific limits for impacts in treaty fisheries for Middle Columbia River steelhead, but harvest rates have remained the same since the 2016 5-year review (NMFS 2016m) and have not changed under the 2018 Management Agreement (NMFS 2018e).

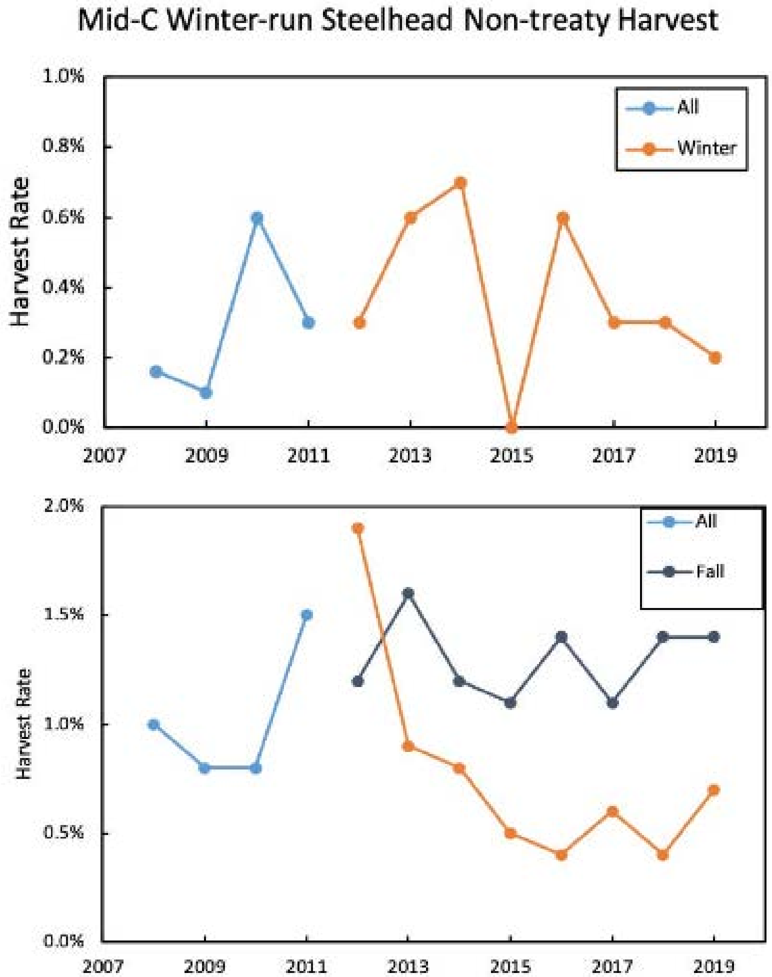


Figure 53. Non-treaty harvest impacts on natural winter- (upper panel) and summer-run (lower panel) steelhead from the Middle Columbia River steelhead DPS. As of 2012, harvest management reporting is broken into two periods, FA and W/SP/SU, where previously reporting was done by full calendar year (Figure reproduced from Ford (2022)).

2.2.6.3.1.1.2 Spatial Structure and Diversity

Updated information on spawner and juvenile rearing distribution does not support a change in status due to spatial structure improvements for Middle Columbia River steelhead DPS populations, though the newly re-established run in the White Salmon River and the developing time series of population data from the Klickitat River and Rock Creek do warrant consideration in the DPS recovery plan (Ford 2022). Viability indicators for within-population diversity have changed for some populations since the previous viability review (NWFSC 2015), although in most cases the changes have not been sufficient to shift composite risk ratings for a particular population (Ford 2022).

2.2.6.3.1.1.2.1 Hatcheries

The proportions of hatchery-origin returns in natural spawning areas varies between the MPGs within the Middle Columbia River steelhead DPS (Table 59), with low proportions observed in the Yakima and John Day River MPGs, and larger proportions in the Umatilla/Walla Walla and Cascades Eastside Slope Tributaries MPGs (Ford 2022). The management of the fish being propagated at the various programs has changed recently to focus production on individual populations using only fish from within that population (NMFS 2007e; 2008k; 2017o; 2018e; 2019d).

Out-of-DPS hatchery strays may pose a risk to some Oregon Middle Columbia River steelhead populations, particularly the Eastside and Westside Deschutes and John Day populations (NMFS 2022g). NMFS's 2016 5-year review (NMFS 2016m) noted a decrease in the proportion of strays in the John Day River basin and identified a need for additional information to assess the effects of hatchery strays on natural production in the Deschutes River and John Day River systems (NMFS 2016m).

Genetic sampling has documented that the Rock Creek steelhead population is highly introgressed with the Snake River Basin steelhead DPS (85% of adult PIT-tag detections with known juvenile origin were of Snake River origin) (NMFS 2022g). With additional data, it should become apparent if steelhead in Rock Creek are a viable naturalized subpopulation or are sustained by an annual influx of stray steelhead originating from the Snake River (NWFSC 2015). Snake River steelhead transport rates have decreased as a result of earlier migrations and higher spill, and transported Snake River steelhead are known to stray at higher rates than fish that migrated in-river as juveniles (NMFS 2022g).

Hatchery programs operated in middle Columbia tributaries – including the Umatilla, Walla Walla, and Westside Deschutes River subbasins – also create some risks due to ecological interactions and genetic introgression (NMFS 2022g). For hatchery programs that incorporate sufficient natural-origin adults into the broodstock or were derived from the endemic population, NMFS has determined that fish produced therein have not changed substantially or displayed a level of genetic divergence from the local population that is greater than the divergence among closely related natural populations within the DPS (85 FR 81822). The Umatilla River summer steelhead and the Touchet River endemic summer steelhead (Walla Walla Basin) programs currently incorporate natural-origin adults into the broodstock (NMFS 2019e), and the Round

Table 59. Five-year mean of fraction natural spawners (sum of all estimates divided by the number of estimates). Blanks mean no estimate available in that 5-year range (Ford 2022).

Population	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Klickitat River	Cascades Eastern Slope Tributaries	—	—	1.00	1.00	1.00
Fifteenmile Creek	Cascades Eastern Slope Tributaries	—	—	—	0.96	0.96
Deschutes River Westside	Cascades Eastern Slope Tributaries	0.67	0.78	0.83	0.94	0.96
Deschutes River Eastside	Cascades Eastern Slope Tributaries	0.51	0.79	0.84	0.86	0.86
Rock Creek	Cascades Eastern Slope Tributaries	—	—	1.00	1.00	1.00
John Day River Lower Mainstem Tributaries	John Day River	0.95	0.86	0.74	0.88	0.97
North Fork John Day River	John Day River	0.95	0.89	0.92	0.98	1.00
Middle Fork John Day River	John Day River	0.95	0.89	0.92	0.98	1.00
South Fork John Day River	John Day River	0.95	0.89	0.92	0.98	1.00
John Day River Upper Mainstem	John Day River	0.95	0.89	0.92	0.98	1.00
Satus Creek	Yakima River	0.89	0.98	0.97	0.98	1.00
Toppenish Creek	Yakima River	0.88	0.98	0.97	0.98	0.99
Naches River	Yakima River	0.89	0.98	0.97	0.98	1.00
Yakima River Upper Mainstem	Yakima River	0.98	0.97	0.99	0.95	0.99
Umatilla River	Umatilla/Walla Walla	0.56	0.71	0.77	0.84	0.85
Walla Walla River	Umatilla/Walla Walla	0.99	0.96	0.97	0.98	0.87
Touchet River	Umatilla/Walla Walla	0.87	0.92	0.76	0.79	0.76

Butte Hatchery summer steelhead program (Deschutes River) is proposing to incorporate natural-origin adults into the broodstock and is currently in an ESA Section 7 consultation (NMFS 2022g).

2.2.6.3.1.1.3 Summary

The Middle Columbia River steelhead DPS does not currently meet the viability criteria described in the Middle Columbia River Steelhead Recovery Plan (NMFS 2009c; 2022g). In addition, several of the factors cited by the 2005 Biological Review Team (Good et al. 2005) remain as concerns or key uncertainties. While recent (5-year) returns are declining across all populations (Figure 52), the declines are from relatively high returns in the previous 5–10-year interval, so the longer-term risk metrics that are meant to buffer against short-period changes in abundance and productivity remain unchanged (Ford 2022). Natural-origin spawning estimates are highly variable relative to minimum abundance thresholds across the populations in the DPS (Ford 2022). Two of the four MPGs in this DPS include at least one population rated at "low" or "very low" risk for abundance and productivity, while the other two MPGs remain in the "moderate" to "high" risk range (Table 58). Updated information indicates that stray levels into the John Day River populations have decreased in recent years (Ford 2022). Out-of-basin hatchery stray proportions, although reduced, remain high in spawning reaches within the Deschutes River basin and the Umatilla, Walla Walla, and Touchet River populations (Table 59). Overall, the Middle Columbia River steelhead DPS remains at "moderate" risk of extinction (Ford 2022), with viability unchanged from the prior review (NWFSC 2015).

2.2.6.3.1.2 Limiting Factors

Understanding the limiting factors and threats that affect the Middle Columbia River Steelhead DPS provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting the species is to ensure that the underlying limiting factors and threats have been addressed. There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Middle Columbia River Steelhead DPS. Factors that limit the DPS have been, and continue to be, loss and degradation of spawning and rearing habitat, impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the viability of natural population in the Middle Columbia River Steelhead DPS. Historically, extensive beaver activity, dynamic patterns of channel migration in floodplains, human settlement and activities, and loss of rearing habitat quality and floodplain channel connectivity in the lower reaches of major tributaries, all impacted the Middle Columbia River Steelhead DPS populations (Ford 2022).

The recovery plan (NMFS 2009c) summarizes information from four regional management unit plans covering the range of tributary habitats associated with the DPS in Washington and

Oregon. Each of the management unit plans are incorporated as appendices to the recovery plan, along with modules for the mainstem Columbia hydropower system and the estuary, where conditions affect the survival of steelhead production from all of the tributary populations comprising the DPS. The recovery objectives defined in the recovery plan are all based on the biological viability criteria developed by the ICTRT (NMFS 2011f).

The recovery plan also provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them. Chapter 6 of the recovery plan describes the limiting factors on a regional scale and how they affect the populations in the Middle Columbia River Steelhead DPS (NMFS 2009c). Chapter 7 of the recovery plan addresses the recovery strategy for the entire DPS and more specific plans for individual MPGs within the DPS (NMFS 2009c). The recovery plan addresses the topics of:

- Tributary habitat conditions,
- Columbia River mainstem conditions,
- Impaired fish passage,
- Water temperature and thermal refuges,
- Hatchery-related adverse effects,
- Predation, competition, and disease,
- Degradation of estuarine and nearshore marine habitat, and
- Climate change

Rather than repeating this extensive discussion from the recovery plan, the discussions in Chapters 6 and 8 are incorporated here by reference.

Overall, the Middle Columbia River Steelhead DPS is not currently meeting the viability criteria (adopted from the ICTRT) in the Mid-Columbia Steelhead Recovery Plan (NMFS 2009c). In addition, several factors cited by the 2005 Biological Review Team remain as concerns or key uncertainties (Good et al. 2005). The population level viability ratings remained largely unchanged from the prior review (NWFSC 2015) for each MPG within the DPS (Ford 2022).

2.2.6.3.2 Upper Columbia River Steelhead DPS

On August 18, 1997, NMFS listed the Upper Columbia River Steelhead DPS as an endangered species (62 FR 43937). The Upper Columbia River steelhead was then listed as a threatened species as of January 5, 2006 (71 FR 834). This DPS was re-classified as endangered on January 13, 2007 (74 FR 42605). However, the status was changed to threatened again in 2009 (74 FR 42605) and was reaffirmed on April 14, 2014 (79 FR 20802). Critical habitat for the Upper Columbia River Steelhead DPS was designated on September 2, 2005 (70 FR 52630). The most recent five-year review for Upper Columbia River Steelhead was released in 2022 (NMFS 2022o).

The Upper Columbia River Steelhead DPS includes all naturally spawned anadromous O. mykiss (steelhead) populations below natural and manmade impassable barriers in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the U.S.-Canada border, as well as six artificial propagation programs (Table 60, Figure 54) (Ford 2022; NMFS 2022o).

As with other Steelhead DPSs, NMFS has defined the Upper Columbia River Steelhead DPS to include only the anadromous members of this species (70 FR 67130). The Upper Columbia River Steelhead DPS is composed of one extant MPG with four extant populations (Table 60 and Figure 54).

The life-history pattern of steelhead in the Upper Columbia River Basin is complex (Chapman et al. 1994). Upper Columbia River steelhead exhibit a stream-type life with individuals exhibiting a yearling life history strategy (NMFS 2016d). Adults return to the Columbia River in the late

Table 60. Upper Columbia River Steelhead DPS description and MPGs (Ford 2022; NMFS 2022o).

DPS Description	
Threatened	Listed under ESA as endangered in 1997 and 2007; reviewed and listed as threatened in 2006 and 2009, and updated in 2014.
3 MPGs	11 historical populations, 4 extant
MPG	***Populations***
North Cascades	Wenatchee River, Entiat River, Crab Creek (functionally extirpated), Methow River, Okanogan River
Upper Columbia River above Chief Joseph Dam (extirpated)	Sanpoil River, Kettle River, Pend Oreille, Kootenay River
Spokane River (extirpated)	Spokane River, Hangman Creek
Artificial production	
Hatchery programs included in DPS (5)	Wenatchee River Program, Wells Complex Hatchery Program (Methow River), Winthrop National Fish Hatchery Program, Ringold Hatchery Program, Okanogan River Program
Hatchery programs not included in DPS (1)	Wells Hatchery Complex summer (Columbia River)

summer and early fall. A portion of the returning run overwinters in the mainstem Columbia River reservoirs, passing into tributaries to spawn in April and May of the following year. Spawning occurs in the late spring of the year following entry into the Columbia River. Steelhead in the Upper Columbia Basin have a relatively high fecundity, averaging between 5,300 and 6,000 eggs (Chapman et al. 1994; UCSRB 2007).

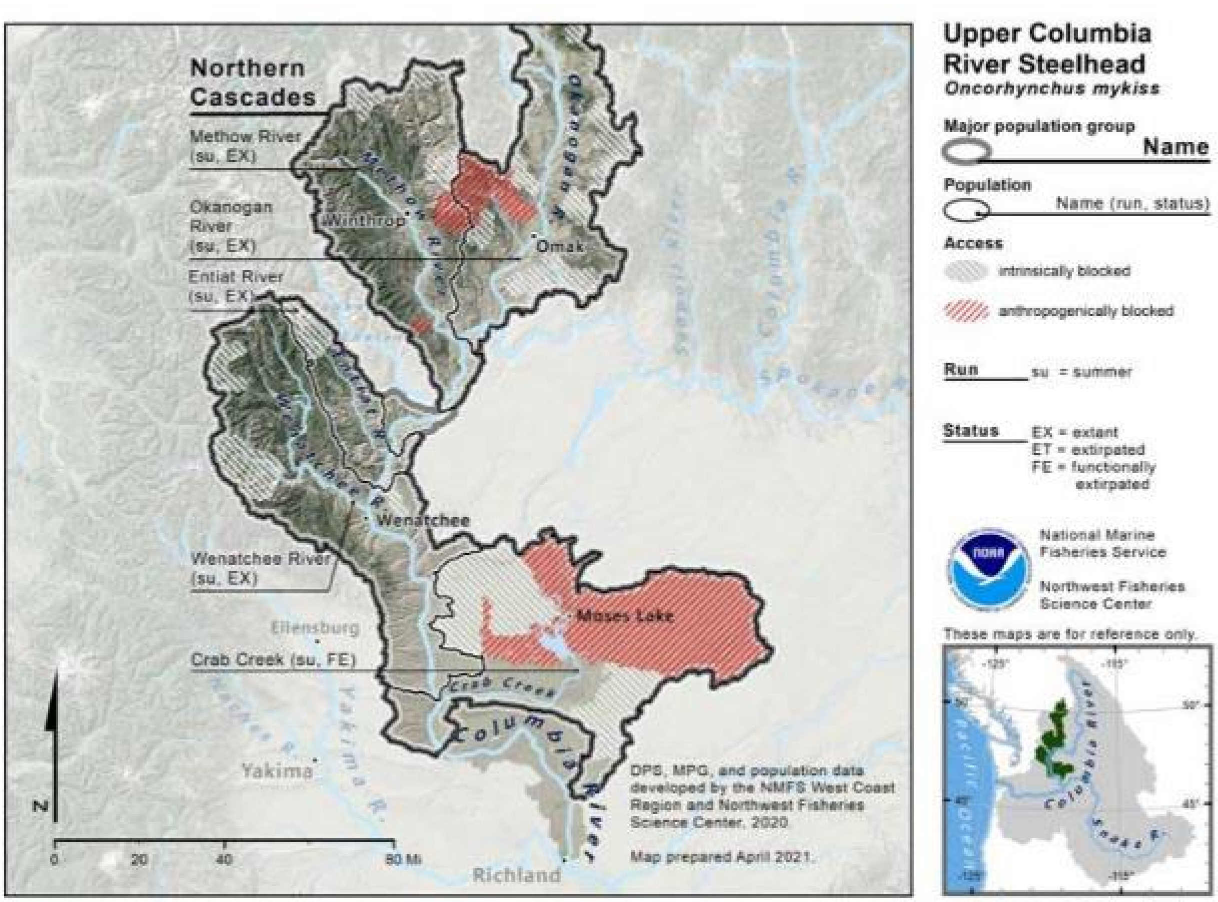


Figure 54. Map of the Upper Columbia River Steelhead DPS's spawning and rearing areas, illustrating natural populations and MPGs (Ford 2022).

2.2.6.3.2.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Upper Columbia River Steelhead DPS, is at high risk and remains at threatened status. The most recent viability assessment (Ford 2022) used updated data series on spawner abundance, age structure, and hatchery-to-wild spawner proportions to generate current assessments of abundance and productivity at the population level. Evaluations were done using both a set of metrics corresponding to those used in the prior reviews as well as a set corresponding to the specific viability criteria based on the ICTRT recommendations for this DPS (Ford 2022).

2.2.6.3.2.1.1 Abundance and Productivity

All four populations in the Upper Columbia River steelhead DPS remain at high overall risk (NMFS 2022o). Natural origin abundance has decreased over the levels reported in the prior review for all populations in this DPS, in many cases sharply (Figure 55). The abundance data for the entire DPS show a downward trend over the last 5 years, with the recent 5-year abundance levels for all four populations declining by an average of 48% (Figure 55). The consistent and sharp declines for all populations in the DPS are concerning. Relatively low ocean survivals in recent years were a major factor in recent abundance patterns.

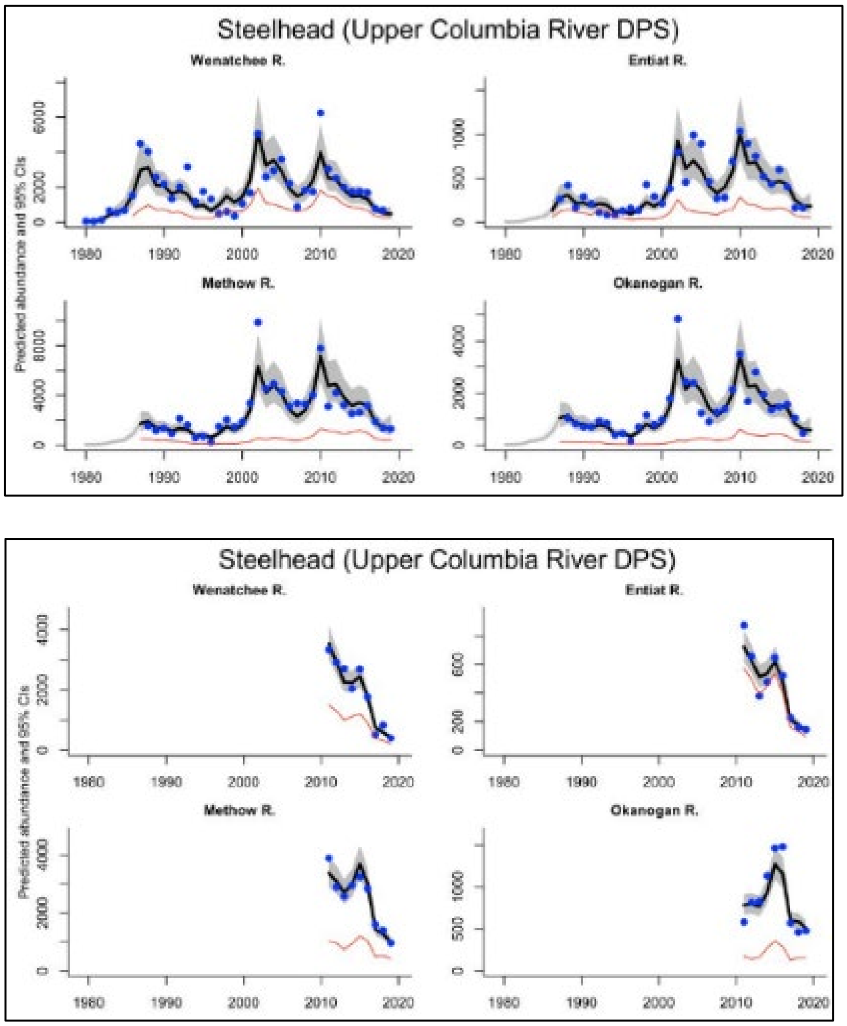


Figure 55. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot. Upper panel is the traditionally generated spawner abundance time series for each population. Lower panel is population estimates based on PIT-tag detections within each population watershed relative to tagging the aggregate upper Columbia River run at large (Ford 2022).

Spatial structure ratings remain unchanged from the prior review and continue to be rated at low risk for the Wenatchee and Methow populations, moderate risk for the Entiat population, and high risk for the Okanogan population (Table 61). The overall diversity ratings remain unchanged at high risk (Table 61). The high risk ratings for diversity are largely driven by high levels of hatchery spawners within natural spawning areas and lack of genetic diversity among the populations (NMFS 2022o). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

Table 61. Upper Columbia River Steelhead DPS: North Cascades MPG population risk ratings integrated across the four VSP parameters. Viability key: Dark Green = highly viable; Green = viable; Orange = maintained; and Red = high risk (does not meet viability criteria) (From NMFS (2022o), adapted using data from Ford (2022)).

		Risk Rating for Spatial Structure/Diversity			
		Very Low	Low	Moderate	High
Risk Rating for Abundance/Productivity	Very Low (<1%)	Highly Viable	Highly Viable	Viable	Maintained
	Low (1–5%)	Viable	Viable	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained	Maintained	High Risk ***Wenatchee***
	High (>25%)	High Risk	High Risk	High Risk	High Risk ***Entiat*** ***Methow*** ***Okanogan***

Given the high degree of year-to-year variability in life stage survivals and the time lags resulting from the 5-year life cycle of the populations, it is not possible to detect incremental gains from habitat actions implemented to date in population level measures of adult abundance or productivity. Based on the information available for this review, the risk category for the Upper Columbia River steelhead remains unchanged from the prior review (Ford 2022). Although, the recent decline of population abundances is concerning, each population remains well above the abundance levels of when they were listed. All four populations remain at high risk (Table 61).

2.2.6.3.2.1.1.1 Harvest

Steelhead encounters in the ocean are rare and incidental impacts to steelhead in ocean fisheries targeting other species are inconsequential (low hundreds of fish each year) to very rare (NMFS 2022o). The majority of harvest on Upper Columbia River steelhead occurs in the mainstem Columbia River (NMFS 2022o). Non-treaty fisheries in the Columbia River are limited to an incidental take of 2% during the combined winter, spring, summer period 2% during the fall management period (NMFS 2018e). Overall, impacts on Upper Columbia River steelhead have remained the same or declined since the last 5-year review. Impacts in non-treaty fisheries have averaged 0.57% and 1.28% for the winter/spring/summer and fall management periods, respectively during the years 2014-2019 (Figure 56). There are no specific limits for impacts in treaty fisheries for Upper Columbia River steelhead but harvest rates have remained the same since the 2016 5-year review and have not changed under the 2018 Management Agreement (NMFS 2018e).

Steelhead were historically taken in tribal and non-tribal gillnet fisheries, and in recreational fisheries in the mainstem Columbia River and in tributaries (Ford 2022). In the 1970s, retention of steelhead in non-treaty commercial fisheries was prohibited, and in the mid-1980s, tributary recreational fisheries in Washington adopted mark-selective regulations (Ford 2022). There is incidental mortality associated with mark-selective recreational fisheries. Sport fisheries targeting hatchery-run steelhead occur in the mainstem Columbia River and in several upper Columbia River tributaries (Ford 2022). In recent years, upper Columbia River exploitation rates have been stable at around 1.5% (Figure 56). As of 2012, rates are estimated over two management intervals per year, Fall and Winter/Spring/Summer (Figure 56).

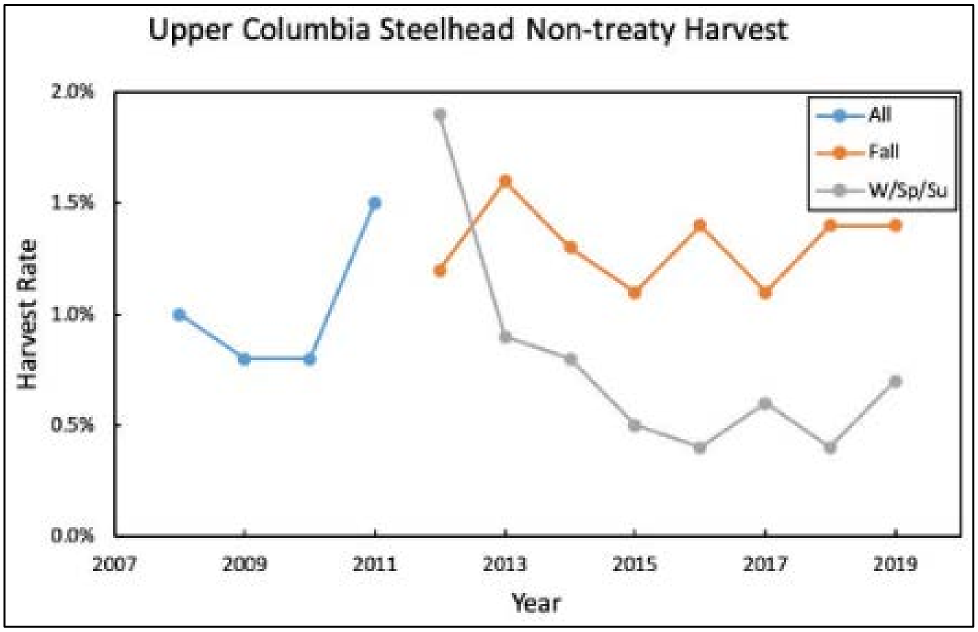


Figure 56. Harvest rates for non-treaty Upper Columbia River steelhead. As of 2012, reporting is generated across two management periods, Fall (orange line) and Winter/Spring/Summer (gray line). Prior to 2012, harvest rate reporting was across all of the calendar year (Figure from Ford (2022)).

2.2.6.3.2.1.2 Spatial Structure and Diversity

With the exception of the Okanogan population, the upper Columbia River steelhead populations were rated as low-risk for spatial structure (Ford 2022). The high-risk ratings for diversity are largely driven by high levels of hatchery spawners within natural spawning areas, and lack of genetic diversity among the populations (Ford 2022). The basic major life-history patterns (summer A-run type, tributary and mainstem spawning/rearing patterns, and the presence of resident populations and subpopulations) appear to be present. All of the populations were rated at high risk for current genetic characteristics by the ICTRT (Ford 2022). Genetics samples taken in the 1980s indicate little differentiation within populations in the Upper Columbia River steelhead DPS (Ford 2022). More recent studies within the Wenatchee River basin have found differences between samples from the Peshastin River, believed to be relatively isolated from hatchery spawning, and those from other reaches in the basin (Ford 2022). This suggests that there may have been a higher level of within- and among-population diversity prior to the advent of major hatchery releases (Seamons et al. 2012). Genetic studies are underway based on sampling in the Wenatchee River, as well as other Upper Columbia River steelhead DPS tributaries, and should allow for future analyses of current genetic structure and any impacts of changing hatchery release practices.

2.2.6.3.2.1.2.1 Hatcheries

The effects of hatchery fish on the status of an ESU or DPS depends upon which of the four key attributes – abundance, productivity, spatial structure, and diversity – are currently limiting the ESU/DPS, and how the hatchery fish within the ESU/DPS affect each of the attributes (70 FR 37204). Hatchery programs can provide short-term demographic benefits such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of the risk depends on the status of affected populations and on specific practices in the hatchery program (NMFS 2022o).

The proportions of hatchery-origin returns in natural spawning areas remain high across the DPS, especially in the Methow and Okanogan river populations (Table 62), but the management of the fish being propagated at the various programs has changed recently to focus production on individual populations using only fish from within that population (NMFS 2022o). Given the recent changes in hatchery practices in the Wenatchee River and the potential for reduced hatchery contributions or increased spatial separation of hatchery- vs. natural-origin spawners, it is possible that genetic composition could trend toward patterns consistent with strong natural selection influences in the future (Ford 2022). Ongoing genetic sampling and analysis could provide information in the future to determine if the diversity risk is abating. The proportions of hatchery-origin returns in natural spawning areas remain high across the DPS, especially in the Methow and Okanogan River populations (Ford 2022).

Table 62. Five-year mean of fraction natural-origin spawners (sum of all estimates divided by the number of estimates) (table from Ford (2022)).

Population	1995–99	2000–04	2005–09	2010–14	2015–19
Wenatchee River	0.41	0.34	0.38	0.56	0.50
Entiat River	0.21	0.24	0.24	0.30	0.33
Methow River	0.13	0.11	0.15	0.24	0.31
Okanogan River	0.05	0.06	0.14	0.21	0.24

2.2.6.3.2.1.3 Summary

The most recent estimates (five-year geometric mean) of total and natural-origin spawner abundance have declined since the NWFSC (2015) viability assessment, largely erasing gains observed over the past two decades for all four populations (Figure 55, Table 62). Recent declines are persistent and large enough to result in small, but negative 15-year trends in abundance for all four populations (Figure 55). The abundance and productivity viability rating for the Wenatchee River exceeds the minimum threshold for 5% extinction risk (Ford 2022). The overall Upper Columbia River steelhead DPS viability remains largely unchanged from the prior review (NWFSC 2015), and the DPS is at high risk driven by low abundance and productivity relative to viability objectives and diversity concerns (Ford 2022).

2.2.6.3.2.2 Limiting Factors

Understanding the limiting factors and threats that affect the Upper Columbia River Steelhead DPS provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting the species is to ensure that the underlying limiting factors and threats have been addressed. It is unlikely that the aboriginal fishing (pre-1930s) was responsible for steelhead declines in the Columbia River (UCSRB 2007). Their artisanal fishing methods were incapable of harvesting Upper Columbia River steelhead at rates that approached or exceeded optimal maximum sustainable yield, probably 69% for steelhead, as estimated in Chapman (1986); UCSRB (2007). Instead, commercial fishing had a significant effect on the abundance of steelhead in the Columbia River. An intense industrial fishery in the Lower Columbia River, employing traps, beach seines, gillnets, and fish wheels, developed in the latter half of the 1800s. Intensive harvest not only affected abundance and productivity of fish stocks, but probably also the diversity of populations (UCSRB 2007).

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Upper Columbia River Steelhead DPS. Factors that limit the DPS have been, and continue to be, hydropower effects, agricultural effects, and habitat degradation; together these factors have affected the populations of this DPS (UCSRB 2007).

The Upper Columbia Recovery Plan (UCSRB 2007) provides a detailed discussion of limiting factors and threats and describes strategies for addressing each of them (Chapters 4, 5, and 8).

Some of the main limiting factors are listed below:

- Mainstem Columbia River hydropower-related adverse effects,
- Impaired tributary fish passage,
- Degraded floodplain connectivity and function, channel structure and complexity, riparian areas, large woody debris recruitment, stream flow, and water quality,
- Hatchery-related effects,

- Predation and competition, and
- Harvest-related effects

The plan indicates that the highest priority for protecting biological productivity of Upper Columbia River salmonids should be to allow unrestricted stream channel migration, complexity and floodplain function. The principal means to meet this objective is to protect riparian habitat in category 1 and 2 sub-watersheds. The highest priority for increasing biological productivity is to restore the complexity of the stream channel and floodplain. Rather than repeating this extensive discussion from the recovery plan, is the discussions in Chapters 4, 5, and 8 are incorporated here by reference.

Although all of the natural populations in the DPS remain at high risk and the DPS remains to be listed as threatened, ongoing genetic sampling and analysis could provide information in the future to determine if the diversity risk is abating. The proportions of hatchery-origin returns in natural spawning areas remain high across the DPS, especially in the Methow and Okanogan River populations (Table 62). The improvements in natural returns in recent years largely reflect several years of relatively good natural survival in the ocean and tributary habitats. Tributary habitat actions called for in the Upper Columbia Salmon Recovery Plan are anticipated to be implemented over the next 25 years, and the benefits of some of those actions will require some time to be realized (Ford 2022).

2.2.6.3.3 Snake River Basin Steelhead DPS

On August 18, 1997, NMFS listed the Snake River Basin Steelhead DPS as a threatened species (62 FR 43937). The threatened status was reaffirmed in 2006 and most recently on April 14, 2014 (79 FR 20802). Critical habitat for the DPS was designated on September 2, 2005 (70 FR 52769). The most recent 5-year status review for Snake River Basin steelhead was released in 2022 (NMFS 2022q).

The Snake River Basin Steelhead DPS includes all naturally spawned anadromous *O. mykiss* originating below natural and manmade impassable barriers in streams in the Snake River Basin of southeast Washington, northeast Oregon, and Idaho (Figure 57) (Ford 2022). Twenty-seven historical populations within six MPGs comprise the Snake River Basin Steelhead DPS. Inside the geographic range of the DPS, 13 hatchery steelhead programs are currently operational. Six of these artificial programs are included in the DPS (Table 63) (NMFS 2022q). Genetic resources can be housed in a hatchery program but for a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS see NMFS (2005b).

This DPS consists of A-Index steelhead, which primarily return to spawning areas beginning in the summer, and B-Index steelhead, which exhibit a larger body size and begin their migration in the fall (NMFS 2011b).

Table 63. Snake River Basin Steelhead DPS description and MPGs (Ford 2022; NMFS 2022q).

DPS Description	
Threatened	Listed under ESA as threatened in 1997; updated in 2014.
6 MPGs	27 historical populations (3 extirpated), 24 extant
MPG	***Populations***
Grande Ronde	Joseph Creek, Upper Mainstem, Lower Mainstem, Wallowa River
Imnaha River	Imnaha River
Clearwater	Lower Mainstem River, North Fork Clearwater (extirpated), Lolo Creek, Lochsa River, Selway River, South Fork Clearwater
Salmon River	Little Salmon/Rapid, Chamberlain Creek, Secesh River, South Fork Salmon, Panther Creek, Lower MF, Upper MF, North Fork, Lemhi River, Pahsimeroi River, East Fork Salmon, Upper Mainstem
Lower Snake	Tucannon River, Asotin Creek
Hells Canyon Tributaries	No associated independent populations
Artificial production	
Hatchery programs included in DPS (6)	Tucannon River summer, Little Sheep Creek summer, East Fork Salmon River Natural A, Dworshak National Fish Hatchery B, South Fork Clearwater (Clearwater Hatchery) B, Salmon River B
Hatchery programs not included in DPS (7)	Lyons Ferry National Fish Hatchery summer, Wallowa Hatchery summer, Hells Canyon A, Pahsimeroi Hatchery A, Upper Salmon River A, Streamside Incubator Project A, Little Salmon River A

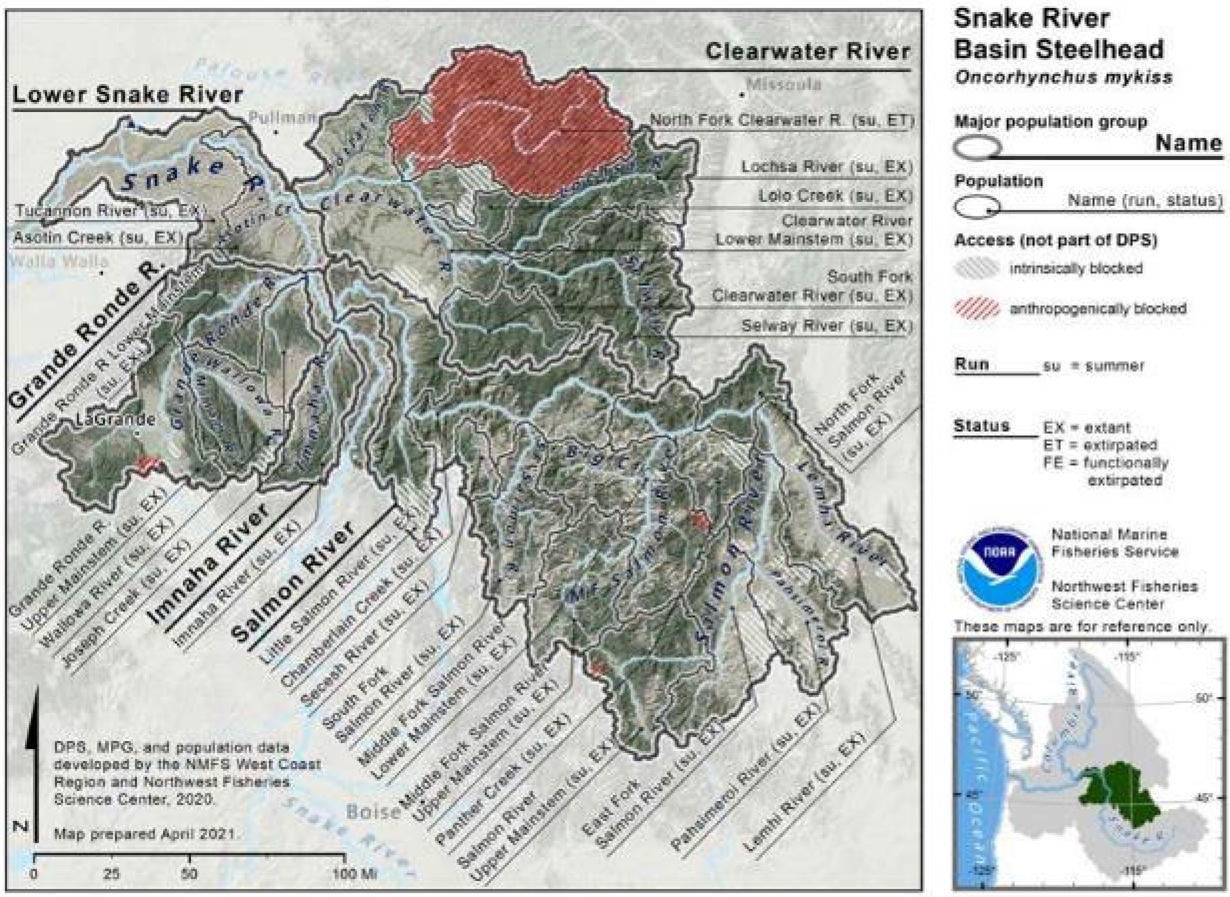


Figure 57. Snake River Basin steelhead DPS spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

As mentioned above, Snake River Basin steelhead exhibit two distinct morphological forms, identified as “A-Index” and “B-Index” fish, which are distinguished by differences in body size, run timing, and length of ocean residence. B-Index fish predominantly reside in the ocean for 2 years, while A-Index steelhead typically reside in the ocean for 1-year (Copeland et al. 2017). As a result of different ocean residence times, B-Index steelhead are generally larger than A-Index fish. The smaller size of A-Index adults allows them to spawn in smaller headwater streams and tributaries. The differences in the two fish stocks represent an important component of phenotypic and genetic diversity of the Snake River Basin Steelhead DPS through the asynchronous timing of ocean residence, segregation of spawning in larger and smaller streams, and possible differences in the habitats of the fish in the ocean (NMFS 2012b).

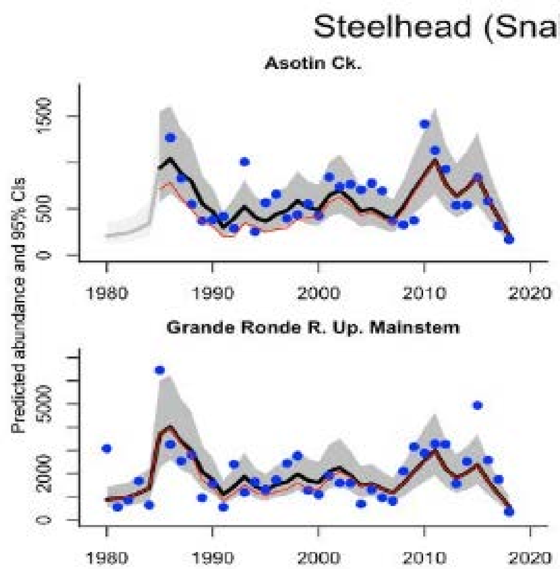
2.2.6.3.3.1 Abundance, Productivity, Spatial Structure, and Diversity

Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Snake River Basin Steelhead DPS, ranges from moderate to high risk and remains at threatened status. The viability assessment (Ford 2022) used new data to inform the analysis on this DPS. Additionally, ODFW has continued to refine sampling methods for various survey types, which has also led to more accurate data available for use. However, a great deal of uncertainty remains regarding the relative proportion of hatchery-origin fish in natural spawning areas near major hatchery release sites. Because of this, it is difficult to estimate changes in the DPS viability (Ford 2022).

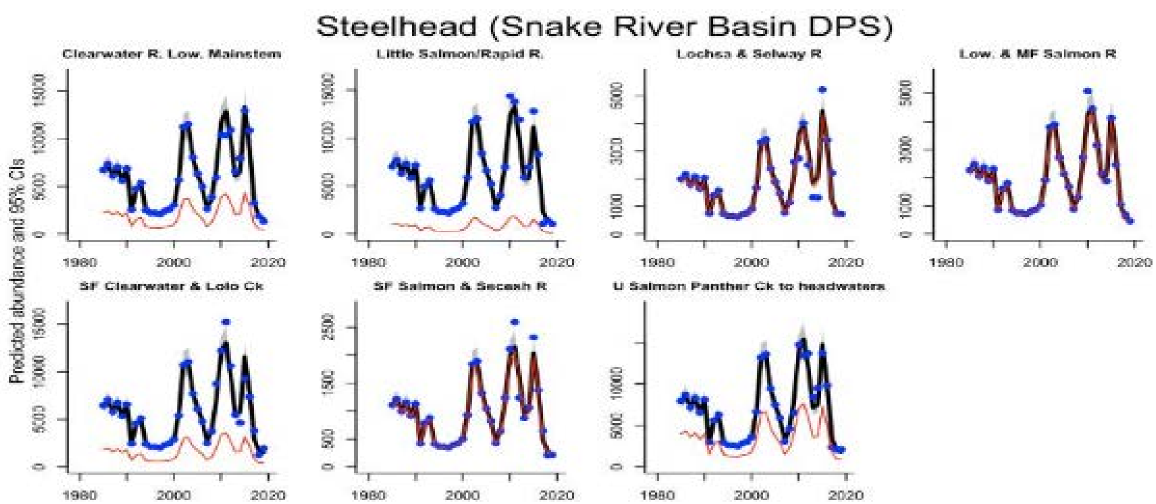
2.2.6.3.3.1.1 Abundance and Productivity

Based on the updated viability information available for this review, none of the five MPGs meet the viability criteria set forth in the 2017 recovery plan, and the viability of many individual populations remains uncertain (Ford 2022; NMFS 2022q). Of particular note, the updated, population-level abundance estimates have made very clear the recent (last 5 years) sharp declines (Figure 58) that are extremely worrisome, were they to continue (Ford 2022; NMFS 2022q). The most recent 5-year metric indicates that each population has decreased by about 50% (Figure 58). The viability metrics used in these analyses (standardized PNW-wide and ICTRT) are intentionally based on long-time periods (10–20 year geometric means) to buffer against the rapid swings in abundance that salmon and steelhead populations are known to exhibit (Ford 2022).

a)


Steelhead (Snake River Basin DPS)
Asotin Ck.
Joseph Ck.
Grande Ronde R. Up. Mainstem
Predicted abundance and 95% CIs

b)


Steelhead (Snake River Basin DPS)
Clearwater R. Low. Mainstem
Little Salmon/Rapid R.
Lochsa & Selway R
Low. & MF Salmon R
SF Clearwater & Lolo Ck
SF Salmon & Secesh R
U Salmon Panther Ck to headwaters
Predicted abundance and 95% CIs

c)

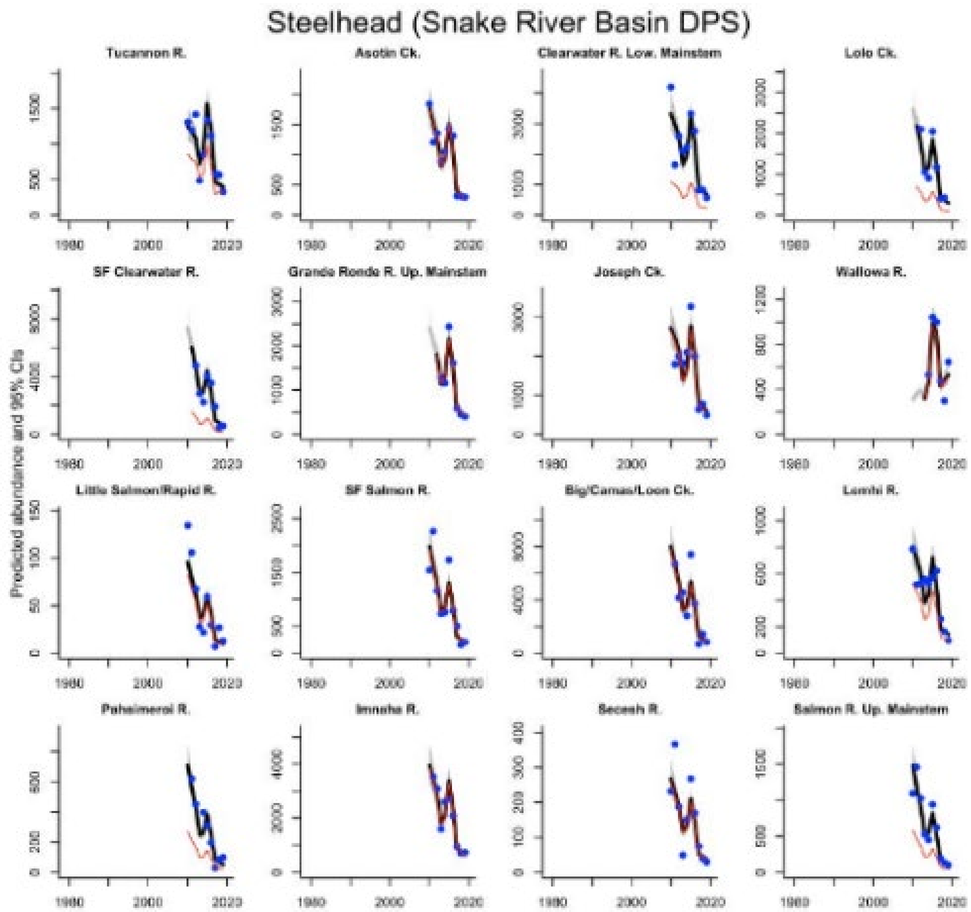


Figure 58. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot (Ford 2022). a) Long-term dataset from weir and redd surveys. b) Super-population groups from Genetic Stock Identification (GSI)-based run partitioning of the run-at-large over Lower Granite Dam. c) PIT-tag-based population estimation method based on mixture model and tag detection network across the DPS.

Based on 20-year geometric means, productivity for all populations remains above replacement (Ford 2022; NMFS 2022q). Cyclical spawner-to-spawner ratios, which reflect combined impacts of habitat, climate, and density dependence, have been strongly below replacement since 2010. Productivity is also expected to decline in the coming years due to recent declines in abundance (Ford 2022; NMFS 2022q).

2.2.6.3.3.1.1.1 Harvest

Systematic improvements in fisheries management since the 2016 5-year review (NMFS 2016s) include implementation of a new *U.S. v. Oregon* Management Agreement for the years 2018–2027, which replaces the previous 10-year agreement (NMFS 2018e). This new agreement maintains the limits and reductions in harvest impacts for the listed ESUs/DPSs that were secured in previous agreements (NMFS 2018e).

Steelhead encounters in the ocean are rare and incidental impacts to steelhead in ocean fisheries targeting other species are inconsequential (low hundreds of fish each year) to very rare (PFMC 2023d). The majority of harvest-related impacts on Snake River Basin steelhead occurs in the mainstem Columbia River (NMFS 2022q). Overall, impacts on Snake River Basin steelhead have declined since the 2016 5-year review (NMFS 2016s). Impacts in treaty fisheries have declined from 13.8% in 2016 5-year review period (NMFS 2016s) to an average of 8.7% during years 2014–2019 (NMFS 2022q). Impacts in non-treaty fisheries have averaged 0.58, 1.28, 0.08, and 1.52% for A-Run winter/spring/summer, A-Run fall, B-Run winter/spring/summer, and B-run fall, respectively during the years 2014–2019 (NMFS 2022q). Harvest rates have decreased since the 2016 5-year review (NMFS 2016s). Impacts in treaty and non-treaty fisheries are limited by the 2018–2027 *U.S. v. Oregon* Management Agreement (NMFS 2018e). Therefore, harvest continues to pose a moderate risk to Snake River Basin steelhead (NMFS 2022q).

Table 64. Summary of viability relative to the ICTRT viability criteria, grouped by MPG. Natural spawning = most-recent 10-yr geometric mean (range). ICTRT productivity = 20-yr geometric mean for parent escapements below 75% of population threshold. Current A/P estimates are geometric means. Range in annual abundance, standard error, and number of qualifying estimates for productivities in parentheses. Populations with no abundance and productivity data are given a default "high" A/P risk rating (Ford 2022).

	Abundance/productivity (A/P) metrics				Spatial structure/diversity (SS/D) metrics			
Population	**ICTRT threshold**	**Natural spawning**	**ICTRT productivity**	**Integrated A/P risk**	**Natural processes**	**Diversity risk**	**Integrated SS/D risk**	**Overall risk rating**
Tucannon River	1,000	n/a	n/a	High	Low	Moderate	Moderate	High
Lower Snake R. (Tucannon R. and Asotin Crk.)[a]	1,500	750 (SD 751)	2.52 (0.21, 12/20)	Moderate	Low	Moderate	Moderate	Maintained
Asotin Creek	500	574 (SD 389)	1.63 (0.41, 3/20)	Low	Low	Moderate	Moderate	Viable
Lower Grande Ronde River	1,000	n/a	n/a	High	Low	Moderate	Moderate	High
Joseph Creek	500	2,327 (SD 1,291)	1.21 (0.14, 0/20)	Low	Very Low	Low	Low	Viable
Grande Ronde River Upper Mainstem	1,500	2,192 (SD 1,227)	2.01 (0.35, 6/20)	Very Low	Very Low	Moderate	Moderate	Viable
Wallowa River	1,000	n/a	n/a	High	Very Low	Low	Low	High
Imnaha River	1,000	1,811 (SD 1,151)	2.36 (0.21, 9/20)	Very Low	Very Low	Moderate	Moderate	Viable
Clearwater River Lower Mainstem	1,500	2,026 (SD 1,382)	2.32 (0.18, 9/20)	Very Low	Very Low	Low	Low	Highly Viable
South Fork Clearwater River	1,000	1,564 (SD 1,275)	2.80 (0.23, 8/20)	Very Low	Low	Moderate	Moderate	Viable
Lolo Creek	500	1,946 (SD 1,426)	1.82 (0.19, 15/20)	Moderate	Low	Moderate	Moderate	Maintained
Selway River	1,000			Moderate	Very Low	Low	Low	Maintained
Lochsa River	1,000			Moderate	Very Low	Low	Low	Maintained
Little Salmon River	500	750 (SD 751)	2.53 (0.21, 12/20)	Very Low	Low	Moderate	Moderate	Viable
South Fork Salmon River	1,000	919 (SD 816)	1.85 (0.19, 15/20)	Moderate	Very Low	Low	Low	Maintained
Secesh River	500			Moderate	Low	Low	Low	Maintained
Chamberlain Creek	500	1,937 (SD 1,566)	2.47 (0.15, 10/20)	Moderate	Low	Low	Low	Maintained
Lower Middle Fork Salmon River	1,000			Moderate	Very Low	Low	Low	Maintained
Upper Middle Fork Salmon River	1,000			Moderate	Very Low	Low	Low	Maintained
Panther Creek	500	3,502 (SD 2,562)	1.88 (0.17, 16/20)	Moderate	High	Moderate	High	High
North Fork Salmon River	500			Moderate	Low	Moderate	Moderate	Maintained
Lemhi River	1,000			Moderate	Low	Moderate	Moderate	Maintained
Pahsimeroi River	1,000			Moderate	Moderate	Moderate	Moderate	Maintained
East Fork Salmon River	1,000			Moderate	Very Low	Moderate	Moderate	Maintained
Salmon River Upper Mainstem	1,000			Moderate	Very Low	Moderate	Moderate	Maintained

[a] Note that the Lower Snake River MPG is discussed as a whole in this table as population-level abundance datasets are not available for the entirety of either of the two populations in this MPG; however, a data series for a large subarea within the Asotin Creek population is available (Ford 2022).

2.2.6.3.3.1.2 Spatial Structure and Diversity

Spatial structure risk ratings for all of the Snake River Basin steelhead populations were low or very low risk (Table 64) given the evidence of broad distribution of natural production within populations (NMFS 2022q). The exception was Panther Creek, which was given a high-risk rating for spatial structure (Table 64) based on the lack of spawning in the upper sections (NMFS 2022q). Based on extensive survey information from the Salmon River and Clearwater River MPGs, the spatial structure ratings for Snake River Basin steelhead populations were maintained at the levels assigned in the original ICTRT assessment (NMFS 2022q). Diversity risk ratings were low to moderate and nearly unchanged from the previous 5-year review period (Table 64).

2.2.6.3.3.1.2.1 Hatcheries

Currently, there are 13 steelhead hatchery programs in the Snake River basin (6 of which are included in the Snake River Basin DPS; Table 63), plus one kelt reconditioning program (NMFS 2022q). The hatchery programs that are considered to be part of the DPS are: Tucannon River, Salmon River B-run, South Fork Clearwater (Clearwater Hatchery) B-run, Dworshak National Fish Hatchery, East Fork Salmon River, and Little Sheep Creek/Imnaha River Hatchery (Table 63).

Several uncertainties exist regarding the effects of hatchery programs on natural-origin Snake River Basin steelhead populations. One of the main areas of uncertainty is the relative proportion (Table 65) and distribution of hatchery-origin spawners in natural spawning areas at the population level, particularly for Snake River Basin steelhead (Ford 2022). Because of this lack of information, the diversity status of most of the populations in the DPS remains uncertain (NMFS 2022q). Information is needed to determine where and to what extent unaccounted for hatchery steelhead are interacting with ESA-listed populations, particularly in Idaho (Ford 2022). Co-managers have continued to install PIT tag arrays throughout the Snake River basin that are likely to provide new information on population abundance and productivity, and hatchery fish proportions and distribution throughout the Snake River basin (NMFS 2022q).

2.2.6.3.3.1.3 Summary

Population abundance declines since the 2016 5-year review (NMFS 2016s) are sharp and are expected to negatively affect productivity in the coming years corresponding with these declines (NMFS 2022q). These declines in abundance, according to short-term metrics, are of greater concern if they continue through the next 5-year review period (NMFS 2022q). However, spatial structure risk is very low as Snake River Basin steelhead are widely distributed throughout their accessible range, and the species exhibits resilience to rapid changes in abundance (NMFS 2022q). Overall, the information analyzed for the 2022 viability assessment (Ford 2022) does not indicate a change in the biological risk status of the DPS, which remains in the moderate extinction risk category (NMFS 2022q).

Table 65. Five-year mean of fraction natural natural-origin spawners (sum of all estimates divided by the number of estimates). Blanks mean no estimate available in that 5-year range. Upper rows: long-term dataset from weir and redd surveys. Middle rows (shaded): super-population groups from GSI-based run partitioning of the run-at-large over Lower Granite Dam. Lower rows: PIT-tag-based population estimation method based on mixture model and tag detection network across the DPS (Ford 2022).

Population	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Asotin Creek	Lower Snake River	0.65	0.90	0.92	0.99	1.00
Joseph Creek	Grande Ronde River	1.00	1.00	1.00	0.98	0.97
Grande Ronde River Upper Mainstem	Grande Ronde River	0.80	0.91	1.00	0.99	0.99
Clearwater River Lower Mainstem	Clearwater River	0.33	0.33	0.33	0.33	0.33
Lochsa and Selway Rivers	Clearwater River	0.97	0.97	0.97	0.97	0.97
South Fork Clearwater River and Lolo Creek	Clearwater River	0.28	0.28	0.28	0.28	0.28
Little Salmon/Rapid River	Salmon River	0.14	0.14	0.14	0.14	0.14
South Fork Salmon and Secesh Rivers	Salmon River	0.80	0.91	1.00	0.99	0.99
Lower and Middle Fork Salmon River	Salmon River	0.97	0.97	0.97	0.97	0.97
Upper Salmon River and Panther Creek to headwaters	Salmon River	0.50	0.50	0.50	0.50	0.50
Tucannon River	Lower Snake River	—	—	—	0.69	0.68
Asotin Creek	Lower Snake River	—	—	—	0.99	1.00
Clearwater River Lower Mainstem	Clearwater River	—	—	—	0.33	0.33
Lolo Creek	Clearwater River	—	—	—	0.32	0.32
South Fork Clearwater River	Clearwater River	—	—	—	0.26	0.26
Grande Ronde River Upper Mainstem	Grande Ronde River	—	—	—	1.00	0.99
Joseph Creek	Grande Ronde River	—	—	—	0.97	0.97
Wallowa River	Grande Ronde River	—	—	—	0.97	0.97
Imnaha River	Imnaha River	—	—	—	0.97	0.97
Little Salmon/Rapid River	Salmon River	—	—	—	0.86	0.86
South Fork Salmon River	Salmon River	—	—	—	0.97	0.97
Big/Camas/Loon Creeks	Salmon River	—	—	—	0.97	0.97
Lemhi River (SU)	Salmon River	—	—	—	0.66	0.66
Pahsimeroi River	Salmon River	—	—	—	0.38	0.38

Population	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Secesh River	Salmon River	—	—	—	0.97	0.97
Upper Salmon River	Salmon River	—	—	—	0.40	0.40

2.2.6.3.3.2 Limiting Factors

Understanding the limiting factors and threats that affect the Snake River Basin Steelhead DPS provides important information and perspective regarding the status of the species. One of the necessary steps in recovery and consideration for delisting the species is to ensure that the underlying limiting factors and threats have been addressed.

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the Snake River Basin Steelhead DPS. Factors that limit the DPS have been, and continue to be, hydropower projects, predation, harvest, hatchery effects, tributary habitat, and ocean conditions; together these factors have affected the natural populations of this DPS (NMFS 2017q). Specifically, limiting factors also include the following:

- Mainstem Columbia River hydropower-related adverse effects,
- Impaired tributary fish passage,
- Degraded, including degradation in floodplain connectivity and function, channel structure and complexity, riparian areas and large woody debris recruitment, stream flow, and water quality as a result of cumulative impacts of agriculture, forestry, and development,
- Impaired water quality and increased water temperature,
- Related harvest effects, particularly for B-Index steelhead,
- Predation, and
- Genetic diversity effects from out-of-population hatchery releases

All five MPGs are currently not meeting the specific viability objectives in the Snake River Recovery Plan (NMFS 2017q), and the status of many individual populations remain uncertain. The additional monitoring programs instituted in the early 2000s to gain better information on natural-origin abundance and related factors have significantly improved the ability to assess status at a more detailed level. The new information has resulted in an updated view of the relative abundance of natural-origin spawners and life history diversity across the populations in the DPS. The more specific information on the distribution of natural returns among stock groups and populations indicates that differences in abundance/productivity status among populations may be more related to geography or elevation rather than the morphological forms (i.e., A-Index versus B-Index). A great deal of uncertainty still remains regarding the relative proportion of hatchery-origin fish in natural spawning areas near major hatchery release sites within individual populations. Overall, the information analyzed for the 2022 status review does not indicate a change in biological risk status (Ford 2022).

2.2.7 Status of Salmon and Steelhead Critical Habitat

This section of the Opinion examines the range-wide status of designated critical habitat for the affected species (Sections 2.2.2–2.2.6). NMFS has reviewed the status of critical habitat affected by the proposed action. Critical habitat is designated within the action area (defined in Section 2.3) for the majority of species affected by the proposed action. These critical habitat designations are described further below. No critical habitat exists within the action area for the California Coastal Chinook Salmon ESU or the Central Valley Spring-run Chinook Salmon ESU.

We review the status of designated critical habitat affected by the proposed action by examining the condition and trends of essential physical and biological features throughout the range of the action area. Examining these physical and biological features is important because these features support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging) and are essential to the conservation of the listed species.

For salmon and steelhead, NMFS categorized watersheds as high, medium, or low in terms of the conservation value that the watersheds provide to each listed species they support[19] within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC_5). To determine the conservation value of each watershed to species viability, NMFS' critical habitat analytical review teams (CHARTs) evaluated the quantity and quality of habitat features (i.e., spawning gravels, wood and water condition, side channels), the relationship of the specific geographic area being examined compared to other areas within the species' range, and the significance to the species of the population occupying that area (NMFS 2005c). Thus, even a location that has poor quality of habitat could be ranked with a high conservation value if it were essential because of factors such as limited availability (e.g., one of a very few spawning areas), a unique contribution to the population it served (e.g., for a population at the extreme end of geographic distribution), or the fact that it serves another important role besides providing habitat (e.g., obligate area for migration to upstream spawning areas).

This section examines relevant critical habitat conditions for the affected anadromous species discussed in the previous section. The analysis is grouped by the similarity of essential physical and biological features for each species and the overlapping critical habitat areas.

NMFS determines the range-wide status of critical habitat by examining the condition of its PBF (also called PCEs, or primary constituent elements, in some designations) that were identified when critical habitat was designated. These features are essential to the conservation of the listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging). The species in Table 4 have overlapping ranges, similar life history characteristics, and, therefore, many of the same PBFs. These PBFs include sites essential to support one or more life stages (spawning, rearing, and/or migration) and contain the physical and biological features essential to the conservation of each species. For example, important features include spawning gravels, forage species, cover in the form of submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side

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

channels, and undercut banks and migration corridors free of artificial obstruction with sufficient water quantity and quality.

The complex life cycle of many salmonids gives rise to complex habitat needs, particularly when the salmonids are in freshwater. For each species, the gravel they utilize for spawning must be a certain size and largely free of fine sediments to allow successful incubation of the eggs and later emergence or escape from the gravel as alevins. Eggs also require cool, clean, and well-oxygenated waters for proper development. Juveniles need abundant food sources, including insects, crustaceans, and other small fish. They need in-stream places to hide from predators (mostly birds and larger fish), such as under logs, root wads, and boulders, as well as beneath overhanging vegetation. They also need refuge from periodic high flows in side channels and off-channel areas and from warm summer water temperatures in cold water springs and deep pools. Returning adults generally do not feed in freshwater, but instead, rely on limited energy stored to migrate, mature, and spawn. Like juveniles, the returning adults also require cool water that is free of contaminants and migratory corridors with adequate passage conditions (timing, water quality/quantity) to allow access to the various habitats required to complete their life cycle (NMFS 2005a).

The watersheds within the action area (as described in Section 2.3) have been designated as essential for spawning, rearing, juvenile migration, and adult migration for many of the listed species in Table 4. Specific major factors affecting PBFs and habitat related limiting factors within the action area are described for each species in Sections 2.2.2. through 2.2.6. However, across the entire action area, widespread development and other land use activities have disrupted watershed processes (e.g., erosion and sediment transport, storage and routing of water, plant growth and successional processes, input of nutrients and thermal energy, nutrient cycling in the aquatic food web, etc.), reduced water quality, and diminished habitat quantity, quality, and complexity in many of the subbasins. Past and/or current land use or water management activities have adversely affected the quality and quantity of stream and side channel areas (e.g., areas where fish can seek refuge from high flows), riparian conditions, floodplain function, sediment conditions, and water quality and quantity; as a result, the important watershed processes and functions that once created healthy ecosystems for salmon and steelhead production have been weakened.

Within estuaries, essential PBFs have been defined as “areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation” (NMFS 2008j).

The conservation role of salmon and steelhead critical habitat is to provide PCEs that support populations that can contribute to conservation of ESUs and DPSs. NMFS’ critical habitat designations for salmon have noted that the conservation value of critical habitat also considers “(1) the importance of the populations associated with a site to the ESU conservation, and (2) the contribution of that site to the conservation of the population either through demonstrated or potential productivity of the area.” (68 FR 55926, September 29, 2003). This means that, in some cases, having a small area within the total area of designated critical habitat with impaired habitat features could result in a significant impact on conservation value of the entire designated area, when that particular habitat location serves an especially important role to the population and the species' recovery needs (e.g., unique genetic or life history diversity, critical spatial structure). In other words, because the conservation value of habitat indicates that its supporting important viability parameters of populations, conservation values themselves therefore may be considered impaired (NMFS 2016d).

2.2.7.1 Puget Sound Recovery Domain

Critical habitat has been designated in Puget Sound for Puget Sound Chinook salmon, Puget Sound steelhead, and Hood Canal Summer-run chum salmon. Major tributary river basins in the Puget Sound basin include the Nooksack, Samish, Skagit, Sauk, Stillaguamish, Snohomish, Lake Washington, Cedar, Sammamish, Green, Duwamish, Puyallup, White, Carbon, Nisqually, Deschutes, Skokomish, Duckabush, Dosewallips, Big Quilcene, Elwha, and Dungeness rivers and Soos Creek.

Critical habitat for Puget Sound Chinook salmon was designated on September 2, 2005 (70 FR 52630). Critical habitat includes 1,683 miles of streams, 41 square mile of lakes, and 2,182 miles of nearshore marine habitat in Puget Sound. The Puget Sound Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value.

Critical habitat for Hood Canal Summer-run chum salmon was designated on September 2, 2005 (70 FR 52630). Critical habitat includes 79 miles of rivers and 377 miles of nearshore marine habitat in Hood Canal. Most freshwater rivers in Hood Canal Summer-run chum salmon designated critical habitat are in fair to poor condition. Many nearshore areas are degraded, but some areas, including Port Gamble Bay, Port Ludlow, and Kilisut Harbor, remain in good condition (Garono et al. 2002; Daubenberger et al. 2017).

Critical habitat for Puget Sound steelhead was designated on February 24, 2016 (81 FR 9252). Critical habitat includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species. There are 66 watersheds within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS. Critical habitat for Puget Sound steelhead includes freshwater spawning sites, freshwater rearing sites, and freshwater migration corridors.

Critical habitat is designated for Puget Sound Chinook salmon and Hood Canal Summer-run chum in estuarine and nearshore areas. Designated critical habitat for Puget Sound steelhead does not include nearshore areas, as this species does not make extensive use of these areas during the juvenile life stage.

Landslides can occur naturally in steep, forested lands, but inappropriate land use practices likely have accelerated their frequency and the amount of sediment delivered to streams. Fine sediment from unpaved roads has also contributed to stream sedimentation. Unpaved roads are widespread on forested lands in the Puget Sound basin, and to a lesser extent, in rural residential areas. Historical logging removed most of the riparian trees near stream channels. Subsequent agricultural and urban conversion permanently altered riparian vegetation in the river valleys, leaving either no trees, or a thin band of trees. The riparian zones along many agricultural areas are now dominated by alder, invasive canary grass and blackberries, and provide substantially reduced stream shade and large wood recruitment (SSDC 2007).

Diking, agriculture, revetments, railroads and roads in lower stream reaches have caused significant loss of secondary channels in major valley floodplains in this region. Confined main channels create high-energy peak flows that remove smaller substrate particles and large wood. The loss of side-channels, oxbow lakes, and backwater habitats has resulted in a significant loss of juvenile salmonid rearing and refuge habitat. When the water level of Lake Washington was lowered 9 feet in the 1910s, thousands of acres of wetlands along the shoreline of Lake Washington, Lake Sammamish and the Sammamish River corridor were drained and converted to agricultural and urban uses. Wetlands play an important role in hydrologic processes, as they store water that ameliorates high and low flows. The interchange of surface and groundwater in complex stream and wetland systems helps to moderate stream temperatures. Forest wetlands are estimated to have diminished by one-third in Washington State (FEMAT 1993; Spence et al. 1996; SSDC 2007).

Loss of riparian habitat, elevated water temperatures, elevated levels of nutrients, increased nitrogen and phosphorus, and higher levels of turbidity, presumably from urban and highway runoff, wastewater treatment, failing septic systems, and agriculture or livestock impacts, have been documented in many Puget Sound tributaries (SSDC 2007).

Peak stream flows have increased over time due to paving (roads and parking areas), reduced percolation through surface soils on residential and agricultural lands, simplified and extended drainage networks, loss of wetlands, and rain-on-snow events in higher elevation clear cuts (SSDC 2007). In urbanized Puget Sound, there is a strong association between land use and land cover attributes and rates of coho spawner mortality likely due to runoff containing contaminants emitted from motor vehicles (Feist et al. 1996). Recent studies have shown that coho salmon show high rates of pre-spawning mortality when exposed to chemicals that leach from tires (McIntyre et al. 2015). Researchers have recently identified a tire rubber antioxidant as the cause (Tian et al. 2021). Although Chinook salmon did not experience the same level of mortality, tire leachate is still a concern for all salmonids. Traffic residue also contains many unregulated toxic chemicals such as pharmaceuticals, polycyclic aromatic hydrocarbons (PAHs), fire retardants, and emissions that have been linked to deformities, injury and/or death of salmonids and other fish (Trudeau 2017; Young et al. 2018).

Dams constructed for hydropower generation, irrigation, or flood control have substantially affected Puget Sound salmon and steelhead populations in a number of river systems. The construction and operation of dams have blocked access to spawning and rearing habitat, changed flow patterns, resulted in elevated temperatures and stranding of juvenile migrants, and degraded downstream spawning and rearing habitat by reducing recruitment of spawning gravel and large wood to downstream areas (SSDC 2007). These actions tend to promote downstream channel incision and simplification (Kondolf 1997), limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects often change flow rates, stranding and killing fish, and reducing aquatic invertebrate (food source) productivity (Hunter 1992). In some instances, such as in the Elwha River, dams have been removed as part of restoration efforts.

Juvenile mortality occurs in unscreened or inadequately screened diversions. Water diversion ditches resemble side channels in which juvenile salmonids normally find refuge. When diversion headgates are shut, access back to the main channel is cut off and the channel goes dry. Mortality can also occur with inadequately screened diversions from impingement on the screen, or mutilation in pumps where gaps or oversized screen openings allow juveniles to get into the system. Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in many Puget Sound tributary basins (SSDC 2007).

The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound's tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand (SSDC 2007).

Degradation of the near-shore environment has occurred in the southeastern areas of Hood Canal in recent years, resulting in late summer marine oxygen depletion and significant fish kills. Circulation of marine waters is naturally limited, and partially driven by freshwater runoff, which is often low in the late summer. However, human development has increased nutrient loads from failing septic systems along the shoreline, and from use of nitrate and phosphate fertilizers on lawns and farms. Shoreline residential development is widespread and dense in many places. The combination of highways and dense residential development has degraded certain physical and chemical characteristics of the near-shore environment (HCCC (Hood Canal Coordinating Council) 2005; SSDC 2007).

NMFS has completed several section 7 consultations on large-scale habitat projects affecting listed species in Puget Sound. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006b), and consultations on Washington State Water Quality Standards (NMFS 2008c), the National Flood Plain Insurance Program (NMFS 2008a), the Washington State Department of Transportation Preservation, Improvement and Maintenance Activities (NMFS 2013b), and the Elwha River Fish Restoration Plan (Ward et al. 2008; NMFS 2014c; 2019c; 2020e).

In 2012, the Puget Sound Action Plan was developed with several federal agencies (e.g., Environmental Protection Agency, NOAA Fisheries, the United States Army Corps of Engineers (USACE), Natural Resources Conservation Service, United States Geological Survey, Federal Emergency Management Agency, and USFWS). The most recent version of the Puget Sound Federal Task Force Action Plan (for years 2022-2026) was released in May 2022[20]. The purpose of the Puget Sound Federal Task Force Action Plan is to contribute toward realizing a shared vision of a healthy and sustainable Puget Sound ecosystem by leveraging Federal programs across agencies and coordinating diverse programs on a specific suite of priorities.

[20]https://www.epa.gov/system/files/documents/2022-06/puget-sound-federal-task-force-action-plan-2022-2026.pdf

In the 2019 Puget Sound steelhead recovery plan approximately 8,000 culverts that block steelhead habitat were identified in Puget Sound (NMFS 2019b), with the plans to address these blockages being extended over many years. Smaller scale improvements in habitat, restoration of riparian habitat and reconnecting side- or off-channel habitats, will allow better access to habitat types and niche diversification.

While there have been some significant improvements in restoring access, it is recognized that land development, loss of riparian and forest habitat, loss of wetlands, demands on water allocation all continue to degrade the quantity and quality of available fish habitat (Ford 2022).

In summary, even with restoration success, like dam removal and blocked culverts being addressed, critical habitat for salmon and steelhead throughout the Puget Sound basin continues to be degraded by numerous management activities, including: hydropower development, loss of mature riparian forests, increased sediment inputs, removal of large wood, intense urbanization, agriculture, alteration of floodplain and stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, dredging, armoring of shorelines, marina and port development, road and railroad construction and maintenance, logging, and mining. Changes in habitat quantity, availability, and diversity, and flow, temperature, sediment load and channel instability are common limiting factors in areas of critical habitat. As mentioned above, development of shoreline and estuary areas of Puget Sound is expected to continue to adversely impact the quality of marine habitat for Puget Sound salmonids. As noted throughout this Opinion, future effects of climate change on habitat quality throughout Puget Sound are expected to be negative.

The Puget Sound recovery domain CHART for Puget Sound Chinook salmon and Hood Canal Summer-run chum salmon (NMFS 2005a) determined that only a few watersheds with PCEs for Chinook salmon in the Whidbey Basin (Skagit River/Gorge Lake, Cascade River, Upper Sauk River, and the Tye and Beckler rivers) are in good-to-excellent condition with no potential for improvement. Most HUC5 watersheds are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some or a high potential for improvement.

2.2.7.2 Willamette/Lower Columbia Recovery Domain

NMFS has designated critical habitat in the Willamette/Lower Columbia recovery domain for the Upper Willamette River Chinook Salmon ESU, Lower Columbia River Chinook Salmon ESU, Lower Columbia River Coho Salmon ESU, Lower Columbia River Steelhead DPS, Upper Willamette River Steelhead DPS, and the Columbia River Chum Salmon ESU. This recovery domain is described in Section 2.3.

Critical habitat for Upper Willamette River Chinook salmon was designated on September 2, 2005 (70 FR 52629). Critical habitat encompasses 60 watersheds within the range of this ESU as well as the lower Willamette/Columbia River rearing/migration corridor, occurring in both Oregon and Washington (70 FR 52629). This includes 1,472 miles of stream habitat and 18 square miles of lake habitat. Nineteen watersheds received a low rating, 18 received a medium rating, and 23 received a high rating of conservation value to the ESU (NMFS 2005a). The lower Willamette/ Columbia River rearing/migration corridor downstream of the spawning range is also considered to have a high conservation value and is the only habitat designated in four of the high value watersheds.

Critical habitat for Lower Columbia River Chinook salmon was designated on September 2, 2005 (70 FR 52706). Critical habitat includes 1,311 miles of stream habitat and 33 square miles of lake habitat. There are 48 watersheds within the range of this ESU. Four watersheds received a low rating, 13 received a medium rating, and 31 received a high rating of conservation value to the ESU (NMFS 2005a). The lower Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in one of the high value watersheds.

Critical habitat was originally proposed for Lower Columbia River coho salmon on January 14, 2013 and was finalized on February 24, 2016 (81 FR 9251). Critical habitat includes 2,300 miles of streams and lakes. There are 55 watersheds within the range of this ESU. Three watersheds received a low conservation value rating, 18 received a medium rating, and 34 received a high rating (NMFS 2015c). The lower Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value.

Critical habitat for Lower Columbia River steelhead was designated on September 2, 2005 (70 FR 52833). Critical habitat includes 2,324 miles of stream habitat and 27 square miles of lake habitat. There are 32 watersheds within the range of this DPS. Two watersheds received a low rating, 11 received a medium rating, and 29 received a high rating of conservation value to the DPS (NMFS 2005a). The lower Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in one of the high value watersheds.

Critical habitat for the Upper Willamette River Steelhead DPS was designated on September 2, 2005 (70 FR 52848). Critical habitat includes 1,276 miles of stream habitat and 2 square miles of lake habitat. There are 38 watersheds within the range of this DPS. Seventeen watersheds received a low rating, 6 received a medium rating, and 15 received a high rating of conservation value to the DPS (NMFS 2005a). The lower Willamette/Columbia River rearing/migration corridor downstream of the spawning range is also considered to have a high conservation value and is the only habitat area designated in four of the high value watersheds.

Critical habitat was designated for Columbia River chum salmon on September 2, 2005 (70 FR 52746). Critical habitat includes 708 miles of stream habitat. There are 20 watersheds within the range of this ESU. Three watersheds received a medium rating and 17 received a high rating of conservation value to the ESU (NMFS 2005a). The lower Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in one of the high value watersheds.

In addition to the Willamette River and Columbia River mainstems, important tributaries to the Willamette/Lower Columbia are also described in Section 2.3 for both Oregon and Washington. Most watersheds have some or a high potential for improvement and the only watersheds in good to excellent condition with no potential for improvement are the watersheds in the upper McKenzie River and its tributaries (NMFS 2016d).

Land management activities have severely degraded stream habitat conditions in the Willamette River mainstem above Willamette Falls and in associated subbasins. In the Willamette River mainstem and lower subbasin mainstem reaches, high density urban development and widespread agricultural effects have reduced aquatic and riparian habitat quality and complexity, and altered sediment composition and water quality and/or quantity, and watershed processes. The Willamette River, once a highly braided river system, has been dramatically simplified through channelization, dredging, and other activities that have reduced rearing habitat by as much as 75% since before modern development began. In addition, the construction of 37 dams in the basin blocked access to more than 435 miles of stream and river habitat, including much of the best spawning habitat in the basin. The dams alter the temperature regime of the Willamette River and its tributaries, affecting the timing and development of naturally-spawned eggs and fry. Logging, agriculture, urbanization, and gravel mining in the Cascade and Coast Ranges have contributed to increased erosion and sediment loads throughout the Willamette/Lower Columbia domain (NMFS 2016d).

On the mainstem of the Columbia River, hydropower projects, including the FCRPS, have significantly degraded salmon and steelhead habitats. The series of dams and reservoirs that make up the FCRPS block an estimated 12 million cubic yards of debris and sediment that would otherwise naturally flow down the Columbia River and replenish shorelines along the Washington and Oregon coasts. The Columbia River estuary has lost a significant amount of the tidal marsh and tidal swamp habitats that are critical to juvenile salmon and steelhead, particularly small or ocean-type species as a result of the FCRPS modifications to these mainstem river processes. Furthermore, habitat and food-web changes within the estuary, and other factors affecting salmon population structure and life histories, have altered the estuary's capacity to support juvenile salmon (NMFS 2016d).

2.2.7.3 Interior Columbia Recovery Domain

Critical habitat has been designated in the Interior Columbia recovery domain, which includes the Snake River Basin, for the Snake River Spring/summer-run Chinook Salmon ESU, Snake River Fall-run Chinook Salmon ESU, Upper Columbia River Spring-run Chinook Salmon ESU, Snake River Sockeye Salmon ESU, Middle Columbia River Steelhead DPS, Upper Columbia River Steelhead DPS, and Snake River Basin Steelhead DPS (Table 4).

Critical habitat for Snake River spring/summer-run Chinook salmon was originally designated on December 28, 1993 (58 FR 68543) but updated most recently on October 25, 1999 (65 FR 57399). The designated habitat for Snake River spring/summer-run chinook salmon consists of river reaches of the Columbia, Snake, and Salmon Rivers, and all tributaries of the Snake and Salmon rivers (except the Clearwater River) presently or historically accessible to Snake River spring/summer chinook salmon (except reaches above impassable natural falls and Hells Canyon Dam).

Critical habitat was designated for Snake River fall-run Chinook salmon on December 28, 1993 (58 FR 68543). The designated habitat for Snake River fall-run chinook salmon consists of river reaches of the Columbia, Snake, and Salmon Rivers, and all tributaries of the Snake and Salmon Rivers presently or historically accessible to Snake River fall-run chinook salmon (except reaches above impassable natural falls, and Dworshak and Hells Canyon Dams).

Critical habitat for the Upper Columbia River spring-run Chinook salmon was designated on September 2, 2005 (70 FR 2732). Critical habitat includes 974 miles of stream habitat and 4 square miles of lake habitat. There are 31 watersheds within the range of this ESU. Five watersheds received a medium rating and 26 received a high rating of conservation value to the

ESU (NMFS 2005a). The Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in 15 of the high value watersheds identified.

Critical habitat was designated for Snake River sockeye salmon on December 28, 1993 (58 FR 68543). The designated habitat for Snake River sockeye salmon consists of river reaches of the Columbia, Snake, and Salmon Rivers, Alturas Lake Creek, Valley Creek, and Stanley, Redfish, Yellow Belly, Pettit, and Alturas Lakes (including their inlet and outlet creeks).

Critical habitat for the Middle Columbia River Steelhead DPS was designated on September 2, 2005 (70 FR 52808). Critical habitat includes 5,815 miles of stream habitat. There are 114 watersheds within the range of this DPS. Nine watersheds received a low rating, 24 received a medium rating, and 81 received a high rating of conservation value to the DPS (NMFS 2005a). The lower Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in three of the high value watersheds identified above.

Critical habitat for the Upper Columbia River Steelhead DPS was designated on September 2, 2005 (70 FR 52630). Critical habitat includes 1,262 miles of stream habitat and 7 square miles of lake habitat. There are 42 watersheds within the range of this DPS. Three watersheds received a low rating, 8 received a medium rating, and 31 received a high rating of conservation value to the DPS (NMFS 2005a). The Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in 11 of the high value watersheds identified.

Critical habitat for the Snake River Basin Steelhead DPS was designated on September 2, 2005 (70 FR 52769). Critical habitat includes 8,049 miles of stream habitat and 4 square miles of lake habitat. There are 289 watersheds within the range of this DPS. Fourteen watersheds received a low rating, 44 received a medium rating, and 231 received a high rating of conservation value to the DPS (NMFS 2005a). The lower Snake/ Columbia River rearing/migration corridor downstream of the spawning range is considered to have a high conservation value and is the only habitat area designated in 15 of the high value watersheds identified above.

In Washington, the Upper Methow, Lost, White, and Chiwawa watersheds are in good-to-excellent condition with no potential for improvement. In Oregon, only the Lower Deschutes, Minam, Wenaha, Upper and Lower Imnaha Rivers HUC_5 watersheds are in good-to-excellent condition with no potential for improvement. In Idaho, some watersheds with PCEs for steelhead (Upper Middle Salmon, Upper Salmon/Pahsimeroi, MF Salmon, Little Salmon, Selway, and Lochsa Rivers) are in good-to-excellent condition with no potential for improvement. Additionally, several Lower Snake River watersheds in the Hells Canyon area, straddling Oregon and Idaho, are in good-to-excellent condition with no potential for improvement (NMFS 2016d).

Habitat quality in tributary streams in the Interior Columbia recovery domain varies from excellent in wilderness and road-less areas to poor in areas subject to heavy agricultural and urban development. Critical habitat throughout much of the Interior Columbia recovery domain has been degraded by intense agriculture, alteration of stream morphology (i.e., through channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer stream flows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in developed areas, including those within the interior Columbia River recovery domain (NMFS 2016d).

Habitat quality of migratory corridors in this area have been severely affected by the development and operation of the FCRPS dams and reservoirs in the mainstem Columbia River, Bureau of Reclamation (BOR) tributary projects, and privately-owned dams in the Snake and Upper Columbia River basins. Hydroelectric development has modified natural flow regimes of the rivers, resulting in higher water temperatures, changes in fish community structure that lead to increased rates of piscivorous and avian predation on juvenile salmon and steelhead, and delayed migration for both adult and juvenile salmonids. Physical features of dams, such as turbines, also kill out-migrating fish. In-river survival is inversely related to the number of hydropower projects encountered by emigrating juveniles. Additionally, development and operation of extensive irrigation systems and dams for water withdrawal and storage in tributaries have altered hydrological cycles (NMFS 2016d).

Many stream reaches designated as critical habitat are listed on Oregon, Washington, and Idaho's Clean Water Act Section 303(d) list for water temperature. Many areas that were historically suitable rearing and spawning habitat are now unsuitable due to high summer stream temperatures. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water for agricultural or municipal use all contribute to elevated stream temperatures. Furthermore, contaminants, such as insecticides and herbicides from agricultural runoff and heavy metals from mine waste, are common in some areas of critical habitat (NMFS 2016d). They can negatively impact critical habitat and the organisms associated with these areas.

2.2.7.4 Estuaries

Critical habitat has been designated in the estuary of the Columbia River for every species included in the Willamette/Lower Columbia and Interior Columbia Recovery Domains. This area is described in Section 2.3. Historically, the downstream half of the Columbia River estuary was a dynamic environment with multiple channels, extensive wetlands, sandbars, and shallow areas. The mouth of the Columbia River was about four miles wide. Winter and spring floods, low flows in late summer, large woody debris floating downstream, and a shallow bar at the mouth of the Columbia River maintained a dynamic environment. Today, navigation channels have been dredged, deepened and maintained, jetties and pile-dike fields have been constructed to stabilize and concentrate flow in navigation channels, marsh and riparian habitats have been filled and diked, and causeways have been constructed across waterways. These actions have decreased the width of the mouth of the Columbia River to two miles and increased the depth of the Columbia River channel at the bar from less than 20 to more than 55 feet (NMFS 2008h).

Over time, more than 50% of the original marshes and spruce swamps in the estuary have been converted to industrial, transportation, recreational, agricultural, or urban uses. More than 3,000 acres of intertidal marsh and spruce swamps have been converted to other uses since 1948. Many wetlands along the shore in the upper reaches of the estuary have been converted to industrial and agricultural lands after levees and dikes were constructed. Furthermore, water storage and release patterns from reservoirs upstream of the estuary have changed the seasonal pattern and volume of discharge. The peaks of spring/summer floods have been reduced, and the amount of water discharged during winter has increased (NMFS 2008h).

In addition, model studies indicate that, together, hydrosystem operations and reduced river flows caused by climate change have decreased the delivery of suspended particulate matter to the lower river and estuary by about 40% (as measured at Vancouver, Washington) and have reduced fine sediment transport by 50% or more. The significance of these changes for anadromous species under NMFS' jurisdiction in this area is unclear, although estuarine habitat is likely to provide ecosystem services (e.g., food and refuge from predators) to subyearling migrants that reside in estuaries for up to two months or more (NMFS 2008h).

NMFS (2005a) identified the PCEs for Columbia basin salmonids in estuaries as follows:

- Estuarine areas free of obstruction with water quality, quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

These features are essential to conservation because, without them, juvenile salmonids cannot reach the ocean in a timely manner and use the variety of habitats that allow them to avoid predators, compete successfully, and complete the behavioral and physiological changes needed for life in the ocean. Similarly, these features are essential to the conservation of adult salmonids because these features in the estuary provide a final source of abundant forage that will provide the energy stores needed to make the physiological transition to fresh water, migrate upstream, avoid predators, and develop to maturity upon reaching spawning areas (NMFS 2008k).

2.2.8 Status of Eulachon (Southern DPS)

On March 18, 2010, NMFS listed the southern DPS of Pacific eulachon (*Thaleichthys pacificus*) as a threatened species (75 FR 13012). Eulachon are endemic to the northeastern Pacific Ocean; they range from northern California to southwest and south-central Alaska and into the southeastern Bering Sea (Figure 59). The southern DPS of eulachon is comprised of fish that spawn in rivers south of the Nass River in British Columbia to, and including, the Mad River in California.

2.2.8.1 Eulachon Life History

Adult eulachon spawning typically occurs in the lower reaches of larger rivers fed by snowmelt, and takes place over sand, coarse gravel, or mineral grains. Eulachon eggs attach to small sediment particles (sand and mineral grains); eggs incubate and develop while being actively carried downstream by river currents. Eggs hatch in 30 to 40 days depending on water temperatures. Newly hatched larvae are transparent and are transported downstream by spring freshets, and are dispersed by estuarine, tidal, and ocean currents into the estuary-nearshore environment. However, larval eulachon may remain in low salinity, surface waters of estuaries for several weeks or longer before entering the ocean (Hay et al. 2000). Once larval eulachon enter the ocean they eventually move from shallow nearshore areas to deeper areas over the continental shelf, typically in waters 66 to 292 feet deep (Hay et al. 2000), and sometimes as deep as 597 feet (Barraclough 1964). Eulachon typically spend 2–5 years in saltwater before returning to freshwater to spawn from late winter through spring, spending 95 to 98 percent of their lives at sea (Hay et al. 2000).

Table 66 provides a summary of listing and recovery plan information, status and major threats for the eulachon. Table 67 provides a summary of eulachon migration/spawning/egg emergence and larval drift for the Columbia River subpopulation, and Table 68 provides a summary of documented river-entry and/or spawn-timing for eulachon (southern DPS and non-listed eulachon).

Annual eulachon run size estimates (spawning stock biomass estimations) are provided for the years 2000 through 2023 for the Columbia River subpopulation and 1995 through 2023 for the Fraser River subpopulation, Figure 60 and Figure 61, to support our impact analysis on the subpopulation and species scales. Run size estimates are not available for the Klamath subpopulation and the British Columbia subpopulation.

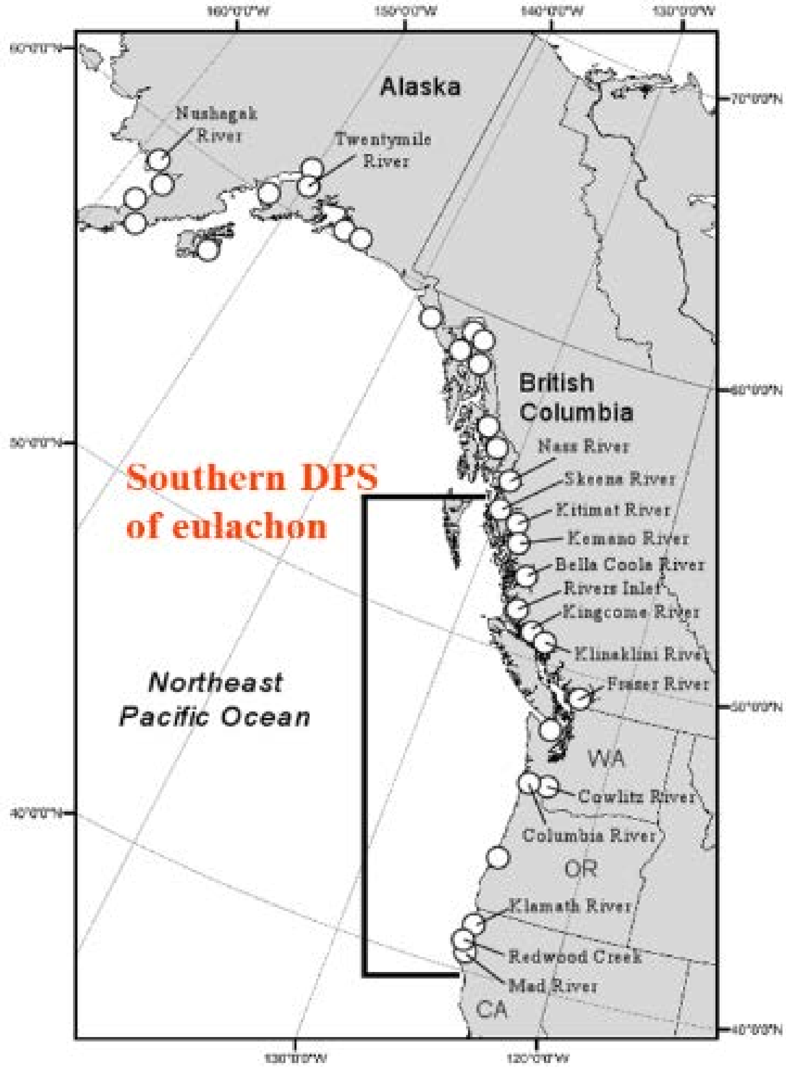


Figure 59. Distribution of the southern district population segment of eulachon.

Table 66. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for eulachon.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Major Threats
Southern DPS of eulachon	Threatened 3/18/10	NMFS (2017i)	NMFS (2022r)	Eulachon are endemic to the northeastern Pacific Ocean; they range from northern California to southwest and south-central Alaska and into the southeastern Bering Sea. The southern DPS of eulachon is comprised of fish that spawn in rivers south of the Nass River in British Columbia to, and including, the Mad River in California. In the most recent status review (NMFS 2022o), none of the eulachon mean SSB estimates for the years 2016 – 2021 met the HIGH demographic recovery criteria for either the Columbia River subpopulation or the Fraser River subpopulation. For the Columbia River subpopulation, the LOW demographic recovery criterion was met in 2020, and for the Fraser River subpopulation, the LOW demographic recovery criterion was met in 2018 and 2020. In 2022 and 2023 none of the eulachon mean SSB estimates met the HIGH demographic recovery criteria for either the Columbia River subpopulation or the Fraser River subpopulation; however for the Columbia River subpopulation the LOW demographic recovbery criteria was met in both years. For the Fraser River subpopulation, the LOW demographic was not met in either 2022 and 2023. And, for the years 2016 thrugh 2023, the eulachon presence, spatial distribution, and frequency of occurrence recovery criterion was met in several, but not all, representative watersheds.	• Climate change impacts on ocean and freshwater habitat • Bycatch in offshore shrimp trawl fisheries • Changes in downstream flow-timing and intensity due to dams and water diversions • Predation

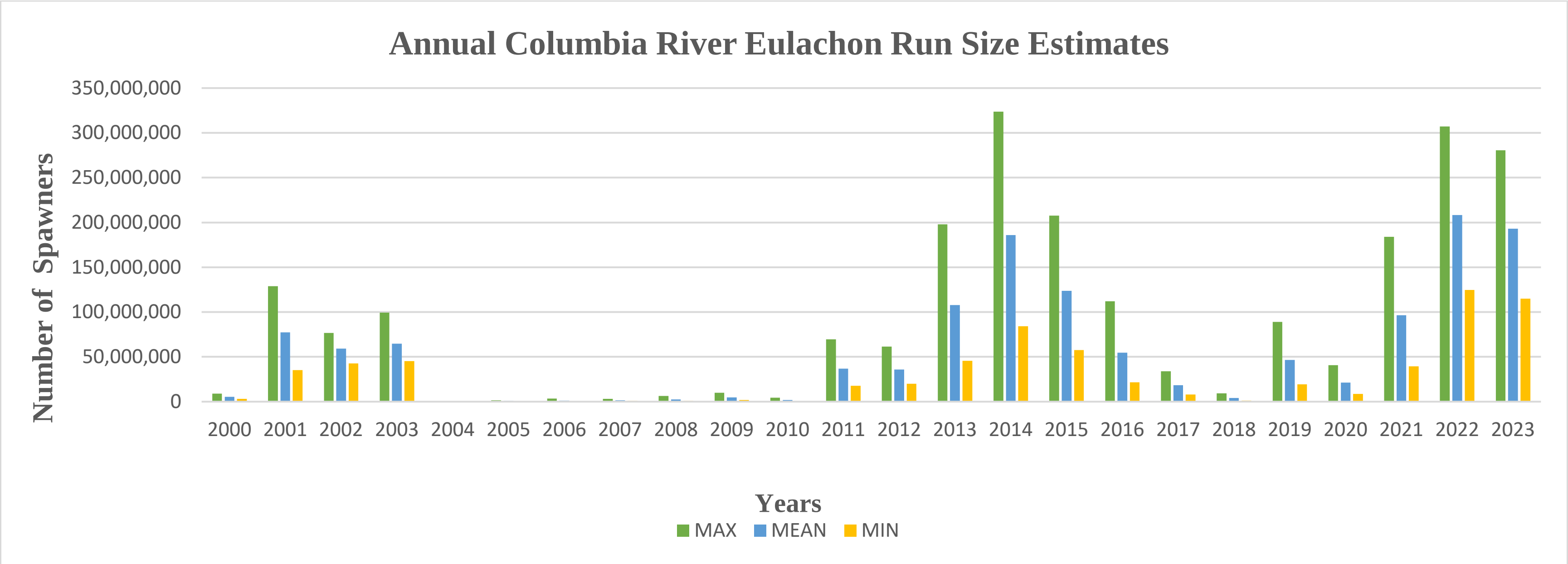


Figure 60. Columbia River subpopulation run size estimations for the years 2000 through 2023.

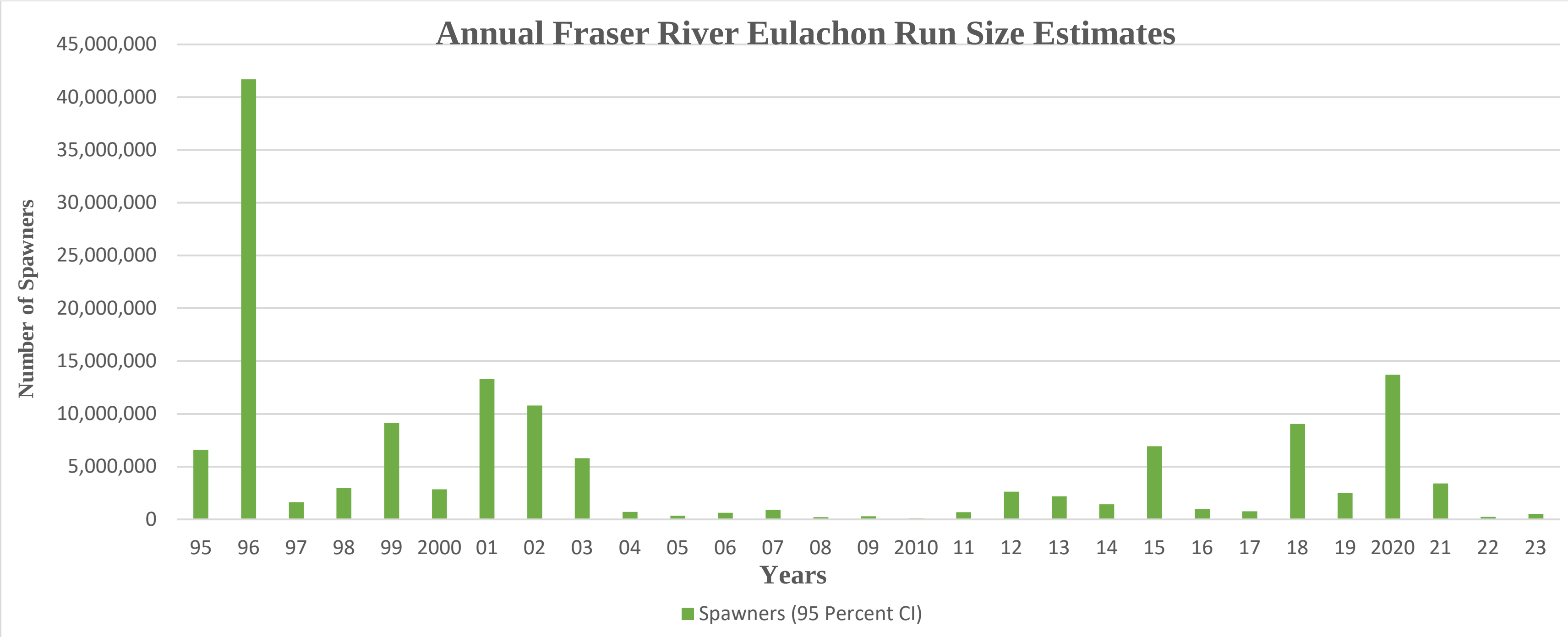


Figure 61. Fraser River subpopulation run size estimations for the years 1995 through 2023.

Table 67. Eulachon migration/spawning/egg emergence and larval drift for the Columbia River subpopulation. Dark grey cells indicate peak activity level and light grey cells indicate non-peak activity level.

Life Stage	Approximate River Miles	River System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Migration[a]	0–146	Columbia												
Adult Migration[b]	0–146	Columbia												
Adult Migration[kk]		Grays												
Adult Migration[kk]		Cowlitz												
Adult Migration[kk]		Kalama												
Adult Migration[kk]		Lewis												
Adult Migration[kk]		Sandy												
Spawning[kk]	30–146	Columbia												
Spawning[kk]	30–146	Columbia												
Spawning[kk]		Grays												
Spawning[c]	30–73	Columbia												
Spawning[kk]		Cowlitz												
Spawning[kk]		Kalama												
Spawning[kk]		Lewis												
Spawning[kk]		Sandy												
Eggs/Larval emergence-drift[kk,ll]	Plume–146	Columbia												
Eggs/Larval emergence-drift[ll]	Plume–146	Columbia												
Eggs/Larval emergence-drift[ll]	Plume–23	Grays												
Eggs/Larval emergence-drift[mm]	Plume–146	Columbia												
Eggs/Larval emergence-drift[ll]	Plume–68	Cowlitz												
Eggs/Larval emergence-drift[kk]	Plume–73	Kalama												
Eggs/Larval emergence-drift[kk]	Plume–85	Lewis												
Eggs/Larval emergence-drift[kk]	Plume–121	Sandy												

[a] (LCFRB 2004)
[b] Table A-9 in Gustafson et al. (2010)
[c] (Romano et al. 2002)

Table 68. Range (gray shading) and peak (black shading) timing of documented river-entry and/or spawn-timing for eulachon.

Basin	Source[a]	December		January		February		March		April		May		June	
California															
Mad River															
Redwood Creek															
Klamath River	1														
Oregon															
Tenmile Creek	7														
Columbia Basin															
Columbia River	10														
Cowlitz River	10														
Sandy River	7														
Washington															
Elwha River	2														
British Columbia															
Fraser River	4,13														
Kemano River	8														
Bella Coola River	15														
Kitimat River	3,9														
Skeena River	16														
Nass River	6														
Alaska															
Copper River	11,12														
Alaganik River	11,12														
Eyak River	11														
Ibeck Creek	11,12														
Twentymile River	5														
Susitna River	14														

[a] 1- Larson et al. (1998); 2- Shaffer et al. (2007); 3-Pedersen et al. (1995); 4- Ricker et al. (1954); Hart et al. (1944); 5- Kubik et al. (1977; 1978);Spangler et al. (2003); 6- Langer et al. (1977); 7- WDFW et al. (2008); 8- Lewis et al. (2002) as cited in Moody (2008); 9- Kelson (1996) as cited in Moody (2008); 10- WDFW et al. (2001); 11- Joyce et al. (2004); 12- Moffitt et al. (2002); 13- Hart (1943); 14- Barrett et al. (1984) as cited in Spangler et al. (2003); 15- Moody (2008); 16- Lewis (1997).

2.2.9 Status of Puget Sound/Georgia Basin Rockfish

2.2.9.1 Geographic Setting and Life History

Detailed assessments of yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*S. paucispinis*) can be found in the recovery plan (NMFS 2017s), and two 5-year status reviews (Tonnes et al. 2016; Lowry et al. 2024), and are briefly summarized here. We describe the status of yelloweye rockfish and bocaccio with nomenclature referring to specific areas of Puget Sound and the Strait of Georgia. Though these water bodies, together with the Strait of Juan de Fuca, collectively make up the Georgia Basin, or Salish Sea, we use Puget Sound in the broad sense to refer to all U.S. waters of the listed DPSs of bocaccio and yelloweye rockfish (Figure 63 and Figure 64). Using this nomenclature, U.S. waters north of the San Juan Islands are considered part of Puget Sound, despite cartographically being the southern Strait of Georgia.

Puget Sound is the second largest estuary in the United States, located in northwest Washington State and covering an area of approximately 900 square miles (2,330 square km), including 2,500 miles (4,000 km) of shoreline. We subdivide Puget Sound into five interconnected subbasins defined by the presence of shallow areas called sills, which restrict water flow and prolong flushing rates such that water chemistry and biology vary substantially. These subbasins largely align with MCAs shown in Figure 62,and are defined as: (1) the San Juan/Strait of Juan de Fuca/southern Strait of Georgia Basin, also referred to as “North Sound” (the portion of MCA 6 east of Port Angeles and all of MCA 7); (2) Main Basin (MCAs 9, 10, and 11); (3) Whidbey Basin (MCAs 8–1 and 8–2); (4) South Sound (MCA 13); and (5) Hood Canal (MCA 12). We use the term “Puget Sound proper” to refer collectively to all basins except North Sound.

The Puget Sound/Georgia Basin DPS of yelloweye rockfish is listed under the ESA as threatened, and the Puget Sound/Georgia Basin DPS of bocaccio is listed as endangered (75 FR 22276, April 28, 2010). On January 23, 2017 (82 FR 7711), we extended the yelloweye rockfish DPS, which initially aligned with the DPS of bocaccio, further north in the Johnstone Strait area of Canada, a difference apparent by comparing Figure 63 and Figure 64. This extension was also the result of new genetic analysis of yelloweye rockfish. The DPSs include all yelloweye rockfish and bocaccio found in waters of Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca east of the Victoria Sill (Figure 63 and Figure 64) regardless of their origin.

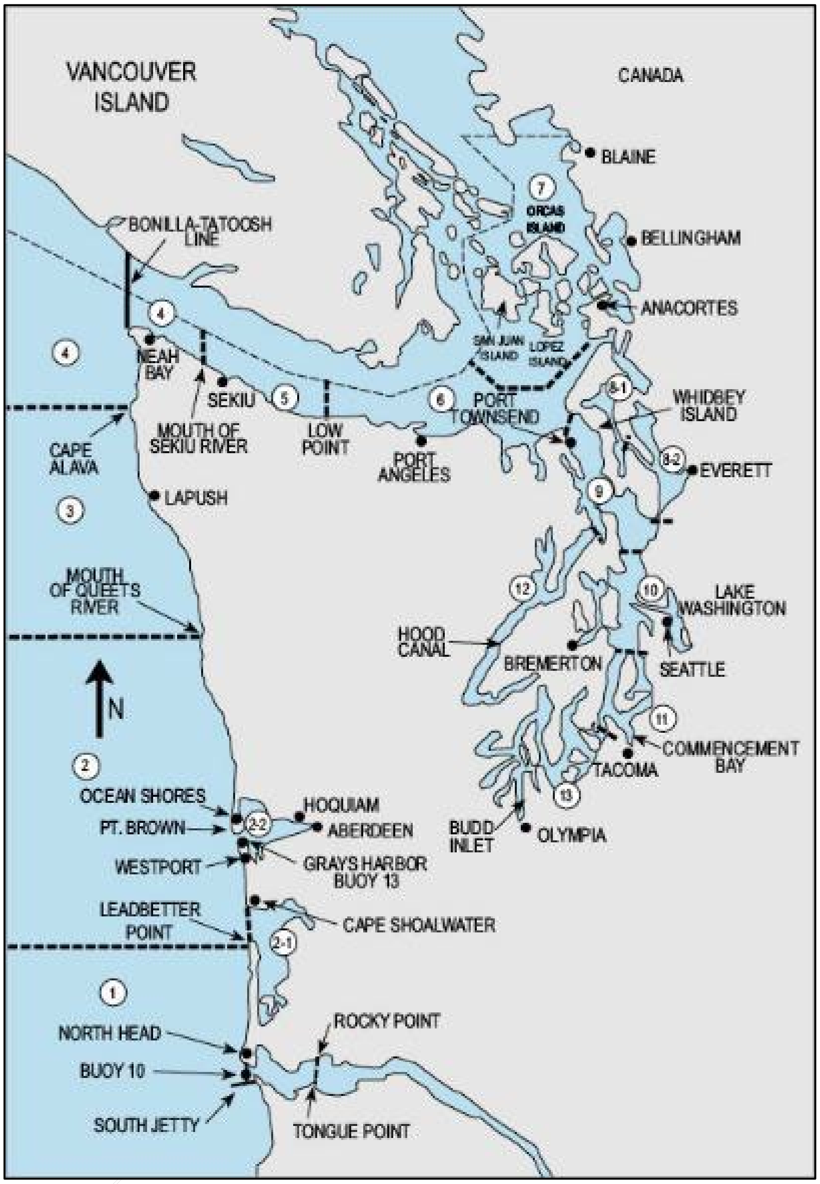


Figure 62. Recreational fisheries marine catch areas off Washington, shown here to reference the subareas described below[21].

[21] WDFW marine area rules and definitions available at: https://www.eregulations.com/washington/fishing/marine-area-rules-definitions

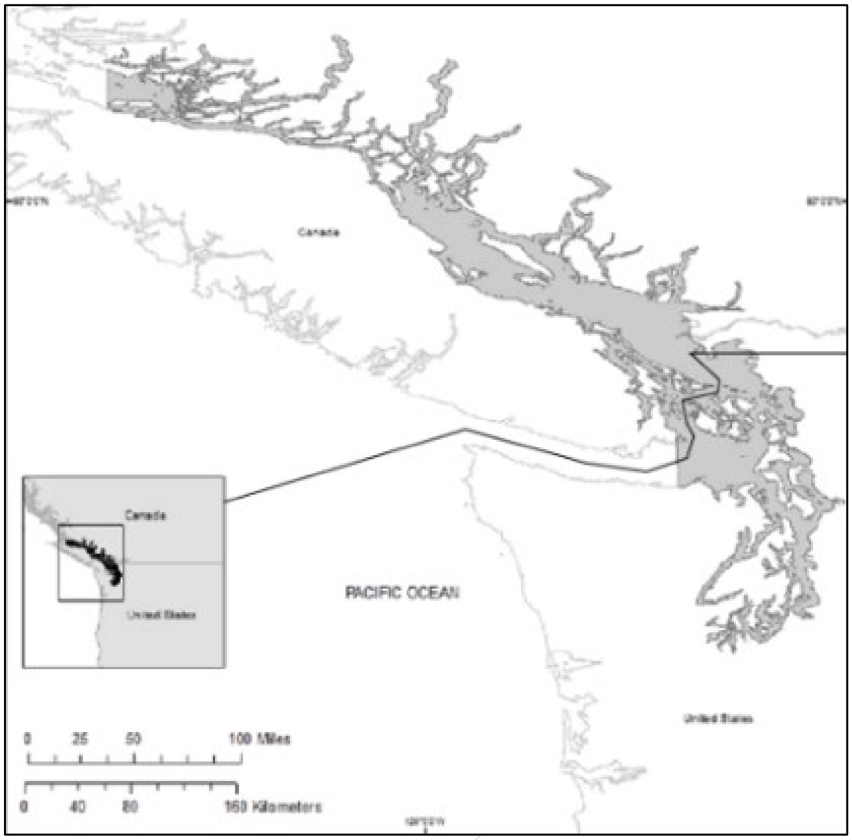


Figure 63. Geographic scope (gray shading) of the yelloweye rockfish distinct population segment (DPS), spanning the U.S.–Canadian border.

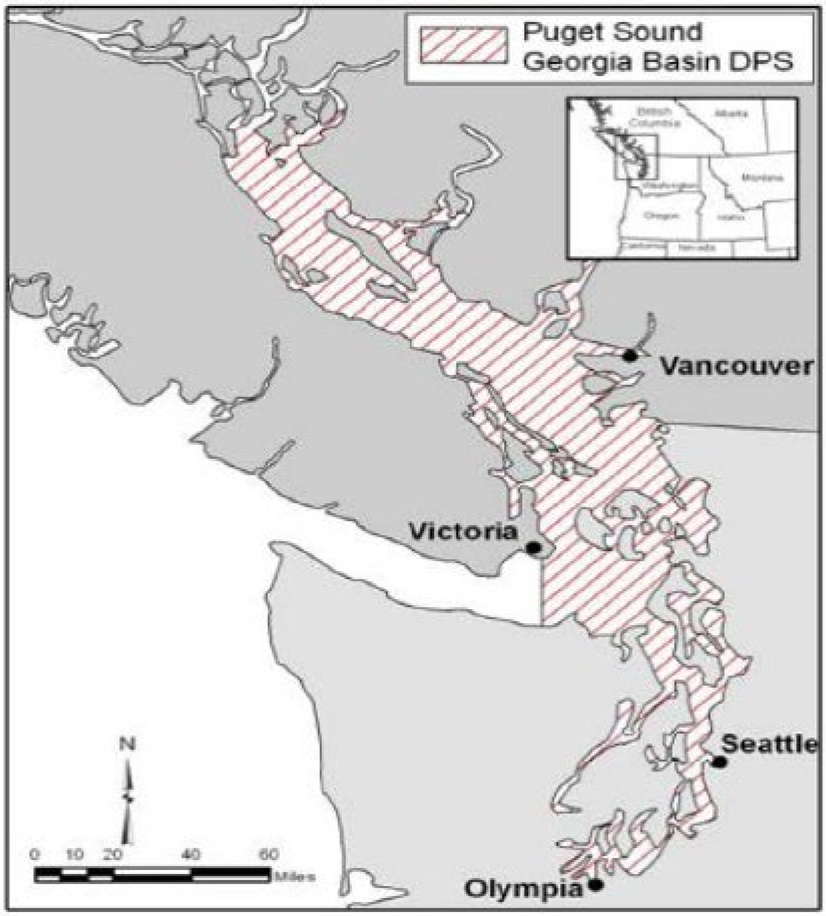


Figure 64. Geographic scope (red hatching) of the bocaccio distinct population segment (DPS), spanning the U.S.–Canadian border.

The life histories of yelloweye rockfish and bocaccio include a larval/pelagic juvenile stage, followed by demersobenthic juvenile, subadult, and adult stages. Much of the life history and habitat use for these two species is similar, with important differences noted below. All species of rockfish employ internal fertilization and young are extruded as free-swimming larvae. A mature female yelloweye rockfish or bocaccio can produce from several thousand to well over a million eggs each breeding cycle (Love et al. 2002; Arthur et al. 2022). Breeding cycles tend to occur annually, but skip spawning (i.e., a biennial reproductive cycle for some individuals) has been recorded in both yelloweye rockfish (Gertseva et al. 2017; COSEWIC 2020; Arthur et al. 2022) and bocaccio (He et al. 2015). Larvae can make small local movements to pursue food immediately after birth (Tagal et al. 2002), but are largely passively distributed with prevailing currents until they are large enough to intentionally select preferred habitats. Unique oceanographic conditions within Puget Sound proper result in most larvae staying within the subbasin where they are released (e.g., Hood Canal) rather than being broadly dispersed (Drake et al. 2010), but dispersal patterns are highly variable among subbasin and season of larval release (Andrews et al. 2021). Larvae released in North Sound may disperse widely throughout inland waters of the DPSs, as well as offshore waters of Washington and British Columbia, before reaching the end of their planktonic period.

When bocaccio reach sizes of 1–3.5 inches (3–9 cm), or approximately 3–6 months old, they settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp (Love et al. 1991; Love et al. 2002). These habitat features offer a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Areas with floating and submerged kelp species support the highest densities of most juvenile rockfish (Carr 1983; Haldorson et al. 1987; Matthews 1989; Hayden-Spear 2006). Unlike bocaccio, juvenile yelloweye rockfish do not typically occupy nearshore waters (Love et al. 1991; Studebaker et al. 2009), but settle in 98 to 131 feet (30 to 40 m) of water near the upper depth range of adults (Yamanaka et al. 2001).

Subadult and adult yelloweye rockfish, and bocaccio, typically utilize habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al. 2002; Drake et al. 2010; Pacunski et al. 2013). Within the boundaries of the DPSs, both species have been documented in areas of high relief rocky and non-rocky substrates such as sand, mud, and other unconsolidated sediments (Washington 1977; Miller et al. 1980; Pacunski et al. 2013; Andrews et al. 2018; Pacunski et al. 2020; Lowry et al. 2022). Yelloweye rockfish remain near the bottom and have small home ranges, while bocaccio have larger home ranges, move long distances, and spend time suspended in the water column (Love et al. 2002). Adults of each species are most commonly found between 131 to 820 feet (40 to 250 m) (Orr et al. 2000; Love et al. 2002).

Yelloweye rockfish are one of the longest-lived of the rockfishes, with some individuals reaching more than 100 years of age (Yamanaka et al. 2006). They reach 50% maturity at sizes around 16 to 20 inches (40 to 50 cm) and ages of 15 to 20 years (Rosenthal et al. 1982; Yamanaka et al. 1997). Bocaccio are notoriously difficult to age, and their maximum age has been reported as being as high as 57 years (Ralston et al. 1998). Application of advanced techniques, however, places the maximum age closer to 40 years (COSEWIC 2002; Pearson et al. 2015), with evidence that this attribute varies with latitude. Bocaccio reach reproductive maturity between ages 3 and 8 (Wyllie-Echeverria 1987; Love et al. 2002).

In the following section, we summarize the condition of yelloweye rockfish and bocaccio at the DPS level according to the following demographic viability criteria: abundance and productivity; spatial structure/connectivity; and diversity. These viability criteria are outlined in McElhany et al. (2000) and reflect concepts that are well founded in conservation biology and are generally applicable to a wide variety of species. These criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk (Drake et al. 2010). There are several common risk factors detailed below at the introduction of each of the viability criteria for both rockfish species. Habitat- and species-limiting factors can affect abundance, productivity, spatial structure, and diversity parameters, and are described.

2.2.9.2 Abundance and Productivity

There is no single reliable historical or contemporary population estimate for yelloweye rockfish or bocaccio within the full range of the Puget Sound/Georgia Basin DPSs (Drake et al. 2010;

NMFS 2017s; Lowry et al. 2024). Despite this limitation, there is clear evidence both species' abundance declined dramatically since the 1970s and has not significantly rebounded (Drake et al. 2010; Williams et al. 2010a; NMFS 2017s; Keppel et al. 2019; Min et al. 2023; Lowry et al. 2024). Analysis of SCUBA surveys, recreational catch, and WDFW trawl surveys indicated total rockfish populations in the Puget Sound region are estimated to have declined between 3.1% and 3.8% per year for the past several decades, which corresponds to a 69% to 76% decline from 1977 to 2014 (Tonnes et al. 2016; Tolimieri et al. 2017). For yelloweye rockfish in the Puget Sound region, models that incorporate recent remotely operated vehicle (ROV) survey data indicate that populations are slowly increasing, but still fall well short of recovery goals (Min et al. 2023; Lowry et al. 2024). For bocaccio, encounter rates within the DPS are now so low that reliably determining a population status trend is impossible.

Catches of yelloweye rockfish and bocaccio declined as a proportion of overall rockfish catch until fisheries were closed in 2010 in response to the ESA listings (Palsson et al. 2009; Drake et al. 2010). Yelloweye rockfish were 2.4% of the harvest in North Sound during the 1960s, occurred in 2.1% of the harvest during the 1980s, but then decreased to an average of 1% from 1996 to 2002 (Palsson et al. 2009). In Puget Sound proper, yelloweye rockfish were 4.4% of the harvest during the 1960s, only 0.4% during the 1980s, and 1.4% from 1996 to 2002 (Palsson et al. 2009).

Bocaccio made up 8%–9% of the overall rockfish catch in the late 1970s and declined in frequency, relative to other species of rockfish, from the 1970s to the 1990s (Drake et al. 2010). From 1975 to 1979, bocaccio averaged 4.6% of the catch. From 1980 to 1989, they were 0.2% of the 8,430 rockfish identified (Palsson et al. 2009; Drake et al. 2010). In the 1990s and early 2000s, bocaccio were not observed by WDFW in the dockside surveys of recreational catch (Drake et al. 2010). Despite concerted efforts to obtain bocaccio specimens for genetic research over the last decade, only a handful of individuals have been observed by the WDFW with their ROV, and even fewer have been successfully captured (Pacunski et al. 2013; Andrew et al. 2019; Pacunski et al. 2020; Lowry et al. 2022; Lowry et al. 2024).

Productivity is the measurement of a population's growth rate through all or a portion of its life cycle. Life history traits of yelloweye rockfish and bocaccio suggest generally low levels of inherent productivity because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Tolimieri et al. 2005; Drake et al. 2010). Overfishing can have dramatic impacts on the size or age structure of the population, with effects that can influence ongoing productivity. When the size and age of females decline, there are negative impacts on reproductive success. These impacts, termed maternal effects, are evident in a number of traits. Larger and older females of various rockfish species have a higher weight-specific fecundity (number of larvae per unit of female weight) (Boehlert et al. 1982; Bobko et al. 2004; Sogard et al. 2008). A consistent maternal effect in rockfishes relates to the timing of parturition. The timing of larval birth can be crucial in terms of corresponding with favorable oceanographic conditions because larvae are typically released annually, with a few exceptions in southern coastal populations and in yelloweye rockfish in Puget Sound (Washington et al. 1978). Several studies of rockfish species have shown that larger or older females release larvae earlier in the season compared to smaller or younger females (Nichol et al. 1994; Sogard et al. 2008). Larger or older females provide more nutrients to larvae by developing a larger oil globule released at parturition, which provides energy to the developing larvae (Berkeley et al. 2004; Fisher et al. 2007b) and, in black rockfish, enhances early growth rates (Berkeley et al. 2004).

Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and chlorinated pesticides appear in rockfish collected in urban areas (West et al. 2001; Palsson et al. 2009). While the highest levels of contamination occur in urban areas, toxins can be found in the tissues of fish throughout Puget Sound (West et al. 2001). Although few studies have investigated the effects of toxins on rockfish ecology or physiology, other fish in the Puget Sound region that have been studied show a substantial impact, including reproductive dysfunction of some sole species (Landahl et al. 1997). Reproductive function of adult rockfish is also likely affected by contaminants (Palsson et al. 2009), and other life history stages may be affected as well (Drake et al. 2010). Larvae may be especially sensitive, given their inability to avoid areas containing high levels of toxic contaminants and the underdeveloped nature of organs, such as the liver, that play a role in detoxification.

Future climate-induced changes to rockfish habitat with the ability to alter their productivity have been identified (Drake et al. 2010). Harvey (2005) created a generic bioenergetic model for rockfish, showing that their productivity is highly influenced by climate conditions. For instance, El Niño-like conditions generally lowered growth rates and increased generation time. The negative effect of the warm water conditions associated with El Niño appear to be common across rockfishes (Moser et al. 2000). Recruitment of all species of rockfish appears to be correlated at large scales. Field et al. (2005) hypothesized that such synchrony was the result of large-scale climate forcing. Exactly how climate influences rockfish in Puget Sound is unknown; however, given the general importance of climate to rockfish recruitment, it is likely that climate strongly influences the dynamics of listed rockfish population viability (Drake et al. 2010). The consequences of climate change to rockfish productivity, however, will likely be small provided sufficient forage exists to fuel reproductive cycles.

2.2.9.2.1 Yelloweye Rockfish Abundance and Productivity

Yelloweye rockfish within U.S. waters of the Puget Sound/Georgia Basin are most abundant within the San Juan Basin. The San Juan Basin has the most suitable rocky benthic habitat (Palsson et al. 2009; Pacunski et al. 2013; Pacunski et al. 2020; Lowry et al. 2022) and historically was the area in which anglers most frequently encountered, and retained, this species (Moulton et al. 1987; Olander 1991).

Productivity for yelloweye rockfish is influenced by long generation times that reflect intrinsically low annual reproductive success. Natural mortality rates have been estimated from 2% to 4.6% (Yamanaka et al. 1997; Wallace 2007). Productivity may also be particularly impacted by Allee effects, which occur as adults are removed by fishing and the density and proximity of mature fish decreases. Adult yelloweye rockfish typically occupy relatively small ranges (Love et al. 2002) and it is unknown the extent to which they may move to find suitable mates. Exploratory tagging and focal individual drop-camera survey efforts in Hood Canal have demonstrated that yelloweye rockfish occupy an area of less than 20 square feet over the course of several weeks (D. Lowry, NOAA Fisheries, personal communication).

In Canada, yelloweye rockfish biomass is estimated to have declined 68%–88% between 1918 and 2019, such that it is now 12% of the unfished stock size on the inside waters of Vancouver Island (DFO Canada 2011; COSEWIC 2020). In 2020, the COSEWIC status of this population was changed from Species of Concern to Threatened, acknowledging persistently depressed abundance. There are no analogous biomass estimates in the U.S. portion of the yelloweye rockfish DPS. However, the WDFW has generated several population estimates of yelloweye rockfish in recent years. ROV surveys in the San Juan Island region in 2008 (focused on rocky substrate) and 2010 (across all habitat types) estimated a population of 47,407 ± 11,761 and 114,494 ± 31,036 individuals, respectively (Pacunski et al. 2013; Pacunski et al. 2020). A 2015 ROV survey of that portion of the DPSs south of the entrance to Admiralty Inlet encountered 35 yelloweye rockfish, producing a preliminary population estimate of 66,998 ± 7,370 individuals (final video review is still under way) (WDFW 2017). A recent effort to model yelloweye rockfish abundance using an historical catch reconstruction and a deterministic population growth model estimated that the U.S. portion of the population could currently be as large as 25% of unfished biomass, but confidence bounds were very wide given a lack of recent catch data (Min et al. 2023).

2.2.9.2.2 Bocaccio Abundance and Productivity

Bocaccio in U.S. waters of the Puget Sound/Georgia Basin were historically most common within the South Sound and Main Basin (Palsson et al. 2009; Drake et al. 2010). Though bocaccio were never a predominant segment of the multi-species rockfish abundance within the Puget Sound/Georgia Basin (Drake et al. 2010), their present-day abundance is a small fraction of their pre-contemporary fishery abundance. Bocaccio abundance is very low in large segments of the Puget Sound/Georgia Basin and, though noting their occasional occurrence in the Strait of Georgia, assessments of the species in Canadian waters do not account for fish occurring in any portion of the DPS (COSEWIC 2013; Fisheries and Oceans Canada 2020). Productivity is driven by high fecundity and episodic recruitment events, largely correlated with environmental conditions. Thus, bocaccio populations do not follow consistent growth trajectories and sporadic recruitment drives population structure (Drake et al. 2010).

In 2016, a settlement event that was 44 times normal levels was documented in coastal Canada, dramatically modifying predictions of stock status and fishery potential (Fisheries and Oceans Canada 2020). This abundance pulse did not, however, manifest within the DPS in any demonstrable way. As a result of modifications made to the definition of the DPS in 2017 (82 FR 7711), individuals born on the outer coast but settling within the boundaries of the DPS would be granted ESA-listed status. Obtaining a genetic profile for the population residing within the DPS prior to this settlement event (i.e., that are too old to be part of the 2016 cohort) will be crucial to evaluating any long-standing genetic differentiation between the coast and inland waters.

Natural annual mortality for bocaccio is estimated to be approximately 8% (Palsson et al. 2009). Tolimieri et al. (2005) found that the bocaccio population growth rate is around 1.01, indicating a very low intrinsic growth rate for this species. Demographically, this species demonstrates some of the highest recruitment variability among rockfish species, with many years of failed recruitment being the norm (Tolimieri et al. 2005). Given their severely reduced abundance in inland waters, Allee effects may be particularly acute for bocaccio, even considering the propensity of some individuals to move long distances and potentially find mates.

In Canada, the median estimate of bocaccio biomass is 3.5% of its unfished stock size (though this only assessed Canadian waters outside of the DPS) (Stanley et al. 2012; COSEWIC 2013). There are no analogous biomass estimates in the U.S. portion of the bocaccio DPS. An ROV survey of the San Juan Islands in 2008 estimated a population of 4,606±4,606 (based on four fish observed along a single transect) (Pacunski et al. 2013), but no estimate could be obtained in subsequent surveys of the San Juans in 2010 or Puget Sound proper in 2012–13 because no individuals were encountered (Pacunski et al. 2020; Lowry et al. 2022). A single bocaccio encountered in 2015 ROV survey produced a statistically invalid population estimate for that portion of the DPS lying south of the entrance to Admiralty Inlet and east of Deception Pass. A handful of bocaccio have been caught in genetic surveys (Andrews et al. 2018) and by recreational anglers in Puget Sound proper (Kraig 2023) in the past several years.

In summary, though abundance and productivity estimates for yelloweye rockfish and bocaccio are relatively imprecise, both demographic traits have been reduced largely by fishery removals within the range of each Puget Sound/Georgia Basin DPS. Recent increases in yelloweye abundance have occurred, but data are insufficient to assess changes in abundance for bocaccio.

2.2.9.3 Spatial Structure and Connectivity

Spatial structure consists of a population's geographic distribution and the processes that generate that distribution (McElhany et al. 2000). A population's spatial structure depends on habitat quality, spatial configuration, and dynamics, as well as dispersal capacity of individuals (McElhany et al. 2000). Prior to contemporary fishery removals from the 1970s through the 1990s, each of the major subbasins in the range of the DPSs likely hosted relatively large populations of yelloweye rockfish and bocaccio (Washington 1977; Washington et al. 1978; Moulton et al. 1987; Drake et al. 2010; Tolimieri et al. 2017). This distribution allowed both species to utilize the full suite of available habitats, thereby enhancing population resilience (Hamilton 2008). This distribution also enabled each species to potentially exploit ephemerally good habitat conditions, and in turn receive protection from relatively small-scale environmental fluctuations. These types of fluctuations may change prey abundance for various life stages and/or may change environmental characteristics and water flow parameters that influence the number of annual recruits. Spatial distribution also provides a measure of protection from larger-scale anthropogenic changes that decrease habitat suitability, such as oil spills or hypoxia, that may be isolated to a single subbasin. Rockfish population resilience is sensitive to changes in connectivity among groups of individuals (Hamilton 2008). Hydrologic connectivity of the subbasins of Puget Sound is naturally restricted by shallow sills located at Deception Pass, Admiralty Inlet, the Tacoma Narrows, and in Hood Canal (Burns 1985). The Victoria Sill, which marks the western edge of the DPSs in U.S. waters, bisects the Strait of Juan de Fuca, runs from east of Port Angeles north to Victoria, and regulates water exchange (Drake et al. 2010). Given that these sills regulate water flow among subbasins, they also moderate the movement of rockfish larvae (Drake et al. 2010; Andrews et al. 2021). When localized depletion of rockfish occurs, it can reduce stock resiliency (Hilborn et al. 2003; Hamilton 2008). The effects of localized depletions of rockfish are likely exacerbated by natural hydrologic constrictions within Puget Sound.

2.2.9.3.1 Yelloweye Rockfish Spatial Structure and Connectivity

Yelloweye rockfish spatial structure and connectivity is threatened by the reduction of fish within each subbasin, and the naturally sedentary disposition of adults. This reduction is likely most acute within the subbasins of Puget Sound proper, given complex geography and prominent sills that affect larval transport among subbasins (Andrews et al. 2021). Yelloweye rockfish are probably most abundant within the San Juan Basin, and transport of larvae to other subbasins is affected by seasonal flow patterns, the exact location of larval release, and the depth of larval release (Andrews et al. 2021). While connectivity may be high at times, distinct genetic traits of at least the portion of the population occupying Hood Canal have arisen (Andrews et al. 2018).

2.2.9.3.2 Bocaccio Spatial Structure and Connectivity

Bocaccio may have been historically limited largely to the Main Basin and South Sound (Drake et al. 2010), with no documented occurrences in the San Juan Basin until 2008 (WDFW 2011; Pacunski et al. 2013). Positive signs for spatial structure and connectivity come from the propensity of some adults and pelagic juveniles to migrate long distances, which could re-establish aggregations of fish in formerly occupied habitat (Drake et al. 2010). The apparent reduction of populations in the Main Basin and South Sound represents a further impairment to the historically limited distribution of bocaccio, and reduces both viability and resilience of the DPS.

In summary, spatial structure and connectivity for both species have been adversely impacted, mostly by fishery removals. These impacts on species viability are likely most acute for yelloweye rockfish because of their sedentary nature as adults, but may also serve to further isolate bocaccio occurring in southern subbasins from source populations elsewhere in the DPS.

2.2.9.4 Diversity

Characteristics of diversity for rockfish include fecundity, timing of the release of larvae and their condition, morphology, age at reproductive maturity, physiology, and molecular genetic characteristics. In spatially and temporally varying environments, there are three broad reasons why diversity is important for species and population viability: (1) physiological diversity allows a species to use a wider array of environments; (2) diversity can insulate a species against short-term spatial and temporal changes in the environment that differentially affect one or more phenotypes; and (3) genetic diversity provides the raw material for adaptation of the population to long-term environmental changes.

2.2.9.4.1 Yelloweye Rockfish Diversity

Yelloweye rockfish size and age distributions have been truncated, based on recreational fishery encounter rates (Figure 65). Yelloweye rockfish caught in the 1970s spanned a broad range of sizes. By the 2000s, there was some evidence of fewer, older fish in the population (Drake et al. 2010). As a result, the reproductive burden may be shifted to younger and smaller fish. This shift could alter the timing and condition of larval release, which may be mismatched with habitat conditions within the range of the DPS, potentially reducing the viability of offspring (Drake et al. 2010). Yelloweye rockfish retention has been prohibited in recreational fisheries since 2010, thus comparable data to estimate size range are not available after this time. Only a handful of adult yelloweye rockfish have been observed within WDFW ROV surveys in U.S. waters of the DPS (Lowry et al. 2022), and all observed fish in 2008 and 2010 surveys of the San Juan Basin were less than 8 inches long (20 cm) (Pacunski et al. 2013; Pacunski et al. 2020). Since these fish were observed several years ago, any that have survived will have grown bigger (Pacunski et al. (2013) and (2020) did not report a precise size for these fish; thus, we are unable to provide a precise estimate of their likely size now). Reliable size distribution data from more recent surveys that occurred in 2015, 2018, and 2020–21 are not yet available due to technical difficulties with the software used to process stereoscopic camera images (Pacunski 2023).

Recent genetic information for yelloweye rockfish further confirmed the existence of fish genetically differentiated within the Puget Sound/Georgia Basin compared to the outer coast (81 FR 43979)(Andrews et al. 2018) and that yelloweye rockfish in Hood Canal are genetically divergent from the rest of the DPS. Yelloweye rockfish in Hood Canal are addressed as a separate recovery unit in the recovery plan (NMFS 2017s), and reaching the recovery goal for the DPS at large requires viability of this population unit.

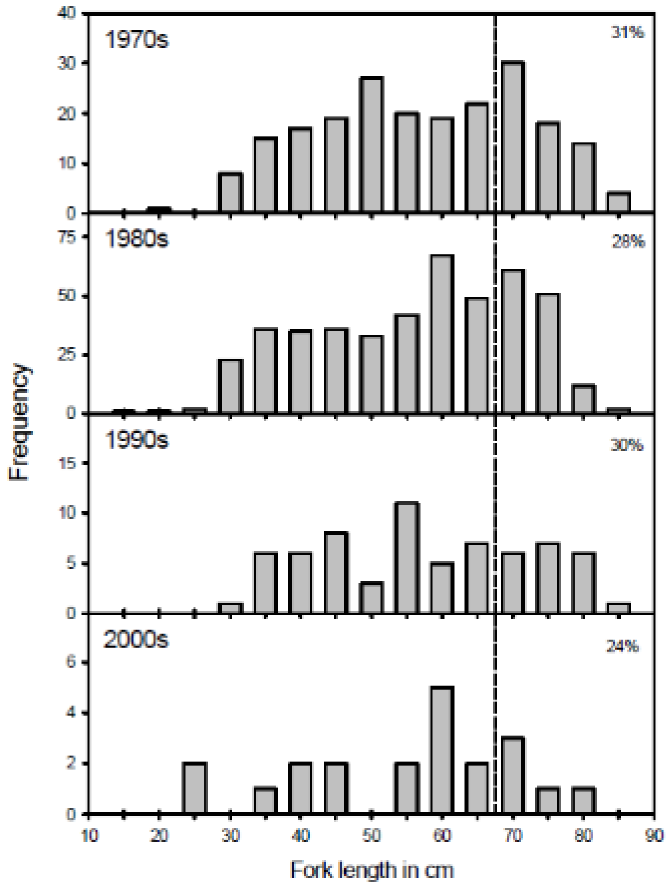


Figure 65. Yelloweye rockfish length frequency distributions (cm) from recreational fisheries in Washington waters, binned by decade. The vertical line depicts the size at which 30% of the population consisted of fish larger than the rest of the population in the 1970s, as a reference point for later decades. Retention of yelloweye rockfish was prohibited in 2010, so comparable data are not available after this.

2.2.9.4.2 Bocaccio Diversity

Size-frequency distributions for bocaccio in the 1970s indicate a wide range of sizes, and two distinct cohorts, with recreationally caught individuals from 9.8–33.5 inches (25–85 cm) (Figure 66). This size distribution profile reflects a spread of ages, indicating successful episodic recruitment over many years. A similar range of sizes is also evident in the 1980s catch data, though size truncation at the upper end of the distribution is beginning to be apparent. Through the 1990s, encounters with bocaccio became rarer, with larger fish disappearing altogether from the catch data. By the 2000s, no size distribution data for bocaccio were available due to a nearly complete lack of encounters. Since 2008, encounters in ROV, trawl, and dedicated hook-and-line surveys have amounted to only a handful of individuals.

Assessments of bocaccio in Canadian waters recognize occasional occurrences of the species in the Salish Sea, but focus biomass estimation and harvest recommendation efforts on fish occupying coastal waters (Fisheries and Oceans Canada 2020). Bocaccio in the Puget Sound/Georgia Basin may have physiological or behavioral adaptations because of the unique habitat conditions in the range of the DPS. The potential loss of diversity in the bocaccio DPS, in combination with their relatively low productivity, may result in a mismatch with habitat conditions and further reduce population viability (Drake et al. 2010).

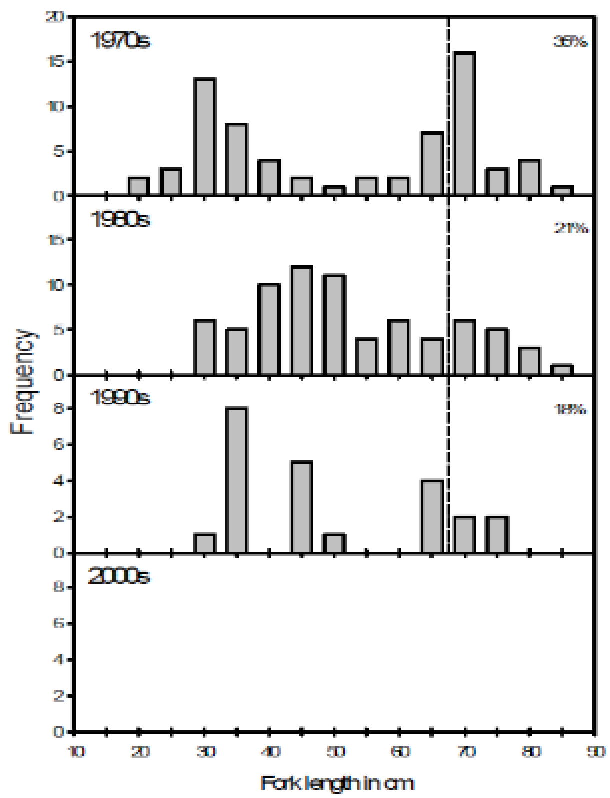


Figure 66. Bocaccio length frequency distributions (cm) from recreational fisheries within four decades. The vertical line depicts the size at which about 30% of the population comprised fish larger than the rest of the population in the 1970s, as a reference point for a later decade. Retention of bocaccio was prohibited in 2010, so no data are available after this.

In summary, diversity for each species has been adversely impacted by historical fishery removals, though minimal removals have occurred since 2010 due to harvest prohibitions. In turn, the ability of fish to utilize habitats within the action area, find mates, and perform important ecological roles has been compromised, but has likely been improving since listing. For yelloweye rockfish, recent encounters of juveniles and more frequent documentation of adults supports this assertion, while for bocaccio minimal evidence to assess population viability is available.

2.2.9.5 Limiting Factors

2.2.9.5.1 Climate Change and Other Ecosystem Effects

As reviewed in ISAB (2007), average annual Northwest air temperatures have increased by approximately 1.8°F (1°C) since 1900, which is nearly twice that for the previous 100 years, indicating an increasing rate of change. Summer temperatures, under the A1B emissions scenario (a “medium” warming scenario), are likely to continue during the next century as average temperatures are projected to increase another 3–10°F, with the largest increases predicted to occur in the summer (Mote et al. 2014). This change in surface temperature has already modified, and is likely to continue to modify, marine habitats of listed rockfish. There is still a great deal of uncertainty associated with predicting specific changes in timing, location, and magnitude of future climate change and species-specific impacts on rockfish.

Climate change effects that have influenced, and will continue to influence, rockfish habitat include: increased ocean temperature; increased stratification of the water column; decreased pH; and changes in the intensity and timing of coastal upwelling (ISAB 2007). These continuing changes will alter primary and secondary productivity, shifting marine community structure (Doney et al. 2012). These perturbations may, in turn, alter listed rockfish trophic dynamics, growth, productivity, survival, and habitat usage. Increased concentration of CO_2 (termed Ocean Acidification, or OA) reduces carbonate availability for shell-forming invertebrates. Ocean acidification adversely affects calcification (i.e., the precipitation of dissolved ions into solid calcium carbonate structures) for a number of marine organisms, altering spatiotemporal prey availability (Feely et al. 2010). Further research is needed to understand the possible implications of OA on trophic functions in Puget Sound to understand how they may affect rockfish. Thus far, studies conducted in other areas have shown that the effects of OA will be variable (Ries et al. 2009) and species-specific (Miller et al. 2009).

In addition to ecological disruptions from OA in marine systems, increased acidity can directly impact the physiology and behavior of individual fish. Munday et al. (2009) demonstrated that larval orange clownfish (*Amphiprion percula*) detect and respond differently to olfactory cues when pH levels are varied over a range (7.6–8.15) predicted to occur in natural systems by 2100. Simpson et al. (2011) later demonstrated that deleterious effects on hearing also occurred in this species, reducing response to reef noise and avoidance of habitats where predation pressure was high. Larval Atlantic herring (*Clupea hargenus*) exposed to elevated carbon dioxide levels during rearing exhibited reduced growth, degraded body condition, and severe tissue damage in several organs (Frommel et al. 2014). While there have been very few studies to date on the direct effect OA may have on rockfish, in a laboratory setting OA has been documented to affect rockfish behavior (Hamilton et al. 2014). After juvenile splitnose rockfish (*Sebastes diploproa*) spent one week under OA conditions projected for the next century in the California shore they spent more time in unlighted environments compared to the control group. Davis et al. (2018a) also reported metabolic and behavior changes in juvenile rockfish with regard to predator avoidance; however, they reported that many of the effects were effectively compensated for and adapted to after three weeks of exposure. Research conducted to understand adaptive responses to OA on other marine organisms has shown that while some organisms are able to adjust to OA, these adaptations may reduce the organism's overall fitness or survival (Wood et al. 2008). Yelloweye rockfish and bocaccio are likely able to adapt to long-term shifts in water chemistry to some degree, but thresholds at which such adaptation becomes unlikely or impossible have not been identified. More research is needed to further understand rockfish-specific responses to OA.

There are natural biological and physical functions in regions of Puget Sound, especially in Hood Canal and South Sound, that cause the water to be corrosive and hypoxic, such as restricted circulation and mixing, respiration, and strong stratification (Newton et al. 2002; Feely et al. 2010). However, these natural conditions, typically driven by climate forcing, are exacerbated by anthropogenic sources such as OA, nutrient enrichment, and land-use changes (Feely et al. 2010). By the next century, OA will increasingly reduce pH and saturation states in Puget Sound (Feely et al. 2010). Areas in Puget Sound susceptible to naturally occurring hypoxic and corrosive conditions are also the same areas where low seawater pH occurs, compounding the metabolically challenging conditions of these areas (Feely et al. 2010). Given that the population of yelloweye rockfish inhabiting Hood Canal displays a divergent genetic profile from populations elsewhere in the DPS (Andrews et al. 2018), impacts from corrosive water and hypoxia here may substantially impede recovery of the DPS at large.

2.2.9.5.2 Commercial and Recreational Bycatch

Listed rockfish are encountered as bycatch in some recreational and commercial fisheries in Puget Sound. This bycatch is described in Section 2.4.3.1 Harvest and Bycatch Effects in the Environmental Baseline. In addition, NMFS permits limit take of listed rockfish for scientific research purposes. This take is described in Section 2.9.1.3, Puget Sound/Georgia Basin Rockfish.

2.2.10 Climate Change Effects on Salmon and Steelhead

This section starts with a general discussion regarding vulnerability of salmonids to climate change and temperature increase (subsection 2.2.10.1), then proceeds with discussions specific to freshwater (subsection 2.2.10.2), estuarine (subsection 2.2.10.3), and oceanic (subsection 2.2.10.4) habitats. It concludes with a discussion on uncertainty in climate predictions (subsection 2.2.10.5).

2.2.10.1 General Vulnerability of Salmonids to Climate Change

Climate change is negatively affecting ESA-listed salmon and steelhead habitat and populations across the Pacific Northwest. These effects are expected to continue and intensify in the coming decades. Climate and climate-related elements of freshwater and marine aquatic habitats in the Puget Sound and Columbia River basin regions have been changing for several decades. Average annual Pacific Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50% more than the global average over the same period (USGCRP 2023). Climate change is expected to continue for many decades into the future, with substantial negative implications to freshwater and marine habitats and the species that currently inhabit these waters. For the

Pacific Northwest, recent climate models project a warming of 1.9–3.5 ºC by the 2050s relative to the period 1950–1999 based on low to high greenhouse gas emissions scenarios (Climate Impacts Group. 2021). By the 2080s, a warming of 2.6–5.6 ºC is projected. The recently-published Fifth National Climate Assessment (USGCRP 2023) provides a detailed overview of the concomitant effects to such environmental conditions as snowpack, streamflow, extreme temperature and precipitation events, drought recurrence and severity, regional sea surface temperatures, and ocean acidification, among others. Changes to these are expected to negatively affect ESA-listed salmon, their habitat, and the food webs upon which they depend.

Climate change has broad and substantial negative implications for salmonids and salmonid habitat in the Pacific Northwest (e.g., Climate Impacts Group 2004; Beechie et al. 2006; Zabel et al. 2006; Battin et al. 2007; ISAB 2007; Mantua et al. 2010; Wade et al. 2013; Tohver et al. 2014; Mauger et al. 2015; Crozier et al. 2019; Crozier et al. 2021; Crozier et al. 2023; McClure et al. 2023). Higher summer water temperatures, lower summer–early fall stream and river flows, increased magnitude of winter peak flows and flooding, and changes to hydrologic regime are expected to have considerable negative effects to salmonid populations in rivers and streams across both regions. Related long-term negative effects include but are not limited to the following: depletion of cool water habitat and refugia; detrimental alterations to adult and juvenile migration patterns; increased egg and fry mortality from increased flooding and sediment loads; increased competition among species; greater vulnerability to predators; and, increased disease susceptibility. Climate change is also expected to detrimentally affect marine habitats and salmonid survival through warmer water temperatures, loss of coastal and estuary habitat from sea level rise, ocean acidification, and changes in water quality and freshwater inputs. As a result, the distribution and productivity of salmonid populations in the Pacific Northwest are expected to be negatively affected by climate change.

Crozier et al. (2019) performed a detailed climate change vulnerability assessment of all ESA-listed Pacific salmon ESUs and steelhead DPSs. Their assessment was based on the following three components of vulnerability: 1) biological sensitivity (a function of individual species characteristics); 2) climate exposure (a function of geographical location and projected future climate conditions); and, 3) adaptive capacity, which describes the ability of an ESU or DPS to adapt to rapidly changing environmental conditions. Most ESUs and DPSs considered in this Opinion were determined to have high vulnerability to climate change (Figure 67). The rest were determined to have either moderate or very high vulnerability.

Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids (e.g., Battin et al. 2007; ISAB 2007; Beechie et al. 2013; Crozier et al. 2019). For example, restoring connections to historical floodplains, off-channel freshwater habitats, and currently-blocked estuarine areas would increase rearing area, provide refugia, and increase floodwater storage. Protecting and restoring riparian buffers would ameliorate stream temperature increases, reduce sediment inputs, and minimize erosion. Purchasing or applying easements to lands that provide important cold water or refuge habitat would also be beneficial. Harvest and hatchery actions can respond to changing conditions associated with climate change by incorporating greater uncertainty in assumptions about environmental conditions, and conservative assumptions about salmon survival, in setting management and program objectives and in determining rearing and release strategies (Beer et al. 2013; Crozier et al. 2019).

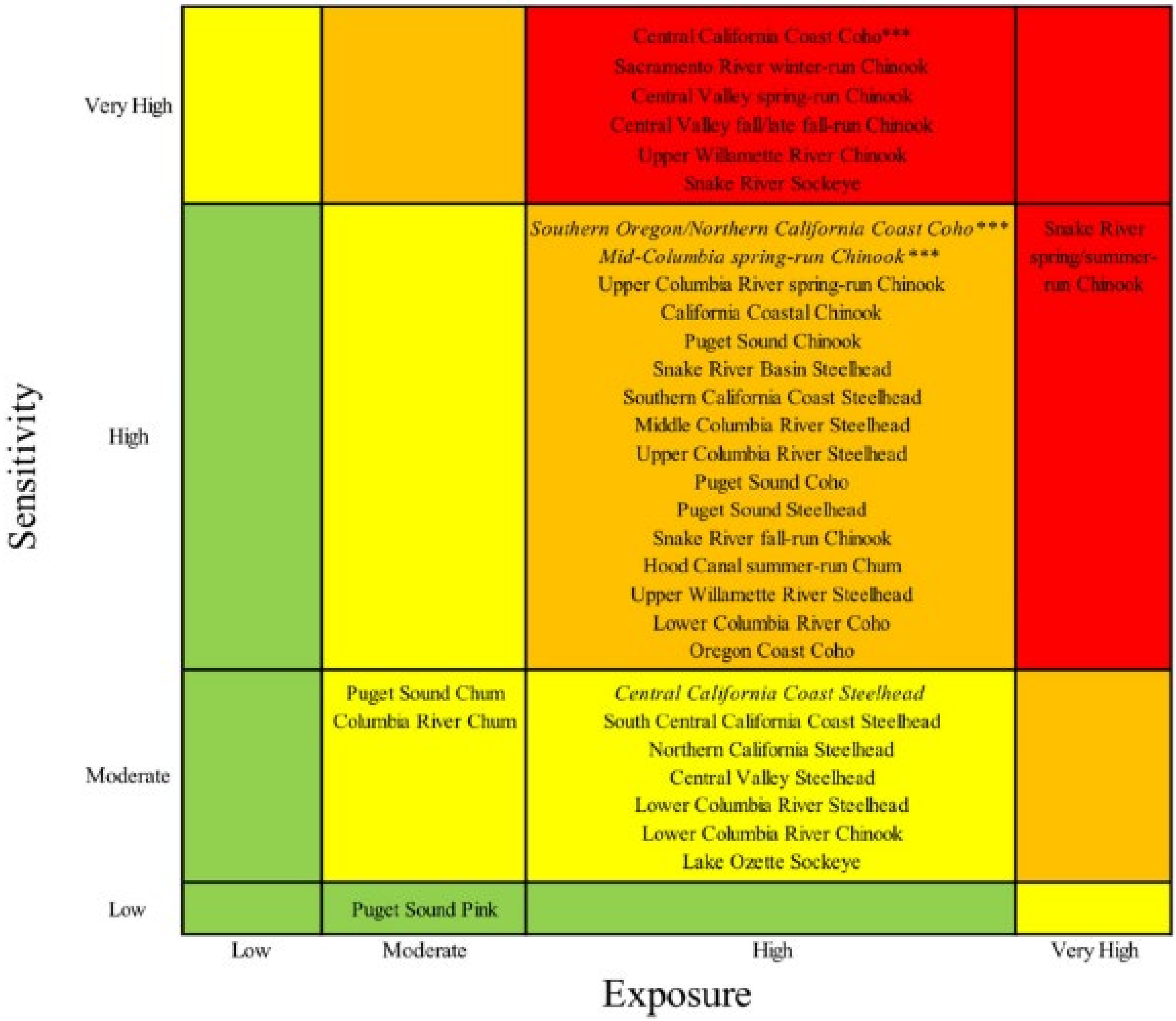


Figure 67. Vulnerability of salmon ESUs and steelhead DPSs to climate change, including those considered in this Opinion, as determined by Crozier et al. (2019). Box colors show final vulnerability rank for each ESU and DPS as a product of sensitivity and exposure scores: red indicates very high vulnerability, orange high, yellow moderate, and green low. From Crozier et al. (2019).

Like most fishes, salmon are poikilotherms (cold-blooded animals). Therefore increasing temperatures in all habitats can have pronounced effects on their physiology, growth, and development rates (see review by Whitney et al. (2016)). Higher ambient air temperatures will likely cause water temperatures to rise (ISAB 2007). In the northeast Pacific Ocean, sea surface temperatures from 2013-2020 were exceptionally high and coincided with widespread declines and low abundances for many west coast salmon and steelhead populations (SWFSC 2022). Increases in water temperatures beyond their thermal optima will likely be detrimental through a variety of processes including: increased metabolic rates (and therefore food demand), decreased disease resistance, increased physiological stress, and reduced reproductive success. As trends progress toward warmer oceans and streams, more extreme winter flood events, summer low flows, loss of snowpack in the mountains, and ocean acidification, salmon face increasing challenges (Ford 2022). All of these processes are likely to reduce survival (Beechie et al. 2013; Wainwright et al. 2013; Whitney et al. 2016). As examples of this, high mortality rates for adult sockeye salmon in the Columbia River have been attributed to higher water temperatures and likewise in the Fraser River, as increasing temperatures during adult upstream migration are expected to result in increased mortality of sockeye salmon adults by 9 to 16% by century's end (Martins et al. 2011). Juvenile parr-to-smolt survival of Snake River Chinook salmon are predicted to decrease by 31–47% due to increased summer temperatures (Crozier et al. 2008a).

Salmonids require cold water for spawning and incubation. Increased temperatures at ranges well below thermal optima (i.e., when the water is cold) can increase growth and development rates. Examples of this include accelerated emergence timing during egg incubation stages, or increased growth rates during fry stages (Crozier et al. 2008b; Martins et al. 2011). Temperature is also an important behavioral cue for migration (Sykes et al. 2009), and elevated temperatures may result in earlier-than-normal migration timing. While there are situations or stocks where this acceleration in processes or behaviors is beneficial, there are also others where it is detrimental (Martins et al. 2012; Whitney et al. 2016).

As climate change progresses and stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmonids with patches of suitable habitat while allowing them to undertake migrations through or to make foraging forays into areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

2.2.10.2 Climate Change in Freshwater

As described previously, climate change is predicted to increase the intensity of storms, reduce winter snow pack at low and middle elevations, and increase snowpack at high elevations in northern areas. Middle and lower elevation streams will have larger fall/winter flood events and lower late summer flows, while higher elevations may have higher minimum flows. How these changes will affect freshwater ecosystems largely depends on their specific characteristics and location, which vary at fine spatial scales (Crozier et al. 2008a; Martins et al. 2012). For example, within a relatively small geographic area (Salmon River Basin, Idaho), survival of some Chinook salmon populations was shown to be determined largely by temperature, while others were determined by flow (Crozier et al. 2006). Certain salmon populations inhabiting regions that are already near or exceeding thermal maxima will be most affected by further increases in temperature and perhaps the rate of the increases while the effects of altered flow are less clear and likely to be basin-specific (Crozier et al. 2008a; Beechie et al. 2013). However, river flow is already becoming more variable in many rivers, and is believed to negatively affect anadromous fish survival more than other environmental parameters (Ward et al. 2015). It is likely this increasingly variable flow is detrimental to multiple salmon and steelhead populations, and likely multiple other freshwater fish species in the Columbia River Basin as well.

Stream ecosystems will likely change in response to climate change in ways that are difficult to predict (Lynch et al. 2016). Changes in stream temperature and flow regimes will likely lead to shifts in the distributions of native species and provide “invasion opportunities” for exotic species. This will result in novel species interactions including predator-prey dynamics, where juvenile native species may be either predators or prey (Lynch et al. 2016; Rehage et al. 2016). How juvenile native species will fare as part of “hybrid food webs,” which are constructed from natives, native invaders, and exotic species, is difficult to predict (Naiman et al. 2012).

2.2.10.3 Climate Change in Estuaries

In estuarine environments, the two big concerns associated with climate change are rates of sea level rise and temperature warming (Wainwright et al. 2013; Limburg et al. 2016). Estuaries will be affected directly by sea-level rise: as sea level rises, terrestrial habitats will be flooded and tidal wetlands will be submerged (Kirwan et al. 2010; Wainwright et al. 2013; Limburg et al. 2016). The net effect on wetland habitats depends on whether rates of sea-level rise are sufficiently slow that the rates of marsh plant growth and sedimentation can compensate (Kirwan et al. 2010).

Due to subsidence, sea level rise will affect some areas more than others, with the largest effects expected for the lowlands, like southern Vancouver Island and central Washington coastal areas (Verdonck 2006; Lemmen et al. 2016). The widespread presence of dikes in Pacific Northwest estuaries will restrict upward estuary expansion as sea levels rise, likely resulting in a near-term loss of wetland habitats for salmon (Wainwright et al. 2013). Sea level rise will also result in greater intrusion of marine water into estuaries, resulting in an overall increase in salinity, which will also contribute to changes in estuarine floral and faunal communities (Kennedy 1990). While not all anadromous fish species are generally highly reliant on estuaries for rearing, extended estuarine use may be important in some populations (Jones et al. 2014), especially if stream habitats are degraded and become less productive.

2.2.10.4 Climate Change in the Ocean

In marine waters, increasing temperatures are associated with observed and predicted poleward range expansions of fish and invertebrates in both the Atlantic and Pacific oceans (Lucey et al. 2010; Asch 2015; Cheung et al. 2015). Rapid poleward species shifts in distribution in response to anomalously warm ocean temperatures have been well documented in recent years, confirming this expectation at short time scales. Range extensions were documented in many species from southern California to Alaska during unusually warm water associated with “The Blob” in 2014 and 2015 (Bond et al. 2015; Di Lorenzo et al. 2016), and past strong El Niño events (Pearcy 2002; Fisher et al. 2015). Overall, the marine heat wave from 2014 to 2016 had the most drastic impact on marine ecosystems in 2015, with lingering effects into 2016 and 2017. Conditions had somewhat returned to “normal” in 2018, but another marine heat wave in 2019 again set off a series of marine ecosystem changes across the North Pacific. One reason for lingering effects of ecosystem response is due to biological lags. These lags result from species impacts at larval or juvenile stages, which are typically most sensitive to extreme temperatures or changes in food supply. It is only once these species grow to adult size or recruit into fisheries that the impact of the heat wave is apparent (Ford 2022).

Exotic species benefit from these extreme conditions as they increase their distributions. Green crab (*Carcinus maenas*) recruitment increased in Washington and Oregon waters during winters with warm surface waters, including 2014 (Yamada et al. 2015). Similarly, Humboldt squid (*Dosidicus gigas*) dramatically expanded their range during warm years from 2004–2009 (Litz et al. 2011). The frequency of extreme conditions, such as those associated with El Niño events or “blobs” are predicted to increase in the future (Di Lorenzo et al. 2016). This is likely to occur to some degree over the next ten years, but at a similar rate as the last ten years.

As with changes to stream ecosystems, expected changes to marine ecosystems due to increased temperature, altered productivity, or acidification, will have large ecological implications through mismatches of co-evolved species and unpredictable trophic effects (Cheung et al. 2015; Rehage et al. 2016). These effects will certainly occur, but predicting the composition or outcomes of future trophic interactions is not possible with the tools available at this time.

Pacific Northwest anadromous fish inhabit as many as three marine ecosystems during their ocean residence period: the Salish Sea, the California Current, and the Gulf of Alaska (Brodeur et al. 1992; Weitkamp et al. 2002; Morris et al. 2007). The response of these ecosystems to climate change is expected to differ, although there is considerable uncertainty in all predictions. It is also unclear whether overall marine survival of anadromous fish in a given year depends on conditions experienced in one versus multiple marine ecosystems. Several are important to Columbia River basin and Puget Sound species, including the California Current and Gulf of Alaska.

In marine habitat, scientists are not certain of all the factors impacting salmon and steelhead survival, but several ocean basin-scale and regional-scale events are linked with fluctuations in salmon and steelhead health and abundance, such as the Oceanic Niño Index (ONI), the Pacific Decadal Oscillation (PDO), and deep-water salinity and temperature (Ford 2022). The NWFSC’s Annual Salmon Forecast[22] provides annual summaries of these ocean indicators and additional indicators based on large-scale physical, regional-scale physical, and local-scale biological data that occur in the year of ocean entry for salmon smolts (Ford 2022). In general, years that are favorable for salmonid survival are characterized by physical conditions that include cold water along the U.S. West Coast before or after outmigration, no El Niño events at the equator, cold and salty water locally, and an early onset of upwelling. Climate change plays a part in salmon and steelhead mortality but more studies are needed.

Wind-driven upwelling is responsible for the extremely high productivity in the California Current ecosystem (Bograd et al. 2009; Peterson et al. 2014). Minor changes to the timing, intensity, or duration of upwelling, or the depth of water column stratification, can have dramatic effects on the productivity of the ecosystem (Black et al. 2014; Peterson et al. 2014). Current projections for changes to upwelling are mixed: some climate models show upwelling unchanged, but others predict that upwelling will be delayed in spring, and more intense during summer (Rykaczewski et al. 2015). Should the timing and intensity of upwelling change in the future, it may result in a mismatch between the onset of spring ecosystem productivity and the

[22]https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

timing of salmon entering the ocean, and a shift towards food webs with a strong sub-tropical component (Bakun et al. 2015). This may result in changes to distribution and availability of salmon prey in the California region (Brady et al. 2017).

Columbia River and Puget Sound anadromous fish also use coastal areas of British Columbia and Alaska, and mid-ocean marine habitats in the Gulf of Alaska, although their fine-scale distribution and marine ecology during this period are poorly understood (Morris et al. 2007; Pearcy et al. 2007). Increases in temperature in Alaskan marine waters have generally been associated with increases in productivity and salmon survival (Mantua et al. 1997; Martins et al. 2012), thought to result from temperatures that have been below thermal optima (Gargett 1997). Warm ocean temperatures in the Gulf of Alaska are also associated with intensified downwelling and increased coastal stratification, which may result in increased food availability to juvenile salmon along the coast (Hollowed et al. 2009; Martins et al. 2012). Predicted increases in freshwater discharge in British Columbia and Alaska may influence coastal current patterns (Foreman et al. 2014), but the effects on coastal ecosystems are poorly understood.

In addition to becoming warmer, the world's oceans are becoming more acidic as increased atmospheric carbon dioxide (CO_2) is absorbed by water. The North Pacific is already acidic compared to other oceans, making it particularly susceptible to further increases in acidification (Lemmen et al. 2016). Laboratory and field studies of ocean acidification show it has the greatest effects on invertebrates with calcium-carbonate shells and relatively little direct influence on finfish (see reviews by Haigh et al. (2015) and Mathis et al. (2015). Consequently, the largest impact of ocean acidification on salmon will likely be its influence on marine food webs, especially its effects on lower trophic levels, which are largely composed of invertebrates (Haigh et al. 2015; Mathis et al. 2015).

A primarily positive or slightly negative pattern in the PDO was in place from 2014 through 2019, though since 2019 the pattern has been primarily negative[23]. The NWFSC's most recent 2022 summary of ocean ecosystem indicators[24] reported 2022 was a mix of good and bad ocean conditions for juvenile salmon in the Northern California Current. The PDO turned negative (cool phase) in January 2020 and has remained negative through 2022 with some of the lowest (coldest) values in the 25-year time series occurring in 2021 and 2022. The ONI also signaled cold ocean conditions. The ONI turned negative in May 2020 and has remained negative throughout 2022 with La Niña conditions (values less than or equal to -0.5 °C) for the last 15 consecutive three-month periods (August 2021 to October 2022). The National Weather Service Climate Prediction Center predicted ONI to remain negative throughout the winter and transition to El Niño Southern Oscillation (ENSO)-neutral conditions in February–April 2023. Despite the lackluster upwelling, the northern copepod biomass anomalies and copepod species richness showed signs of cool conditions in the spring and early summer. Still, the anomalies of northern copepods turned weakly negative by mid-summer, resulting in average biomass anomalies for the May–September period. Weakly positive temperature anomalies occurred in June 2022, following weak upwelling conditions. Strongly positive temperature anomalies followed in July through September. Cool and neutral temperature anomalies returned in September, the

[23] https://www.ncei.noaa.gov/access/monitoring/pdo/

[24] https://www.fisheries.noaa.gov/west-coast/science-data/2022-summary-ocean-ecosystem-indicators

remainder of fall was punctuated by strong positive anomalies. The existing regional climate cycles will interact with global climate changes in unknown and unpredictable ways[5].

2.2.10.5 Uncertainty in Climate Predictions

There is considerable uncertainty in the predicted effects of climate change on the globe as a whole, and on Pacific Northwest in particular and there is also the question of indirect effects of climate change and whether human "climate refugees" will move into the range of salmon and steelhead, increasing stresses on their respective habitats (Dalton et al. 2013; Poesch et al. 2016).

Many of the effects of climate change (e.g., increased temperature, altered flow, coastal productivity, etc.) will have direct impacts on the food webs that species examined in this analysis rely on in freshwater, estuarine, and marine habitats to grow and survive. Such ecological effects are extremely difficult to predict even in fairly simple systems, and minor differences in life history characteristics among stocks of salmon may lead to large differences in their response (e.g., Crozier et al. 2008a; Martins et al. 2011; Martins et al. 2012). This means it is likely that there will be "winners and losers" meaning some salmon populations may enjoy different degrees or levels of benefit from climate change while others will suffer varying levels of harm.

Pacific anadromous fish are adapted to natural cycles of variation in freshwater and marine environments, and their resilience to future environmental conditions depends both on characteristics of each individual population and on the level and rate of change. They should be able to adapt to some changes, but others are beyond their adaptive capacity (Crozier et al. 2008b; Waples et al. 2009). With their complex life cycles, it is also unclear how conditions experienced in one life stage are carried over to subsequent life stages, including changes to the timing of migration between habitats. Systems already stressed due to human disturbance are less resilient to predicted changes than those that are less stressed, leading to additional uncertainty in predictions (Bottom et al. 2011; Naiman et al. 2012; Whitney et al. 2016).

Climate change is expected to impact anadromous fish, (e.g., salmon, steelhead, and green sturgeon), during all stages of their complex life cycle. In addition to the direct effects of rising temperatures, indirect effects include alterations in stream flow patterns in freshwater and changes to food webs in freshwater, estuarine and marine habitats. There is high certainty that predicted physical and chemical changes will occur; however, the ability to predict bio-ecological changes to fish or food webs in response to these physical/chemical changes is extremely limited, leading to considerable uncertainty.

2.3 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The extent of the action area for this consultation is defined largely in terms of areas where juvenile, subadult, and adult hatchery-origin Chinook salmon from the hatchery programs proposed to receive federal SRKW prey program funds are known or likely to occur and affect the listed species considered in this Opinion. This includes the following areas:

2.3.1 ESA-listed salmon and steelhead

For ESA-listed salmon and steelhead, the action area includes all rivers and streams that are accessible to anadromous salmonids in the Columbia River basin and the Salish Sea. It also includes marine waters of the Salish Sea, including stream and river estuaries. In the Pacific Ocean, the extent of the action area is defined in terms of the effects of the proposed action on listed salmonids. In delimiting this part of the action area, we considered both: 1) the oceanic range and distribution of hatchery-origin Chinook from Puget Sound, the Columbia River basin, and the Washington coast; and, 2) the potential effects to ESA-listed fish within this range. Broadly speaking, there are two primary parts of the ocean to consider in terms of delineating the action area: the continental shelf and the open ocean. All Pacific salmon species and steelhead trout occur across vast expanses of the open ocean, as well as transit and/or reside on the continental shelf for a period of time. Open ocean ranges and distributions at the scale of populations, let alone ESUs and DPSs, are unknown (Beamish 2018). Thus, we do not know the spatiotemporal scale at which hatchery salmon may overlap with ESA-listed salmonids given the vast area over which these species may range. Though research is limited, we found no evidence of either inter- or intra-specific ecological effects in the open ocean to any listed salmonid species from hatchery-origin Chinook salmon originating from the continental United States. For these reasons, the open ocean is not included in the action area.

Ecological interactions from hatchery-origin Chinook salmon may occur on the continental shelf, where juveniles of most species (all except steelhead trout) rear for at least several months. The first year at sea is a critical period for juvenile salmonids, when negative density-dependent interactions are more likely to occur than at later life history stages (Beamish 2018). Along the North American continental shelf, there is some limited, and in some cases equivocal, evidence of competition and negative density-dependent interactions occurring within some groups or populations of Chinook salmon (Riddell et al. 2018). Hatchery-origin salmon may contribute to density-dependent effects in areas where hatchery fish occur in relatively high abundances and densities. However, available data are insufficient to be able to predict precisely where such areas may occur, other than that they may occur at some level within certain broad geographic regions. On the continental shelf, the substantial majority of hatchery-origin Chinook salmon from the proposed action (≥ 95%) inhabit and migrate through marine waters along the North American continental shelf, from Cape Falcon, Oregon in the south to Yakutat Bay, Alaska in the north, where they may interact with ESA-listed salmonids from Puget Sound and the Columbia River (Figure 68 and Figure 69) (Fisher et al. 2014; Quinn 2018; Riddell et al. 2018, and references therein; Shelton et al. 2019; Van Doornik et al. 2019a; Shelton et al. 2021). These areas are included in the action area.

We considered whether areas to the south of Cape Falcon, Oregon should be included in the action area. Several studies have found Columbia River basin-origin juvenile Chinook salmon, including hatchery-origin fish, in southern Oregon and northern California continental shelf waters by early summer (June–July) (Brodeur et al. 2004; Fisher et al. 2014; Hassrick et al. 2016). In addition, modelling based on CWT recoveries (Shelton et al. 2019; Shelton 2024a; Shelton 2024b) indicates that a small proportion of hatchery-origin fish from Puget Sound, the Columbia River basin, and the Washington coast (< 5%) may occur south of Cape Falcon,

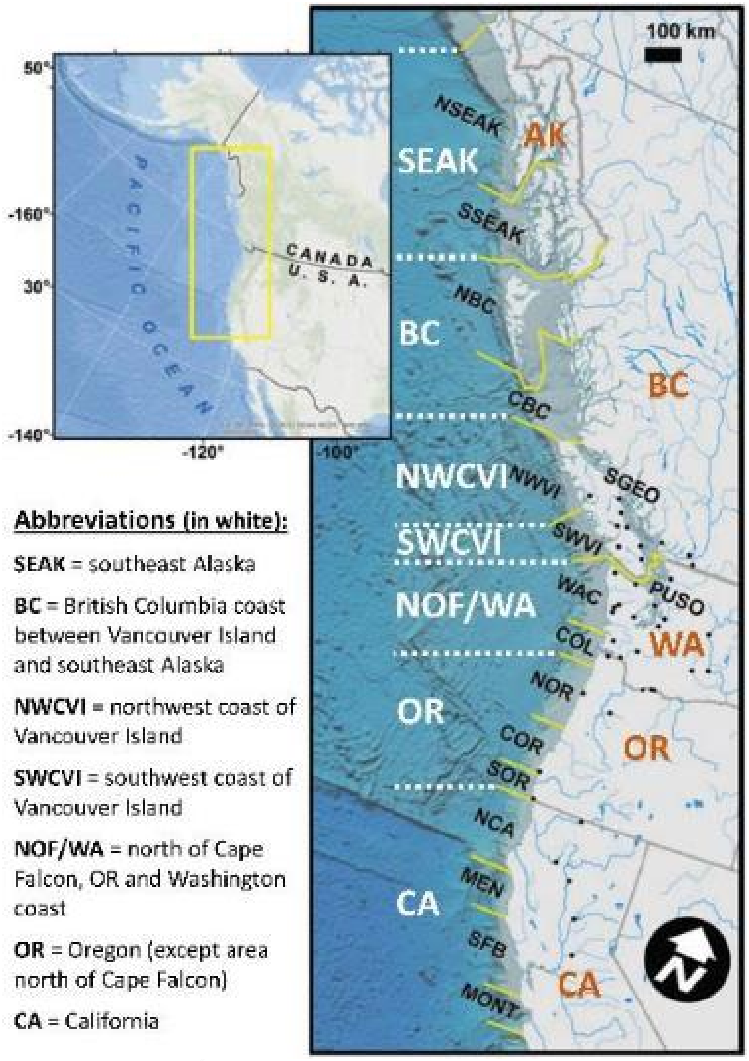


Figure 68. Areas of the Pacific Ocean along the North American continental shelf commonly used for managing fisheries and describing ocean distribution of Chinook salmon (black text and yellow lines). Coarser-scale segmentation (white text and lines) are used for some purposes within this Biological Opinion. The oceanic portion of this Biological Opinion's action area includes waters overlying the continental shelf in the following areas: NOF (North of Falcon)/WA, SWCVI, NWCVI, BC, SEAK. Figure adapted from Shelton et al. (2019).

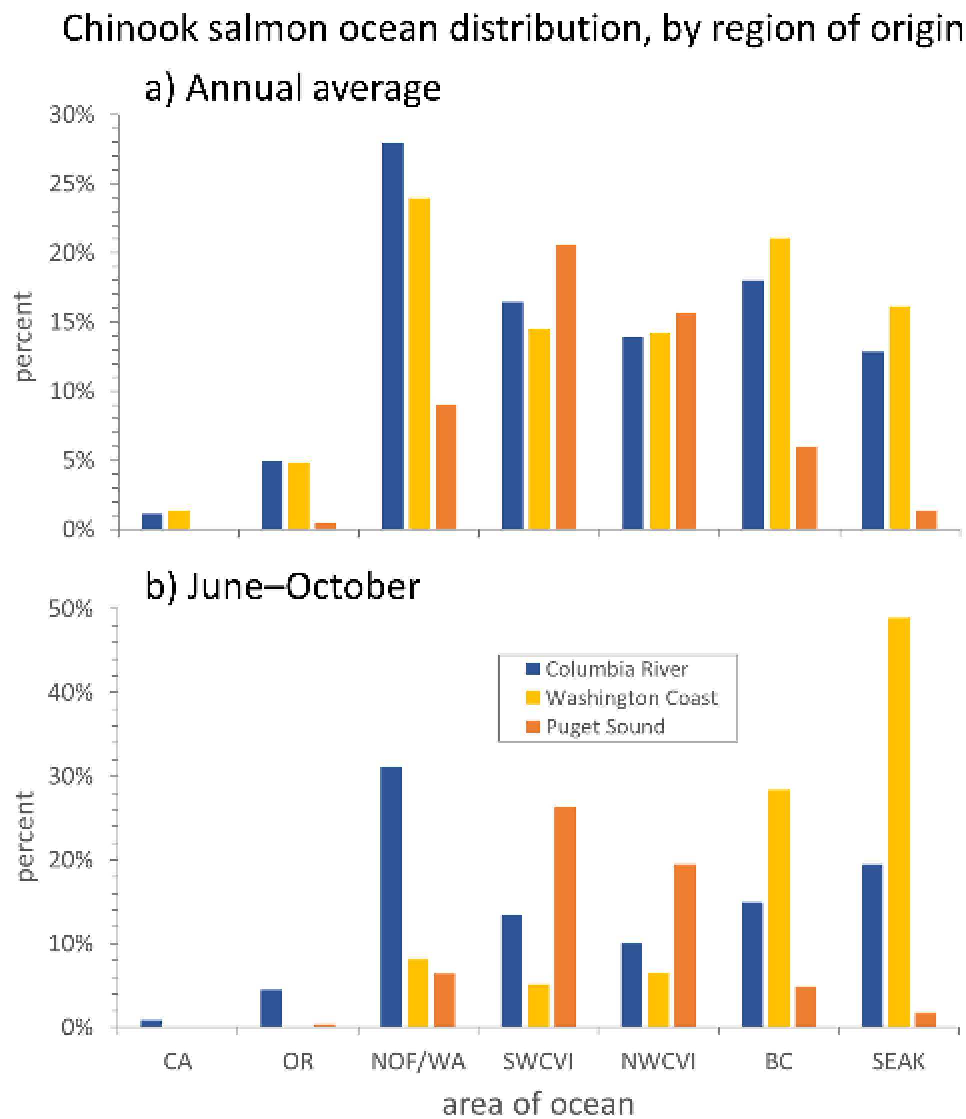


Figure 69. Modeled Chinook salmon (ages 3–5 years) ocean distribution, by area of origin (Columbia River, Washington coast, Puget Sound). Panel a shows average annual distribution. Panel b shows average distribution during the summer/fall time period (June–October). Data from Shelton (2024a). Note difference in y-axis range between the two panels. Ocean area abbreviations are as shown in Figure 68.

Oregon as subadults and adults (Figure 69). As a result, the proposed action may increase abundance of 3- to 5-year-old Chinook salmon in these areas by very small amounts, no more than 1% (Figure 70). Our analysis found that relatively high abundances and densities of hatchery-origin fish may contribute to ecological interactions in continental shelf areas. Because of the very small abundance of hatchery-origin fish from the proposed action expected to move south of Cape Falcon, Oregon, and the inability to detect any effects from such a small abundance of hatchery-origin fish, we did not include this area in the action area.

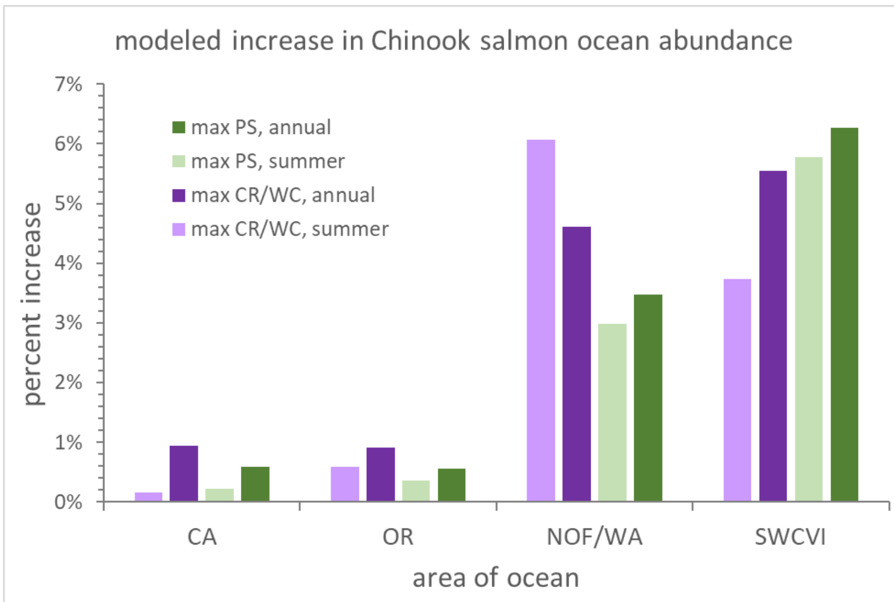


Figure 70. Modeled increase in 5-year mean Chinook salmon (ages 3–5 years) ocean abundance based on the FRAM-Shelton model (Appendix A). Release scenarios shown are as described in Section 1.3 (max PS = Puget Sound capacity maximized; max CR/WC = Columbia River and Washington coast capacity maximized). Summer is represented by the July–September time period. Ocean area abbreviations are as shown in Figure 68. Estimates for increase in abundance in NWCVI, BC, and SEAK are not available because these regions are not part of the FRAM-Shelton model.

2.3.2 Eulachon (southern DPS)

For eulachon, the action area includes all rivers and streams that are accessible to eulachon in the Columbia River basin. It also includes marine waters of the Salish Sea, and the coastal estuaries in Washington State to Cape Falcon, Oregon. In the Pacific Ocean, the extent of the action area includes coastal marine waters from the Dixon Entrance to Cape Falcon, Oregon. These are areas where hatchery Chinook salmon released as part of the proposed action may interact with eulachon.

2.3.3 Yelloweye rockfish and bocaccio (Puget Sound/Georgia Basin DPSs)

For yelloweye rockfish and bocaccio, the action area includes marine waters of Puget Sound and the Georgia Basin. Reproduction occurs throughout the entirety of the DPS, resulting in the overlap of larval rockfish with predatory hatchery Chinook salmon that may consume them (see Section 2.5.4).

2.4 Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The impacts to listed species or designated critical habitat from federal agency activities or existing federal agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

2.4.1 Salmon and steelhead

The environmental baseline for listed salmon and steelhead and their designated critical habitat across the action area can be described by the following five dimensions: habitat, hydropower, hatcheries, harvest, and climate change. Each of these is discussed below, both generally across the relevant Recovery Domains described in Section 2.4.1.2, and, where pertinent, specifically within each Recovery Domain. In general, a wide array of human activities are responsible for the current condition of ESA-listed salmon and steelhead and critical habitat PBFs in the action area. It is difficult to overstate how much the quantity and quality of habitat has been diminished throughout the Columbia River and Salish Sea basins over the last 150 years. Habitat destruction, surface water management (damming, water withdrawal, flow modification), logging, urbanization, pollution, competition with and predation by non-native introduced species, fishing pressure, and genetic and ecological effects from hatchery production have influenced the condition of salmon and steelhead in the action area (NRC 1996). Many of these stressors are persistent, though some improvements have been made over the past several decades. These are also described below.

2.4.1.1 Habitat

2.4.1.1.1 Freshwater (exclusive of Columbia River and Snake River mainstems)

Salmon and steelhead from the following Recovery Domains are expected to occur within the freshwater portion of the action area (exclusive of Columbia River and Snake River mainstems):

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

The environmental baseline for listed salmon and steelhead in these Recovery Domains is broadly similar in regards to habitat conditions and conditions of their designated critical habitat. In general, salmonid habitat is substantially altered and diminished in quantity and quality throughout Columbia River and Puget Sound basin freshwater areas. Watershed processes that create and sustain abundant, high-quality habitat have also been substantially impaired. The history and nature of these many and varied alterations, and their effects on salmon and steelhead, are well-documented and described on a broad scale in such documents as NRC (1996). Collectively, these altered, diminished, and impaired conditions and processes are a primary factor that both: 1) contributed to the decline and ESA listing of the ESUs and DPSs considered in this Opinion; and, 2) continue to limit their productivity and recovery.

Baseline freshwater habitat conditions are described in detail in the documents cited in the following paragraphs. To summarize, many stream and riparian areas have been degraded by the effects of land and water use, including urbanization, road construction, forest management, agriculture, mining, transportation, and water development. Some streams have suffered little disturbance and maintain good habitat quality but are subject to the risk of new development in the floodplain. Other streams with high habitat quality are on Federal lands and are not subject to industrial, commercial, or residential development. Development activities have contributed to a myriad of interrelated factors causing the decline of species considered in this Opinion. Among the most important of these are changes in stream channel morphology; reduced instream roughness and cover; loss and degradation of off-channel areas, refugia, estuarine rearing habitats, riparian areas, spawning areas, and wetlands; degradation of water quality (e.g., temperature, sediment, dissolved oxygen, contaminants); and blocked fish passage. In addition to habitat loss, development has modified fluvial processes like channel migration, which has ecological consequences. The loss of mature riparian forests have reduced riparian functions and aquatic habitat quality due to decreases in habitat complexity (e.g., overhang banks, large wood), bank stability (i.e., increased erosion), shading (i.e., increased temperature), and prey sources. Dams constructed throughout the region have had additional effects, which are detailed in subsection 2.4.1.2.

Anadromous fish species have been greatly affected by land conversion due to urban and agricultural development. Dikes and levees constructed to protect infrastructure and agriculture have isolated floodplains from their river channels and restricted fish access. Development (e.g., urbanization, roads, agriculture) and their associated actions (e.g., shipping, dredging, roads, water withdrawals) have reduced and degraded anadromous fish habitat in numerous ways, including but not limited to the following:

- filling floodplains and wetlands,
- straightening and armoring rivers,
- reducing available in- and off-channel habitat,
- simplifying remaining habitat,

- restricting lateral channel movement,
- accelerating flow velocities,
- increasing erosion,
- decreasing cover,
- reducing prey sources,
- modifying stormwater runoff pathways,
- reducing groundwater infiltration,
- modifying subsurface flows,
- increasing flood elevations,
- contributing contaminants,
- increasing water temperatures,
- degrading water quality,
- reducing water quantity,
- removing riparian vegetation,
- modifying floodplain forest development, and
- reducing quantity and quality of in-channel shade and wood.

The existing transportation system contributes to a poor environmental baseline condition in several ways. Many miles of roads and rail lines parallel streams, which has degraded stream bank conditions by encouraging bank armoring with rip rap, degraded floodplain connectivity by adding fill to floodplains, and discharge of untreated or marginally treated stormwater runoff to streams. Culvert and bridge stream crossings have similar effects and create additional problems for fish when they act as physical or hydraulic barriers that prevent fish access to spawning or rearing habitat, or contribute to adverse stream morphological changes upstream and downstream of the crossing itself.

Significant efforts to protect and restore habitat and habitat-forming processes by federal, state, local, and tribal entities across both basins have been ongoing for decades. These are summarized in NMFS 5-year status review documents (e.g., NMFS 2016e; 2016b; NMFS 2022p; 2022j; 2022m; 2022l; 2022o; 2022q; 2022g), incorporated here by reference. These efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations. However, overall habitat improvement has been relatively modest compared to the extensive, persistent, and widespread nature of the loss and degradation. There currently is no evidence demonstrating that habitat restoration efforts, much of which has occurred since initial ESA-listings in the mid-1990s, have led to long-term population viability improvements necessary to achieve recovery targets (e.g., Bilby et al. 2022; Bilby et al. 2023; Jaeger et al. 2023). That said, it is generally expected to take up to five decades to demonstrate increases in viability resulting from habitat improvements. Ongoing habitat protection and restoration efforts are expected to continue to make modest, incremental improvements at the scale of the action area and ESUs and DPSs, while increasing human population and climate change are expected to exert negative pressures on habitat conditions across the region.

In the Puget Sound basin, baseline habitat conditions affecting the Chinook and chum salmon ESUs and the steelhead DPS are described in detail in salmon and steelhead habitat limiting factors analysis reports issued by the Washington State Conservation Commission at the state-wide scale (WSCC 2005) and the scale of individual Puget Sound watersheds (Haring 1999; Kerwin 1999b; 1999a; WSCC 1999; WRIA 2000; Kerwin 2001; Correa 2002; Haring 2002; Kuttel 2002; Smith 2002; Correa 2003; Kuttel 2003; Smith 2003), incorporated here by reference. NMFS 5-years status reviews (NMFS 2011c; 2016b), incorporated here by reference, describe recent and ongoing Federal, state, tribal, and private efforts to conserve and improve habitat conditions at the scale of each ESU and DPS.

In the Columbia River basin, specific baseline habitat conditions for each salmon ESU and steelhead DPS are thoroughly described in NMFS (2020c), NMFS (2008i), and ODFW et al. (2011), all of which are incorporated here by reference. The baseline habitat conditions described in these documents have not substantively changed since they were issued. The proposed action of the 2020 Opinion on the Continued Operation and Maintenance of the Columbia River System (NMFS 2020c) includes habitat mitigation intended to improve habitat conditions in tributaries and the estuary. Other recent and ongoing Federal, state, tribal, and private efforts to conserve and improve habitat conditions at the scale of each ESU and DPS are described in the most recent NMFS 5-year status review documents (NMFS 2016e; 2022p; 2022j; 2022m; 2022l; 2022o; 2022q; 2022g), incorporated here by reference.

NMFS has completed several ESA section 7 consultations on large scale projects affecting listed species in the Puget Sound and the Columbia River basins. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006b), and consultations on Washington State Water Quality Standards (NMFS 2008c), Washington State Department of Transportation Preservation, Improvement, and Maintenance Activities (NMFS 2013b), and the National Flood Insurance Program (NMFS 2008a; 2016d). These documents considered the effects of proposed actions that would occur during the next 50 years on the ESA listed salmon and steelhead species in the Puget Sound basin. Information on the status of these species, the environmental baseline, and the effects of the proposed actions are reviewed in detail. The environmental baselines in these documents consider the effects from timber, agriculture and irrigation practices, urbanization, and hatcheries, and tributary habitat, estuary, and large scale environmental variation. These Opinions and Habitat Conservation Plans, in addition to the information mentioned above, provide a current and comprehensive overview of baseline habitat conditions in Puget Sound and are incorporated here by reference.

2.4.1.1.2 Columbia River and Snake River mainstems to Bonneville Dam

Salmon and steelhead from the following Recovery Domains are expected to occur within the Columbia River and Snake River mainstems upriver from Bonneville Dam:

- Interior Columbia River: all salmon ESUs and steelhead DPSs

Mainstem habitat in the Columbia River and the lower Snake River has been substantially altered by basinwide water management operations, the construction and operation of mainstem hydroelectric projects, the growth of native avian and pinniped predator populations, the introduction of non-native species (e.g., smallmouth bass, walleye, channel catfish, and invertebrates), and other human practices that have degraded water quality and habitat. Effects of dams on habitat are summarized below and discussed in more detail in Section 2.4.1.2. The environmental baseline incorporates, by reference, the environmental baseline and the relevant actions and their effects that are the subject of the recent Biological Opinion on federal Columbia and Snake River dams and their operations (NMFS 2020c).

On the mainstem of the Columbia and Snake Rivers, water storage projects—including the Columbia River System (CRS) and reservoirs in Canada operated under the Columbia River Treaty—and related flow regulation for flood control, hydropower, and consumptive (agricultural and municipal) uses have altered the quantity and timing of flows and have significantly degraded salmon and steelhead habitats (Bottom et al. 2005; Fresh et al. 2005; NMFS 2013g). Reduced spring and summer flows have increased travel times during outmigration for upper basin salmonids and, combined with the construction of dikes and levees, have reduced access to high-quality estuarine habitats from May through July. NMFS and the CRS action agencies have attempted to manage Columbia and Snake River water resources to more closely approximate the shape of the natural hydrograph in order to enhance flows and water quality and to improve juvenile and adult fish survival. The action agencies attempt to maintain seasonal flows above threshold objectives given the amount of runoff expected in a given year. Achieving these seasonal flow objectives provides multiple benefits for smolts in the migration corridor, estuary, and plume. Higher spring flow helps reduce fish travel time, increases juvenile access to shallow water habitat along the river banks, increases the flux of invertebrate prey to shoreline habitat, increases turbidity (which can reduce predation on juvenile migrants), and increases the size of the Columbia River plume, which is a key transition corridor for smolts to the nearshore ocean environment. Conversely, when seasonal flow objectives are not met, juvenile survival may be reduced via these same pathways of ecological effects. From 1998 to 2019, spring flow objectives were met in 48% and 81% of years at Lower Granite and McNary Dams, respectively. Summer objectives were met in only 18% and 14% of years at Lower Granite and McNary Dams, respectively.

The BOR operates 23 irrigation projects in the Columbia River basin, reducing the annual runoff volume at Bonneville Dam by about 5.5 million acre feet. These depletions occur primarily during the spring and summer as the reservoirs are refilled and as water is diverted for irrigation purposes. Spring flow reductions have both beneficial and adverse effects on fish survival. During above average water years, flow reduction during reservoir refill reduces involuntary spills, which are known to cause undesirable total dissolved gas (TDG) conditions in the migratory corridor. However, this beneficial effect is small because the amount of flow attenuation provided is generally too small to greatly affect involuntary spill events below Hells Canyon and Chief Joseph Dams. Flow depletions associated with the BOR's projects contribute to juvenile migration delay and decrease juvenile migrant survival. In addition to these mainstem flow effects, several of the projects below Hells Canyon and Chief Joseph Dams affect listed salmonids in the tributary streams where the project is located or where irrigation return flows occur.

Water quality in mainstem areas is impaired. Common toxic contaminants include PCBs, PAHs, PBDEs, dichlorodiphenyltrichloroethane (DDT) and other legacy pesticides, current use pesticides, pharmaceuticals and personal care products, and trace elements (LCREP 2007;

Herger et al. 2017). Growing population centers throughout the Columbia and Snake River basins and numerous smaller communities contribute municipal and industrial waste discharges to the lower Columbia River. Common water-quality issues with urban development and residential septic systems include warmer water temperatures, lowered dissolved oxygen, increased nutrient loading, increased fecal coliform bacteria, and increased chemicals associated with pesticides and urban runoff (LCREP 2007). Mining areas scattered around the basin deliver high background concentrations of metals into nearby waterbodies. Highly developed agricultural areas of the basin also deliver fertilizer, herbicide, and pesticide residues to the river. Concentrations of copper are present at levels that could interfere with crucial salmon behaviors. Under these environmental conditions, fish in the action area are stressed. While the magnitude of effects to juvenile or adult salmon and steelhead is unclear, stress is likely to lead to reductions in biological reserves, altered biological processes, increased disease susceptibility, and altered performance of individual fish (e.g., growth, osmoregulation, and survival). Effects can be direct or indirect and lethal or, more likely, sublethal. The interaction of co-occurring stressors may have a greater impact on salmon than if they occur in isolation (Dietrich et al. 2014). Together, these contaminants are likely affecting the productivity and abundance of Columbia River basin salmon and steelhead, especially during the rearing and juvenile migration life stages.

Water temperatures in the Columbia and Snake Rivers are a concern for salmon and steelhead. Both rivers are included on the Clean Water Act §303(d) list of impaired waters established by the relevant states because of temperature standard exceedances. Temperature conditions in the basin are affected by many factors, including the following: 1) natural variation in weather and river flow; 2) the presence and operation of the dam and reservoir system, which create large reservoir surface areas and slower river velocities contributing to warmer late summer/fall water temperatures; 3) increased temperatures of tributaries due to water withdrawn for irrigated agriculture, and due to grazing and logging; 4) point source thermal discharges from cities and industries; and, 5) climate change.

In general, the mainstem dams have the following effects on water temperature: 1) maximum summer water temperature is slightly reduced; 2) water temperature variability is decreased; and, 3) water temperatures stay cooler longer into the spring and warmer later into the fall, a phenomenon termed thermal inertia. These hydrosystem effects (which stem from both upstream storage projects and run-of-river mainstem projects) continue downstream and, along with tributaries, influence temperature conditions in the lower Columbia River. At a broad scale, water temperature affects salmonid distribution, behavior, and physiology (Groot et al. 1991). At a finer scale, temperature influences migration swim speed of salmonids (Salinger et al. 2006), timing of river entry (Peery et al. 2003), susceptibility to disease and predation (Groot et al. 1991), and survival at temperature extremes.

Since the mid-1990s, water releases from Dworshak Dam (North Fork Clearwater River, Snake River basin) during the summer have been managed to reduce temperatures and enhance flows in the lower Snake River such that temperatures at the tailrace of Lower Granite Dam do not exceed 68°F (20°C). This action reduces temperatures through the downstream mainstem reaches of the Snake River basin, but has little to no discernible effect on temperature in the Columbia River downstream of the Snake River confluence. Despite this flow augmentation, temperature criterion exceedances occur frequently in downstream reaches of the Snake River from mid-July to mid-September (EPA 2021). The thermal inertia of large upper basin storage projects has largely reduced the risk that salmon and steelhead will encounter elevated temperatures in the middle and lower Columbia River during spring, although summer-migrating fish and, in low flow years, late-spring migrants may encounter elevated water temperatures due to the hydrosystem. For example, adult Upper Columbia River spring-run Chinook salmon migrating at the end of their respective runs (June–July) adult Middle Columbia River steelhead migrating in the late summer may be at elevated risk.

In August 2021, EPA issued a TMDL for addressing exceedances of various state and tribal criteria for temperature in the Columbia River and lower Snake River. As part of the 2015 Opinion on EPA's approval of water-quality standards, including temperature (NMFS 2015d), EPA committed to work with Federal, state, and tribal agencies to identify and protect thermal refugia and thermal diversity in the lower Columbia River and its tributaries. These areas of cold water refugia are important to summer migrating salmonids.

Historically, TDG supersaturation was a major contributor to juvenile salmon mortality in that it induces gas bubble trauma (GBT). However, infrastructure modifications (e.g., "flip lips") and state regulatory requirements for monitoring TDG levels and GBT prevalence, and for limiting spill when thresholds are exceeded, have curtailed this problem. Under recent operations (2008 to 2019), exposure to elevated TDG levels exceeding state standards was restricted to involuntary spill, most often between mid-May and mid-June, affecting most yearling spring Chinook salmon smolts and adults. Monitoring data from 1998 to 2022 indicate that TDG did not increase instantaneous mortality rates for juvenile yearling Chinook in the CRS (DeHart et al. 2023).

The series of dams and reservoirs in the CRS has blocked natural sediment transport. Total sediment discharge into the estuary and Columbia River plume is only one-third of 19-century levels (Simenstad et al. 1982; Sherwood et al. 1990; Simenstad et al. 1990; Weitkamp 1994; NRC 1996; NMFS 2008k). In a more recent study, Bottom et al. (2005) estimated that, together, hydrosystem operations and reduced river flows caused by climate change have decreased the delivery of sediment to the lower river and estuary by more than 50% (as measured at Vancouver, Washington). The overall reduction in sediment, combined with bank armoring and in-water structures that focus flow in the navigation channel, has reduced the availability of shallow water habitat along the margins of the river.

Industrial harbor and port development is a significant influence on the lower Snake and lower Columbia Rivers (Bottom et al. 2005; Fresh et al. 2005; NMFS 2013g). Since 1878, the USACEs has dredged 100 miles of river channel within the mainstem Columbia River, its estuary, and the Willamette River as a navigation channel. Originally dredged to a 20-foot minimum depth, the Federal navigation channel of the lower Columbia River is now maintained at a depth of 43 feet and a width of 600 feet. The dredging, along with diking, draining and fill material placed in wetlands and shallow habitat, disconnects the river from its floodplain, resulting in the loss of shallow-water rearing habitat and the ecosystem functions that floodplains provide (e.g., supply of prey, refuge from high flows, temperature refugia) (Bottom et al. 2005).

The introduction of exotic species has altered the ecosystem through competition, predation, disease, parasitism, and alterations in the food web (NPCC 2004; Sytsma et al. 2004). Numbers of one of these introduced species, the American shad, now exceed 4 million annually (NPCC 2004). Planktivorous shad exert tremendous pressure on the estuarine food web because of the sheer weight of their biomass and energetic requirements. Some evidence suggests they reduce the abundance and size of *Daphnia* in the mainstem reservoirs, reducing this food resource for subyearling fall-run Chinook salmon. However, Haskell et al. (2017) found that juvenile shad were eaten by subyearling Chinook salmon in John Day Reservoir, especially in late July and early August when *Daphnia* populations diminish, so there is uncertainty regarding their net effect on the growth and survival of listed salmonids.

2.4.1.1.3 Columbia River estuary

Salmon and steelhead from the following Recovery Domains are expected to occur within the Columbia River estuary, which includes all areas from Bonneville Dam to the river's mouth at the Pacific Ocean:

- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

The Columbia River estuary provides important rearing and/or migratory habitat for ESA-listed juvenile salmonids. Since the late 1800s, 68–74% of the vegetated tidal wetlands of the Columbia River estuary have been lost to diking, filling, bank hardening, flow regulation, and other modifications (Kukulka et al. 2003; Bottom et al. 2005; Marcoe et al. 2017; Brophy et al. 2019). Disconnection of tidal wetlands and floodplains has reduced the production of wetland macrodetritus supporting salmonid food webs (Simenstad et al. 1990; Maier et al. 2009), both in shallow water and for larger juveniles migrating in the mainstem.

Restoration actions in the estuary, such as those highlighted in the recent 5-year reviews (NMFS 2022j; 2022p; 2022m; 2022l; 2022q), have improved access and connectivity to floodplain habitat. From 2007 through 2019, the Action Agencies implemented 64 projects, including breaching or lowering dikes and levees, and removing or upgrading tide-gates. Combined, these projects reconnected over 6,100 acres of historical tidal floodplain habitat to the mainstem and another 2,000 acres of floodplain lakes. This represents more than a 2.5% net increase in the connectivity index for these important floodplain habitats that either are used extensively by some species and life history stages of listed salmonids (e.g., subyearling Chinook salmon). These habitats also produce and export large amounts of prey—particularly chironomid insects—to the migratory corridor where it is accessible to other species and life history stages of listed salmonids (e.g., steelhead, yearling Chinook salmon). In addition to this extensive reconnection effort, about 2,500 acres of currently functioning floodplain habitat have been acquired for conservation.

Floodplain habitat restoration can affect the performance of juvenile salmonids whether they move onto the floodplain or stay in the mainstem. Wetland food production supports foraging and growth within the wetland (Johnson et al. 2018a), but these prey items (primarily chironomid insects and corophiid amphipods) (PNNL and NMFS 2018; 2020) are also exported to the mainstem and off-channel habitats behind islands and other landforms, where they become available to salmon and steelhead migrating in these locations (Roegner et al. 2023). Thus, while some species and life history stages typically do not enter tidal wetland channels, they still derive benefits from these habitats. Improved opportunities for feeding on prey that drift into the mainstem are likely to contribute to survival at ocean entry. Blood serum levels of insulin-like growth factor-1 (IGF-1) for yearling steelhead and spring and summer Chinook salmon collected in the estuary were higher than are typically found in hatchery fish before release, suggesting that prey quality and quantity in the estuary were sufficient for growth (PNNL and NMFS 2020; Weitkamp et al. 2022). However, variation in IGF-1 levels was substantial (two to three times higher in some individuals than in others) (Weitkamp et al. 2022), both within and between genetic stocks, indicating differences in feeding and migration patterns. Continuing to grow during estuary transit may be part of a strategy to escape predation during the ocean life stage through larger body size.

Past and continuing releases of toxic contaminants from both estuarine and upstream sources have degraded habitat quality and the food web in the estuary (Fresh et al. 2005; LCREP 2007), similar to that discussed in subsection 2.4.1.1.3. Historically, levels of contaminants in the Columbia River were low, except for some metals and naturally occurring substances (Fresh et al. 2005). Today, levels in the estuary are much higher, as it receives contaminants from more than 1,000 point sources that discharge into basin waterways and numerous non-point sources of runoff (Fuhrer et al. 1996). With Portland and other cities on its banks, the Columbia River below Bonneville Dam is the most urbanized section of the river. Sediments in the river at Portland are contaminated with various toxic compounds, including metals, PAHs, PCBs, chlorinated pesticides, and dioxin (EPA 2017). Contaminants have been detected in aquatic insects, resident fish species, salmonids, river mammals, and osprey, indicating that contaminants are widespread throughout the estuarine food web (e.g., Fuhrer et al. 1996; Tetra Tech 1996; Johnson et al. 2007a; Johnson et al. 2007b; LCREP 2007; Herger et al. 2017). The diversity of toxic contaminants present can induce a variety of effects to individual animals and the ecosystem as a whole, though more research is needed on contaminant uptake and impacts to different populations and life-history types of listed salmonids.

2.4.1.1.4 Puget Sound marine waters

Salmon and steelhead from the following Recovery Domains are expected to occur within the freshwater portion of the action area (exclusive of Columbia River and Snake River mainstems):

- Puget Sound: all salmon ESUs and steelhead DPSs

Puget Sound marine areas can generally be divided into two broad categories: 1) nearshore, which includes inner estuaries, all intertidal areas (including outer estuaries), and other areas close to the shoreline; and, 2) offshore—also broadly referred to as pelagic or limnetic—which are deeper-water areas not considered in the nearshore. Regarding designated critical habitat in these areas, NMFS has identified the physical or biological features essential to salmon and steelhead conservation, which are described in Section 2.2.7.

The baseline condition of Puget Sound marine habitat is a degraded state overall, with reduced water quality, reduced forage and prey availability, reduced quality of forage and prey communities, reduced amount of estuarine habitat, reduced quality of nearshore and estuarine habitat, and reduced condition of migration habitat. Each of these conditions of the baseline exerts downward pressure on listed salmonid species considered in this Opinion for the duration of their time in the action area. The baseline currently constrains the carrying capacity of the action area and limits its potential for serving recovery of these species. Overall, the nearshore is impacted in many areas by the degradation from coastal development and pollution. The status of pelagic habitat is impacted by degraded water quality and pollution, among other factors. The input of pollutants affects water quality, sediment quality, and food resources in the marine areas of critical habitat.

Both nearshore and pelagic areas are fundamental to many life histories of salmon and steelhead. The nearshore is particularly crucial for ESA-listed juvenile chum and Chinook salmon in Puget Sound. The nearshore is the zone where salt water, freshwater, and terrestrial landscapes come together to form a complex mosaic of processes and habitats. It is the foundation of biologic productivity in Puget Sound. The nearshore encompasses the shoreline from the top of the upland bank or bluff on the landward side down to the depth of water that light can penetrate and where plants can photosynthesize (the photic zone). The upper extent of the nearshore includes the terrestrial upland, which contributes sediment, shade, organic material (leaf litter), and forage resources (insects). The lower extent of the nearshore extends to the bottom of the photic zone, about 30 to 100 feet below Mean Lower Low Water (MLLW) depending on water clarity (Williams et al. 2001). The nearshore includes a variety of environments such as marine shallows, eelgrass meadows, kelp forests, mudflats, beaches, salt marshes, rocky shores, river deltas, estuaries, barrier islands, spits, marine riparian zones, and bluffs. This wide range of habitats supports many species. ESA-listed juvenile chum and Chinook salmon use nearshore habitat extensively during their early marine rearing period (Duffy et al. 2005), a critical time for salmon growth, as larger, faster-growing fish have increased probabilities of surviving to adulthood (Beamish et al. 2004; Beauchamp et al. 2011). The elimination and degradation of nearshore habitat is considered a factor in the loss of Puget Sound salmon abundance and productivity. Reduction in nearshore habitat quality has reduced survival at multiple life stages.

Throughout Puget Sound, nearshore areas have been extensively modified by human activity over the last century, disrupting the physical, biological, and chemical interactions that are vital for creating and sustaining the diverse ecosystems of Puget Sound that support ESA-listed salmonids. There are approximately 503,106 acres of overwater structure in the nearshore of Puget Sound (Schlenger et al. 2011). Currently, 30% of Puget Sound’s shorelines are armored (Schlenger et al. 2011). Such armoring has multiple negative effects on salmon including reductions in prey (via reduction in forage fish spawning habitat) and reductions in shallow water rearing habitat and refuge (Whitman 2011; Davis et al. 2020). Other modifications include jetties and breakwaters designed to dissipate wave energy, and structures such as tide gates, dikes, and marinas, overwater structures, including bridges for railways, roads, causeways, and artificial fill. Shoreline modifications are usually intended for erosion control, flood protection, sediment management, or for commercial, navigational, and recreational uses. In addition to those noted above, the following anthropogenic changes affect salmon habitat in the Puget Sound nearshore (Fresh et al. 2011; Simenstad et al. 2011):

- In the 16 largest river deltas, 56% of tidal wetlands have been eliminated and shoreline length has been decreased by 27%.
- 93% of freshwater tidal and brackish marsh habitat has been eliminated.
- 40% of Puget Sound shorelines have some type of anthropogenic structure that impacts habitat quality.
- Shoreline length has been decreased by 15% due to shoreline straightening.
- Small coastal embayments have been decreased by 46%.

Although shoreline modifications occur and are typically evaluated on the site scale, the combination of these individual impacts diminish and disrupt entire ecosystems at the landscape scale. Shoreline modification can cause fragmentation of the landscape that disrupts connectivity and reduces the productivity and biological diversity of Puget Sound watersheds. These impacts leave ecosystems less resilient.

There is evidence that elimination and degradation of nearshore habitat is detrimentally altering the life history composition of PS Chinook salmon. Very few returning adults (≤ 3%) exhibited the fry outmigrant life history in rivers that have suffered the most extreme estuary habitat loss and degradation (Green and Puyallup Rivers) (Simenstad et al. 2011; Beechie et al. 2017; Campbell et al. 2017; Hall et al. 2021). This outmigrant life history makes the most extensive and prolonged use of estuary habitat. Conversely, one-quarter to one-third (24–36%) of returning adults exhibited this strategy in rivers with considerably more intact and ecologically functional estuaries (Skagit and Nooksack Rivers).

Between November 9, 2020, and May 11, 2022, the NMFS issued three Opinions on a total of 65 proposed projects in the nearshore of Puget Sound (NMFS 2020e; 2021i; 2022h). In these Opinions, the NMFS determined that the USACE actions to permit many of the 65 projects were likely to jeopardize the continued existence of listed Puget Sound Chinook salmon and SRKW, and was likely to adversely modify those species' designated critical habitats. NMFS also determined that the actions were not likely to jeopardize listed Puget Sound steelhead, Puget Sound/Georgia Basin rockfish (bocaccio and yelloweye rockfish), or Hood Canal Summer-run Chum salmon, or adversely modify designated critical habitat for those four species. The conclusions for Chinook salmon were based in part on the following:

- Under the environmental baseline described in those Opinions, nearshore habitat in Puget Sound could not support the full biological requirements of Puget Sound Chinook salmon needed for recovery.
- The condition of the environmental baseline described in those Opinions was such that additional impacts on the quality of nearshore habitat was likely to impair the ability of that habitat to support conservation of Puget Sound Chinook salmon.
- The actions evaluated in those Opinions would further reduce the quality of nearshore habitat in Puget Sound.
- The actions evaluated in those Opinions would exacerbate habitat limiting factors identified by the Puget Sound Chinook salmon recovery plan and were inconsistent with recovery actions identified in the plan.

- Due to demand for future human development, the cumulative effects described in those Opinions on nearshore habitat quality were expected to be mostly negative.

Each of these opinions included a similar RPA that contained the following five pathways for avoiding jeopardy to the species and adverse modification of critical habitat: on-site habitat improvements; off-site habitat improvements; provide funding to a habitat restoration sponsor; purchase credits from a conservation bank in-lieu fee program or crediting provider; and, project modifications.

Despite several decades of efforts by federal, state, local, and tribal entities to restore and recover nearshore, including estuarine, habitats and processes, overall habitat improvement has been relatively modest compared to the extensive, persistent, and widespread nature of the loss and degradation. Ongoing restoration efforts are expected to make incremental increases in habitat quantity and quality. However, these are not expected to substantively alter the generally degraded conditions over the foreseeable future for the following reasons: 1) regulatory and permitting measures do not avoid all negative impacts and largely fail to include methods to rectify unavoided impacts; 2) increasing human population and concomitant development pressure continues to impact habitat in marine and freshwater areas; 3) climate change will exert negative pressure and exacerbate effects of existing habitat degradation; and, 4) changes in human activities that minimize resource impacts are relatively slow to develop and spread. Ongoing habitat protection and restoration efforts are expected to continue to make modest, incremental improvements at the scale of the action area and ESUs and DPSs, while increasing human population and climate change are expected to exert negative pressures on habitat conditions across the region.

Stormwater is the most important pathway for most toxic contaminants into Puget Sound, transporting more than half of total known toxic load (Ecology et al. 2011; Mackenzie et al. 2018). During a robust Puget Sound monitoring study, toxic chemicals were detected more frequently and at higher concentrations during storm events compared with baseflow for diverse land covers, pointing to stormwater pollution (HEC 2011). The Puget Sound basin has over 4,500 unnatural surface water and stormwater outfalls, nearly half of which (47%) discharge directly into Puget Sound (Gaeckle et al. 2015).

In general, pollutants in stormwater discharge are diverse. The discharge itself comes from rainfall or snowmelt moving over and through the ground, also known as “runoff.” As runoff moves across the landscape, it accumulates natural and anthropogenic pollutants (Dressing et al. 2016). Pollutants in stormwater discharge typically include the following:

- Excess fertilizers, herbicides, insecticides and sediment from landscaping and agriculture.
- Oil, grease, PAHs and other toxic chemicals from roads and parking areas used by motor vehicles.
- Bacteria and nutrients from pet wastes and faulty septic systems.
- Atmospheric deposition from surrounding land uses.
- Metals, PAHs, PBDEs, and phthalates from roof runoff.
- Chemicals and salts from de-icing agents applied on sidewalks, driveways, and parking areas.

- Erosion of sediment and attached pollutants due to hydromodification.

2.4.1.1.5 Pacific Ocean

Salmon and steelhead from the following Recovery Domains are expected to occur within the oceanic portion of the action area:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs
- North Central California Coast: California Coastal Chinook Salmon
- Central Valley: Central Valley Spring-Run Chinook Salmon

In the oceanic portion of the action area, salmonid growth and survival is influenced by a variety of interrelated local physical (temperature, upwelling, currents) and biological (primary productivity, abundance of predators, prey, and competitors) variables. These local variables are driven by larger-scale processes that operate on longer time scales, such as the PDO, the North Pacific Gyre Ocillation (NPGO), and the ENSO. These variables and processes combine each year to result in conditions that may be unfavorable, intermediate, or favorable for salmon growth and survival (Beamish 2018). See for example NMFS' Ocean Ecosystem Indicators of Pacific Salmon Marine Survival in the Northern California Current[25].

In the southern part of the action area (west coast of Vancouver Island and south), herring, anchovy, and sardine dominate the surface-oriented fish community (Orsi et al. 2007). These species may compete with juvenile salmonids during their early marine residence (Trudel et al. 2007), but provide a forage resource as the salmon grow larger, particularly for more piscivorous species such as Chinook and coho salmon (e.g., Daly et al. 2009). In these southern areas, juvenile salmon make up a small proportion (about 2–13%) of the surface-oriented fish community. This is in stark contrast to northern areas, where juvenile salmon are most abundant, particularly pink, chum, and sockeye salmon, and to a lesser extent coho salmon (Orsi et al. 2007; Orsi et al. 2011; Orsi et al. 2012; Orsi et al. 2013; Orsi et al. 2014; 2015; 2016; Fergusson et al. 2018). Here, juvenile salmon comprise about 35–83% of the surface-oriented fish community.

In the ocean, ESA-listed salmonids are affected by climate change (described in subsection 2.4.1.5, Climate Change) and by fish harvest activities (described in subsection 2.4.1.4, Harvest). ESA-listed salmonids have also been affected by marine mammal protection (e.g., the 1972 Marine Mammal Protection Act and 1973 Endangered Species Act in the United States; the 1970 Fisheries Act and 2002 Species at Risk Act in Canada). As a result, populations of several marine mammal species have increased throughout the action area, leading, for example, to a substantial increase in consumption of Chinook salmon (Chasco et al. 2017b; Couture et al. 2024) and possibly also contributing to the observed decline in body size of Chinook salmon

[25] https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

(Ohlberger et al. 2018; Ohlberger et al. 2019). Section 2.4.1.1.6, Predation has additional information pertaining to predation in the ocean.

2.4.1.1.6 Predation

Salmon and steelhead from the following Recovery Domains are expected to be affected by predation in freshwater and/or marine parts of the action area:

- Puget Sound: all salmon ESUs and steelhead DPSs (freshwater and marine)
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs (freshwater and marine, except Puget Sound)
- Interior Columbia River: all salmon ESUs and steelhead DPSs (freshwater and marine, except Puget Sound)
- North-Central California Coast: California Coastal Chinook Salmon (marine only, except Puget Sound)
- Central Valley: Central Valley Spring-Run Chinook Salmon (marine only, except Puget Sound)

A variety of avian and fish predators consume juvenile listed salmon and steelhead on their migration from rearing areas to the ocean. Pinnipeds eat adults from the ocean through lower river reaches. High predation rates have been observed for some predators on some species at certain times and places.

In Puget Sound, pinniped predation is a concern for both steelhead trout and Chinook salmon. Puget Sound steelhead populations experience extremely high mortality during their short residence in Puget Sound (Moore et al. 2010; Moore et al. 2015), much more so than during their time in the Pacific Ocean (Kendall et al. 2017; Sobocinski et al. 2020). There is strong evidence that predation—particularly though not exclusively by harbor seals—is the most dominant cause of mortality in Puget Sound waters (PSSMSW 2018, and references therein; Sobocinski et al. 2020; Pearsall et al. 2021). For Chinook salmon, the time spent rearing in Puget Sound is one of the most critical periods impacting their fitness and survival (Greene et al. 2005; Sobocinski et al. 2020; Pearsall et al. 2021). Based on a comprehensive review of the science to date, the Synthesis Committee of the Salish Sea Marine Survival Project[26] (SCSSMSP) noted that the following factors appear to be most influential to Chinook salmon mortality in Puget Sound: predator abundance (particularly seals), contaminants, water quality, prey availability, and growth during the early marine "critical period" (Pearsall et al. 2021). Harbor seals in particular appear to have the greatest impact relative to other pinnipeds (Chasco et al. 2017a; Nelson et al.

[26] The Salish Sea Marine Survival Project, launched in 2013, describes itself as follows (Pearsall et al. 2021): "[The Salish Sea Marine Survival Project is] a US-Canada research collaboration to identify the primary factors affecting the survival of juvenile Chinook, Coho, and steelhead in the Salish Sea marine environment. From 2014–2018, this international collaborative of over 60 federal, state, tribal, nonprofit, academic, and private entities implemented a coordinated research effort that encompassed all major hypothesized impacts on Chinook, Coho, and steelhead as they entered and transited the Salish Sea. Ultimately, several hundred scientists collaborated to implement over 90 studies…[The Synthesis Report (i.e., Pearsall et al. 2021)] synthesizes the work to date and provides [the Synthesis Committee's] perspectives regarding the primary factors affecting survival and the next steps in research and management."

2019a). A recent review by the Washington State Academy of Sciences (WSAS 2022) concluded that "…the preponderance of evidence supports the hypothesis that current populations of pinnipeds are a contributing factor in the decline and depression of salmon populations in Washington State waters…", but there is "…substantial uncertainty about the degree to which pinnipeds have and currently are depressing salmon stocks, including those that remain listed under the Endangered Species Act and across the entirety of marine ecosystem of Washington State."

As noted above, dams and reservoirs throughout the Columbia River basin block sediment transport. As a result, total sediment discharge into the river's estuary and plume is about one-third of 19th-century levels (Bottom et al. 2005). Reduced sediment discharge to the lower river, especially during spring, contributes to reduced turbidity, which may make juvenile outmigrants more vulnerable to visual predators like piscivorous birds and some piscivorous fishes.

Piscivorous colonial waterbirds, especially terns, cormorants, and gulls, have a significant impact on the survival of juvenile listed salmonids in the Columbia River (Roby et al. 2021). For example, Caspian terns *(Hydroprogne caspia)* on Rice Island, an artificial dredged-material disposal island in the Columbia River estuary, consumed 5–15% of all salmonid smolts reaching the estuary in 1997 and 1998 (Roby et al. 2003). In 1999, this tern colony was moved 13 miles closer to the ocean to East Sand Island where their diet could diversify to include marine forage fish, resulting in a 59% reduction in salmonid smolt consumption from 2001 to 2015. Similarly, double-crested cormorants (*Phalacrocorax auritus*) in the Columbia River estuary consumed 1.8–7.5% of all outmigrating juvenile listed salmonids from 2003 to 2014 except for those from two ESUs. Predation on the Lower Columbia Chinook Salmon ESU was very high at 25.5% during this period. Avian predation also occurs at mainstem dams, though management measures required by the 2008 Opinion helps minimize predation at these areas. Smolts migrating through the interior Columbia plateau have been vulnerable to predation by terns nesting in colonies on islands in McNary Reservoir, in the Hanford Reach, and in Potholes Reservoir. Management efforts are ongoing to reduce salmonid consumption by terns and cormorants in the Columbia River estuary and throughout the basin. The extent to which management measures and subsequent predation reduction affects adult returns is uncertain.

The native northern pikeminnow (*Ptychocheilus oregonensis*) is a significant predator of juvenile salmonids in the Columbia and Snake Rivers followed by non-native smallmouth bass and walleye (reviewed in Friesen et al. 1999; ISAB 2011; 2015). Northern pikeminnow consumed about 8% of outmigrating juvenile salmonids annually before the start of the Northern Pikeminnow Management Program (NPMP) in 1990. This program typically reduces predation by around 30% (Winther et al. 2023). Combined, the NPMP's Sport Reward Fishery and Dam Angling Programs remove about 100,000 to 200,000 piscivorous pikeminnow per year (Winther et al. 2023). Relatively small numbers of Chinook, coho, and sockeye salmon and steelhead trout are incidentally caught by anglers while participating in these programs (e.g., Williams et al. 2016a; Williams et al. 2017; Williams et al. 2018; 2019; Winther et al. 2020; 2021; Winther et al. 2022; Winther et al. 2023). Regarding smallmouth bass and walleye, the Oregon and Washington Departments of Fish and Wildlife, which manage these two non-native predator species, taken actions such as removing bag limits to help reduce predation pressure on juvenile salmonids. These programs for removing pikeminnow, smallmouth bass, and walleye are expected to incrementally improve juvenile salmonid survival during their migration to the ocean.

The abundance of pinnipeds—which prey on juvenile and/or adult salmonids—has increased considerably in the Pacific Northwest since the Marine Mammal Protection Act (MMPA) was enacted in 1972 (Carretta et al. 2023). California sea lions *(Zalophus californianus)*, Steller sea lions *(Eumetopias jubatus)*, and harbor seals *(Phoca vitulina)* all consume salmonids from the mouth of the Columbia River and its tributaries up to the tailrace of Bonneville Dam. Rub et al. (2019) found that non-harvest mortality of adult spring Chinook salmon through the estuary was 20–44% annually from 2010 to 2015, and presented evidence that much of this was attributable to pinniped predation. Hydroelectric dams can delay upstream fish passage and congregate fish searching for ladder entrances (Kareiva et al. 2000; Quiñones et al. 2015). Such delays and spatial constrictions can make fish vulnerable to predation by pinnipeds (Naughton et al. 2011; Stansell et al. 2014). Pinniped abundance in the Bonneville Dam tailrace generally increased from 2002 to a peak in 2015, but has declined since then to pre-2010 levels (Tidwell et al. 2023). From 2018 to 2022, pinnipeds in the 1.25-mile reach below the dam have annually consumed 7.2–8.7% of the steelhead run, 2.5–3.3% of the spring Chinook salmon run, and 2.5–3.3% of all adult salmonids combined. Sea lion excluder gates are designed to reduce predation vulnerability and are installed at all eight ladder entrances at Bonneville Dam. From 2008 to 2019, NMFS permitted pinniped hazing and lethal removal of California sea lions in certain areas of the lower Columbia River basin to help reduce predation. These approvals were expanded in August 2020 to include lethal removal of Stellar sea lions. The authorization allows for removal of up to 540 California sea lions and 176 Steller sea lions through August 2025.

There is evidence that marine mammal predation on Chinook salmon has also increased in marine waters outside of Puget Sound and the Columbia River estuary. Chasco et al. (2017a) found that marine mammal predation on Chinook salmon increased substantially from 1975 to 2015. The number of individual Chinook salmon consumed increased by a factor of 6.3 (from from 5 to 31.5 million fish) and the biomass consumed increased by a factor of 2.5 (from 6,100 to 15,200 metric tons). Stocks from the Columbia River and Puget Sound made up about two-thirds of consumed fish and biomass. As mentioned above, substantial marine mammal predation occurs within Puget Sound and the Columbia River estuary. However, Chasco et al. (2017a) provided evidence that a sizeable proportion of increased consumption occurs in marine waters outside of these areas, likely due in part to increased killer whale abundance. Abundance of Northern Resident Killer Whales—whose range overlaps the primary ocean distribution of Puget Sound and Columbia River Chinook salmon stocks—has doubled since 1980 (Towers et al. 2020). Further, Ohlberger et al. (2019) attributed range-wide declines in Chinook salmon size and age at maturity to increasing resident killer whale abundance.

Ohlberger et al. (2019) indicated that other apex marine predators such as salmon sharks (*Lamna ditropis*) may compound effects of killer whale predation. Though salmon sharks have not been well studied, there is evidence that salmon shark abundances have increased in some areas of the northeast Pacific Ocean (Okey et al. 2007). Salmon sharks may consume large numbers of Chinook salmon (Manishin et al. 2019; Seitz et al. 2019) and may have a substantial influence on Chinook salmon abundance and age structure (Manishin et al. 2021). A large summer-time aggregation of salmon sharks has been documented in British Columbia's Queen Charlotte Sound (Williams et al. 2010b). The Queen Charlotte Sound and nearby areas are known to be used by Chinook salmon from Puget Sound and the Columbia River basin during the summer (Shelton et al. 2019; Shelton et al. 2021).

2.4.1.2 Dams and Hydropower

Salmon and steelhead from the following Recovery Domains are expected to occur within the portion of the action area affected by dams and hydropower:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

The general effects of mainstem and tributary dams on salmonid habitat and designated critical habitat include the following:

- Inundation and loss of historical spawning sites and rearing areas (critical habitat PBFs 1 and 2: conditions supporting spawning; physical habitat conditions, cover, and side channels);
- Lost access to historical spawning areas upstream from dams built without fish passage facilities (critical habitat PBF 3: safe passage in migration corridors);
- Juvenile and adult passage survival at dams with passage facilities (critical habitat PBF 3: safe passage in migration corridors);
- Water quantity (i.e., flow) and seasonal timing of water delivery (critical habitat PBFs 2, 3, and 4: water quantity and velocity; cover/shelter; food/prey; riparian vegetation; floodplain connectivity and space in rearing areas, including the estuarine floodplain; safe passage in migration corridors);
- Temperature, both in the reaches below the large mainstem storage projects and in rearing areas and migration corridors (critical habitat PBFs 2 and 3: water quality; safe passage in the migration corridor);
- Sediment transport and turbidity in rearing areas and migration corridors (critical habitat PBFs 2 and 3: water quality; safe passage in the migration corridor);
- Total dissolved gas in rearing areas and migration corridors (critical habitat PBFs 2 and 3: water quality; safe passage in the migration corridor);
- Food webs, including both predators and prey (critical habitat PBFs 2 and 3: food/prey; safe passage in migration corridors).

Several large and small dams are present throughout Puget Sound, including the following: two Baker River and three mainstem Skagit River mainstem dams in the Skagit River watershed; the Howard Hanson Dam on the Green River; and the Mud Mountain Dam on the White River. Several large dams have been removed, including the Elwha, Glines Canyon, Pilchuck, and Middle Fork Nooksack dams, and passage facilities have been added or improved at others (e.g., Cushman on the North Fork Skokomish River; Baker in the Skagit River watershed). However, substantial fish barriers and concerns remain in other places, such as Electron Dam on the Puyallup River, Howard Hanson Dam on the Green River, and the Buckley Diversion Dam on the White River (tributary to Puyallup River). Passage impediments exist at a multitude of other smaller barriers around the region.

The Columbia River Basin has more than 450 dams, which are managed for hydropower, flood control, water supply, and other uses. The total water storage in the Columbia River system is 55 million acre-feet, of which 42 million acre-feet are available for coordinated water management (e.g., power production, flood control, water supply, fish operations) (BPA et al. 2001). Flow management operations at large storage reservoirs in the interior of the Columbia River Basin (e.g., Grand Coulee, Dworshak) affect habitat in the lower Columbia River mainstem and estuary, and the volume of the Columbia River plume.

The CRS is a series of 14 multipurpose, hydroelectric facilities on the mainstem Columbia, Snake, and Clearwater (tributary to Snake River) Rivers, constructed and operated by the USACE and the BOR. Eight dams are on the mainstem lower Snake and Columbia Rivers. These are all operated as run-of-river projects. The other six dams are in upstream areas and are operated as storage projects. The BPA markets and transmits the power produced at CRS dams. NMFS has been consulting on the effects of the CRS (formerly Federal Columbia River Power System, or FCRPS) since the first salmonid species in the basin was listed under the ESA in 1992 (Snake River sockeye salmon). Most recently, NMFS completed an Opinion in 2020 (NMFS 2020c) for the continued operations and maintenance of the hydropower system. The proposed action included salmon conservation measures, including additional spill to improve passage conditions for juvenile salmon, as well as other measures including but not limited to conservation-oriented structural modifications, predator management, and estuary restortation.

In addition, NMFS has completed consultation with the Federal Energy Regulatory Commission (FERC) on effects of the run-of-river hydroelectric projects in the middle reach of the Columbia River (upstream of the confluence with the Snake River), which are operated by three public utility districts (PUDs). These include the following: Douglas PUD’s Wells Hydroelectric Project at Columbia RM 515 (NMFS 2003a); Chelan PUD’s Rocky Reach Hydroelectric Project at Columbia RM 453 (NMFS 2003b); and, Grant PUD’s Priest Rapids Hydroelectric Project at Columbia RM 379 (NMFS 2008j). In general, passage effects of these PUD projects are similar to those described below for the eight mainstem CRS run-of-river dams in the lower Snake and Columbia Rivers. NMFS has also completed consultation on effects of the Willamette Project, a series of 13 USACE high-head storage dams within the Willamette River basin (NMFS 2008i).

As discussed in more detail below, dams and their associated reservoirs present fish-passage obstacles, causing passage delays and varying rates of injury and mortality. The altered habitats in project reservoirs reduce smolt migration rates and create more favorable habitat conditions for fish predators. These effects have been the subject of the ESA section 7 Opinions cited above for the Columbia River PUD dams, the Willamette Project dams, and a series of Opinions for the CRS projects.

The Columbia River hydropower system can affect migrating salmon and steelhead by delaying downstream juvenile passage and increasing direct and indirect mortality of juvenile migrants. The hydropower projects have converted much of the once free-flowing migratory river corridor into a stair-step series of slower pools (though juveniles do feed and rear in the reservoirs).

Construction of the mainstem dams increased the time it took for smolts to migrate through the lower Snake and Columbia rivers with migration delays most pronounced in low flow years (Williams et al. 2005). The addition of surface spillway weirs at CRS dams and increased levels of spill during the last fifteen years has reduced delay for yearling fish, particularly for steelhead (Smith 2014). Though migration times have been reduced, delays likely continue to impact smolts by: (1) increasing their exposure to predation, disease, and thermal stress in the reservoirs; (2) disrupting their arrival time in the estuary; (3) depleting their energy reserves; and, (4) for steelhead, substantial delay has been shown to cause residualism (a loss of migratory behavior).

Juvenile salmon and steelhead can be killed while migrating through the dams, both directly through collisions with structures and abrupt pressure changes during passage through turbines and spillways, and indirectly, through non-fatal injury and disorientation that leave fish more susceptible to predation and disease, resulting in delayed, or latent, mortality. Actions over the last 20 years have improved passage conditions for all listed Columbia River salmon and steelhead species. By 2009, each of the eight mainstem lower Snake and lower Columbia River dams was equipped with a surface passage structure (spill bay weirs, powerhouse corner collectors, or modified ice and trash sluiceways) to improve passage of smolts, which primarily migrate in the upper 20 feet of the water column in the lower Snake and Columbia Rivers. Other improvements included the relocation of juvenile bypass system outfalls to avoid areas where predators collect, changes to spill operations, installation of avian wires to reduce juvenile losses to avian predators, and structures that reduce dissolved gas concentrations that might otherwise limit spill operations. Nevertheless, while these and other changes have improved smolt survival in recent years, dam passage impacts remain. The degree to which mortality in the estuary and ocean is caused by the prior experience of juveniles passing through the FCRPS (i.e., delayed or latent mortality) is unknown, and hypotheses regarding the magnitude of this effect vary greatly (ISAB 2007; 2012).

Adult migration is likely less affected by the dams and reservoirs than juvenile migration. Adult salmonids can pass each of the eight mainstem dams in the lower Snake and Columbia Rivers volitionally at fish ladders, which in general are highly effective. Except during recent years with high summer water temperatures, the migration rates of adults through the mainstem CRS projects is similar to that before the dams were built (Ferguson et al. 2005). Any delay that adults experience as they search for and navigate through fish ladder entrances is balanced by the faster rate of migration through the lower velocity reservoir environments. The dams have altered the thermal regime of mainstem areas, likely to the benefit of species that migrate from spring through mid-summer (i.e., spring and summer Chinook salmon; early migrating sockeye salmon and steelhead). However, late summer and fall migrating fish—such as sockeye salmon and steelhead—are exposed to elevated temperatures compared to the predevelopment period. Upriver stocks experience a loss of about 7–11% moving through the system of mainstem dams and reservoirs. Sources of this loss include the following: 1) stresses that occur during upstream migration that are influenced by temperature, spill, and a variety of other factors; 2) straying; 3) illegal harvest; 4) indirect effects of harvest such as injury and delayed mortality from contact with fishing gear; and, 5) injuries sustained during predation attempts by predators such as pinnipeds.

In the Willamette River basin, 13 federal and several other non-federal dams that operate for flood control and hydropower have the following effects to salmon and steelhead and their habitat (NMFS 2008i; ODFW et al. 2011): 1) blocked or impaired fish passage for adults and juveniles; 2) loss of some riverine habitat (and associated functional connectivity) due to reservoirs; 3) reduction in instream flow volume due to water withdrawals; 4) lack of sediment transport and role in habitat function; 5) altered physical habitat structure; and, 6) altered water temperature and flow regimes.

Within the Willamette River basin, the largest flood control/hydropower complex is the Willamette Project, managed principally as a flood control system by the USACE. The most recent Opinion for the Willamette Project (NMFS 2008i), and supporting references within, provides an extensive review of the multiple impacts this project has on Upper Willamette River Chinook salmon and steelhead populations and habitats within subbasins, but also as they contribute to habitat quality impacts in the Willamette River mainstem. Within the Willamette subbasins where these projects are located, the flood control structures block or delay adult fish passage to major portions of the historical holding and spawning habitat for Upper Willamette River Chinook salmon (North Santiam, South Santiam, McKenzie and Middle Fork Willamette subbasins), and for Upper Willamette River steelhead in the North Santiam and South Santiam basins. In addition, most Willamette Project dams have limited facilities or operational provisions for safely passing juvenile Chinook salmon and steelhead downstream of the facilities. Past operations and current configurations of the Willamette Project have impacted several salmonid life stages, through impacts on water flows, water temperatures, TDG, sediment transport, and channel structure.

In addition to the Federally owned and operated flood control/hydropower facilities in the Willamette River basin, other subbasin facilities such as the Portland General Electric complex in the Clackamas basin, the EWEB Carmen Smith complex (and associated structures) in the McKenzie basin, and municipal flow control facilities contribute to the flood control/hydropower limiting factors and threats to salmon and steelhead in the Willamette River watershed. Improvements for anadromous fish at these facilities are negotiated and formalized under processes and subsequent relicensing under the FERC.

2.4.1.3 Hatcheries

Production of hatchery fish affects salmon and steelhead from the following Recovery Domains in freshwater and/or marine parts of the action area:

- Puget Sound: all salmon ESUs and steelhead DPSs (freshwater and marine)
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs (freshwater and marine, except Puget Sound)
- Interior Columbia River: all salmon ESUs and steelhead DPSs (freshwater and marine, except Puget Sound)
- North-Central California Coast: California Coastal Chinook Salmon (marine only, except Puget Sound)
- Central Valley: Central Valley Spring-Run Chinook Salmon (marine only, except Puget Sound)

Freshwater portions of the action area are affected exclusively by hatchery production from the Puget Sound and Columbia River basins. Hatchery production from these basins also comprise the majority of hatchery fish in the marine part of the action area. For these reasons, this section emphasizes hatchery production from the Puget Sound and Columbia River basins. Hatchery production from regions outside of Puget Sound and the Columbia River—including the Washington and Oregon coasts, the British Columbia portion of the Salish Sea, and the west coast of Vancouver Island—contribute to effects in the marine part of the action area, though to a lesser extent than hatchery production from Puget Sound and the Columbia River. Hatchery production from these other regions do not contribute to affects to salmon and steelhead in freshwater parts of the action area. Therefore, hatchery production from these other regions will be described more generally than that from Puget Sound and the Columbia River basin.

This section describes the effects of hatchery operations occurring prior to this consultation, as well as the continued operation of hatchery programs that have already undergone separate ESA section 7 consultation. The effects of future operations of hatchery programs with expired ESA section 7 consultation and those programs yet to undergo ESA section 7 consultation are not included in the environmental baseline. However, included in the environmental baseline are effects from such programs that are still occurring or expected to occur due to operations occurring in the past. For example, hatchery smolts released in April 2024 from a program lacking ESA consultation will have effects from now until the adults return. These effects are included in the environmental baseline. As explained below, the adverse effects from hatchery programs that have not undergone ESA consultation are considered in this environmental baseline section (and cumulative effects section, as appropriate).

The history and evolution of hatcheries are important factors in analyzing their past and present effects. The first hatcheries, beginning in the late 19th century, provided fish to supplement harvest levels, as anthropogenic habitat-altering activities and harvest negatively impacted natural salmon and steelhead populations. As anthropogenic habitat alteration expanded and intensified (e.g., dam construction as part of the CRS between 1939 and 1975), hatcheries were used to mitigate for lost salmon and steelhead harvest attributable to the concomitant habitat degradation and reduction in survival. As a result, hatchery release abundances increased rapidly along the U.S. west coast, from about 50 million fish released per year in the late 1940s, to over 500 million fish released per year during the 1980s and early 1990s (Figure 71). During this time, negative effects of hatchery programs and practices to wild populations were not widely recognized or considered (NRC 1996). By the mid-1990s, however, it was clear that hatchery production was having substantive negative demographic, genetic, and ecological effects to wild populations. Such negative effects were a contributing factor to many ESUs and DPSs being ESA-listed during the 1990s. The primary negative effects can be summarized as follows (see Appendix C for detailed descriptions):

- Demographic. Historically, harvest rates were based on the large abundances of hatchery fish available with little to no regard for impact on wild populations. There was no way to distinguish hatchery from wild fish in the fisheries. Less productive wild populations were becoming overfished as a result. Affected wild populations were potentially being driven toward extirpation as the number of fish escaping the fisheries to spawn was, in many cases, not enough to sustain the population.

- Genetic.
  - Outbreeding Effects. Hatchery fish that spawn in the wild and breed with natural fish can alter the genetic composition of the affected natural populations and, consequently, the fitness and survival of fish from the affected natural populations. Of particular concern are hatchery fish with genetic lineages from outside the basin (e.g., a Columbia River hatchery program propagating fish with Puget Sound origin) and hatchery fish from programs with high levels of domestication and/or low genetic diversity (see following bullet points).
  - Hatchery-Influenced Selection (Domestication). Fish that become adapted to hatchery propagation often lose their ability to survive in the wild. Hatchery practices (e.g., timing of broodstock collection) and environments (e.g., rearing at unnaturally high densities in raceways; feeding on inanimate pellets near the surface) both play a role in producing fish that are less adapted to survive in nature.
  - Within-Population Genetic Diversity. Insufficient numbers of broodstock and inappropriate mating protocols can diminish within-population genetic diversity, leading to reductions in fitness and survival of fish from affected natural populations.
- Ecological
  - Competition. Large abundances of hatchery fish may deplete forage resources in freshwater, estuarine, and/or marine habitats. Consequently, lower prey abundances may result in slower-growing natural fish that are more susceptible to starvation or predation.
  - Predation. Hatchery fish released at a large size may prey on wild juvenile salmonids, particularly in freshwater habitats at times and places where wild juveniles are very small (i.e., fry-size).
  - Disease. Hatcheries and hatchery-produced fish may magnify and transmit pathogens in the natural environment, increasing infection rates and mortality in wild fish.

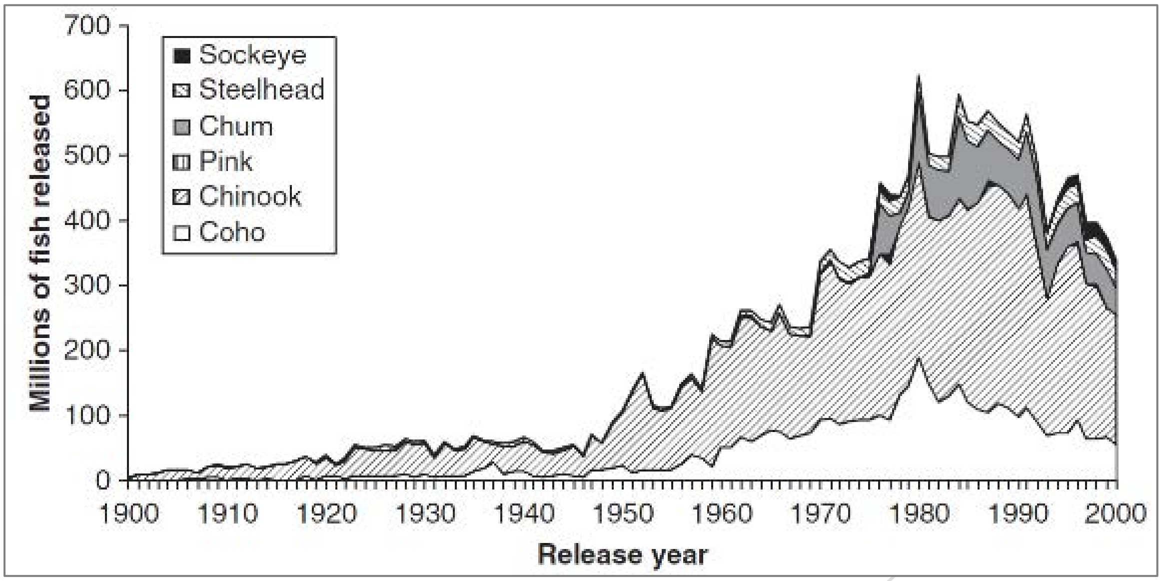


Figure 71. Number, in millions, of hatchery Pacific salmon and steelhead (all life stages) released from hatcheries in the continental United States. From Naish et al. (2007).

Since the mid-1990s, most hatchery programs have been tasked to maintain fishable returns of adult salmon and steelhead, usually for cultural, social, recreational, or economic purposes, as the capacity of natural habitat to produce salmon and steelhead remains substantially diminished despite widespread and extensive habitat restoration and other mitigation measures (e.g., flow criteria for improved survival, predator management). Though many hatcheries continue to operate for harvest augmentation purposes, a new role for hatcheries emerged during the 1980s and 1990s after naturally produced salmon and steelhead populations declined to unprecedented low levels. Because genetic resources that represent the ecological and genetic diversity of a species can reside in fish spawned in a hatchery, as well as in fish that spawn in the wild, hatcheries began to be used for conservation purposes (e.g., Snake River sockeye salmon). Such hatchery programs are designed to preserve the salmonid genetic resources until the factors limiting salmon and steelhead viability are addressed. In this role, hatchery programs reduce the risk of extirpation and extinction (NMFS 2005b; Ford et al. 2011). However, hatchery programs that conserve vital genetic resources are not without risk to the natural salmonid populations because the manner in which these programs are implemented can affect the genetic structure and evolutionary trajectory of the target population (i.e., natural population that the hatchery program aims to conserve) by reducing genetic and phenotypic variability and patterns of local adaptation (HSRG 2014; NMFS 2014d). A full description how hatchery programs can affect ESA-listed salmon and steelhead can be found in Appendix C.

Population viability and reductions in threats are key measures for salmon and steelhead recovery (NMFS 2013c). Beside their role in conserving genetic resources, hatchery programs also are a tool that can be used to help improve viability (i.e., supplementation of natural population abundance through hatchery production). In general, these hatchery programs increase the number and spatial distribution of naturally spawning fish by increasing the natural production with returning hatchery adults. These programs are not, however, a proven technology for achieving sustained increases in adult production (ISAB 2003), and the long-term benefits and risks of hatchery supplementation remain untested (Christie et al. 2014).

Recognizing the considerable negative impacts of hatcheries on the one hand, and the importance of hatcheries to meeting harvest and conservation goals on the other, the U.S. Congress established the Hatchery Reform Project in 2000. A key part of this was the creation of the Hatchery Scientific Review Group[27] (HSRG), an independent scientific review panel tasked with comprehensively reviewing all federal, tribal, and state hatcheries and hatchery programs throughout the Pacific Northwest, and making recommendations for their improvement (https://www.streamnet.org/home/data-maps/hatchery-reform/about-hsrg/). Desired outcomes included the following:

- Conserve indigenous salmonid genetic resources
- Assist with the recovery of naturally spawning salmonid populations
- Provide sustainable fisheries
- Improve the quality and cost-effectiveness of hatchery programs.

By 2009, the HSRG completed reviews and provided recommendations for all hatcheries and hatchery programs across Puget Sound, the Washington coast, and the Columbia River basin, totaling more than 100 hatcheries and 300 hatchery programs (HSRG 2015). In 2014, the HSRG reported that:

> "Hatchery reform has been implemented across the region in a wide range of programs including treaty, state, federal, harvest, and conservation programs. The most frequently implemented program changes include installing weirs (allows better management of hatchery broodstocks and natural spawning populations), developing locally adapted broodstocks (improves survival and productivity of hatchery and wild populations), marking all hatchery releases (promotes effective broodstock management, wild stock assessment, and selective fisheries), and establishing new and more intensive selective fisheries (increases catch of hatchery-origin fish and survival of natural-origin fish). Some programs have developed comprehensive monitoring and evaluation plans that incorporate an adaptive management process." (HSRG 2014)

In addition to (though not in conjunction with) the HSRG reviews, NMFS has completed ESA consultations on most hatchery programs across Puget Sound and the Columbia River basin (additional detail is provided below; see Appendix B for a complete list of hatchery programs and consultation status). Washington coastal programs do not require site-specific NMFS ESA consultation because there are no ESA-listed salmonids under NMFS jurisdiction in coastal watersheds. NMFS ESA consultations utilize the best available science and information to

[27] Two Hatchery Scientific Review Groups were formed, one for California and one for the Pacific Northwest. In this Biological Opinion, all references to the "Hatchery Scientific Review Group" or "HSRG" refer to the Pacific Northwest group.

determine whether hatchery programs can be operated in such a manner that they do not jeopardize the survival or recovery of ESA-listed species. NMFS ESA consultations, as well as the broader hatchery reform effort and HSRG reviews, have resulted in substantial improvements to hatchery programs that affect listed species. A detailed description of such improvements within each subregion of the action area is provided at the end of this section. Some of the more widespread and substantive improvements are listed below as they pertain to the primary negative effects described at the beginning of this section:

- Demographic. With some minor exceptions, hatchery fish subject to fisheries are now mass-marked so that they can be readily distinguished from natural fish in fisheries. This allows for close monitoring and management of fisheries to prevent overharvest of natural at-risk populations. For example, many fisheries may only retain hatchery-origin (marked) fish; any captured fish that are natural-origin (unmarked) must be released. The impact of fisheries on natural populations is now also closely monitored using these data.
- Genetic effects have been reduced by the following measures:
    - Many programs that utilized broodstock with out-of-basin lineages have been terminated or transitioned to broodstock with endemic natural-origin lineages.
    - Many programs that were historically operated using a segregated genetic management strategy transitioned to integrated or “stepping-stone” strategies so that hatchery fish better reflect natural population genetics and outbreeding effects are reduced (see Definitions, section 2.5.1.2.2, and Appendix C for descriptions of segregated, integrated, and “stepping-stone” genetic management strategies).
    - “Sliding scale” approaches to genetic management have been implemented for many conservation and recovery programs. These approaches allow more hatchery fish on the spawning grounds, and thus greater hatchery influence, during years when natural population abundance is low. This accepts a greater genetic risk to gain demographic benefits (greater overall number of spawners) and thus lessen the extirpation or extinction risk presented by the low number of natural-origin spawners. During years when the natural population abundance is higher and risk of extirpation or extinction is reduced, genetic risk is curtailed by requiring higher PNI and lower pHOS (see Definitions, section 2.5.1.2.2, and Appendix C for descriptions of PNI and pHOS).
    - The abundance of hatchery-origin spawners on the spawning grounds is monitored via carcass surveys or weirs. Weirs are utilized in many places to manage and limit pHOS.
    - Broodstock is often collected throughout the natural run timing helping to reduce hatchery-influenced selection.

    - Factorial mating systems[28] have replaced 1:1 mating[29] in many cases, helping to maintain within-population genetic diversity.
- Ecological effects have been reduced by the following:
    - The practice of releasing hatchery fish prior to their physiological readiness to outmigrate from freshwater to marine habitats has largely been discontinued. These fish were likely to rear in freshwater habitats for prolonged periods where they could compete with and/or prey on natural-origin salmonids. Instead, most hatchery fish are now released as smolts and migrate rapidly to marine habitats, minimizing their time, and thus any competitive or predatory effects, in freshwater habitats.
    - Hatchery production has been reduced from peaks during the 1980–1994 time period, thereby reducing competition and predation in freshwater and marine habitats. In the Columbia River basin and Puget Sound, Chinook salmon hatchery smolt production during the 2010–2023 period was about 24% and 17% less, respectively, and coho salmon smolt production was about 43% and 37% less, respectively, relative to the 1980–1994 period (Figure 72). These two species comprise the majority of hatchery production across the region. In the ocean, hatchery-released fish from other regions are also present, though Chinook salmon from the Columbia River and Puget Sound dominate release numbers across the Pacific Northwest (Figure 73). Considering all Pacific Northwest regions combined, Chinook salmon hatchery smolt production during the 2010–2023 period was about 21% less relative to the 1980–1994 period (Figure 73).
    - Hatchery programs avoid releasing hatchery fish at times and in places where large abundances of vulnerable recently-emerged fry of listed species are present (i.e., in and near spawning grounds, which are documented and well-known, during the seasonal fry emergence time, which is known and predictable), thereby reducing predation effects.
    - Rigorous pathogen and disease prevention, monitoring, and control policies and protocols have been developed and are followed. These limit the possibility of hatcheries magnifying pathogens in the watersheds within which they operate, and substantially limit disease prevalence in released fish.

[28] Factorial mating typically involves dividing the milt from each male and eggs from each female so that each female is mated with more than one male and vice versa. For example, in a simple 2x2 design (2 males and 2 females), milt from male 1 would be used to fertilize half the eggs from female 1 and half the eggs from female 2. Milt from male 2 would be used to fertilize the other half of the eggs from each female. Factorial mating schemes as simple as 2x2 confer considerable genetic benefits, namely by increasing effective population size, relative to other common mating schemes used at hatcheries (Busack and Knudsen 2007).

[29] 1:1 mating is when milt from one male is used to fertilize all of the eggs from one female. The milt from the male is not used with eggs from any other females, with certain possible exceptions (e.g., as a “backup” male).

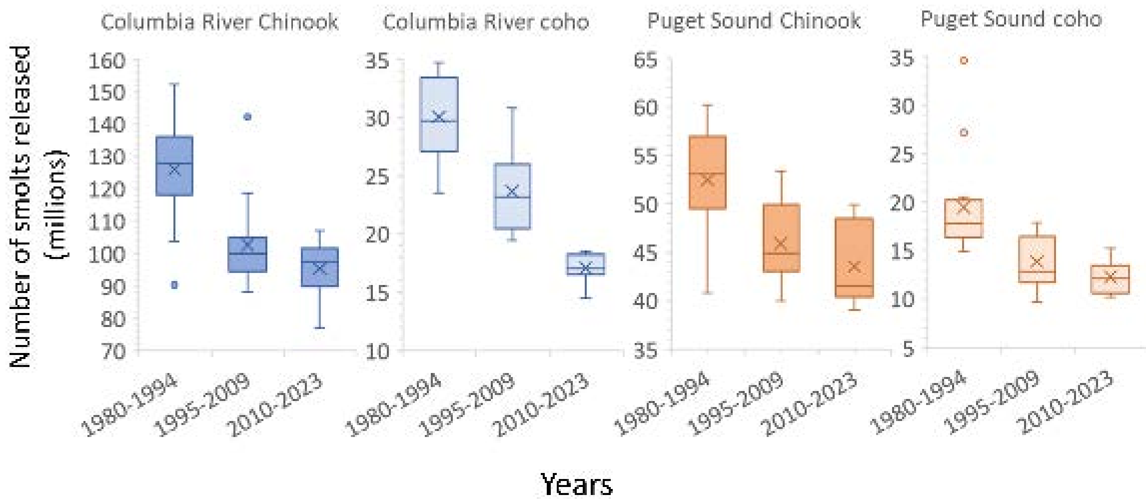


Figure 72. Box plots[30] of Chinook and coho salmon smolt abundances released from Columbia River and Puget Sound hatcheries for all purposes and from all funding sources, 1980–2023. Note scale differences in y-axes. Data source: RMIS queries, March 2024 (Chinook), June 2024 (coho).

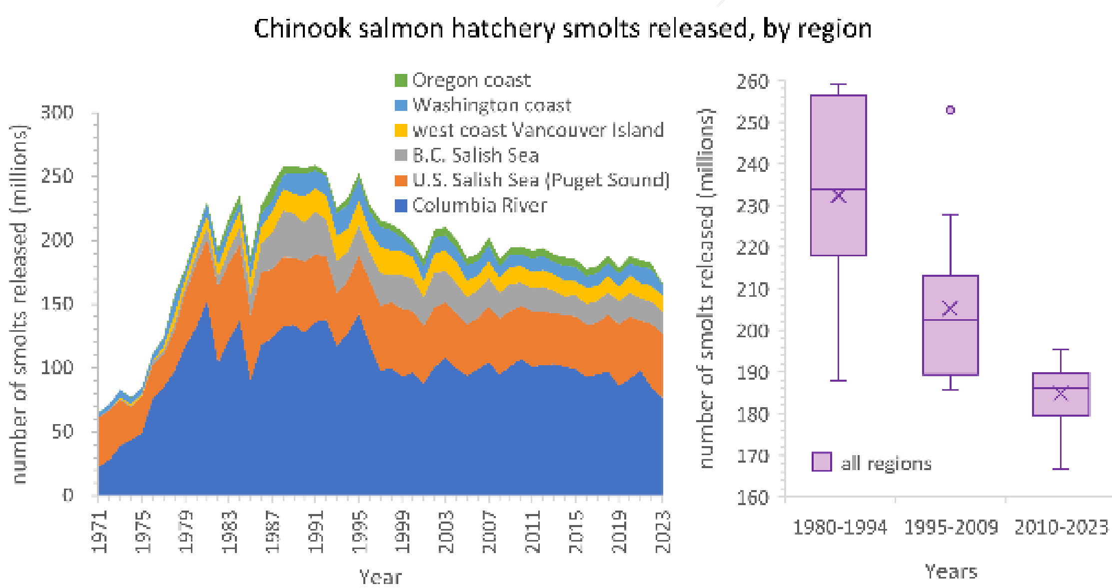


Figure 73. Pacific Northwest hatchery Chinook salmon smolt release abundances, by year and region (left panel) and all regions combined for select time periods (right panel). Note scale differences in y-axes. Data source: RMIS queries, March 2024. See Figure 72 for description of box plot (right panel) elements.

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30 Box plots include the following elements: interquartile range (IQR) = shaded boxes; median = horizontal line across each box; mean = X's within each box; minimum and maximum (excluding outliers) = ends of vertical lines extending outward from each box; outliers (data points that fall outside the IQR by a factor of 1.5 times the IQR) = small circles above the maximum or below the minimum, as applicable.

In recent decades, approximately 325 hatchery programs have been operating across the Puget Sound basin (approximately 100 programs), the Columbia River basin (approximately 150 programs), and the Washington coast (approximately 75 programs), producing all five species of Pacific salmon and steelhead trout. The substantial majority of these programs are ongoing and continue to operate. As such, their effects are reflected in the most recent status of the species, which NMFS recently re-evaluated in 2022 (Ford 2022) and summarized in relevant ESU- and DPS-specific subsections of Sections 2.2.2–2.2.6 of this Opinion.

In Puget Sound, NMFS has completed site-specific ESA section 7 consultations on 53 programs (Appendix B), the effects of which are included in the environmental baseline. There are 47 Puget Sound programs which have not yet completed ESA consultation[31]. As mentioned above, the effects from hatchery programs that have not undergone ESA consultation are considered in this environmental baseline section (and cumulative effects section, as appropriate). The effects of fish released to date from these 47 programs are therefore included in the environmental baseline. The status of ongoing and reinitiated ESA consultations for hatchery programs contributing to effects within the action area will evolve as NMFS continues to work through completing site-specific consultations. Although many of these programs are ongoing, the effects of future releases are not included in the baseline because ESA consultation has not yet been completed; instead, those future effects from future releases are captured in the cumulative effects section (Section 2.6).

In the Columbia River basin, NMFS has completed site-specific section 7 consultations on the substantial majority of currently-operating hatchery programs (Appendix B). In addition, programmatic consultations have been completed for hatchery production associated with the 2018–2027 *U.S. v. Oregon* Management Agreement NMFS (2018e) and for that funded by the Mitchell Act for FYs 2016–2025 (NMFS 2017o). NMFS also completed an Opinion evaluating the effects of federal and non-federal hatchery programs that collect, rear and release unlisted fish species in the Columbia River Basin (NMFS 1999d). Effects of these ongoing hatchery programs and programmatic actions with completed ESA consultations are included in the environmental baseline. The effects of fish released to date from Washington coast programs are included in the environmental baseline, but effects of future releases are not as future releases have not undergone consultation.

For hatchery programs that have completed site-specific ESA consultations, detailed descriptions and evaluations of effects can be found in the site-specific Opinions noted above (i.e., Appendix B; NMFS (2018e); NMFS (2017o)). Those analyses are incorporated here by reference, and an overview of effects are summarized in the following paragraphs. In addition, a detailed description of how hatchery programs affect ESA-listed salmon and steelhead can be found in Appendix C.

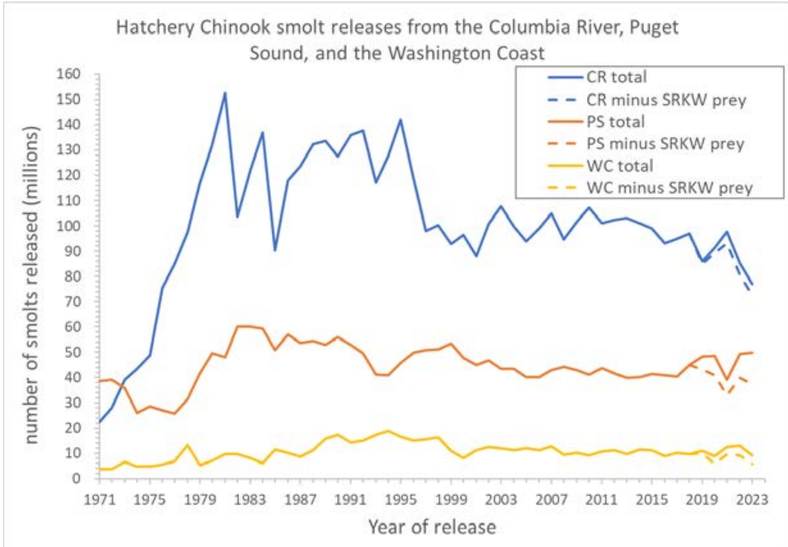
Chinook salmon hatchery programs have been widespread across the Puget Sound (approximately 33 programs), the Columbia River basin (approximately 73 programs), and the Washington coast (approximately 14 programs), producing fish for a variety of reasons,

[31] ESA consultations on these 47 programs are in progress.

including harvest, harvest management, mitigation for hydropower impacts, and conservation and recovery of the species.

In 2018, the federal government (Dygert 2018) and Washington State (WA Exec. Order No. 18-02, 2018) considered production of additional hatchery Chinook salmon to help the endangered SRKW. Low prey abundance of salmon in general and Chinook salmon in particular had been identified as a primary factor limiting SRKW recovery. Priority SRKW prey Chinook salmon stocks were identified (NOAA Fisheries and WDFW 2018; PFMC 2020c), and hatchery operators identified available production capacity at existing hatchery facilities that could produce fish from these priority stocks (e.g., WDFW 2019) (Table 69). In 2019, hatchery operators began releasing Chinook salmon smolts for the explicit purpose of providing prey for SRKW, with annual funding provided by NMFS through the federal SRKW prey program and/or the State of Washington (Table 69).

Prior to the beginning of using hatcheries for SRKW prey enhancement, Chinook salmon hatchery production had been largely stable (Figure 74). From 2009 to 2018, Chinook salmon hatchery production averaged 41.7 million smolts from Puget Sound, 100.0 million smolts from the Columbia River, and 10.2 million smolts from the Washington coast. From 2019 through 2023, the number of smolts released for SRKW prey (from both federal and state funding sources) was a small to moderate proportion of the overall Chinook salmon hatchery production from these areas (Figure 74, Figure 75, Figure 76). The number of smolts released from both funding sources combined has increased from 7.1 million smolts in 2019, to 19.9 million smolts in 2023 (Figure 75), and was approximately 22.7 million smolts in 2024 based on abundance of fish rearing in the hatchery or already released, and hatchery operators stated release goals and funding allocated in the previous federal fiscal years (FYs 2022 and 2023) and Washington State biennium (2021–2023). Relative to the 2009–2018 period, the additional production for SRKW prey (2019–2023) contributed to an overall increase in Chinook salmon hatchery releases from Puget Sound (12.8% increase; 41.7 million to 47.1 million smolts) and the Washington coast (6.3% increase; 10.2 million to 10.9 million smolts). Chinook releases from the Columbia River declined (12.6% decrease; 100.0 million to 87.5 million smolts) despite an average of 3.4 million smolts released for SRKW prey.



Sources: Total production from all funding sources, RMIS (Regional Mark Information System, https://www.rmpc.org/data-selection/rmis-queries/), accessed October 2023 and March 2024; WDFW and NMFS for SRKW production (Table 69).

Figure 74. Number of Chinook salmon smolts released from Columbia River (CR), Puget Sound (PS), and Washington coast (WC) hatcheries for all purposes and from all funding sources, 1971–2023. The dashed lines show the number of Chinook salmon smolts released for all purposes other than SRKW prey enhancement (federal and state funded).

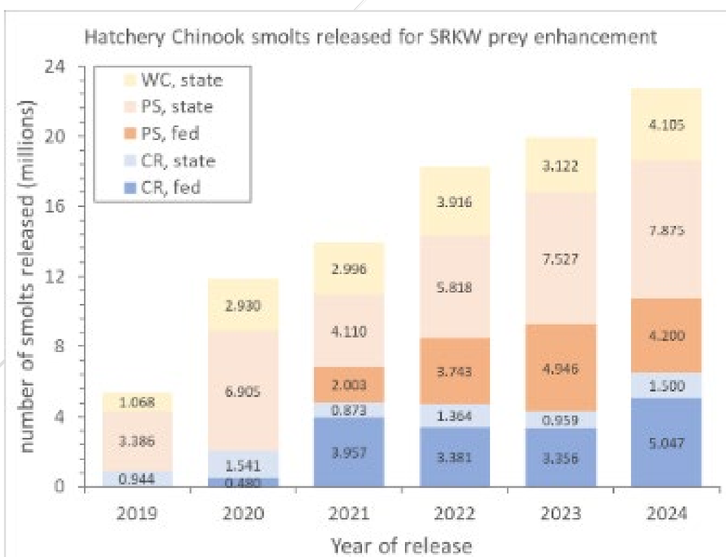


Figure 75. Number of Chinook salmon smolts released (2019–2023) or planned to be released (2024) for SRKW prey enhancement from Columbia River (CR), Puget Sound (PS), and Washington coast (WC) hatcheries. Release numbers are shown separately for those funded by the federal prey program (fed) and the State of Washington (state).

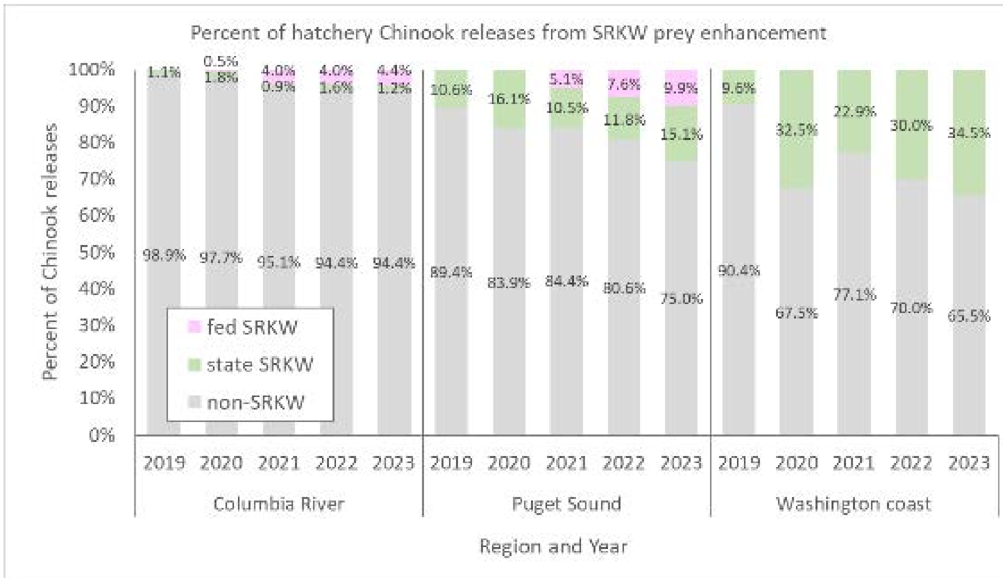


Figure 76. Percent of hatchery Chinook releases funded by the federal SRKW prey program (fed SRKW), the State of Washington SRKW prey program (state SRKW), and all other purposes and funding sources (non-SRKW) by region and year, 2019–2023.

Table 69. Hatchery programs that have released hatchery Chinook salmon smolts specifically for SRKW prey base enhancement, 2019–2024. Also shown are current smolt production capacities for SRKW prey base enhancement and completed site-specific ESA consultations. Releases are shown separately for those funded by NMFS via the federal prey program (N) and by the State of Washington (W). Releases denoted with an asterisk (*) were funded by the State of Washington and did not have site-specific ESA coverage at the time of release.

Chinook salmon hatchery program[a]	Program operator[b]	Number of smolts released (millions)						Current capacity[c] (millions of smolts)	Site-specific ESA consultation[d]
		2019	2020	2021	2022	2023	2024[e]		
Puget Sound programs									
Lummi Bay Hatchery, Spring (SY)	LN	-	W: 0.050*	W: 0.222*	W: 0.499*	W: 0.504*	W: 0.500*	0.500	NC
Skookum Creek, Spring (SY)	LN	-	W: 0.870*	W: 0.795*	-	W: 0.762*	W: 1.000*	1.000	NC
University of Washington Hatchery, Fall (SY)	MIT	-	-	-	-	-	-	0.180	NMFS (2021g)
White River, Spring (SY)	MIT	-	-	W: 0.168*	W: 0.238*	W: 0.273*	W: 0.200*	0.200	NC
Clarks Creek, Fall (SY)	PTI	-	W: 0.376*	W: 0.196*	W: 0.612*	W: 0.675*	W: 0.675*	0.675	NC
Puyallup, Fall (SY)	PTI	-	-	-	-	-	-	1.000	NC
Wilkeson Creek, Fall (SY)[f]	PTI	-	W: 0.404*	W: 0.176*	W: 0.400*	W: 0.386*	W: 0.400*	0.400	NC
Squaxin/South Sound Net Pens, Fall (SY + Y)	SIT	-	-	-	-	-	W: 0.500*	0.500	NC
Tulalip Bernie Gobin Hatchery, Summer (SY)	TT	-	-	-	N: 0.958	N: 1.809	N: 1.100	2.000	NMFS (2021e)
Hupp Springs, Spring (SY)	WDFW	W: 0.260*	W: 0.389*	W: 0.543*	W: 0.516*	W: 0.477*	W: 0.500*	0.500	NC
Issaquah Hatchery, Fall (SY)	WDFW	-	-	-	N: 0.707	N: 1.000	N: 1.000	1.000	NMFS (2021g)
Kendall, Spring (SY)	WDFW	W: 0.704*	W: 0.449*	W: 0.382*	W: 0.636*	W: 0.533*	W: 0.500*	0.500	NC
Marblemount, Spring (SY)	WDFW	-	W: 0.246*	W: 0.160*	W: 0.128*	W: 0.204*	W: 0.100*	0.100	NC
Marblemount, Spring (Y)	WDFW	W: 0.087*	W: 0.405*	W: 0.415*	-	W: 0.499*	W: 0.500*	0.500	NC
Minter, Fall (SY)	WDFW	W: 0.763*	W: 0.321*	W: 0.333*	W: 0.291*	W: 0.419*	W: 0.400*	0.400	NC
Samish, Fall (SY)	WDFW	W: 1.089*	W: 1.218*	-	W: 0.906*	W: 1.043*	W: 1.000*	1.000	NC

Chinook salmon hatchery program[a]	Program operator[b]	Number of smolts released (millions)						Current capacity[c] (millions of smolts)	Site-specific ESA consultation[d]
		2019	2020	2021	2022	2023	2024[e]		
Soos Creek-Palmer Pond Hatchery, Fall (SY)	WDFW	W: 0.283	W: 1.211	N: 2.003	N: 2.078	N: 2.137	*N: 2.100*	2.000	NMFS (2019f)
Wallace River, Summer (SY)	WDFW	-	W: 0.261	W: 0.184	W: 1.049	W: 1.152	*W: 1.000*	1.200	NMFS (2021e)
Wallace River, Summer (Y)	WDFW	-	W: 0.035	W: 0.044	-	W: 0.079	*W: 0.100*	0.250	NMFS (2021e)
Whatcom Creek, Fall (SY)	WDFW	W: 0.200*	W: 0.670*	W: 0.492*	W: 0.543*	W: 0.521*	*W: 0.500**	0.500	NC
Columbia River basin programs									
Wells Hatchery, Summer (SY)	DPUD/ WDFW	-	W: 0.541	W: 0.483 N: 0.483	W: 0.520 N: 0.520	W: 0.514 N: 0.514	*W: 0.500* *N: 0.500*	1.000	NMFS (2020a)
Dworshak NFH, Spring (Y)	NPT	-	-	-	N: 0.509	N: 0.494	N: 0.194	0.500	NMFS (2017n)
Bonneville Hatchery, Tule Fall (SY)	ODFW	-	-	N: 0.344	N: 0.250	N: 0.235	N: 0.256	0.250	NMFS (2017o)
Round Butte Hatchery, Tule Fall (SY)[g]	ODFW	-	-	N: 0.167	-	-	-	n/a	NMFS (2017o)
SAFE, Spring (Y)	ODFW	-	-	N: 1.345	N: 1.507	N: 1.431	N: 1.392	1.500	NMFS (2021f)
Umatilla and Bonneville Hatcheries, URB Fall (SY)	ODFW	-	-	-	N: 0.128	-	*N: 0.140*	0.130	NMFS (2011f)
Carson NFH, Spring (Y)	USFWS	-	-	-	-	N: 0.074	N: 0.061	0.100	NMFS (2007a)
Little White/Willard NFH, URB Fall (SY)	USFWS	-	N: 0.480	N: 0.649	-	-	-	0.650	NMFS (2007a)
Little White/Willard NFH, Spring (Y)	USFWS	-	-	-	N: 0.381	N: 0.498	N: 0.646	0.650	NMFS (2007a)
Spring Creek NFH, Tule Fall (SY)	USFWS	-	-	N: 0.689	N: 0.066	-	N: 1.769	2.000	NMFS (2007a)
Lewis River, Spring (SY)	WDFW	W: 0.944	-	W: 0.390	W: 0.269	W: 0.290	-	1.000	NC
East Bank and Marion Drain Hatcheries, Summer (SY)	YN	-	-	N: 0.280	-	-	N: 0.089	0.500	NMFS (2013a)
East Bank and Marion Drain Hatcheries, Summer (Y)	YN	-	-	-	N: 0.020	N: 0.110	-	0.500	NMFS (2013a)
Klickitat Hatchery, Fall (SY)	YN	-	W: 1.000	-	W: 0.575	W: 0.155	*W: 1.000*	1.000	NMFS (2017o)

Chinose salmon hatchery program[a]	Program operator[b]	Number of smolts released (millions)						Current capacity[c] (millions of smolts)	Site-specific ESA consultation[d]
		2019	2020	2021	2022	2023	2024[e]		
Washington coast programs									
Bear Springs, Summer (SY)	QN	-	-	W: 0.148	W: 0.115	W: 0.073	*W: 0.160*	0.160	Coastal programs do not require site-specific NMFS ESA consultation because there are no listed species under NMFS jurisdiction in coastal watersheds. These programs may require site-specific USFWS consultation.
Bear Springs, Summer (Y)	QN	-	W: 0.070	W: 0.071	W: 0.080	W: 0.020	*W: 0.075*	0.075	
Quinault Lake, Fall (SY)	QIN	-	-	W: 0.500	W: 0.447	W: 0.500	*W: 0.500*	0.500	
Forks Creek, Fall (SY)	WDFW	W: 0.568	W: 2.278	W: 0.257	W: 0.108	W: 0.084	*W: 0.050*	0.050	
Naselle, Fall (SY)	WDFW	-	-	W: 1.472	W: 2.578	W: 1.826	*W: 2.500*	2.500	
Sol Duc, Summer (SY)	WDFW	W: 0.500	W: 0.582	W: 0.480	W: 0.559	W: 0.554	*W: 0.770*	0.770	
Sol Duc, Summer (Y)	WDFW	-	-	W: 0.068	W: 0.029	W: 0.065	*W: 0.050*	0.050	

[a] Hatchery facility, run of Chinook salmon produced (spring, summer, or fall), and age at release (SY = subyearling; Y = yearling).
[b] CTWS = Confederated Tribes of Warm Springs; DPUD = Douglas County Public Utility District; LN = Lummi Nation; MIT = Muckleshoot Indian Tribe; NPT = Nez Perce Tribe; ODFW = Oregon Department of Fish and Wildlife; PTI = Puyallup Tribe of Indians; QIN = Quinault Indian Nation; QN = Quileute Nation; SIT = Squaxin Island Tribe; TT = Tulalip Tribes; USFWS = United States Fish and Wildlife Service; WDFW = Washington Department of Fish and Wildlife; YN = Yakama Nation.
[c] This column shows the maximum SRKW-related production goal identified by hatchery operators based on available capacity and, where applicable, included in the completed site-specific consultation.
[d] NC = site-specific ESA consultation is not yet complete.
[e] Italicized entries indicate releases for which the precise release abundance was not available at the time of writing. The 2024 release goal is shown instead.
[f] The Wilkeson Creek program is managed as an extension of the Clarks Creek program and is thus included as part of the Clarks Creek HGMP.
[g] Broodstock from Bonneville; all smolts released at Bonneville.

The following paragraphs describe the past and present effects of all hatchery programs affecting the ESUs and DPSs in the action area. The following paragraphs also describe the anticipated effects of hatchery programs that have completed ESA section 7 consultation (anticipated effects of hatchery programs that have not completed ESA section 7 consultation are considered in cumulative effects, Section 2.6). Hatcheries generally pose risks to the naturally-spawning salmon and steelhead populations wherever they come into contact, as described above and discussed in detail in the site-specific consultations for each hatchery program, in the 2018–2027 *U.S. v. Oregon* NMFS (2018e) and Mitchell Act (NMFS 2017o) consultations, and in Appendix C. This is the case, generally, with the hatchery programs included in the baseline, and those effects and risks will be perpetuated by the ongoing operation of the programs. These risks are fully described in the site-specific consultations, the effects section of this Opinion, and in Appendix C. These risks include genetic risks, competition with and predation on natural-origin fish, disease, and broodstock collection and facility effects. However, as described throughout this section and in the referenced hatchery program consultations, in many cases measures have been and continue to be implemented to reduce the associated impacts and risks. Thus, while in our assessment of effects we include the continued negative impacts of the hatcheries that have completed ESA consultation, we also consider the extent to which those operations have and, where applicable, continue to reduce their effects.

2.4.1.3.1.1 Puget Sound Recovery Domain

2.4.1.3.1.1.1 Puget Sound ESUs/DPS

Beginning in the 1990s, Washington State and tribal co-managers took steps to reduce risks identified for Puget Sound hatchery programs as better information became available (PSTT et al. 2004) in response to reviews of hatchery programs (e.g., Currens et al. 1995; HSRG 2002), and as part of the region-wide Puget Sound salmon recovery planning effort (SSDC 2007). The intent of hatchery reform has been to reduce negative effects of artificial propagation on natural populations while retaining proven harvest and potential conservation benefits. Conservation hatchery programs in Puget Sound are described in Section 2.2.2. Hatchery programs in the Pacific Northwest are phasing out use of dissimilar broodstocks, such as out-of-basin or out-of-ESU stocks, and replacing them with fish derived from, or more compatible with, locally adapted populations. Producing fish that are better suited for survival in the wild is now an explicit objective of many salmon hatchery programs. Hatchery programs are also incorporating improved production techniques with changes proposed to ensure that existing natural salmonid populations are preserved, and that hatchery-induced genetic and ecological effects on natural populations are minimized.

There are 33 hatchery programs producing Chinook salmon in the Puget Sound and Strait of Juan de Fuca (Table 69). NMFS has completed site-specific ESA consultations on 13 of these, nearly all of which (12) were completed in 2016 or later. In many cases, the ESA consultation process and/or reform-oriented initiatives resulted in program modifications that reduced risks to natural populations. Examples include the following:

- The virtual elimination of hatchery-origin Chinook salmon fry releases, which averaged around 10 million fry per year prior to 2000. Relative to seawater-ready smolts, fry are much more likely to remain in freshwater habitats for extended periods of time where they may compete with natural-origin fish.

- An overall region-wide 16% reduction in the number of hatchery-origin Chinook salmon released, from a mean of 51.9 million smolts released annually prior to ESA listing (1980–1999) to 43.4 million smolts released since (2000–2022).
- Changes in broodstock protocols so that hatchery fish better reflect natural population genetics, including but not limited to the following: eliminating Chinook salmon hatchery programs in the Snohomish River watersheds that were founded from Green River-origin fish; transitioning two segregated Chinook salmon programs in the Snohomish River watershed to stepping stone programs that incorporate natural-origin broodstock and increase PNI in the watershed; and, genetically linking integrated and segregated hatchery program components in the Lake Washington basin.
- Establishment of two natural production emphasis areas in Soos Creek (Green River watershed) and Issaquah Creek (Lake Washington watershed), where only natural-origin Chinook salmon are passed above weirs.
- Facility upgrades which include but are not limited to the following: replacements of surface water intake structures to meet current fish passage and screening requirements have been completed (Dungeness River) or stipulated in Opinions (e.g., Skagit River); major improvement to adult broodstock holding conditions (Snohomish River, Wallace Hatchery), allowing for more natural-origin fish to be held for broodstock and increasing PNI for the three related production components.

2.4.1.3.1.2 Willamette/Lower Columbia Recovery Domain

2.4.1.3.1.2.1 Lower Columbia River ESUs/DPSs

NMFS directs Federal funding to many hatchery programs that affect Lower River ESUs/DPSs through the Mitchell Act. NMFS first completed ESA consultation on the Mitchell Act program in 1999 (NMFS 1999d). Since that time, operators have carried out reforms including: improved monitoring of the status of salmon and steelhead populations; changes in the use of local broodstock; changes in production levels; use of weirs to selectively remove hatchery fish from the spawning grounds; and use of alternative release locations. These measures helped reduce adverse impacts to ESA-listed species.

To comply with the National Environmental Policy Act with respect to its hatchery funding decisions under the Mitchell Act, NMFS released a final environmental impact statement (FEIS) to inform its decisions regarding what kind of hatchery programs to fund with Federal appropriations provided under the Mitchell Act. In its NEPA Record of Decision, NMFS made a final decision in 2017 after careful consideration of a range of comments received during public review of the final EIS. Following the FEIS, NMFS' approach to hatchery reform evolved to gain a better understanding of how artificial propagation programs affect ESA-listed populations and the fundamental ecology of the Columbia River's ecosystem. Further analysis revealed the need for an increase in hatchery reform actions, as evident in the 2017 Mitchell Act Opinion (NMFS 2017o), which sought to determine the efficacy of these reform actions over time. The Opinion set an unprecedented hatchery policy that aimed to futurize federally funded programs with an impetus of monitoring programs' success for their intended harvest opportunities and their regional impacts on ESA-listed populations. The Mitchell Act Opinion looked to a pulse-checking approach to see how effective hatchery program reforms would work under the short duration ofa few salmon and steelhead generations. As a result, several additional reform measures were implemented including the following:

- NMFS suggested programs look to eliminate the collection and transfer of brood from other MPGs and instead focus on integrating programs with localized broodstock from within the population's MPG. The intent was to better align hatchery production broodstock with the diversity of the natural-origin populations that could be potentially affected by the hatchery programs.
- Coded Wire Tag (CWT) analyses and new modeling techniques provided helpful insight into Lower Columbia River hatchery programs, leading to a phased impact reduction approach, eliminating some programs and reducing production for others. NMFS aimed to measure these hatchery reforms over time to evaluate the new management approach.
- NMFS also looked to weirs as a potential tool to further enhance the hatchery reforms by reducing the number of hatchery-origin adults spawning naturally and/or integrating into natural-origin populations. Co-managers agreed to implement and operate weirs in key tributaries to reduce the impacts of local hatchery programs and determine the effectiveness of weirs as a tool in the Lower Columbia River. This pulse-check approach would also provide a more in-depth look into the abundance and productivity of natural populations. For weir operations, not all of the weirs were implemented as expected.
- NMFS also identified the need for hatchery facilities to comply with new standards for water intake screens to minimize adverse impacts to ESA-listed fish, which were also not all fully implemented.

As a result of some of the reforms not being fully implemented in the timeline NMFS anticipated, we have since reinitiated consultation on our funding action of Mitchell Act hatchery programs. It is our expectation to have a new Opinion on funding Mitchell Act hatchery programs complete by 2025.

2.4.1.3.1.2.2 Willamette River ESU/DPS

Congress recognized that the 13 dams and 42 miles of revetments associated with the Willamette Project would adversely impact the fisheries resources of the Willamette River and authorized the construction, operation, and maintenance of hatcheries and related facilities to mitigate for fish losses (HD 544, 75th Congress, 3rd Session, 1938; Public Law 732, 79th Congress, 2nd Session, 1946). The USACE funds ODFW to manage and operate all facilities associated with the Willamette Hatchery Mitigation Program. Hatchery facilities are distributed throughout the Willamette Basin in tributaries with USACE dams that formerly contained large historical populations of spring Chinook salmon and winter steelhead. Most of the hatcheries also operate satellite fish collection facilities for broodstock collection and as collection sites for adult fish that are released into areas upstream of USACE dams.

Since the listing of Upper Willamette River spring Chinook salmon and winter steelhead under the ESA, hatchery programs in the Willamette Basin have needed ESA authorization. The first section 7 consultation on the Willamette hatchery programs occurred with a Opinion issued in 2000 to the co-managers (NMFS 2000a). This opinion authorized the programs for three years. Another section 7 consultation on the Willamette Project (all of the USACE dams and associated hatchery programs) was completed in 2008 with the issuance of a new Opinion to the co-managers (NMFS 2008i), with specific RPAs for the hatchery programs including transition to natural broodstocks for the Chinook programs which was implemented in 2019. Another Opinion was issued in 2019 for all of the hatchery programs and analyzed implementation of additional reforms to the spring Chinook salmon and summer steelhead programs to ensure ESA-listed species are not jeopardized. The Chinook HGMPs were exempted from take under limit 4 of the 4d Rule.

2.4.1.3.1.3 Interior Columbia Recovery Domain

2.4.1.3.1.3.1 Middle and Upper Columbia River ESU/DPS

The hatchery programs affecting the Middle and Upper Columbia River ESUs and DPS have changed over time, reducing adverse effects on ESA-listed species. Specifically, the hatchery programs funded by the public utility districts were reduced in size starting in 2014 because of a revised calculation of the districts' mitigation responsibility based on increased survivals through the Upper Columbia River dams. Reducing hatchery production has reduced pHOS and associated genetic risk. It has also reduced the number of natural-origin fish removed for hatchery broodstock.

Integrated programs in the UCR are managed using an abundance-based sliding scale that accommodates fluctuations in the abundance of natural-origin spawners. That is, for a given abundance of hatchery-origin spawners, hatchery influence (as measured by annual pHOS and PNI estimates) will vary with natural-origin spawner abundance. Thus, the sliding-scale approach accepts greater hatchery influence in years when natural-origin fish returns are critically low, but compensates for this by minimizing pHOS in years when natural-origin returns are high. Management of PNI in this fashion accepts the greater hatchery influence when low abundances present an elevated extinction risk, but increases natural-origin influence in the population as abundance increases.

In addition, several reform measures have been incorporated into hatchery programs affecting Middle Columbia River steelhead and Upper Columbia River spring-run Chinook salmon, including the following:

- The Winthrop National Fish Hatchery spring Chinook salmon program changed their broodstock practices by implementing a "stepping stone" program so that hatchery-origin fish better reflect natural-origin Chinook salmon genetics. Returning hatchery-origin fish from the segregated part of the program (which are uniquely marked) are removed through harvest or weirs prior to entering spawning grounds, thus posing little additional risk to natural-origin populations. Hatchery-origin adults from the integrated part of the program (which are also uniquely marked) are allowed to spawn in controlled numbers so that they contribute to natural production, but do not overwhelm the genetic contribution of natural-origin returns.

- Hatcheries in this ESU/DPS continued improving spring and summer/fall Chinook salmon hatchery rearing practices through feeding and growth monitoring to minimize early maturation and residualization.
- Leavenworth National Fish Hatchery modified their water use, providing more stream flow in Icicle Creek during summer months and reducing the potential for dewatering, thereby reducing risks to the Upper Columbia River spring-run Chinook Salmon ESU and Upper Columbia River Steelhead DPS.
- The Methow component of the Wells Complex steelhead program changed their broodstock practices by implementing a “stepping stone” program so that hatchery-origin fish better reflected natural-origin Chinook salmon genetics.
- Management of adult hatchery-origin steelhead returning to the Wenatchee River Basin was modified to reduce pHOS and genetic risk to the Upper Columbia River Steelhead DPS.
- The Touchet River steelhead program now uses an endemic local stock to supplement the natural-origin population, and removes all returns from the segregated harvest program (Wallowa stock) through harvest and collection at weirs.
- The Walla Walla summer steelhead hatchery program now uses an endemic local stock to supplement the natural-origin population, and removes all returns from the segregated harvest program (Wallowa stock) through harvest and collection at weirs.

2.4.1.3.1.3.2 Snake River ESUs/DPS

<u>Snake River fall-run Chinook Salmon ESU</u>

NMFS completed consultations on the Snake River fall-run Chinook salmon hatchery programs in 2012 and 2018. Under the 2012 proposed actions, we concluded that the pHOS, coupled with the presumed proportion of natural-origin fish in the broodstocks (pNOB), led to a PNI that was considerably lower than the 67% that would be recommended for a population of high conservation concern. This posed a fitness risk through hatchery-influenced selection. In addition, the broodstock collection protocol—typically collection only at Lower Granite Dam—would limit conservation or development of subpopulation structure, posing a diversity risk.

The hatchery programs that affect the SR fall-run Chinook salmon ESU have changed over time, and these changes have likely reduced adverse genetic effects on ESA-listed species. In particular, the recent proposed action from the *U.S. v. Oregon* Biological Opinion NMFS (2018e), as well as a new SR fall-run Chinook salmon hatchery biological opinion (NMFS 2018a), included the movement of the 1 million fall Chinook salmon that Idaho Power Company released from the Hells Canyon reach into the Salmon River. This action was consistent with the recovery plan strategy to evaluate and adapt SR fall-run Chinook salmon hatchery programs to address uncertainties regarding the effect of hatchery fish on productivity of natural fish and to enhance our understanding of the status of the natural-origin population (NMFS 2017x). Specifically, the change in juvenile release locations may also make it possible to implement Recovery Scenario C, which focused on creating one or more Natural Production Emphasis

Areas (NPEAs) to make it possible to directly evaluate the productivity of the natural population and ensure that a substantial proportion of the population is subject to natural selection rather than hatchery processes. While there are uncertainties about the feasibility of establishing an NPEA (and while it remains important to maintain opportunities to pursue any of the potential recovery scenarios), updated homing fidelity information (Cleary et al. 2017) suggests that it may be possible to create such a scenario under the Idaho Power Company's plan to move hatchery releases from Hells Canyon to the Salmon River, and the reprogramming of the Idaho Power Company releases should lessen the genetic effects of the hatchery programs in the upper Snake River area (above the confluence of the Salmon River) (NMFS 2018a). While we anticipate that this change will substantially reduce genetic risk from current levels, considerable uncertainty remains. In addition, the population is now being managed at a much higher PNI level than it was previously. Although the hatchery programs continue to pose a risk, the level is considerably reduced from previous levels and at this point does not appear to pose a risk to the survival or recovery of SR fall-run Chinook salmon (NMFS 2018a).

Snake River spring/summer-run Chinook Salmon ESU

There are 18 spring/summer-run Chinook salmon hatchery programs in the Snake River Basin. Most of these programs release hatchery fish into rivers with ESA-listed natural-origin spring/summer-run Chinook salmon. However, some of these hatchery programs release fish into the Clearwater River, where spring/summer-run Chinook salmon are not listed under the ESA.

Over the years, hatchery programs in the Salmon River have made improvements to their hatchery programs. In particular, program managers have better integrated natural-origin fish into their broodstock, thereby creating integrated components of their hatchery programs. The South Fork Salmon River summer Chinook salmon hatchery program operated from the McCall Fish Hatchery, historically operated solely using the segregated genetic management strategy, has transitioned to a "stepping-stone" strategy instead (see definitions). Risk is further reduced by intercepting and removing returning adults from the segregated component—through harvest or at weirs—before they can reach the South Fork Salmon River spawning grounds. Returning adults from the integrated component are allowed to spawn in controlled numbers so that they contribute to natural production without overwhelming the genetic contribution of natural-origin returns.

The South Fork Salmon River summer Chinook salmon hatchery program also contributes eyed-eggs to the South Fork Chinook salmon eggbox program, meaning segregated hatchery fish produced with this program are also genetically linked, which is an improvement from when this program operated as the "Dollar Creek Eggbox Program". According to NMFS' site-specific Opinion (NMFS 2017u), genetic analyses using a PNI model indicate that, depending on natural-origin returns, PNI in any given year in the South Fork Salmon River population may range from 5% in years when natural-origin returns are low, to 67% in years when natural-origin fish returns are high. This abundance-based sliding scale approach (see definitions) allows more hatchery influence when there is a higher risk of extinction because of the low abundance, but increases natural-origin influence in the population as abundance increases. NMFS considers this to be a considerable improvement to the genetic structure of the population, compared to when the segregated and integrated components were not genetically linked.

The Rapid River and Hells Canyon programs are segregated and operated for harvest purposes. As reflected in the most recent Opinion (NMFS 2019m), these programs adopted new strategies to limit straying and ecological interactions between hatchery and ESA-listed natural-origin fish.

The Johnson Creek Artificial Propagation Enhancement program has always used 100% natural-origin fish in their broodstock, so there are only minor genetic risks associated with this program, and this program will continue to operate with these same conservation considerations and standards.

The Sawtooth hatchery program in the Upper Salmon River also adopted a genetically linked aspect to their integrated and segregated program components. This reduced genetic risk to the ESU. In addition, the Panther Creek hatchery program was initiated for the purpose of re-establishing a natural-origin population and thus reducing risk to the ESU. This program is integrated with the natural origin returns and adheres to PNI values consistent with the abundance-based sliding scale gene flow management (see definitions) objectives described in the Opinion (NMFS 2017t) in order to appropriately manage gene flow into the affected natural population . The Pahsimeroi and Yankee Fork hatchery programs have also implemented similar abundance-based sliding scale management strategies to manage genetic interactions between hatchery-origin fish and natural-origin fish on spawning grounds. Through the conditions in the Biological Opinion, the hatchery programs in the Upper Salmon River have also implemented strategies to limit hatchery straying and ecological interactions with ESA-listed natural-origin fish. The effectiveness of these strategies are monitored and adaptively managed to ensure their ongoing effectiveness.

There have also been some improvements in recent years to hatchery programs located in northeast Oregon. The Catherine Creek, Imnaha, and Lostine hatchery programs now use abundance-based sliding scale approaches (see definitions) to manage gene flow into the affected population (NMFS 2016l).

The Clearwater hatchery programs operate where ESA-listed Snake River spring/summer-run Chinook salmon are not present. Furthermore, as described in the site-specific Opinion (NMFS 2017n), these hatchery programs have implemented strategies to limit straying of program fish into areas where ESA-listed fish are present. The effectiveness of these strategies are monitored and adaptively managed to ensure their ongoing effectiveness.

<u>Snake River Sockeye Salmon ESU</u>

The purpose of the Snake River sockeye hatchery program is to support Snake River sockeye conservation with the goal of restoring sockeye salmon runs to Stanley Basin waters leading, eventually, to sockeye salmon recovery and Tribal and non-Tribal harvest opportunity (NMFS 2023b). The hatchery program was initiated in 1991, and the Snake River Sockeye Salmon ESU might now be extinct if not for the hatchery program (NMFS 2013e; 2023b). The hatchery program is expected to accelerate recovery of the Snake River Sockeye Salmon ESU by increasing the number of natural-origin spawners faster than what may occur naturally (NMFS 2013e; 2023b). In addition, the sockeye salmon hatchery program will continue to provide a genetic reserve for the Snake River Sockeye Salmon ESU to prevent the loss of unique traits due to catastrophes.

The Snake River sockeye salmon hatchery program is using the following three-phase approach:

- Phase 1: increase genetic resources and the number of adult sockeye returns (captive brood phase)
- Phase 2 (current phase): incorporate more natural-origin returns into hatchery spawning designs and increase natural spawning escapement (population re-colonization phase)
- Phase 3: move towards the development of an integrated program that meets PNI goals established by the Columbia River Hatchery Scientific Review Group (HSRG) (local adaptation phase). During Phase 3, captive broodstock will be phased out, and only anadromous-origin fish returning to Stanley Basin lakes will be used.

Growth of sockeye salmon in the Stanley Basin lakes is often density-dependent and related to zooplankton density (NMFS 2015f). Juvenile sockeye salmon rear one or two years in the lakes before emigrating to the ocean, and, during their stay in the lakes, sockeye juveniles feed almost entirely on certain assemblages of zooplankton (Burgner 1987). The Stanley Basin lakes' zooplankton communities declined drastically after the sockeye populations declined and other fish (e.g., trout and non-native kokanee) were introduced (NMFS 2015f), and the types of zooplankton available changed to assemblages less supportive of sockeye salmon (Koenings et al. 1997). The ongoing operation of the hatchery program would continue to help sockeye salmon reestablish their biological niche and may result in an increase in zooplankton levels as kokanee abundance declines. This change would be expected to increase the growth rate of juvenile sockeye salmon and improve their survival during the long seaward migration from their nursery lakes. However, in the short-term, increasing the number of juvenile sockeye salmon in the lakes may increase competition for food. Therefore, ongoing studies to determine the carrying capacity of the lakes will continue and allow permit holders to adjust release levels if needed.

2.4.1.3.1.3.2.1 <u>Snake River Basin Steelhead DPS</u>

There are 14 steelhead hatchery programs in the Snake River watershed and one kelt[32] reconditioning program. Typically, shortly after spawning, a kelt is in fairly poor condition, and its chances of surviving the downstream migration may be low. The objective of kelt reconditioning is to improve the condition of kelts by feeding and treating any disease in a protected and controlled (i.e., hatchery) environment, so that the kelts can be returned to the river in a healthier state (Hatch et al. 2017).

The kelt reconditioning program consists of the collection of up to 700 post-spawned steelhead greater than 60 cm, and the administration of disease-preventative medications and feed for the purpose of improving survival over what would be expected in the wild. Upon release, these fish

[32] A kelt is an adult steelhead that has survived spawning and migrates back to marine habitats afterward.

are intended to return to natal populations, thereby increasing spawner escapement and productivity if reconditioned individuals successfully spawn.

Most of the steelhead hatchery programs are operated to augment harvest or A-Index and B-Index steelhead, but one program is for supplementation. NMFS concluded in its 2017 site-specific Opinion that straying is low for all of the segregated harvest steelhead programs in the Snake River Basin, and is not expected to affect the abundance, productivity, diversity or spatial structure of the DPS because of the low potential for interbreeding and competition for spawning space between hatchery and natural-origin steelhead (NMFS 2017m). The East Fork Salmon River Natural program is the only integrated program. Genetic effects on the East Fork population are limited by the use of natural-origin broodstock, and an expected PNI of < 0.5 on average is a reasonable target for a population targeted for “maintained” in the recovery scenario (NMFS 2017q) and is likely to benefit the DPS through increased abundance and productivity for the East Fork population.

2.4.1.4 Harvest

2.4.1.4.1 Salmon-directed Fisheries

Fisheries targeting salmon occur throughout the action area and are managed by different entities under different regulatory regimes. Fisheries throughout the action area are managed consistent with the PST between the U.S. and Canada, and are also managed under domestic laws such as the MSA, the ESA, and the law concerning tribal fishing rights.

The PST includes management regimes for fisheries affecting various salmon species and geographic areas. In the U.S., the PST is implemented under the Pacific Salmon Treaty Act of 1985 (16 USC 3631, et seq.). The management regimes, described in Chapters to an Annex to the PST, are renegotiated periodically. In 2018, U.S. and Canadian representatives reached agreement to amend versions of five expiring Chapters of Annex IV (Turner et al. 2018); both countries have since executed this agreement. Management must be carried out in a manner consistent with the provisions of the new regimes for their duration, unless otherwise modified by a new agreement between the U.S. and Canada (the “Parties”). Consistency with the new regimes means that both countries will regulate their domestic fisheries so as not to exceed the catch or mortality levels specified in the regimes. The U.S. fisheries managed consistent with the provisions of the PST include salmon fisheries in SEAK, the Washington and Oregon coasts, Puget Sound and freshwater river flowing into it, and the Columbia River. It is important to note that there is no provision in the PST that requires harvest to occur at a particular level; either Party may harvest at levels less than the upper limits allowed in the regimes. This point is especially relevant as some U.S. fisheries, particularly the southern area fisheries, are routinely constrained by U.S. domestic regulations and plans to a greater degree than required by the bilateral agreement (i.e. due to more stringent ESU-specific constraints necessitated by the ESA).

2.4.1.4.1.1 Management under the PST

The effects of the past salmon fisheries include reducing the abundance of the targeted salmon. Beginning in 1999, NMFS consulted on the effects of fisheries managed under each 10-year agreement. In our 1999 Opinion (NMFS 1999b), NMFS considered the effects on listed species resulting from SEAK fisheries managed under the new regime for the 1999 summer and 1999/2000 winter seasons. NMFS subsequently completed consultation on the full scope of the 1999 PST Agreement on November 18, 1999 (NMFS 1999b). Once the ESA and funding contingencies were satisfied, the 1999 PST Agreement was finalized by the governments and provided the basis for managing the affected fisheries in the U.S. and Canada during the ten-year term of the 1999 PST Agreement. Subsequently, in 2008 NMFS considered effects on listed species resulting from fisheries managed based on a newly negotiated regime described in the 2009 PST Agreement (NMFS 2008f).

The PST Agreement was most recently revised in 2019. The 2019–2028 PST Agreement includes reductions in allowable harvest levels for all Chinook fisheries within its scope, and refines the management of sockeye, pink, chum, and coho salmon caught in these areas. The Agreement includes reductions in the allowable annual catch of Chinook salmon in the SEAK and Canadian West Coast of Vancouver Island and Northern British Columbia fisheries by up to 7.5 and 12.5%, respectively, compared to the previous agreement (2008–2019). The level of reduction depends on the Chinook abundance in a particular year. This comes on top of the reductions of 15 and 30% for those same fisheries that occurred as a result of the prior 10-year agreement (2009 through 2018). Harvest rates on Chinook salmon stocks caught in southern British Columbia and U.S. salmon fisheries are reduced by up to 15% from the previous agreement (2009 through 2018). Beginning in January 2020 this resulted in an increased proportion of abundances of Chinook salmon migrating to waters more southerly in the U.S. Pacific Coast Region portion of the EEZ than under prior PST agreements. Although provisions of the updated agreement are complex, they were specifically designed to reduce fishery impacts in all fisheries to respond to conservation concerns for a number of U.S. and Canadian stocks.

2.4.1.4.1.2 Southeast Alaska salmon fisheries

Salmon fisheries in Southeast Alaska are managed by the State of Alaska under authority delegated by NMFS and the North Pacific Fishery Management Council (NPFMC) consistent with the MSA. Fisheries in SEAK impacting Chinook salmon are managed as AABM fisheries consistent with the PST Agreement – in other words they are managed to stay within an annual catch level that is determined based on the annual estimated abundance of all of the Chinook salmon stocks present in SEAK. Often these fisheries are managed to stay within the annual catch level but are not managed to account for the abundance of the individual stocks in the fishery. In its 2019 Opinion on domestic actions related to the 2019–2028 PST Agreement (NMFS 2019j), NMFS assumed that the State of Alaska would manage its SEAK salmon fisheries consistent with the provisions of the Agreement. ESA-listed coho, chum, sockeye salmon and steelhead are not likely to be adversely affected by SEAK Chinook salmon fisheries due to their range and life histories, and the nature of the fisheries themselves (NMFS 2019j).

2.4.1.4.1.3 Canadian salmon fisheries

NMFS does not have detailed information on the implementation of salmon fisheries in Canadian waters, however, a general description of what is known about likely interception of

ESA-listed species in Canadian salmon fisheries is described here. In salmon fishery consultations, particularly those on the SEAK fishery prior to the 1999 PST Agreement, NMFS generally tried to anticipate the effect of Canadian fisheries on the species status. Based on past PST Agreement performance, NMFS has been able to rely on those to project Canadian fishing levels in its Opinions. In order to describe fishery performance under past agreements and account for changing ocean conditions, NMFS has recently used the 1999 to 2018 timeframe to characterize and present Canadian harvest-related impacts that are part of the environmental baseline. As described in (NMFS 2019j), Canadian fisheries were managed subject to provisions of the 1999 PST Agreement from 1999 to 2008, and subject to the 2009 PST Agreement from 2009 to 2018. Management provisions that applied to Canadian fisheries under those agreements are described in the respective Opinions (NMFS 1999b; 2008f).

As discussed above, Chapter 3 of Annex IV of the PST describes a comprehensive and coordinated Chinook fishery management program that uses an abundance-based framework to manage all Chinook fisheries that are subject to Chapter 3. Harvest regimes are based on annual indices of abundance that are responsive to changes in production, that take into account all fishery induced mortalities, and that are designed to meet maximum sustainable yield (MSY) or other agreed biologically-based numeric escapement or exploitation rate objectives (NMFS 2024e). The harvest regime in this management program includes an AABM, which is an abundance-based regime that constrains catch or total mortality to a numerical limit computed from either a pre-season forecast or an in-season estimate of abundance, from which a harvest rate index can be calculated.

Additionally, the PST Agreement limits the impact of Canadian and U.S. fisheries on natural coho salmon stocks originating in southern British Columbia, Puget Sound, and along the northern and central Washington coast (NMFS 2008f). The Agreement also limits the impact of U.S. and Canadian fisheries on the subject coho salmon stocks to specified exploitation rate limits that vary as a function of the annual status forecast of those runs. ESA-listed coho salmon are distributed off the west coast and rarely migrate as far north as Canada. As a consequence, harvest impacts on ESA-listed coho salmon in Canadian fisheries are quite low (NMFS 2008f).

The nearest marine area fisheries targeting chum salmon that might affect the Columbia River Chum Salmon ESU occur in terminal areas near Vancouver Island and in the Strait of Juan de Fuca. Chum salmon fisheries in Canada occur inside Barkley Sound, on the west coast of Vancouver Island, and near Nitnat on the south coast of the island. These are terminal fisheries directed at local stocks with little or no impact to stocks from outside areas. Commercial fisheries also occur in the western and eastern parts of the Strait of Juan de Fuca directed at chum salmon returning to Puget Sound and the Fraser River and the end of their spawning migration. Chum salmon stocks from the Washington coast are present in low abundance in these fisheries, but there are no reports of chum salmon from the Columbia River or their nearest neighbor on the northern Oregon coast. ESA-listed Hood Canal summer-run chum salmon are rarely caught in ocean fisheries (NMFS 2008f). The PST Agreement contains requirements for Canadian fishermen to release chum salmon caught in purse seine gear when Hood Canal summer-run chum salmon are thought to be present (NMFS 2008f). In addition, Canadian coho salmon fisheries that historically occurred through the latter part of September, and likely intercepted some late returning Hood Canal summer chum, have been closed since 1994 and are expected to remain closed due to Canadian domestic management concerns. A significant factor in the low exploitation rate has also been the severe constraint on Canadian sockeye and pink salmon fisheries in recent years due to concerns about weak sockeye salmon stocks and changes in the allocation of sockeye and pink salmon in Canadian fisheries.

In previous consultations NMFS has found no information to suggest that Snake River sockeye salmon were subject to significant harvest in ocean fisheries (56 FR 58619). Mature sockeye salmon from the Snake River are not likely to be taken in Alaska or Canada because they exit the ocean prior to the onset of intercepting sockeye salmon fisheries.

Steelhead are not targeted in marine area fisheries, and are caught rarely and only incidentally in fisheries targeting other species (NMFS 2008f). Retention of steelhead in marine fisheries is generally prohibited. As a consequence, there is relatively little information on the harvest of steelhead in ocean and marine fisheries. The adult freshwater timing, the ocean distribution patterns, and the greater relative abundance of Puget Sound and Canadian-origin steelhead compared with the listed Lower Columbia River and Upper Willamette winter steelhead stocks, make it unlikely that Canadian fisheries would encounter more than a few steelhead per year from any of the listed Columbia River ESUs (NMFS 2008f). The catch of Puget Sound steelhead in Canadian fisheries is unknown, but is presumed to be low based on the low number of steelhead caught in the fisheries (NMFS 2008f).

2.4.1.4.1.4 U.S. West Coast salmon fisheries

South of the U.S./Canadian border from the northern Washington boundary, NMFS promulgates regulations for salmon fisheries in the EEZ off the Pacific Coast of Washington, Oregon, and California pursuant to the MSA. The Pacific Coast Salmon Plan (FMP) provides a framework for setting annual regulations that define catch levels and allocations based on year-specific circumstances (PFMC 2022). The PFMC implements the FMP through a public process that leads to recommendations to NMFS for annual regulations. The current FMP requires that the PFMC manage fisheries consistent with NOAA Fisheries' ESA-related impact limits and other measures, in order to avoid jeopardy to any of the ESA listed species affected by the fisheries (PFMC 2022), consistent with biological opinions issued by NMFS as described below. Additionally, the FMP includes control rules and other measures to ensure that fishery impacts on non-ESA-listed salmon are sustainable. Each year, the PFMC recommends a set of fishery management measures to NMFS for approval and implementation under the MSA.

Since 1991, 28 salmon ESUs and steelhead DPSs from the west coast of the U.S have been listed under the ESA. NMFS has issued biological opinions addressing the effects of the fisheries on all of these listed species, and has reinitiated consultation when new information became available on the status of a species or the impacts of the FMP on a species. Table 70 lists the current Opinions that considered the effects of the PFMC fisheries on listed species and their duration.

Table 70. NOAA Fisheries' ESA decisions regarding ESUs and DPSs affected by PFMC fisheries and the duration of the 4(d) Limit determination or Opinion (BO). Only those decisions currently in effect are included.

Date (Decision type)	Citation	Species Considered
	Salmonid Species	
March 8, 1996 (BO)	(NMFS 1996c)	Snake River Spring/summer Chinook Salmon Snake River Fall-run Chinook Salmon Snake River Sockeye Salmon
April 28, 1999 (BO)	(NMFS 1999c)	Central California Coast Coho Salmon Oregon Coast Coho Salmon Southern Oregon/Northern California Coast Coho Salmon
April 28, 2000 (BO)	(NMFS 2000b)	Central Valley Spring-run Chinook Salmon California Coastal Chinook Salmon
April 30, 2001 (BO)	(NMFS 2001c)	Upper Willamette River Chinook Salmon Columbia River Chum Salmon Ozette Lake Sockeye Salmon Upper Columbia River Spring-run Chinook Salmon 10 Distinct Population Segments (DPS) of Steelhead
September 14, 2001 (BO, 4(d) Limit)	(NMFS 2001a)	Hood Canal Summer-run Chum Salmon
April 27, 2012 (BO)	(NMFS 2012f)	Lower Columbia River Chinook Salmon
April 9, 2015 (BO)	(NMFS 2015a)	Lower Columbia River Coho Salmon
March 30, 2018 (BO)	(NMFS 2018c)	Sacramento River Winter-run Chinook Salmon
April 28, 2022 (BO)	(NMFS 2022e)	Southern Oregon/Northern California Coast Coho Salmon
May 13, 2022 (BO)	(NMFS 2022a)	Puget Sound Chinook Salmon Puget Sound Steelhead
	Non-Salmonid Species	
April 30, 2007 (BO)	(NMFS 2007b)	Southern DPS Green Sturgeon
April 30, 2011 (BO)	(NMFS 2010a)	Puget Sound/Georgia Basin DPS Canary and Yelloweye Rockfish, and Bocaccio
April 30, 2011 (BO)	(NMFS 2011a)	Southern DPS Eulachon
April 21, 2021 (BO)	(NMFS 2021c)	Southern Resident DPS Killer Whale

Additional information on baseline conditions on the West Coast is discussed every year in the PFMC's annual Review of Ocean Salmon Fisheries. The most recent report was released in February 2024 (PFMC 2024a). The Review focuses in particular on the status of salmon stocks, as is reflected by escapement trends over recent decades. The review also provides detailed catch information for the West Coast salmon fishery, and other areas such as the Puget Sound and Columbia River.

2.4.1.4.1.5 Puget Sound salmon fisheries

Puget Sound salmon fisheries are managed by the State of Washington and the Indian tribes with treaty rights to fish in Puget Sound. These fisheries are managed to provide for the exercise of tribal treaty rights, to meet the requirements of the PST Agreement, and to avoid jeopardy to ESA-listed species, particularly Puget Sound Chinook. As such, the state and tribal managers develop management regimes for Puget Sound salmon fisheries that are designed to be consistent with all of these goals. The Puget Sound Chinook Salmon ESU comprises 22 Puget Sound Chinook salmon populations that are aggregated for management purposes into 14 management units. The populations have distinct migration patterns that affect where harvest impacts occur and the relative magnitude of harvest impacts. The Puget Sound Treaty Tribes and State of Washington manage Puget Sound salmon fisheries to stay within population-specific impact limits (often described for all fisheries or all Southern U.S. fisheries) that have been developed on an annual basis. These limits are specific to each management unit (comprised of one or more populations) and vary considerably depending on the status of each unit. The effects of Puget Sound fisheries on Puget Sound management units are higher than the effects to other stocks of Chinook. Recent year Exploitation Rates on Puget Sound Chinook populations in Puget Sound fisheries ranged from 3.2% to 44.4% since 1999 depending on management units (NMFS 2019j; 2024a). In recent years, NMFS has consulted with the BIA and USFWS as well as with itself on federal actions related to implementation of the Puget Sound salmon fisheries. In the resulting Opinions, NMFS has considered the effects of the proposed state and tribal fisheries for the year on Puget Sound Chinook, steelhead, rockfish, eulachon, and SRKW. The most recent Opinion, issued in May 2024, concluded the fisheries were not likely to jeopardize any of these listed species and not likely to adversely modify their critical habitat (NMFS 2024a). The Puget Sound co-managers have submitted a new long-term RMP with conservation objectives they expect to use for management for the next decade, these are similar to the objectives used to plan the 2024-25 fisheries.

The trends in total exploitation rates for the Puget Sound Chinook salmon management units vary considerably. Most are relatively stable, but some show increasing or decreasing trends over time (NMFS 2019j). The distribution of exploitation rates among SEAK, Canadian, and southern west coast U.S. salmon fisheries also varies considerably (NMFS 2019j; 2024a). The Nooksack populations are particularly vulnerable to harvest in Canada and have an exploitation rate that averages 32.3% (NMFS 2019j; 2024a). The average exploitation rate on Strait of Juan de Fuca populations (Elwha and Dungeness) is 25.8%. exploitation rates on South Puget Sound populations range from 27.9% to 60%. For mid-Puget Sound populations, exploitation rate s range from 22.5% to 56.1%.

2.4.1.4.2 Other fisheries

2.4.1.4.2.1 Canadian groundfish fisheries

Canadian groundfish fisheries historically catch Chinook salmon as bycatch while conducting fisheries with mid-water gear types in Canadian trawl fisheries. Chinook salmon bycatch in these fisheries ranged from 2,469 to 26,273 from 2008 to 2023, and averaged 8,283 (Lagasse et al. 2024). Canada estimates these fish as total encountered, with the vast majority retained, but some are released. The composition is sampled for CWT and PBT genetic identification to determine salmon stock identification (Lagasse et al. 2024). In addition to stock identification, results from the PBT analysis provided information on brood year composition, which can be used to calculate salmon age by subtracting the year a fish was caught from the brood year. For example, Chinook salmon from the 2020 brood year would represent age 2 fish if caught in 2022, and age 3 fish if caught in 2023. This is done where possible, as many of the salmon caught are juvenile fish rearing in this area of the ocean. This is younger than most Chinook salmon catch in salmon-directed fisheries and therefore catch numbers in trawl and salmon fisheries may not be directly comparable in terms of adult equivalent mortality. Chinook salmon represent greater than 80% of Pacific salmon bycatch in most Canadian groundfish fishing years from 2008/09 to 2022/23 (Lagasse et al. 2024).

2.4.1.4.2.2 Gulf of Alaska groundfish fisheries

Chinook salmon are caught incidentally in the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA) groundfish fisheries. However, the BSAI fisheries occur outside the action area considered in this Opinion, and occur outside the known migratory path of the four ESA-listed species of Chinook salmon considered in this Opinion. We reviewed all sources of available data on stocks of Chinook salmon contributing to these incidental catches, and there is no information to suggest that any of the affected ESA-listed salmon ESUs considered in this Opinion are affected by these fisheries. They are therefore not discussed further.

Groundfish fishing areas in the GOA are managed pursuant to the MSA through the NPFMC GOA Groundfish FMP[33]. GOA Groundfish FMP fishing areas and salmon fishing areas in SEAK overlap, although most of the groundfish fishing occurs to the west of the salmon fishing areas. The incidental bycatch of salmonids in the GOA groundfish fishery is limited primarily to Chinook and chum salmon. In previous Opinions (NMFS 1999a; 2007c; 2012c; Stelle 2014), NMFS considered the NPFMC's proposed annual bycatch limit of 40,000 Chinook salmon for the GOA fishery and other related management actions. These Opinions concluded that the proposed action would not jeopardize any of the affected Chinook salmon species. From 2008 to 2022 the bycatch of Chinook salmon has averaged 20,548 and ranged from 8,396 to 54,559 (Kurland 2023).

NMFS last reviewed the effects of the GOA groundfish fishery on ESA-listed salmon species through Section 7 consultation in 2012 (NMFS 2012c). Estimates of the take of ESA-listed Chinook salmon come from a review of coded-wire tags that have been recovered in the fishery over the last 20 years[34].

2.4.1.4.2.3 PFMC groundfish fisheries

PFMC groundfish fisheries historically catch Chinook salmon as bycatch while conducting fisheries pursuant to the Pacific Coast Groundfish FMP. Chinook salmon bycatch in the

[33] For incidental bycatch monitoring see: https://www.fisheries.noaa.gov/alaska/bycatch/chinook-salmon-bycatch-management-alaska
[34] For annual estimates of Chinook salmon incidental catch see https://www.fisheries.noaa.gov/s3/2023-03/2022-chinook-incidental-catch-esa-annual-rpt.pdf

groundfish fishery ranged from 3,068 to 15,319 from 2008 to 2015 and averaged 6,806 (NMFS 2017v). Bycatch consists of primarily subadult Chinook salmon taken annually in the groundfish fisheries.

NMFS concluded in previous Opinions on PFMC groundfish fishery implementation that the effects on ESA-listed Chinook salmon, of the ESUs most likely to be subject to measurable impacts, were very low (NMFS 2017v). Although both listed and unlisted ESUs contributed to bycatch, the major contributors to Chinook salmon bycatch in the at-sea sector were from ESUs not listed under the ESA. The at-sea sector the contributions were, on average, Klamath/Trinity Chinook salmon (28%) followed by Southern Oregon/Northern California Coast (25%), Oregon Coast (10%), and northern British Columbia (11%) Chinook salmon (NMFS 2017v). Samples from Chinook salmon bycatch in the shore side whiting sector showed contributions from Central Valley Chinook salmon (13%). Oregon Coast showed a similar contribution, as well as a very low contribution from British Columbia Chinook salmon (NMFS 2017v). The remainder of stocks, which included contributions from listed ESUs, contributed 5% or less of the Chinook salmon bycatch in either fleet on average.

The low contribution rates to bycatch from the ESA-listed Chinook salmon ESUs (i.e., 5% or less) are consistent with qualitative characterizations of likely bycatch levels in analyses prior to the 2017 Opinion (NMFS 2017v).

Salmon are also caught during commercial and recreational halibut fisheries occurring in the PFMC area. However, these catches are accounted for as part of the Pacific Coast Salmon FMP management framework when salmon fisheries are legally open for retention. Therefore, they are accounted for in the environmental baseline under the information reported above in the PFMC Salmon Fisheries section. When salmon fishing is prohibited, halibut fisheries may occasionally encounter salmon. Injuries and death from encounters with fishing gear and handling, during times and areas where salmon fishing is otherwise closed, are expected to result in the take of 4.3 fish per year from each of the following ESA-listed ESUs: Puget Sound Chinook salmon, Lower Columbia RiverChinook salmon, and Snake River fall-run Chinook salmon. Puget Sound salmon fisheries catch Lower Columbia River Chinook salmon, Upper Willamette River Chinook salmon, and Snake River fall-run Chinook salmon on occasion. However, the ERs in these fisheries, on these particular ESUs, are just fractions of 1% (NMFS 2019j).

2.4.1.4.2.4 Other Puget Sound fisheries

Halibut Fisheries. Commercial and recreational halibut fisheries occur in the Strait of Juan de Fuca and San Juan Island areas of Puget Sound. NMFS previously concluded that salmon are not likely to be caught incidentally in the commercial or tribal halibut fisheries when using halibut gear (NMFS 2018f), and later determined that encounters were expectionally rare (NMFS 2023a). The total estimated non-retention mortality of Chinook salmon in Puget Sound recreational halibut fisheries is extremely low, averaging just under two Chinook salmon per year. Of these, the estimated catch of listed fish (hatchery and wild) is between one and two Puget Sound Chinook salmon per year. As the fishery occurs in mixed stock areas and the impact levels are very low, different populations within the ESUs are likely affected each year.

Puget Sound bottomfish and shrimp trawl fisheries. Recreational fisheries targeting bottom fish, and the shrimp trawl fishery, in Puget Sound can incidentally catch listed Puget Sound Chinook salmon. In 2012 NMFS issued an incidental take permit to the WDFW for listed species caught in these two fisheries, including Puget Sound Chinook salmon (NMFS 2012f). The permit was in effect for 5 years and authorized the total incidental take of up to 92 Puget Sound Chinook salmon annually. Some of these fish would be released. Some released fish were expected to survive; thus, of the total takes, NMFS authorized a subset of lethal take of up to 50 Chinook salmon annually. As of 2023 this permit has not been renewed. WDFW has applied for a permit allowing incidental take of 137 Chinook salmon annually in the coming years and it is currently being evaluated.

2.4.1.4.3 Tribal Indian fisheries

Native Americans have lived along the western coast of the present-day United States for thousands of years. Along this coast, and further south, anthropological and archaeological evidence suggests that for more than 10,000 years Native Americans have fished for salmon and steelhead, as well as for other species for ceremonial, subsistence, and economic purposes (Campbell et al. 2010). In the late 1800s, in the contiguous U.S., they ceded most of their ancient lands to the federal government as waves of settlers encroached west and forced treaties took their lands, rivers, and fishing rights. Salmon and steelhead from the ocean have always had spiritual and cultural significance for tribes, and the fish had economic importance as both a trade and food item. The health of Native Americans was heavily reliant on these resources whose diets traditionally included certain quantities and qualities of fish (Harper et al. 2015).

Anadromous fish have been harvested in the Columbia River Basin for as long as the area has been inhabited. Anthropological and archaeological evidence suggests that for more than 10,000 years Native Americans have fished for salmon and steelhead, as well as for other species, in the tributaries and mainstem of the Columbia River for ceremonial, subsistence, and economic purposes (Campbell et al. 2010). A wide variety of gears and methods were used, including hoop and dip nets at cascades such as Celilo and Willamette Falls, to spears, weirs, and traps (usually in smaller streams and headwater areas).

Commercial fishing developed rapidly with the arrival of European settlers and the advent of preservation technologies in the 1800s. In the 1820s, the salting and export of salmon began, led by the Hudson's Bay Company. The packing industry initially relied heavily upon Native American-caught salmon. As demand grew, the non-Indian commercial fishery expanded as well (Johnson 1983). Even greater expansion was spurred by the opening of the first salmon cannery on the Columbia by Hapgood, Hume and Company in 1864 (Johnson 1983; Dietrich 1995). The canning industry reached its peak in 1883 with 55 canneries in operation packing 630,000 cases of salmon. The 1883 commercial harvest was 43 million pounds (Netboy 1974; Brown 1975). Fishing pressure, especially in the late nineteenth and early twentieth centuries has long been recognized as a key factor in the decline of Columbia River salmon runs (NRC 1996).

In 1855, Columbia River Basin Native Americans entered into the Treaties of 1855 with the United States government, ceding the majority of their land but expressly reserving, among other things, the right to fish. The subsequent historical progression of legal interpretation of the

Treaty Indian fishing right is described in (NMFS 2018e).

Fisheries along the U.S. West Coast, in the Puget Sound area, and in the Columbia River Basin include tribal fisheries implementing treaty fishing rights. Implementing Indian treaty fishing rights involves, amongst other things, application of the sharing principles established in various legal precedents. These precedents were established through multiple cases affecting PFMC salmon fishery implementation (e.g., *United States v. Oregon (302 F. Supp. 899, D. Or. 1969); Unites States v. Washington (384 F. Supp. 312, W.D. Wash. 1974), and Parravano v. Babbitt, (70 F.3d 539, 9th Cir. 1995))*. Exploitation rate, escapement, and harvest level calculations, to which the sharing principles apply, are dependent upon various biological parameters. These parameters include: the estimated run sizes for the particular year, the mix of stocks present, the status of other species intercepted, the allowable fisheries, and the anticipated fishing effort.

2.4.1.4.3.1 United States v. Oregon

As described in NMFS (2018e), aspects of treaty Indian fishing rights in the Columbia River Basin are addressed under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case of *United States v. Oregon* (Civil Case No. 68-513, Oregon 1968). In at least a half-dozen published Opinions and several unpublished Opinions in *US v Oregon*, as well as dozens of rulings in the parallel case of *U.S. v. Washington* (interpreting the same treaty language for Tribes in Western Washington), the courts have established a large body of case law setting forth the fundamental principles of treaty rights and the permissible limits of conservation regulation of treaty fisheries.

Since 1992 (NMFS 1992), NMFS has consulted under section 7 of the ESA on proposed *US v Oregon* fisheries in the Columbia River Basin. After the initial consultation (NMFS 1992), NMFS conducted a series of consultations to consider the effects of proposed fisheries as additional species were listed, as new information became available, and as fishery management provisions evolved to address the needs of ESA-listed species. Currently, tribal and non-tribal fisheries in the Columbia Basin are managed under the framework established in the 2018 Management Agreement, in effect for 10 years.

NMFS completed an Opinion on the 2018 agreement on February 23, 2018 (NMFS 2018e). The Opinion concluded that fisheries management, subject to the proposed agreement, was not likely to jeopardize any of the affected ESA-listed species. The incidental take limits and expected incidental take (as a proportion of total run size) of listed salmonids for treaty Indian and non-Indian fisheries under the current agreement are captured in Table 71. Table 71 summarizes the allowed impact rates for each ESU/DPS along with the observed annual average postseason performance after fisheries were implemented during the course of the current agreement.

Table 71. Authorized level of incidental take (as proportion of total run-size) of listed anadromous salmonids for non-Indian and treaty Indian fisheries included for the 2008 agreement. From TAC (2018; 2019; 2020; 2021; 2022; 2023).

ESU or DPS	Take Limits from 2018-2027 (%)	Range of take observed from 2018-2023 (%)	Average annual take (%)
Snake River fall-run Chinook Salmon	21.5 – 45.0 [a]	21.5 – 29.6	27.0
Snake River spring/summer-run Chinook Salmon	5.5 – 17.0 [a,b]	6.1 – 11.2[b]	8.5
Lower Columbia River Chinook Salmon	Managed by components listed below		
spring-run component	Managed For Hatchery Escapement Goals	Hatchery escapements met all but 2019 and 2020	[c]
tule component (fall run)	30.0 – 41.0 [a,d]	25.7 – 37.7[d]	31.5[d]
bright component (late-fall run)	Managed For 5,700 Fish Escapement Goal	Escapement goal met all but 2018	n/a
Upper Willamette River Chinook Salmon[e]	15.0	3.0 – 6.4	4.4
Snake River Basin Steelhead	Managed by components listed below		
A-Index Component, non-treaty	4.0 [f]	0.8 – 2.1	1.3
B-Index Component, non-treaty	2.0 [g]	0.4 – 1.6	0.9
B-Index Component, treaty	15 – 22 [a,g]	5.3 – 13.0	8.4 [g]
Lower Columbia River Steelhead	Managed by components listed below		
winter component	2.0 [e,h]	0.2 – 0.3	0.3
summer component	4.0 [e]	0.6 – 0.9	0.7
Upper Willamette River Steelhead	2.0 [f,h]	0.2 – 0.3	0.3
Middle Columbia River Steelhead	Managed by components listed below		
winter component	2.0 [f,h]	0.2 – 0.3	0.3
summer component	4.0 [e]	0.8 – 2.1	1.3
UCR spring-run Chinook Salmon	5.5 – 17.0 [a,b]	6.1 – 11.2 [b]	8.5
CR Chum Salmon	5.0	0.0 – 1.6	0.6
UCR Steelhead, non-treaty	4.0 [f]	0.8 – 2.1	1.3
Snake River Sockeye Salmon	6.0 – 8.0 [a]	1.9 – 7.1	4.9
Lower Columbia River Coho Salmon	10.0 – 30.0	7.0 – 19.5	12.2
Monitoring, Evaluation, and Research	0.1 - 0.5 [i]		

[a] Allowable take depends on run size.

[b] Impacts in treaty fisheries on listed wild fish can be up to 0.8% higher than the river mouth runsize harvest rates (indicated in table above) due to the potential for changes in the proportion wild between the river mouth and Bonneville Dam.

[c] NMFS (2012e) determined fisheries have ranged from exploitation rates of 2% to 28% over the last ten years, and are expected to remain within this range through managing for hatchery escapement until actions concerning terminal fish passage in the tributaries are addressed.

[d] Total exploitation rate limits include ocean and mainstem Columbia River fisheries. NMFS (2012e) evaluated the PFMC's harvest matrix for total exploitation, including ocean and mainstem Columbia River fisheries, tiered on abundance.

[e] Limit is consistent with Upper Willamette River Chinook salmon recovery plan (ODFW et al. 2011)

[f] Applies to non-Indian fisheries only; 2% in winter/spring/summer seasons and 2% in fall season.

[g] For fall fisheries only.

[h] There is no specific harvest rate limit proposed for treaty fisheries on winter steelhead above Bonneville Dam or on A-Index summer steelhead.
[i] Includes research, monitoring and evaluation that is currently in place. For Chinook and coho ESU's, the range is 0.1–0.5% for each ESU. For Steelhead DPS' and the Snake River Sockeye Salmon ESU the range is 0.1–0.3%.

2.4.1.4.3.2 United States v. Washington

United States v. *Washington* is the ongoing Federal court proceeding that enforces and implements reserved treaty fishing rights with regard to salmon and steelhead returning to western Washington. Various orders of the *United States* v. *Washington* settlement mandate that many aspects of fishery management, including, but not limited to harvest and artificial production actions, be jointly coordinated by the State of Washington and the Western Washington Treaty Tribes (*United States* v. *Washington* 1974).

Findings of *United States* v. *Washington* (384 F. Supp. 312), commonly referred to as the Boldt Decision, clarified these treaties with regard to allocation of salmon harvests between tribal and non-tribal fishers, holding that tribes are entitled to a 50-percent share of the harvestable run of fish in their "usual and accustomed areas". Hoh v. Baldridge (522 F. Supp. 683), a subsequent case, established the principle that fishery management plans must consider returns to individual streams if the fisheries might affect an individual tribe, thus establishing another key management principle of river-by-river or run-by-run management. These decisions added to the findings in *United States v. Oregon*, which held that the state is limited in its power to regulate treaty Indian fisheries.

The State of Washington and Puget Sound Treaty Tribes manage salmon fisheries under the purview of U.S. v. Washington, and on an annual or multi-year basis by agreement. As described above, in recent years, they developed agreed annual management plans for the fisheries, however, they have submitted a multi-year Resource Management Plan (RMP) to NMFS for approval under its 4(d) rule.

Salmon fisheries subject to U.S. v. Washington catch ESA-listed Lower Columbia River Chinook salmon, Upper Willamette River Chinook salmon, and SRFC salmon on occasion, but the ERs in these fisheries on these ESUs are just fractions of 1% (NMFS 1996c; 2012e). The effects of salmon fisheries within the U.S. v. Washington case area on Puget Sound stocks are of course higher than the effects to other stocks, because they are focused on mainly Puget Sound fish. As described previously, Puget Sound salmon fisheries are managed to keep fishery impacts (total or SUS) within management unit-specific management objectives. This multi-year long-term RMP has been submitted to NMFS, and is currently under review. The management objectives in the RMP are similar to those used for 2024-2025.

Recent year ERs in Puget Sound fisheries ranged from 3.2 to 44.4 % since 1999 depending on stock (Table 72), and accounted for 9.9 to 73.40 % of each stock's total ER (Table 73). Not surprisingly, a higher proportion of the overall harvest impact on the Puget Sound Chinook

Salmon ESU occurs in Puget Sound fisheries than in SEAK fisheries for stocks from the south and mid-Sound areas (Table 73).

Table 72. Puget Sound Chinook salmon ERs in marine area fisheries between 1999 and 2018.

Stock	SEAK Exploitation	Canadian Exploitation	PFMC Exploitation	Puget Sound Exploitation	Total Exploitation
	Average 1999 – 2018				
Nooksack River (early)	3.5%	23.3%	2.3%	3.2%	32.3%
Skagit River (early)	0.3%	13.6%	0.9%	7.6%	22.5%
Skagit River (summer/fall)	7.3%	18.9%	1.1%	12.6%	39.9%
Stillaguamish River	1.7%	20.5%	1.9%	6.8%	30.9%
Snohomish River	0.3%	14.6%	1.7%	7.2%	23.8%
Lake Washington	0.2%	14.2%	4.9%	11.0%	30.3%
Duwamish-Green River	0.2%	14.2%	4.9%	24.1%	43.4%
Puyallup River	0.2%	14.2%	4.9%	30.3%	49.6%
Nisqually River	0.1%	9.8%	6.1%	44.4%	60.4%
White River (early)	0.1%	9.6%	1.3%	16.7%	27.9%
Skokomish River	0.5%	12.6%	6.1%	36.9%	56.1%
Mid-Hood Canal Rivers	0.5%	12.8%	6.2%	5.9%	25.4%
Dungeness River (early)	1.8%	18.5%	1.5%	4.0%	25.8%
Elwha River	1.8%	18.6%	1.5%	3.8%	25.8%

Table 73. The proportional distribution of harvest impacts of Puget Sound Chinook salmon distribution in marine areas and Puget Sound fisheries between 1999 and 2018.

Stock	SEAK % of Exploitation	Canadian % of Exploitation	PFMC % of Exploitation	Puget Sound % of Exploitation
	Average 1999 – 2018			
Nooksack River (early)	10.80%	72.20%	7.20%	9.90%
Skagit River (early)	1.50%	60.70%	4.00%	33.80%
Skagit River (summer/fall)	18.20%	47.30%	2.80%	31.60%
Stillaguamish River	5.50%	66.30%	6.30%	21.90%
Snohomish River	1.40%	61.10%	7.30%	30.20%
Lake Washington	0.50%	47.00%	16.20%	36.20%
Duwamish-Green River	0.40%	32.80%	11.30%	55.50%
Puyallup River	0.30%	28.70%	9.90%	61.00%
Nisqually River	0.10%	16.30%	10.10%	73.40%
White River (early)	0.50%	34.60%	4.80%	60.10%
Skokomish River	1.00%	22.40%	10.90%	65.80%
Mid-Hood Canal Rivers	2.10%	50.40%	24.40%	23.10%
Dungeness River (early)	7.10%	71.60%	5.90%	15.40%
Elwha River	7.10%	72.00%	5.90%	14.90%

2.4.1.5 Climate Change

In Section 2.2.10, we describe the on-going and anticipated temperature and marine effects of climate change. Because the impacts of climate change are ongoing, the effects are reflected in the most recent biological viability assessment for Pacific Northwest salmon and steelhead (Ford 2022) and summarized in Section 2.2.10 above. Changes in climate and ocean conditions happen on several different time scales, as explained in Section 2.2.10, and have had a profound influence on distributions and abundances of marine and anadromous fishes. Evidence suggests that marine survival among salmonids fluctuates in response to 20- to 30-year cycles of climatic conditions and ocean productivity. Recalling the more detailed discussion about the likely effects of large-scale environmental variation on salmonids described in Section 2.2.10 across their entire range, effects in the environmental baseline that may occur from climate change on salmon and steelhead include warmer water temperatures, loss of cold water refugia, altered stream flows (e.g., lower low flows in summer; higher high flows in winter), loss of coastal habitat due to sea level rise, ocean acidification, and changes in water quality and freshwater inputs (Mauger et al. 2015).

2.4.2 Eulachon

The best scientific information presently available demonstrates that a multitude of factors, past and present, have contributed to the decline of eulachon. In the 2010 status review (Gustafson et al. 2010), the BRT categorized climate change impacts on ocean conditions as the most serious threat to the persistence of eulachon in all four subpopulations of the DPS: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River. Climate change impacts on freshwater habitat and eulachon bycatch in offshore shrimp fisheries were also ranked in the top four threats in all subpopulations of the DPS. Dams and water diversions in the Klamath and Columbia rivers and predation in the Fraser and British Columbia coastal rivers filled out the last of the top four threats (Gustafson et al. 2010). These threats, together with large declines in abundance, indicated to the BRT that eulachon were at moderate risk of extinction throughout all of its range (Gustafson et al. 2010). Thus, as a general matter, eulachon have at least some biological requirements that are not being met in the action area. Eulachon are still experiencing the impact of a variety of past and ongoing federal, state, and private activities in the action area and that impact is expressed in the threats listed above in section 2.2.8—all of which, in combination, are currently keeping the species from recovering and actively preventing them from having all their biological requirements met.

2.4.3 Puget Sound/Georgia Basin Yelloweye Rockfish and Bocaccio

The Puget Sound and Georgia Basin comprise the southern arm of an inland sea located on the Pacific Coast of North America that is directly connected to the Pacific Ocean. Most of the water exchange in Puget Sound proper is through Admiralty Inlet near Port Townsend, and the configuration of sills and deep basins results in the partial recirculation of water masses and the retention of contaminants, sediment, and biota (Rice 2007). Tidal action, freshwater inflow, and ocean currents interact to circulate and exchange salty marine water at depth from the Strait of

Juan de Fuca, and less dense fresh water from the surrounding watersheds at the surface produce a net seaward flow of superficial waters (Rice 2007).

Most of the benthic, deepwater (i.e., deeper than 90 feet [27.4 m]) habitats of Puget Sound proper consist of unconsolidated sediments, such as sand, mud, and cobbles (Pacunski et al. 2020; Lowry et al. 2022). The vast majority of the rocky-bottom areas of Puget Sound occur within the San Juan Basin, with the remaining portions spread among the rest of Puget Sound proper (Palsson et al. 2009). Depths in the Puget Sound extend to over 920 feet (280 meters).

Benthic habitats within Puget Sound have been influenced by a number of factors. The degradation of some rocky habitat, loss of eelgrass and kelp, introduction of non-natural-origin species that modify habitat, and degradation of water quality are threats to marine habitat in Puget Sound (Palsson et al. 2009; Drake et al. 2010; NMFS 2017s). Some benthic habitats have been impacted by derelict fishing gear that include lost fishing nets, and shrimp and crab pots (Good et al. 2010; Natural Resources Consultants 2018). Derelict fishing gear can continue "ghost" fishing and is known to kill rockfish, salmon, and marine mammals, as well as degrade rocky habitat by altering bottom composition and killing numerous species of marine fish and invertebrates that are eaten by rockfish (Good et al. 2010). Thousands of nets have been documented within Puget Sound and most have been found in the San Juan Basin and the Main Basin. The Northwest Straits Initiative has operated a program to remove derelict gear throughout the Puget Sound region. In addition, the WDFW and the Lummi, Stillaguamish, Tulalip, Nisqually, and Nooksack Tribes, and others, have supported or conducted derelict gear prevention and removal efforts. Net removal has mostly concentrated in waters less than 100 feet (33 m) deep where most lost nets are found (Good et al. 2010). Several hundred derelict nets have been documented in waters deeper than 100 feet deep, however, and directed efforts to develop novel methods and remove them are ongoing (Natural Resources Consultants 2013). The removal of over 5,811 nets and over 6,175 derelict pots have restored over 860 acres of benthic habitat (Northwest Straits Foundation 2024), though many derelict nets and crab and shrimp pots remain in the marine environment. Over 200 rockfish have been documented within recovered derelict gear. Because habitats deeper than 100 feet (30.5 m) are most readily used by adult yelloweye rockfish and bocaccio, there is an unknown but potentially significant impact from deepwater derelict gear on rockfish habitats within Puget Sound.

Over the last century, human activities have introduced a variety of toxins into the Georgia Basin at levels that can affect adult and juvenile rockfish habitat and/or the prey they consume. Toxic pollutants in Puget Sound include oil and grease, PCBs, phthalates, PBDEs, and heavy metals that include zinc, copper, and lead. Several urban embayments in Puget Sound have high levels of heavy metals and organic compounds (West et al. 2001). There are no studies to date that define specific adverse health effects thresholds for particular toxicants in any rockfish species; however, it is likely that PCBs pose a risk to rockfish health and fitness (Palsson et al. 2009). About 32% of the sediments in the Puget Sound region are considered to be moderately or highly contaminated (PSAT 2007), though some areas are undergoing clean-up operations that have improved benthic habitats (Sanga 2015). In a rare study of the impacts of heavy metals on rockfishes, Barst et al. (2015) demonstrated that mercury and other metals are filtered and isolated by the liver, but did not attempt to identify adverse effects thresholds associated with exposure.

Washington State has a variety of marine protected areas managed by 11 Federal, state, and local agencies (Van Cleve et al. 2009), though some of these areas are outside of the range of the rockfish DPSs. The WDFW has established 25 marine reserves within the boundary of the DPSs, and 16 host rockfish (Palsson et al. 2009), though most of these reserves are within waters shallower than those typically used by adult yelloweye rockfish or bocaccio. The WDFW reserves total 2,120.7 acres of intertidal and subtidal habitat. The total percentage of the Puget Sound region within reserve status is unknown, though Van Cleve et al. (2009) estimate that 1% of the subtidal habitats of Puget Sound are designated as a reserve. Compared to fished areas, studies have found higher fish densities, sizes, or reproductive activity in the assessed WDFW marine reserves (Palsson et al. 1995; Palsson 1998; Eisenhardt 2001; Palsson et al. 2004; LeClair et al. 2018). These reserves were established over several decades with unique and somewhat unrelated ecological goals, and encompass relatively small areas (average of 23 acres).

We cannot quantify the effects of degraded habitat on listed rockfish because these effects are poorly understood. However, there is sufficient evidence to indicate that ESA-listed rockfish productivity may be negatively impacted by the habitat structure and water quality stressors discussed above (Drake et al. 2010).

We discuss fisheries management pertinent to rockfish that is part of the environmental baseline as context for the fisheries take authorized within previous section 7 consultations (e.g., NMFS 2016n; 2023d; 2023a). In 2010, the Washington State Fish and Wildlife Commission formally adopted regulations that ended the retention of rockfish by commercial harvesters and recreational anglers in greater Puget Sound, and closed fishing for bottomfish in all waters deeper than 120 feet (36.6 m). On July 28, 2010, the WDFW enacted the following package of regulations by emergency rule for the following non-tribal commercial fisheries in Puget Sound in order to protect dwindling rockfish populations:

1) Closure of the set net fishery
2) Closure of the set line fishery
3) Closure of the bottom trawl fishery
4) Closure of the inactive pelagic trawl fishery
5) Closure of the inactive bottom fish pot fishery

As a precautionary measure, the WDFW closed the above-listed commercial fisheries eastward of the entrance to the Strait of Juan de Fuca (Cape Flattery), which is westward of the DPSs' by approximately 60 mi (96.6 km). The WDFW extended the closure west of the DPSs to prevent commercial fishermen from concentrating gear in that area. The commercial fisheries closures listed above were initially enacted on a temporary basis, but later made permanent in February of 2011.

Both natural- and hatchery-origin salmonids of various species consume larval and young-of-the-year rockfishes (Fresh et al. 1981; Love et al. 2002; Daly et al. 2009; Duffy et al. 2010; Fergusson et al. 2013; Litz et al. 2017; Davis et al. 2020; Fennie et al. 2020; Fergusson et al. 2020). As noted in Section 1.2 Consultation History above, in 2020 we evaluated existing hatchery programs for salmon and steelhead that release fish into Puget Sound to determine their effects on listed rockfish population status (NMFS 2020d). Using diet composition data from studies of juvenile salmon, estimates of the proportion of rockfish in Puget Sound that are listed, knowledge of salmonid outmigration timing patterns, and estimates of the temporal availability of larval rockfish, we estimated the total number of listed rockfish larvae consumed annually by hatchery Chinook using a bioenergetic model (Beauchamp et al. 2020; NMFS 2020d). Information about listed rockfish fecundity was then used to compare this consumption rate to the reproductive capacity of the yelloweye rockfish and bocaccio populations within the DPSs (NMFS 2020d). We determined that, at 2020 operating levels (51.7 million Chinook), hatchery-origin salmon consumed approximately 2.1 million larval listed rockfish annually, but that this amounts to the reproductive output of roughly one mature female yelloweye or bocaccio (Love et al. 2002). The analysis also considered a scenario with a *high* level of hatchery releases (88.1 million Chinook), which produced a predation estimate of 3.6 million larvae consumed annually, which is equivalent to the reproductive output of only 3–4 listed rockfish (Beauchamp et al. 2020; NMFS 2020d). We note that the *high* hatchery release scenario has not been realized in Puget Sound in recent years for a variety of logistical reasons, including the global Covid-19 pandemic. The environmental baseline, then, includes juvenile Chinook salmon releases from hatcheries into Puget Sound at 2020 operating levels rather than the *high* release scenario evaluated in 2020 (NMFS 2020d).

2.4.3.1 Puget Sound/Georgia Basin Rockfishes Harvest and Bycatch Effects in the Environmental Baseline

In this section, we summarize past and present impacts on rockfish from federal and state-managed fisheries within the portion of the action area in the Puget Sound/Georgia Basin. Recreational fishermen targeting bottomfish, and the commercial shrimp trawl fishery in Puget Sound, sometimes incidentally catch listed rockfish. In 2012, we issued an incidental take permit (ITP) to the WDFW for listed rockfish taken in these fisheries (Table 74). This ITP expired in 2017 and we are currently working with the WDFW and tribal co-managers in their preparation of a new ITP application that will provide renewed coverage for these fisheries, as well as providing novel coverage for recreational and commercial pot/trap-based shrimp fisheries throughout greater Puget Sound.

In 2023, we estimated that up to 117 yelloweye rockfish and 145 bocaccio will be incidentally caught annually by recreational anglers targeting salmon (NMFS 2023d), and that 56% (66 yelloweye) and 53% (77 bocaccio) of these incidentally caught fish will be mortalities. In a separate evaluation, we estimated that recreational, commercial, and tribal fishing for Pacific halibut in Puget Sound could result in cumulative, lethal bycatch of 18 bocaccio and 270 yelloweye rockfish annually (NMFS 2023a). Given management sideboards that structure the seasonality, duration, and effort of these activities, we anticipate similar numbers of mortalities in the salmon and halibut fisheries, and the fisheries in Table 74, for the foreseeable future.

Table 74. Anticipated Maximum Annual Takes for Bocaccio and Yelloweye Rockfish by the fisheries within the WDFW ITP (2012–2017)) (WDFW 2012).

	Recreational bottomfish		Shrimp trawl		Total annual take	
	Lethal	**Non-lethal**	**Lethal**	**Non-lethal**	**Lethal**	**Non-lethal**
Bocaccio	12	26	5	0	17	26
Yelloweye Rockfish	87	55	10	0	87	65

2.4.4 Scientific Research Effects in the Environmental Baseline

The listed salmon and rockfish species in this Opinion are the subject of scientific research and monitoring activities. The impacts of these research activities pose both benefits and risks. Research on the listed species in the action area is currently provided coverage under section 7 of the ESA or under the ESA 4(d) research programs, or included in the estimates of fishery mortality discussed in Section 2.5, Effects of the Proposed Action, in this opinion.

For the year 2023, NMFS has issued several ESA section 10(a)(1)(A) scientific research permits allowing lethal and non-lethal take of listed species within the action area (NMFS 2023c). Table 75 displays the total take for the ongoing research authorized under ESA sections 4(d) and 10(a)(1)(A) within the action area for the listed Puget Sound/Georgia Basin rockfish species DPSs, Puget Sound Chinook Salmon ESU, Lower Columbia River Chinook Salmon ESU, Lower Columbia River Coho Salmon ESU, and Snake River Fall-run Chinook Salmon ESU.

Actual take levels associated with these activities are almost certain to be substantially lower than the permitted levels. There are three reasons for this: (1) most researchers do not handle the full number of individuals they are allowed – our research tracking system reveals that researchers, on average, end up taking about 37% of the number of fish they estimate needing; (2) the estimates of mortality for each proposed study are purposefully inflated (the amount depends upon the species) to account for potential accidental deaths, and it is therefore likely that fewer fish (in some cases many fewer), especially juveniles, than the researchers are allotted are killed; and (3) researchers within the same watershed are encouraged to collaborate on studies (i.e., share fish samples and biological data among permit holders) so that overall impacts on listed species are reduced (NMFS 2023c).

Table 75. Total requested take of ESA-listed species for scientific research and monitoring approved for 2023, plus the permits evaluated in the Opinion covering new scientific research (NMFS 2023c).

Species	Life Stage	Origin[a]	Total Requested Take	Percent of Abundance	Lethal Take	Percent of ESU/DPS killed
Puget Sound/Georgia Basin bocaccio	Adult	Natural	26	2.323[b]	15	0.977[b]
	Subadult	Natural	2		1	
	Juvenile	Natural	79		29	
Puget Sound/Georgia Basin yelloweye rockfish	Adult	Natural	32	0.081[b]	20	0.047b
	Subadult	Natural	2		1	
	Juvenile	Natural	59		33	
Puget Sound Chinook salmon[b]	Adult	LHAC	960	7.107[a]	62	0.336[a]
		LHIA	691		16	
		Natural	853	3.650	37	0.158
	Juvenile	LHAC	223,285	9,569	0.871	0.037
		LHIA	275,089	3.169	5,596	0.064
		Natural	770,310	20.661	13,768	0.369
Lower Columbia River Chinook salmon	Adult	LHAC	151	0.866[a]	13	0.069[a]
		LHIA	12		0	
		Natural	420	1.434	19	0.065
	Juvenile	LHAC	2,	0.010	664	0.002
		LHIA	428	0.045	45	0.005
		Natural	514,518	4.621	6,483	0.058
Lower Columbia River coho salmon	Adult	LHAC	676	4.433[a]	42	0.263[a]
		LHIA	31		0	
		Natural	1,121	5.990	19	0.102
	Juvenile	LHAC	19,776	0.249	1,101	0.014
		LHIA	875	0.270	116	0.036
		Natural	241,705	29.226	2,926	0.354
Snake River fall Chinook salmon	Adult	LHAC	83	0.786[a]	14	0.101[a]
		LHIA	34		1	
		Natural	87	1.198	9	0.124
	Juvenile	LHAC	2,630	0.101	283	0.011
		LHIA	2,013	0.068	144	0.005
		Natural	4,529	0.566	264	0.033

[a] Abundances for adult hatchery salmonids are LHAC and LHIA combined.
[b] Abundance for these species are only known for the adult life stage, which is used to represent the entire DPS
[c] Abundances for all adult components are combined.

2.5 Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action but that are not part of the action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.02).

This Biological Opinion considers programmatic-level effects of federal funding hatchery Chinook salmon smolt production, as described in Section 1.3, Proposed Federal Action. In general, the federal prey program will have the same types of effects as those described in the Environmental Baseline and in Appendix C. As described in this section, the Proposed Action is expected to have both watershed-scale and combined effects, both of which are evaluated in this Opinion and described as follows:

- Watershed-scale effects. Many hatchery effects occur solely within the watershed[35] that a hatchery program operates in. Such effects thus impact one, some, or all of the listed population(s) natal to that watershed. Where multiple hatchery programs operate within the same watershed, effects to listed populations within that watershed may be compounded. The Proposed Action requires that site-specific Biological Opinions be completed as one condition of any particular hatchery program to receive funding. With few exceptions, NMFS' site-specific Biological Opinions are performed at the watershed-scale, meaning that all hatchery programs within a given watershed are evaluated in the same Biological Opinion. Because the Proposed Action is programmatic in nature, we do not perform a site-specific analysis in this Opinion. The specific nature, scope, and magnitude of watershed-scale effects are unique to each hatchery and hatchery program. The degree of risk from watershed-scale effects to individual ESA-listed populations will vary depending on a variety of factors including but not limited to the following: the abundance of the affected population(s); the number, size, and location(s) of released hatchery fish; unique features of hatchery infrastructure and operations within the particular riverscape setting; and, unique features of the watershed(s) where fish are released. Thus, in this Biological Opinion, we consider the types of effects that hatcheries and hatchery programs are generally known to have, as well as the range over which the severity of risk is likely to vary depending on these factors.

- Combined effects. Combined effects are those that accrue from hatchery releases originating from different watersheds. The federal prey program may fund hatchery releases into multiple watersheds across Puget Sound, the Columbia River basin, and the Washington coast. Combined effects occur in the waters in which fish from some or all of these areas may commingle, even if at somewhat broad spatial and/or temporal scales. Such areas include the mainstem Columbia River, estuaries (except for Puget Sound natal

[35] For purposes of this Biological Opinion, watersheds are defined at the scale of tributaries entering Puget Sound (e.g., Skagit River watershed) and the mainstems of the Columbia River (e.g., Yakima River watershed) and Snake River (e.g., Clearwater River watershed).

inner estuaries), and marine waters. Combined effects are simply effects that occur in these areas from the en masse release of federal prey program-funded hatchery Chinook salmon from multiple watersheds.

This Biological Opinion describes both watershed-scale effects at the general level and combined effects of the federal prey program across the described Action Area (Section 2.2.10). The effects analysis described in this section is based on the following factors and assumptions:

- The number of federal prey program-funded hatchery salmon produced each year will likely vary depending on the funding amount and other factors such as hatchery operational expenses and broodstock[36] availability. Typical variables associated with rearing live fish (e.g., individual female salmon fecundity, in-hatchery egg-to-smolt[37] survival) may also cause annual release numbers to fluctuate. In site-specific ESA consultations, NMFS accounts for overages relative to production goals. Such overages are common and arise from the nature of managing for the aforementioned variables. Thus, the number of federal prey program-funded smolts released in a given year to achieve the goal of the program (i.e., a meaningful increase of 4–5% in SRKW prey abundance) will vary, but is expected to be up to approximately 20 million smolts to achieve these specified adult abundances in the ocean, as explained in the NEPA preferred alternative (NMFS 2024e). Up to 22 million smolts may be released in any given year due to the variables described above. However, we expect that the average releases over any 5-year period will not exceed 21 million smolts.

- The Proposed Action describes releasing Chinook salmon smolts from three main areas: Puget Sound, the Washington coast, and the Columbia River basin. As described in the Environmental Baseline, hatchery operators in these areas have limited capacity at their hatcheries to produce Chinook salmon for the federal prey program because they produce hatchery salmon and steelhead to fulfill other needs (e.g., harvest augmentation, salmon conservation and recovery). Thus, we assumed that the maximum number of smolts that could be released from each area is constrained by the available hatchery production capacity identified by the hatchery operators.

- The current estimated production capacity available for SRKW prey production that meet criteria 1 and 4 of the Proposed Action is 14.4 million smolts for Puget Sound region facilities and 13.9 million smolts for the region comprising Columbia River (9.8 million smolts) and Washington coast (4.1 million smolts) facilities[38]. We use these to represent

[36] Broodstock are the mature adult hatchery salmon that are used to produce more progeny in the hatchery.

[37] A smolt is a young salmon life stage, after the parr stage, when it becomes silver and migrates from fresh water to the sea.

[38] Puget Sound and Columbia River figures are based on WDFW's survey of available hatchery capacity (WDFW 2019), HGMPs submitted to NMFS and, where completed, in site-specific Biological Opinions (see Table 72 in the Environmental Baseline section). The Washington coast estimate is based on verbal and written communication from hatchery operators. Actual capacity available for SRKW prey production may vary slightly depending on changes to other salmon and steelhead programs operated at hatcheries (e.g., harvest, harvest management, conservation and recovery programs), though any changes to these other programs are expected to be minor.

approximate upper limits on SRKW prey program production goals from each of these regions, pending satisfaction of criteria 2, 3, 5, and 6 of the Proposed Action. However, assuming all criteria were satisfied, these levels would not be achieved for both regions in the same year because the total available capacity (28.3 million smolts) would exceed the prey program's goal of a 4–5% increase in SRKW prey abundance. Thus, we assume that the regional distribution of hatchery releases may vary annually within a range set by the available production capacity in each region, as described above and summarized in Table 76.

Table 76. Regional limits to federal prey program-funded Chinook salmon annual smolt production goals considered in this Opinion. CR = Columbia River; PS = Puget Sound; WC = Washington coast.

<table>
<tr><th rowspan="2">Smolt production area</th><th rowspan="2">Available hatchery capacity to produce Chinook salmon smolts for SRKW prey</th><th colspan="2">Maximum regional federal prey program-funded smolt production goals with all available hatchery capacity utilized in either PS or CR/WC</th></tr>
<tr><th>High PS, Low CR/WC (PS capacity maximized)</th><th>Low PS, High CR/WC (CR, WC capacity maximized)</th></tr>
<tr><td>Puget Sound</td><td>14.4 million</td><td>14.4 million</td><td>6.1 million</td></tr>
<tr><td>Columbia River</td><td>9.8 million</td><td rowspan="2">5.6 million</td><td>9.8 million</td></tr>
<tr><td>Washington coast</td><td>4.1 million</td><td>4.1 million</td></tr>
<tr><td>**TOTAL**</td><td>**28.3[a]**</td><td>**20 million**</td><td>**20 million**</td></tr>
</table>

[a] The total available capacity for all regions combined would not be funded in any given year because the total available capacity (28.3 million smolts) would exceed the prey program's goal of up to a 4–5% increase in SRKW prey abundance.

- We assume that federal prey program-funded hatchery production will occur at existing hatchery facilities, and may occur at any existing hatchery facility that has produced salmon or steelhead for any purpose previously. Though our expectation for regional limits on federal prey program-funded smolt production (i.e., Table 76) is based on available hatchery production capacity that is not being utilized for other purposes, we do not limit our consideration to only those facilities that have available capacity. For example, a hatchery currently producing at full capacity to meet needs unrelated to the federal prey program may experience future budget cuts and reduced production, thereby creating newly-available capacity. Such hatchery could subsequently apply for federal prey program funding to utilize the newly-available capacity. Federal prey program funding could be used to increase facility-wide production up to capacity, assuming all 6 criteria of the Proposed Action are met. Such instances are likely to be limited and, therefore, unlikely to cause federal prey program-funded production to exceed the regional production limits noted in the proposed action and in Table 76.

2.5.1 Salmon and steelhead

The methodology and best scientific information NMFS uses for analyzing hatchery effects is summarized in subsection 2.5.1.1 and application of the methodology to and analysis of the Proposed Action is in subsection 2.5.1.2.

2.5.1.1 Factors That Are Considered When Analyzing Hatchery Effects

NMFS has substantial experience evaluating hatchery programs utilizing best available science (Hard et al. 1992; McElhany et al. 2000; NMFS 2004; 2005f; Jones 2006; NMFS 2008g; 2012d). For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes; abundance, productivity, spatial structure, and diversity and then relates effects of the Proposed Action at the population scale to the MPG level and ultimately to the survival and recovery of an entire ESU or DPS.

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

NMFS’ analysis of the Proposed Action is in terms of effects we expect on ESA-listed species and on designated critical habitat, based on the best scientific information available. This allows for quantification (wherever possible) of the effects of the six factors (listed below) of hatchery operation on each listed species. This in turn allows the combination of all such effects with other effects accruing to the species to determine whether or not the Proposed Action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.

As mentioned, our analysis of the Proposed Action for its effects on ESA-listed species and on designated Critical Habitat depends on six factors. These factors are:

1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock
2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities
3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary and ocean
4. RM&E that exists because of the hatchery program
5. The operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program
6. Fisheries that exist because of the hatchery program, including terminal fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds.

NMFS' analysis assigns an effect category for each factor (negative, negligible, or positive/beneficial) on each ESU or DPS based on general salmon population viability. The effect category assigned is based on: 1) an analysis of each factor weighed against the affected population(s) current risk level for abundance, productivity, spatial structure and diversity; 2) the role or importance of the affected natural population(s) in salmon ESU or steelhead DPS recovery; and, 3) the target viability for the affected natural population(s). For more information on how NMFS evaluates each factor, please see Appendix C.

2.5.1.2 Effects of the Proposed Action on ESA-Listed Salmon and Steelhead

2.5.1.2.1 Factor 1: The hatchery program does or does not remove fish from the natural population and use them for broodstock

The federal prey program will only produce Chinook salmon. Therefore, only ESA-listed Chinook salmon may be affected by removal of natural fish for broodstock. Federal prey program broodstock collection operations will occur exclusively within Puget Sound, the Columbia River basin, and the Washington coast. Therefore, only Chinook salmon from Recovery Domains that overlap these areas may be affected under Factor 1. Thus, Chinook salmon from the following Recover Domains may be affected:

- Puget Sound
- Willamette/Lower Columbia River: all Chinook salmon ESUs
- Interior Columbia River: all Chinook salmon ESUs

Some federal prey program hatchery programs may remove fish from a nearby natural population and use them for broodstock. Effects of this removal occur solely at the watershed scale (i.e., they are watershed-scale effects) are thus considered at a general level here. The exact scope and magnitude of effects to specific affected populations are evaluated in site-specific Biological Opinions.

Removing natural-origin fish for broodstock is an essential aspect of programs with integrated and stepping stone genetic management strategies (see definition section for descriptions of these strategies) that seek to maintain natural population genetics within the hatchery program, and thus reduce genetic risks of those programs to the affected natural populations (see further discussion in the Genetic effects section below). Typically, some proportion of returning hatchery-origin adults from these programs will spawn in the wild with the natural population, thereby partially or fully compensating—in terms of spawner abundance—for the fish taken for broodstock. This compensation thus maintains a natural spawner abundance at or near what it would have been had no fish been removed for broodstock. However, there are genetic implications of hatchery-origin fish spawning in the wild with natural origin fish. These genetic implications are discussed in the Factor 2 Genetic effects section below. For conservation and recovery programs, the risk of collecting natural-origin broodstock is outweighed by the demographic benefits of increased spawner abundance. For programs employing integrated and stepping-stone genetic management strategies, any demographic risks of collecting natural-origin broodstock are generally lower than the genetic risks of operating the program as segregated instead. Natural-origin fish are not removed for programs using the segregated genetic management strategy. The physical process of collecting hatchery broodstock and the effect of the process on ESA-listed species is considered under Factor 2 in the Adult Collection subsection.

NMFS ensures that safeguards are in place so that proposed removal for hatchery broodstock does not pose an unacceptable risk to natural populations. During site-specific consultations, NMFS evaluates whether safeguards proposed by hatchery operators are sufficient for minimizing risk. If they are not sufficient, NMFS imposes Terms and Conditions so that risk is sufficiently minimized. Safeguards may include but not be limited to limits on how many fish can be removed, and lower limits during times when returns or forecasted returns are particularly low. For programs that rely on run forecasts to determine the allowable level of collection, because run forecasts are inherently imperfect, there may be years when actual natural spawner abundance falls below established thresholds and too many natural-origin fish are collected for that level of abundance. As part of NMFS site-specific Biological Opinions, annual reports are required as a Term and Condition. NMFS reviews these annual reports to ensure that actions and their effects are consistent with the analyses in the Biological Opinions. If Terms and Conditions are not met or if actions and their effects are not consistent with the analyses, NMFS works with the hatchery operator(s) to resolve discrepancies, potentially including reinitiation.

The suite of prey-program funded hatchery programs are likely to employ various genetic management strategies (segregated, integrated, stepping-stone). Thus, some programs may not have any Factor 1 effects (i.e., segregated programs), while others may present negligible to moderate degrees of risk from Factor 1 effects depending on the status of the affected natural population, and, for programs that rely on run forecasts, how often actual natural spawner abundance falls below established thresholds and too many natural-origin fish are collected for that level of abundance. Moderate risk to a population from Factor 1 effects is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. Most populations are likely to incur only negligible or low risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). Not all populations within a given ESU may be affected. This is because federal prey program-funded hatchery production will occur in areas with existing hatchery facilities, and some populations exist in areas without hatchery facilities. Thus, only natural populations affected by existing facilities may be affected by the federal prey program. For these reasons, we expect that Factor 1 effects will result in negligible to low negative risk at the ESU scale.

2.5.1.2.2 Factor 2: Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities

There are three main categories of effects evaluated under Factor 2: genetic effects, ecological effects, and effects of adult collection for hatchery broodstock. The first category, genetic effects, will only affect Chinook salmon because Chinook salmon are not known to interbreed with other salmonids (except in very rare instances with coho and pink salmon). The latter two Factor 2 effects—ecological and adult collection—may affect Chinook salmon as well as other listed salmonids. For example, hatchery Chinook salmon spawners may benefit many species ecologically by their delivery of marine-derived nutrients, which can boost overall stream productivity to the benefit of all species present. Conversely, such hatchery Chinook salmon spawners may negatively affect individuals of various species if they try to spawn at the same time and place. Finally, hatchery broodstock collection (e.g., at weirs and traps) may inadvertently intercept individuals of other species that may be present at the same time and place as the targeted Chinook salmon broodstock. These are discussed in more detail below.

The federal prey program will release hatchery Chinook salmon only. All spawning grounds and adult collection facilities are in freshwater (spawning grounds) or upstream from river mouths (adult collection facilities). Federal prey program fish will be released exclusively within Puget Sound, the Columbia River basin, and the Washington coast. Therefore, ESA-listed salmon and steelhead from the following Recovery Domains may be affected:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

Salmon and steelhead from other Recovery Domains are not expected to occur in the areas described above. Further, federal prey program Chinook salmon are not expected to stray into freshwater areas or areas upstream of river mouths where ESA-listed salmonids from other Recovery Domains may be affected by Factor 2 effects. Therefore, salmon and steelhead from other Recovery Domains will not be affected by Factor 2 effects.

All Factor 2 effects occur solely at the watershed scale (i.e., they are watershed-scale effects) because they do not take place (broodstock collection) or are not detected (genetic, ecological) beyond the watershed that the hatchery operates within. Thus, they are considered at a general level here. The exact scope and magnitude of effects to specific affected populations are evaluated in site-specific Biological Opinions.

2.5.1.2.2.1 Genetic effects

The genetic effects described in this section occur through breeding and reproductive processes. Therefore, only Chinook salmon will be affected. The genetic effects described in this section apply to Chinook salmon ESUs in the Puget Sound, Interior Columbia River, and Willamette/Lower Columbia River Recovery Domains, where federal prey program Chinook salmon may be released and interact with ESA-listed Chinook salmon. No genetic effects will be incurred in other Chinook salmon Recovery Domains because no federal prey program Chinook salmon will be produced there, and because federal prey program Chinook salmon are not expected to stray into freshwater areas of these other domains where breeding and reproduction takes place.

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

First, within-population genetic diversity is a general term for the quantity, variety, and combinations of genetic material in a population (Busack et al. 1995). Within-population diversity is gained through mutations or gene flow from other populations (described below under outbreeding effects) and is lost primarily due to genetic drift, a random loss of diversity due to population size. The rate of loss is determined by the population's effective population size[39] (N_e), which can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, the effective size should be in the hundreds (e.g., Lande 1987), and diversity loss can be severe if N_e drops to a few dozen (Appendix C).

Hatchery programs, simply by virtue of creating more fish, can increase N_e. In very small populations, this increase can be a benefit, making selection more effective and reducing other small-population risks (e.g., Lacy 1987; Whitlock 2000; Willi et al. 2006). Conservation hatchery programs can thus serve to protect genetic diversity. However, hatchery programs can also directly depress N_e. in various ways, including by removing natural-origin fish for broodstock, by using hatchery mating systems that limit the number of male-female crosses (e.g., 1-to-1 mating), or by large abundances of hatchery-origin fish that spawn with the natural population. These are described in more detail in Section 1.2.1.2.1 of Appendix C.

Inbreeding depression, another N_e -related phenomenon, is caused by the mating of closely related individuals (e.g., siblings, half-siblings, cousins). The smaller the population, the more likely spawners will be related. Related individuals are likely to contain similar genetic material, and the resulting offspring may then have reduced survival because they are less variable

[39] The effective size of a population is the size of a genetically "ideal" population (i.e., equal numbers of males and females, each with equal opportunity to contribute to the next generation) that will display as much genetic drift (i.e., the random loss of diversity due to population size) as the population being examined (e.g., Falconer and MacKay 1996; Allendorf et al. 2013). See Section 1.2.1.2.1 of Appendix C for further explanation.

genetically or have double doses of deleterious mutations. The lowered fitness of fish due to inbreeding depression accentuates the genetic risk problem, helping to push a small population toward extinction. The protective hatchery environment masks the effects of inbreeding which becomes apparent when fish are released into the natural environment and experience decreased survival (Thrower et al. 2009). Inbreeding concerns in salmonids related to hatcheries have been reviewed by Wang et al. (2002) and Naish et al. (2007). Hatchery populations should be managed to avoid inbreeding depression. If hatcheries produce inbred fish which return to spawn in natural spawning areas the low genetic variation and increased deleterious mutations can lower the fitness, productivity, and survival of the natural population (Christie et al. 2014).

Outbreeding effects, the second major area of genetic effects of hatchery programs, are caused by gene flow from one distinct population to another. When used in reviews of hatchery programs, we are specifically referring to flow of genes from hatchery populations to natural populations. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1993; 1997). Natural straying serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources. A hatchery's rearing and release practices, as well as the ancestral origin of the hatchery fish, can contribute to hatchery fish straying outside of natural patterns (Appendix C). The rate of gene flow from hatchery- to natural-origin populations is usually expressed with the following metrics: pHOS (the proportion of fish on a population's spawning grounds consisting of hatchery-origin fish); and, PNI (the proportion of natural influence, which is a function of pHOS and the proportion of natural-origin fish in the broodstock[40], or pNOB) (Appendix C). The Pacific Northwest Hatchery Scientific Review Group (HSRG) developed gene-flow guidelines based on mathematical models developed by Ford (2002) and Lynch et al. (2001). Guidelines for isolated programs are based on pHOS, whereas guidelines for integrated programs are based on pHOS and PNI. PNI is, in theory, a reflection of the relative strength of selection in the hatchery and natural environments; a PNI value greater than 0.5 indicates dominance of natural selective forces. NMFS relies heavily on the Pacific Northwest HSRG gene flow guidelines, though has not formally adopted them per se, as described in detail in Appendix C.

Hatchery-influenced selection (often called domestication), the third major area of potential hatchery genetic effects, occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with hatchery-origin fish.

Critical information for analysis of hatchery-influenced selection includes the number, location, and timing of naturally spawning hatchery fish, the estimated level of gene flow (i.e., pHOS and PNI, as applicable) between hatchery programs and natural populations, the genetic ancestry of the hatchery stock (the more distant the genetic ancestry compared to the affected natural population, the greater the threat), the level and intensity of hatchery-influenced selection, and the length of time the hatchery program has operated in a particular way. Because gene flow is

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

generally more readily managed than the selection strength of the hatchery environment, efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between natural-origin and hatchery-origin fish[41]. For example, the Interior Columbia Technical Recovery Team (ICTRT) developed guidelines based on pHOS (Figure 77). Many of the actions described above that minimize outbreeding effects also minimize hatchery-influenced selection effects.

Hatchery programs minimize genetic risk by implementing many of the actions listed in Table 77.

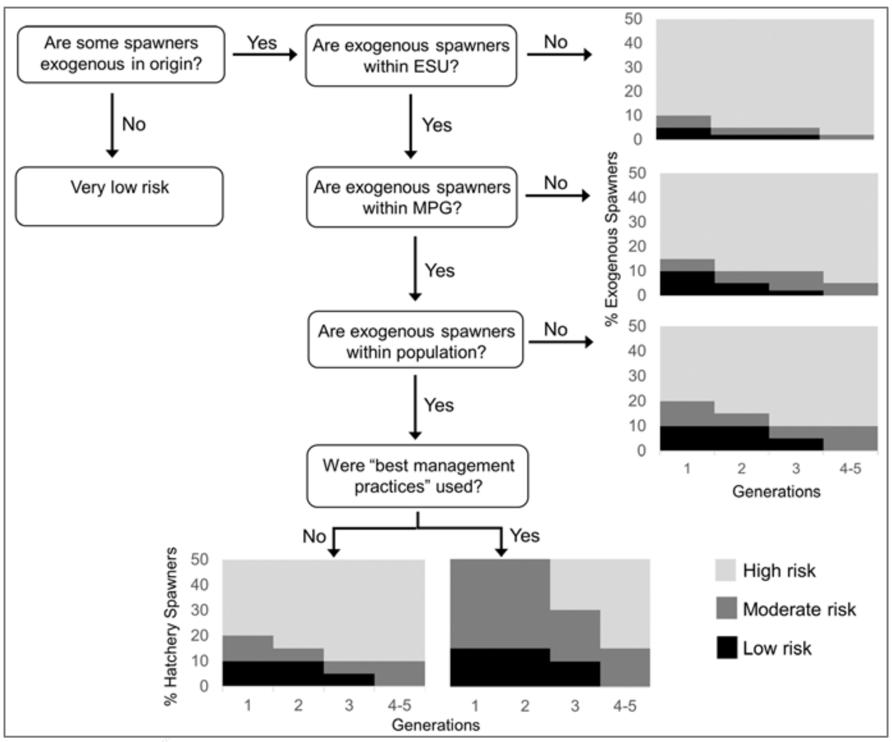


Figure 77. ICBTRT (2007) risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Exogenous fish are considered to be all fish hatchery-origin, and non-normative strays of natural-origin.

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

Table 77. Genetic risk reduction measures commonly implemented by hatchery operators, and corresponding genetic risks that are reduced.

Genetic risk reduction measure	Genetic risk(s) reduced
Apply pHOS and PNI gene flow guidelines, as applicable, based on the natural population's role in recovery (e.g., more stringent guidelines applied to populations with higher conservation importance) (Table 1 in Appendix C)	Hatchery-influenced selection
Monitor and maintain pHOS and PNI recommendations	Hatchery-influenced selection
Implement "stepping stone" programs to genetically link integrated and segregated hatchery program components to natural-origin populations[a]	Outbreeding effects
Develop sliding scale approaches to reduce pHOS and increase pNOB and PNI as the abundance of natural-origin returns increases (e.g., NMFS 2017w)	Hatchery-influenced selection
Manage returning adults to remove hatchery-origin fish at dams or weirs (when they are unneeded for supplementing natural populations)	Outbreeding effects
Support establishment of Natural Production Emphasis Areas (e.g., Snake River Fall Chinook, see section 2.2.2.3.1)	Outbreeding effects
Marking and/or tagging all hatchery fish so they can easily be identified and managed	Outbreeding effects
Employ rearing and release strategies to maximize homing fidelity	Outbreeding effects
Transition away from broodstock with non-endemic genetic lineage, and toward locally adapted broodstock	Outbreeding effects
Equalize sex ratio in broodstock	Hatchery-influenced selection
Collecting and using broodstock throughout the run time period	Hatchery-influenced selection
Incorporate older spawners into the broodstock to prevent age structure changes	Hatchery-influenced selection
Implement factorial mating strategies	Hatchery-influenced selection

[a] Initial analysis by NMFS of programs connected this way shows that these linked programs pose considerably less risk of hatchery-influenced selection than solely segregated programs (Busack 2015)

The federal prey program will increase adult abundance of hatchery-origin fish in freshwater areas, including on the spawning grounds where they may spawn with ESA-listed natural fish. We determined that the federal prey program may increase adult returns to river mouths by up to median 34% (range: 4–295%) depending upon hatchery stock and river of return (Appendix A). These additional returns are not expected to result in similar increases in pHOS due to in-river (pre-spawn) mortality from commercial and recreational fisheries, natural predation, natural mortality, and collection at hatchery facilities. The specific details of each hatchery program will be evaluated in site-specific Biological Opinions to determine the precise effects on pHOS and other hatchery-related effects to specific affected populations. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the effects on pHOS after accounting for fisheries, natural mortality, and hatchery collection efficiency. For example, the federal prey program may increase Willamette spring Chinook salmon returns by up to 20%, or 18,802 fish (Appendix A). However, this additional production occurs in the lower Columbia River's Select Area Fishery Enhancement (SAFE) program near Astoria, Oregon. This program is located to provide off-channel commercial fisheries in the estuary while minimizing effects to ESA-listed populations. Nearly all of the returns to these SAFE areas in the estuary are harvested, NMFS (2021f), and thus the effects to pHOS in lower Columbia River populations are minimal. In addition, no natural stocks of spring Chinook salmon occur in the adjacent areas, further limiting the likelihood of hatchery fish presence on spawning grounds. Therefore, the increase in abundance from the federal prey program, in this example, is not expected to affect pHOS. This is one reason why site-specific analysis is required before any federal funding is provided; that is, to determine the precise level of effects to affected populations.

The most recent available population-specific 10-year average pHOS values representing conditions absent the federal prey program are for return years 2010–2019 (Ford 2022). The substantial majority of hatchery Chinook salmon contributing to pHOS during this time were released as smolts from 2007 through 2016. Relative to this 2007–2016 time period, the federal prey program may increase total annual smolt release abundances by up to 38% and 11% across Puget Sound and the Columbia River basin, respectively. Actual production increases affecting each population, and resulting population-specific pHOS increases, will vary and be assessed in site-specific Biological Opinions. However, it is important to note that pHOS does not increase by the same factor as hatchery-origin spawner abundance for a natural population at constant abundance. That is, a 38% increase in hatchery-origin spawner abundance, for example, does not result in a 38% increase in pHOS (Figure 78) (see Appendix D for the underlying mathematics). As the examples in Figure 78 show, pHOS may increase by small to moderate amounts (up to

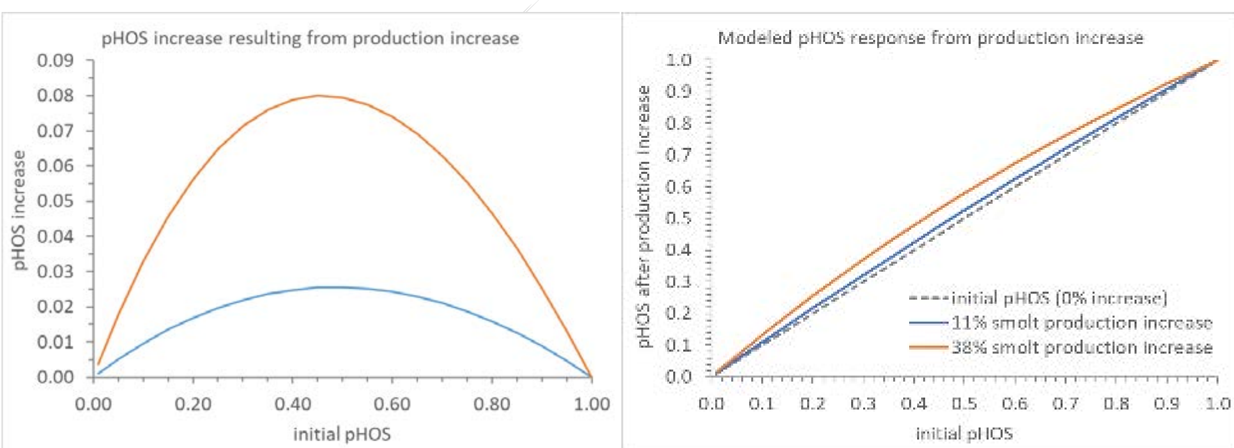


Figure 78. Modeled pHOS increase (left panel) and resultant pHOS (right panel) for smolt production increases of 38% and 11% at a generalized population scale, assuming the abundance of hatchery-origin spawners increases by the same magnitude as the smolt production increase.

0.08) in populations affected by a 38% hatchery production increase, and small amounts (up to 0.03) in populations affected by an 11% hatchery production increase.

The level of risk to a natural population from pHOS, and any increase in pHOS, is inextricably linked to the context provided by both the hatchery program and the affected natural population. As described above, many factors contribute to determining both the level of risk itself, as well as the acceptable level of risk to a population, including but not limited to the following:

1. The genetic management strategy employed by the hatchery program (i.e., segregated, integrated, or stepping-stone).
2. Whether the hatchery program contributes to the conservation and recovery of the natural population.
3. The genetic ancestry of the hatchery broodstock (e.g., proportion of natural-origin broodstock; in-basin or out-of-basin; degree of hatchery-influenced selection).
4. The genetic ancestry of the natural population (i.e., nature and degree of historical hatchery influence).
5. The conservation importance of the natural population to the ESU.
6. The viability status of the natural population.

pHOS values and increase in pHOS values are not very informative for assessing risk outside of the context provided by these factors. For example, a moderate increase to a high initial pHOS may pose less risk than a small increase to a small initial pHOS, depending on the unique set of factors present in each situation. The unique set of factors present within an area are considered in site-specific Biological Opinions to assess risk to specific populations. To summarize, for all Puget Sound and Columbia River basin Chinook Salmon ESUs, genetic risks to affected populations may vary from beneficial to moderate depending on the genetic management strategies employed, the actual abundance of fish released, and other watershed-scale factors described above. Most populations are likely to incur only negligible or low risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). Moderate risk to a population from genetic effects is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. For these reasons, risk at the ESU scale is expected to be negligible to low.

2.5.1.2.2.2 Ecological effects

Ecological effects for Factor 2 refer to effects of hatchery-origin fish on the spawning grounds, including beneficial effects from marine-derived nutrients and ecological services, and negative effects from spawning site competition and redd superimposition, as well as disease. Combined, ecological effects on the spawning grounds may range from positive to negative.

Historically, adult returns of naturally-spawning anadromous Pacific salmon delivered large quantities of nutrients to freshwater ecosystems across Washington, Oregon, and California, including Puget Sound (Gresh et al. 2000). However, widespread declines in salmon abundance have substantially diminished this subsidy of marine-derived nutrients to freshwater ecosystems (NRC 1996; Gresh et al. 2000). In Puget Sound, recent biomass and nutrient imports from adult salmon returns were estimated to be 12–25% of their historical values (Gresh et al. 2000). Spawning salmon often provide a substantial and important nutrient subsidy to freshwater ecosystems (e.g., Cederholm et al. 1999; Gende et al. 2002; Schindler et al. 2003; Janetski et al. 2009; Wipfli et al. 2010; Walsh et al. 2020) that can increase growth and survival of fish (e.g., Bilby et al. 1998; Wipfli et al. 2003; Moore et al. 2008; Copeland et al. 2011; Bentley et al. 2012; Rinella et al. 2012; Nelson et al. 2015) as well as benefit the aquatic ecosystem and watershed as a whole, which in turn benefits the productivity of listed salmonid populations.

Adult salmon spawners provide additional ecological services, including streambed disturbance, nutrient release and retention, and release of aquatic invertebrates and salmon eggs from the substrate (e.g., Collins et al. 2015, and references therein). These services may function synergistically with the import of marine-derived nutrients to boost aquatic ecosystem productivity. As a result, abundances of resident and freshwater-rearing anadromous salmonids have increased with increasing spawner abundances in some systems (e.g., Nelson et al. 2014; Swain et al. 2015; Benjamin et al. 2020). Conversely, low spawner numbers may deprive the river system of nutrients and suppress the productivity of fish populations and the aquatic ecosystem (Scheuerell et al. 2005b; Copeland et al. 2011). Together, these findings raise concerns about negative consequences to freshwater ecosystem generally, and natural salmonid productivity in particular, resulting from low or depressed adult spawner abundances.

Returning hatchery-origin Chinook salmon from the federal prey program may provide marine-derived nutrients and ecological services to the freshwater areas of the action area. Pathways for delivery of these benefits include hatchery-origin fish that spawn in the wild, and carcasses from returns to the hatchery (either spawned or surplussed) that are outplanted into nearby watersheds.

Salmon have been noted to transfer contaminants into ecosystems via their carcasses (Ewald et al. 1998; O'Toole et al. 2006). Persistent organic chemicals such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) are transferred through the food chain and are retained within the tissues of salmon. Analyses show that as the fish burn fat on their spawning migration, they do not metabolize these pollutants (Ewald et al. 1998). These contaminants, acquired during the salmons' ocean migration, concentrate in their tissues and roe. They are ultimately passed (i.e., bio-transferred) on to the freshwater ecosystem to which the salmon return and are introduced into the food chain. There is currently no evidence to suggest that salmon—either hatchery- or natural-origin of any species—introduce contaminants into freshwater ecosystems at levels that measurably affect the abundance, reproduction, or survival of listed species. Risk from contaminant transfer is therefore considered negligible.

Regarding spawning site competition and redd superimposition as it pertains to the proposed action, the most risk comes from hatchery Chinook salmon affecting natural Chinook salmon in nearby areas. Essington et al. (2000) found that aggression between spawners increases with spawner density and is most intense with conspecifics, though females tended to act aggressively towards heterospecifics as well. The potential for redd superimposition exists when there is spatial overlap between natural-and hatchery-origin spawners of the same or different species. In this context, superimposition is when a hatchery-derived fish constructs a redd in the same specific location of a previously constructed redd by an ESA-listed species, thereby destroying the eggs and embryos of that ESA-listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (e.g., Fukushima et al. 1998).

Hatchery fish from integrated and stepping stone programs may replace, to a certain extent, natural fish removed for broodstock (see discussions in Factor 1 and Factor 2, Genetic Effects). Thus, effects from these fish are expected to be reasonably close to what would be expected if no natural-origin fish were removed for broodstock. For programs that contribute to a population’s conservation and recovery, the intended demographic benefits of increasing spawner abundance via hatchery supplementation outweighs risks from spawning site competition and redd superimposition. Conversely, natural spawning of fish from segregated programs is generally undesirable and not intended. Effects of superimposition from these fish may thus present a greater risk. Hatchery-origin fish that spawn in the wild typically concentrate near where they were released as juveniles, which is often a much more limited distribution relative to natural populations. This may serve to diminish or intensify superimposition risk at the population scale depending on the location of release within a watershed relative to the location and distribution of the affected natural population. Spawning habitat in many watersheds is generally underutilized, meaning that there are fewer spawners, and thus lower spawner density, than what the habitat is able to support, diminishing superimposition risk in these areas.

Chinook salmon spawning is typically segregated wholly or partially in space and/or time from that of other salmon species. Steelhead spawn later in the season, and thus would not be affected by hatchery Chinook salmon. Chinook typically start spawning earlier than chum and coho salmon, and finish spawning before these other species. In addition, Chinook salmon typically spawn in faster, deeper water with larger substrate than chum, coho, and sockeye salmon. Thus, the potential for spawning site competition and redd superimposition with these other species is minimal.

Adults returning to hatchery facilities can bear infectious pathogens, potentially transmitting them to ESA-listed species and amplifying them in the natural environment. Hatchery monitoring and control protocols are designed to minimize pathogen transmission and amplification (e.g., NWIFC and WDFW 2006; Naish et al. 2008, and references therein). For example, adults held and used for broodstock are routinely screened for pathogens considered “regulated” by the Tribal and state disease control policy. Usually, pathogens detected in adult broodstock are endemic within the watershed. Occasionally, fish being held for broodstock are administered prophylactic treatments to minimize disease presence and spread. Returning hatchery-origin Chinook salmon adults, including those held for broodstock, do not typically present pathogen risks beyond baseline levels (i.e., that present naturally from natural-origin fish). Based on these factors, the risk of disease transmission and amplification from returning hatchery-origin adults to the watershed, including those held for broodstock, is considered low.

The extent to which Factor 2 ecological effects combine to result in overarching net beneficial, neutral, or positive effects to affected salmon and steelhead populations depends on a variety of factors, including but not limited to the following: 1) the relative abundance of hatchery- and natural-origin spawners; and, 2) the relative spatiotemporal distribution and overlap of hatchery- and natural-origin spawners. These, and other relevant factors, are evaluated in site-specific Biological Opinions to determine the exact effect to the specific affected populations. Affected populations are likely to realize some degree of ecological benefits, though the science is not developed enough to be able to quantify this benefit. Expected increases in Chinook salmon abundances are relatively small to moderate considering historical (pre-colonization) abundances (Gresh et al. 2000) and abundances of other salmon species—coho, chum, pink, and/or sockeye salmon—that similarly deliver marine derived nutrients and ecological services to many action area watersheds. Therefore, ecological benefits to listed species from the proposed action are likely to be relatively small.

Based on the information described above, we conclude that Factor 2 ecological risks are likely to result in net beneficial to net moderate negative risk to affected populations depending on the status of the specific affected natural populations, the actual abundance of hatchery fish released, and spatiotemporal overlap of hatchery-origin and natural-origin fish, among other factors. Most populations are likely to incur only negligible or low risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). Moderate risk to a population from Factor 2 ecological effects is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. Not all populations within a given ESU or DPS may be affected. This is because federal prey program-funded hatchery production will occur in areas with existing hatchery facilities, and some populations exist in areas without hatchery facilities. For these reasons, risk at the ESU and DPS scale is expected to be negligible to low.

2.5.1.2.2.3 Adult collection

This section addresses risks from the physical process of collecting fish for broodstock. Genetic risks of broodstock selection (i.e., natural- and/or hatchery-origin) and collection are addressed in Factor 2, Genetic Effects, and demographic risks of removing natural-origin fish for broodstock are addressed in Factor 1.

Adult broodstock collection may affect non-target fish by altering fish behavior and injuring or killing eggs, juveniles, and adults. Some programs collect their broodstock without the use of in-stream structures such as weirs, relying instead on fish volunteering into the hatchery itself, typically into a ladder and holding pond. The number of natural fish entering hatcheries via this manner (i.e., volitional-entry off-channel ladder) is typically very small. Of programs that use channel-blocking structures like weirs to collect broodstock, some are operated in areas where relatively few natural fish occur (e.g., in small tributaries). Other programs sort through the run at large to collect broodstock, usually at a weir, ladder, or sampling facility.

Collection structures, such as weirs, can degrade habitat function and reduce or block access to spawning and rearing habitats. Many hatchery programs use instream structures, such as weirs or fish ladders, to collect broodstock or remove hatchery-origin fish from the river to prevent them from spawning naturally. Some hatchery facilities operate intentionally-impassable weirs that, by design, block access to upstream habitat. The amount of habitat blocked is typically small, and there is typically higher quality and more abundant habitat available nearby. Some fish may pass upstream of these weirs inadvertently (e.g., during high flow events). Any juvenile or adult fish that move upstream of weirs may become stranded above the weirs. These fish may be vulnerable to delayed or prohibited migration, starvation, or predation, particularly if the area they are stranded in lacks cover and suitable habitat conditions. At the population scale, risks from stranding or entrainment are typically low because relatively few fish are likely affected. Some programs may implement active capture techniques (e.g., gill or tangle netting, seining, angling). Factors influencing risk from broodstock collection are described below and evaluated in site-specific Biological Opinions to determine the exact effect to the specific affected populations.

This analysis considers the effects from encounters with natural-origin fish during broodstock collection. Here, NMFS analyzes effects from sorting, holding, and handling natural-origin fish in the course of broodstock collection. As described above, some programs collect their broodstock from fish volunteering into the hatchery itself, typically into a ladder and holding pond, while others sort through the run at large, usually at a weir, ladder, or sampling facility. Generally speaking, the more a hatchery program accesses the run at large for hatchery broodstock—that is, the more fish that are handled or delayed during migration—the greater the negative effect on natural-origin and hatchery-origin fish that are intended to spawn naturally and to ESA-listed species. Handling of natural-origin fish at broodstock collection facilities would be expected to increase the potential for injury and stress due to delay, crowding in the trap, sorting (including netting, handling, anethsitizing), and from transport and release. The information NMFS uses for this analysis includes a description of the facilities, practices, and protocols for collecting broodstock, the environmental conditions under which broodstock collection is conducted, and the encounter rate for ESA-listed fish.

NMFS also analyzes the effects of structures, either temporary or permanent, that are used to collect hatchery broodstock or to remove hatchery fish from rivers and streams and prevent them from spawning naturally. A weir is one type of device that is employed to effectively block upstream migration and force returning adult fish to enter a trap and holding area. Trapped fish are counted and sampled, and can be either retained or released to spawn naturally. The physical presence of a weir or trap can affect salmonids in a number of ways, including the following:

- Delaying upstream migration.
- Increasing fish vulnerability to predation through corralling effects and fish holding behaviors at the weir.
- Causing the fish to reject the weir or fishway structure, thus inducing spawning downstream of the trap (displaced spawning), potentially in suboptimal areas.
- Contributing to “fallback” of fish that have been released above the weir. This is when fish move back downstream of the weir after release.

- Injuring or killing fish when they attempt to jump the barrier (Hevlin et al. 1993; Spence et al. 1996).
- Affecting the spatial distribution of juvenile salmon and steelhead seeking preferred habitats.

Impacts associated with operating a weir or trap include the following:

- Physically harming the fish during their capture and retention whether in the fish holding area or within a weir or trap.
- Harming fish by holding them for long durations.
- Physically harming fish during handling.
- Increasing their susceptibility to downstream displacement and predation while they recover after release.
- Latent effects and delayed mortality associated with stress from capture, confinement, and handling.

NMFS analyzes the design and operation of the weirs and traps to determine their potential negative impacts (Hevlin et al. 1993; NMFS 2011g). The installation and operation of weirs and traps are very dependent on water conditions at the trap site. High flows can delay the installation of a weir or make a trap inoperable. A weir or trap is usually operated in one of two modes: 1) continuously, when up to 100% of the run is collected and sampled and those fish not needed for broodstock or retained for other reasons are released upstream to spawn naturally; or, 2) periodically, when the weir is operated for a number of days each week to collect a representative sample and otherwise left opened to provide fish unimpeded passage for the rest of the week. The mode of operation is established during the development of site-based collection protocols and can be adjusted based on in-season escapement estimates and environmental factors.

NMFS analyzes effects on fish, juveniles and adults, from broodstock collection and effects on habitat conditions that support and promote viable salmonid populations. NMFS wants to know, for example, if the spatial structure, productivity, or abundance of a natural population is affected when fish encounter a structure used for broodstock collection, usually a weir or ladder. NMFS also analyzes changes to riparian habitat, channel morphology and habitat complexity, water flows, and in-stream substrates attributable to the construction/installation, operation, and maintenance of these structures.

To minimize the effects of broodstock collection, best management practices include, but are not limited to, constructing and operating structures consistent with applicable NMFS criteria (NMFS 2022d), and ensuring that weirs do not negatively affect spatial structure, productivity, or abundance of natural populations. Pursuant to that goal, all fish collection structures are monitored to ensure minimal fish migration delay. Trap holding structures (e.g., cages, ponds) are checked frequently for fish presence. If captured, non-target listed salmonids may be retained for short periods of time (e.g., up to about 24 hours for confined cages; up to about one week for holding ponds). Holding ponds are often relatively large, fed with continuously-flowing surface water, and protected from predators by fencing around the perimeter. These conditions help minimize stress, injury, and mortality from captivity. ESA-listed natural-origin fish, if inadvertently intercepted and not targeted for broodstock, are released as soon as possible. Handling and transport time are minimized to minimize fish stress. Fish are handled in a way that minimizes handling time (both in and out of water), strain, scale loss, and mucous loss. In transport vessels (e.g., totes, trucks), holding time is minimized and fish density kept low. Fish are released into slow-moving areas where they can acclimate and re-orient. Staff that handle fish are trained and knowledgeable on safe fish handling procedures. Risks to ESA-listed fish at the population scale are typically negligible to minor.

In site-specific Biological Opinions, NMFS ensures that safeguards—including but not limited to those described above—are in place so that adult broodstock collection does not pose an unacceptable risk to natural populations. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the precise effects on natural populations.

Not all populations within a given ESU or DPS may be affected by adult broodstock collection. This is because federal prey program-funded hatchery production will occur in areas with existing hatchery facilities, and some populations exist in areas without hatchery facilities. Thus, only natural populations affected by existing facilities may be affected by the federal prey program. At a population scale, risk from adult broodstock collection may range from negligible to moderately negative depending on a variety of factors, including but not limited to the nature and timing of the collection activities and the proportion of the population exposed to the collection activities. Most populations are likely to incur only negligible or low risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). Moderate risk to a population from adult collection is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. For these reasons, we expect that adult broodstock collection will result in negligible to low negative risk at the ESU and DPS scale.

2.5.1.2.3 Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the estuary and ocean

Natural-origin ESA-listed salmon and steelhead may be exposed to ecological effects—that is, competition, predation, and/or disease—from hatchery-released fish and the progeny of hatchery-origin fish that spawn in the wild. Numerous factors may influence the degree of ecological effects, including but not limited to the degree of spatial and temporal overlap between hatchery- and natural-origin fish, relative sizes of hatchery- and natural-origin fish, and amount of available rearing space and forage resources, among other factors. See Appendix C for a more detailed overview of the factors that influence ecological effects of hatchery-origin fish, and how these factors are considered in NMFS hatchery consultations.

As for competition, generally speaking, competition and a corresponding reduction in productivity and survival may result from direct or indirect interactions between hatchery-origin and natural-origin fish. Direct interactions occur when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish, and indirect interactions occur when the utilization of a limited resource by hatchery fish reduces the amount available for natural-origin fish (Rensel et al. 1984). Natural-origin fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, take up residency before naturally produced fry emerge from redds, and residualize. Hatchery fish might alter natural-origin salmonid behavioral patterns and habitat use, making natural-origin fish more susceptible to predators (Hillman et al. 1989; Steward et al. 1990). Hatchery-origin fish may also alter natural-origin salmonid migratory responses or movement patterns, leading to a decrease in foraging success by the natural-origin fish (Hillman et al. 1989; Steward et al. 1990). Actual impacts on natural-origin fish would thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward et al. 1990).

Predation, for the purposes of considering effects of the federal prey program, occurs when a fish released as part of the federal prey program consumes an ESA-listed natural-origin fish. More broadly, predation may occur in reverse, with natural-origin fish preying on hatchery fish. However, any benefits of ESA-listed fish consuming federal prey program Chinook salmon are likely negligible because juvenile salmon are not generally known to be a primary component of Pacific salmon and steelhead diet. Therefore, only the former (risk of predation from hatchery-origin fish) and its impacts to abundance and productivity of listed species will be discussed further in this section.

Hatchery fish may indirectly have negative or positive effects on predation of natural fish by other predators (e.g., birds, fish, marine mammals) in freshwater and marine habitats. Large concentrations of migrating hatchery fish may attract predators and consequently contribute indirectly to predation of emigrating wild fish (Steward et al. 1990). The presence of large numbers of hatchery fish may also alter natural-origin salmonid behavioral patterns, potentially influencing their vulnerability and susceptibility to predation (Hillman et al. 1989; Kostow 2009). Hatchery fish released into natural-origin fish production areas, or into migration areas during natural-origin fish emigration periods, may therefore pose an elevated, indirect predation risk to commingled listed fish. Alternatively, a mass of hatchery fish migrating through an area may overwhelm established predator populations, providing a beneficial, protective effect to co-occurring natural-origin fish (i.e., predator “buffering” or “swamping”; see definitions section). Newly released hatchery-origin smolts generally exhibit reduced predator avoidance behavior relative to co-occurring natural-origin fish (Flagg et al. 2000). Also, newly released smolts have been found to survive at a reduced rate during downstream migration relative to their natural-origin counterparts (Flagg et al. 2000; Melnychuk et al. 2014). These studies suggest that predator selection for hatchery-origin and natural-origin fish in commingled aggregations is not equal. Rather, the relatively naïve hatchery-origin fish may be preferentially selected in any mixed schools of migrating fish until they acclimate to the natural environment, and hatchery fish may in fact sate (and swamp) potential predators of natural-origin fish, shielding them from avian, mammal, and fish predation.

We recognize that predator buffering (also termed predator swamping) may yield beneficial effects to affected natural populations. However, this mechanism is not well studied, well understood, or predictable. As such, the extent to which it may offset, partially or wholly, negative effects of competition and predation is unknown. Therefore, in the context of this Biological Opinion, we will assume that any beneficial effects of predator buffering are negligible.

2.5.1.2.3.1 Competition and Predation in Freshwater (not including mainstem Columbia and Snake Rivers)

Federal prey program Chinook salmon will be released exclusively within Puget Sound, the Columbia River basin, and the Washington coast. Therefore, competition and predation in freshwater may affect ESA-listed salmon and steelhead from the following Recovery Domains:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

Salmon and steelhead from other Recovery Domains are not expected to occur in the areas described above. Further, federal prey program Chinook salmon are not expected to stray into freshwater areas or areas upstream of river mouths where ESA-listed salmonids from other Recovery Domains occur. Therefore, salmon and steelhead from other Recovery Domains will not be affected by competition and predation in freshwater.

With the exception of the mainstem Columbia and Snake Rivers, competition and predation in freshwater occurs solely at the watershed scale (i.e., they are watershed-scale effects) because they are not detected beyond the watershed that the hatchery operates within. Thus, such effects are considered at a general level here. The exact scope and magnitude of effects to specific affected populations are evaluated in site-specific Biological Opinions. Effects of competition and predation in the mainstem Columbia and Snake Rivers are described and evaluated later in this section.

Specific hazards associated with competitive impacts of hatchery salmonids on listed natural-origin salmonids may include competition for food and rearing sites (Appendix C). Several factors influence the risk of competition posed by hatchery releases: whether competition is intraspecific or interspecific; the duration of freshwater co-occurrence of hatchery and natural-origin fish; relative body sizes of the two groups; prior residence of shared habitat; environmentally induced developmental differences; and density in shared habitat (Tatara et al. 2012). Intraspecific competition would be expected to be greater than interspecific, and competition would be expected to increase with prolonged freshwater co-occurrence. Hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors. However, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitat. Tatara et al. (2012) further reported that hatchery-influenced developmental differences from co-occurring natural-origin fish are variable and can favor both hatchery- and natural-origin fish. They concluded that of all factors, fish density of the composite population in relation to habitat carrying capacity likely exerts the greatest influence.

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

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a period of time in the vicinity of the release point. These non-migratory smolts (residuals) may directly compete for food and space with natural-origin juvenile salmonids of similar age. Although this behavior has been studied and observed, most frequently in the case of hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well. Adverse impacts of residual hatchery Chinook and coho salmon on natural-origin salmonids can occur, especially given that the number of smolts per release is generally higher than steelhead releases; however, the issue of residualism for these species has not been as widely investigated compared to steelhead. Therefore, for all species, monitoring of natural stream areas in the vicinity of hatchery release points may be necessary to determine the potential effects of hatchery smolt residualism on natural-origin juvenile salmonids.

Hatchery programs typically minimize risk associated with competitive interactions between hatchery- and natural-origin fish by:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile naturally produced fish in freshwater (Steward et al. 1990; California HSRG 2012).
- Operating hatcheries such that hatchery fish are reared to a size sufficient to ensure that smoltification occurs in nearly the entire population.
- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing by naturally produced juveniles.
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with naturally rearing juveniles is determined likely.

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

Rensel et al. (1984) rated most risks associated with predation as unknown because there was relatively little documentation in the literature of predation interactions in either freshwater or marine areas at the time. More studies are now available, but they are still too sparse to allow many generalizations to be made about risk. Newly released hatchery-origin yearling salmon and steelhead may prey on juvenile fall Chinook salmon and steelhead and other juvenile salmon in the freshwater and marine environments (Hargreaves et al. 1986; Hawkins et al. 1999; Pearsons et al. 1999). However, predation rates have been reported for released steelhead juveniles as low (Hawkins et al. 1999; Naman et al. 2012). Hatchery steelhead release timing and protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook salmon fry, which had already emigrated or had grown large enough to reduce or eliminate their susceptibility to predation when hatchery steelhead entered the rivers (Sharpe et al. 2008). Hawkins (1998) documented hatchery spring Chinook salmon yearling predation on naturally produced fall Chinook salmon juveniles in the Lewis River. Predation on smaller Chinook salmon was found to be much higher in naturally produced smolts (coho salmon and cutthroat, predominately) than their hatchery counterparts.

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

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

We expect hatchery programs producing Chinook salmon for the federal prey program to minimize risk associated with predation of hatchery-origin fish on natural-origin fish by implementing most or all of the following practices:

- Releasing all hatchery fish as actively migrating smolts through volitional release practices so that the fish migrate quickly seaward, limiting the duration of interaction with any co-occurring natural-origin fish downstream of the release site.
- Ensuring that a high proportion of the population have physiologically achieved full smolt status. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery fish and naturally produced fish present within, and downstream of, release areas.
- Releasing hatchery smolts in lower river areas near river mouths and below upstream areas used for stream-rearing young-of-the-year naturally produced salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.
- Operating hatchery programs and releases to minimize the potential for residualism.

Not all populations within a given ESU or DPS may be affected by competition and predation in freshwater. This is because federal prey program-funded hatchery smolts will be released in areas with existing hatchery facilities, and some populations exist in areas without hatchery facilities. Thus, only natural populations affected by existing programs may be affected by the federal prey program. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the precise effects on natural populations. Risk to individual affected populations is expected to range from negligible to moderate depending on the variables described above. Most populations are likely to incur only negligible or low risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). Moderate risk to a population from competition and predation in freshwater is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. For these reasons, we expect that competition and predation in freshwater will result in negligible to low negative risk at the ESU and DPS scale.

2.5.1.2.3.2 Competition and Predation in the Mainstem Columbia and Snake Rivers

To further elucidate potential ecological effects of the federal prey program to salmon ESUs and steelhead DPSs in the Columbia River basin, we applied PCD Risk model outputs from the 2018 ESA consultation on the *U.S. v. Oregon* Management Agreement (*U.S. v. Oregon*, or Agreement) (NMFS 2018e) to anticipated SRKW federal prey program releases. The *U.S. v. Oregon* Biological Opinion (NMFS 2018e) used the PCD (Predation, Competition, Disease) Risk model (Pearsons et al. 2012) to simulate predation and competition on natural-origin salmon and steelhead juveniles from all of the hatchery-origin juveniles included in the Agreement, from their release sites to the mouth of the Columbia River. This was done to complement the qualitative analysis that was presented to better understand combined competition and predation effects. The analysis evaluated release of hatchery fish from across the Columbia River basin, including up to 69.364 million hatchery Chinook salmon smolts, as well as hatchery releases of coho and sockeye salmon and steelhead trout.

Appendix B in NMFS (2018e), incorporated here by reference, provides a detailed description of the PCD Risk model, the inputs and parameters that were used to model effects of *U.S. v. Oregon* hatchery releases, and caveats to consider in interpreting results. Importantly, the PCD Risk model is not a total simulation of ecological interactions between hatchery and wild fish. Competition is represented in the model as only direct interactions between hatchery- and natural-origin fish; the model does not include potential density-dependent effects from resource depletion, for example. The model does not include predation or competition from non-hatchery fish (salmonids or otherwise) nor from non-fish species such as piscivorous birds or mammals. It also does not account for the possible beneficial effects of juvenile hatchery-origin fish releases, such as providing prey for natural-origin salmon and steelhead or buffering effects from non-hatchery origin predators. Another limitation is that neither species grows during the simulation. In reality, of course, fish growth could greatly change competition dynamics and susceptibility to predation. Finally, and perhaps most relevant, PCD Risk is limited to evaluating interactions between one hatchery-origin species and one natural-origin species under specified conditions in a specified area over a limited time.

The 2018 *U.S. v. Oregon* PCD Risk analysis evaluated large numbers of Chinook salmon hatchery releases from three sub-regions of the Columbia River basin (Upper Columbia River, Snake River, Mid-Columbia River) (Table 78). The SRKW federal prey program is anticipated to release hatchery Chinook salmon in smaller numbers from these same three sub-regions, as well as the Lower Columbia River sub-region. For the present analysis, we scaled the 2018 *U.S. v. Oregon* results for each sub-region to the anticipated available capacity to produce Chinook salmon smolts for SRKW prey from the matching sub-regions (Table 78). For example, *U.S. v. Oregon* Chinook salmon hatchery releases into the Upper Columbia River were modeled to result in 159 natural-origin Chinook salmon Adult Equivalent mortalities[42] (AEs) per 1 million smolts released[43]. The available capacity to produce additional Chinook salmon smolts for SRKW prey in the Upper Columbia River sub-region is estimated to be 2.200 million smolts annually (after accounting for production goal overage of up to 10%). Thus, using the available capacity to produce smolts for SRKW prey is estimated to result in up to 351 AE mortalities to natural-origin Chinook salmon (2.200 million smolts released times 159 AE mortalities per 1 million smolts released). For the Lower Columbia River sub-region, we used model results from the Bonneville-to-river mouth segment of the 2018 *U.S. v. Oregon* Mid-Columbia releases. This was applied to 45.5% of the Lower Columbia River estimated available capacity. We assumed that the balance of 54.5% would be released at or very near the river mouth (e.g., SAFE program), thereby having no ecological effects in freshwater.

[42] Figure represents modeled AE mortalities to all Chinook salmon ESUs combined, from upper Columbia River to mouth.

[43] The *US v. Oregon* Biological Opinion NMFS (2018e) did not use modeled AE mortalities as an absolute indicator of the degree of mortality expected because, as explained in that Opinion, "…outputs from the PCD Risk model should not be considered estimates of the actual predation and competition impact on natural-origin salmon and steelhead from hatchery-origin juveniles because the PCD Risk model is not a total simulation of ecological interactions between hatchery and wild fish." Instead, that Opinion used the model output (AE mortalities) as a relative indicator of which ESUs/DPSs may be more impacted than others. We take the same approach here. The AE mortalities in the example mentioned here are provided only to illustrate how we scaled and applied the *US v. Oregon* modelling results to this Opinion's proposed action.

Table 78. Hatchery Chinook salmon smolt release numbers modeled in PCD Risk for the *U.S. v. Oregon* Biological Opinion (NMFS 2018e), and estimated available capacity for producing Chinook salmon smolts for SRKW prey, by Columbia River basin sub-region.

Columbia River basin sub-region	Annual hatchery Chinook releases, in millions of smolts (% by sub-region of release[a])	
	Modeled release abundance for *U.S. v. OR* Biological Opinion (NMFS 2018e)	Available capacity for producing smolts for SRKW prey
Upper Columbia River	20.830 (30%)	2.200 (20%)
Snake River	20.302 (29%)	0.550 (5%)
Mid-Columbia River	28.232 (41%)	4.983 (46%)
Lower Columbia River	-	3.025 (28%)
TOTAL	**69.364**	**10.758**

[a] Percentages may not add to 100% due to rounding error.

To apportion estimated AE mortalities to individual ESUs and DPSs, the same methodology implemented in NMFS (2018e) was used. Columbia River basin ESUs and DPSs vary greatly in natural spawner abundance (Ford 2022). Thus, a given level of AE mortalities can reasonably be expected to have a greater relative impact on smaller ESUs or DPSs compared to larger ones. To account for this, we calculated a relative index of ecological effects to provide a relative indicator of which ESUs and/or DPSs may be most impacted by SRKW federal prey program hatchery releases. To do this, we first calculated an abundance-based impact metric for each ESU and DPS by dividing each ESU's and DPS's AE mortalities by its 2015–2019 geometric mean natural spawner abundance (Ford 2022). The relative index of ecological effects for each ESU and DPS was then calculated by dividing this abundance-based impact metric for each ESU and DPS by the maximum impact metric score of all ESUs and DPSs. The result is an index that ranges from 0 to 1, with the least affected ESUs and DPSs having the lowest values, and the most affected ESUs and DPSs having the highest values. For example, the abundance-based impact metric score for the Upper Columbia Spring Chinook ESU was 0.053. This was the maximum of all ESUs and DPSs. The relative index of ecological effects for this ESU was therefore 1 (0.053 divided by 0.053), indicating that using all available capacity to produce Chinook salmon smolts for SRKW prey will affect this ESU more than any of the other ESUs or DPSs. Similarly, the abundance-based impact metric score for the Snake River Fall Chinook ESU was 0.002. It's relative index of ecological effects was then 0.042 (0.002 divided by 0.053), indicating that using all available capacity to produce Chinook salmon smolts for SRKW prey will affect this ESU substantially less than the Upper Columbia Spring Chinook ESU.

This relative index of ecological effects indicated that the Upper Columbia Spring Chinook ESU, Upper Columbia Steelhead DPS, Lower Columbia River Coho ESU, and Snake River Spring/Summer Chinook ESU, in that order, would be most impacted by using all available capacity to produce Chinook salmon smolts for SRKW prey (Figure 79). An index score was not calculated for Snake River sockeye salmon because the model, given its limitations, was not expected to yield reliable results due to this ESUs extremely low abundance. Snake River sockeye salmon rear in lakes far upstream from hatchery facilities, and outmigrate as yearlings or older. Therefore, no predation from hatchery Chinook salmon is expected on Snake River sockeye salmon for the following reasons: 1) hatchery Chinook salmon do not overlap with Snake River sockeye salmon when the latter are small juveniles rearing in lakes; and, 2) outmigrating Snake River sockeye salmon smolts are too large to be consumed by hatchery Chinook salmon when they overlap in time and space. Competition effects would be limited to the smolt outmigration period when Snake River sockeye salmon overlap with hatchery Chinook salmon. Competition effects may be similar to those for coho and steelhead given that these species also outmigrate at a large size.

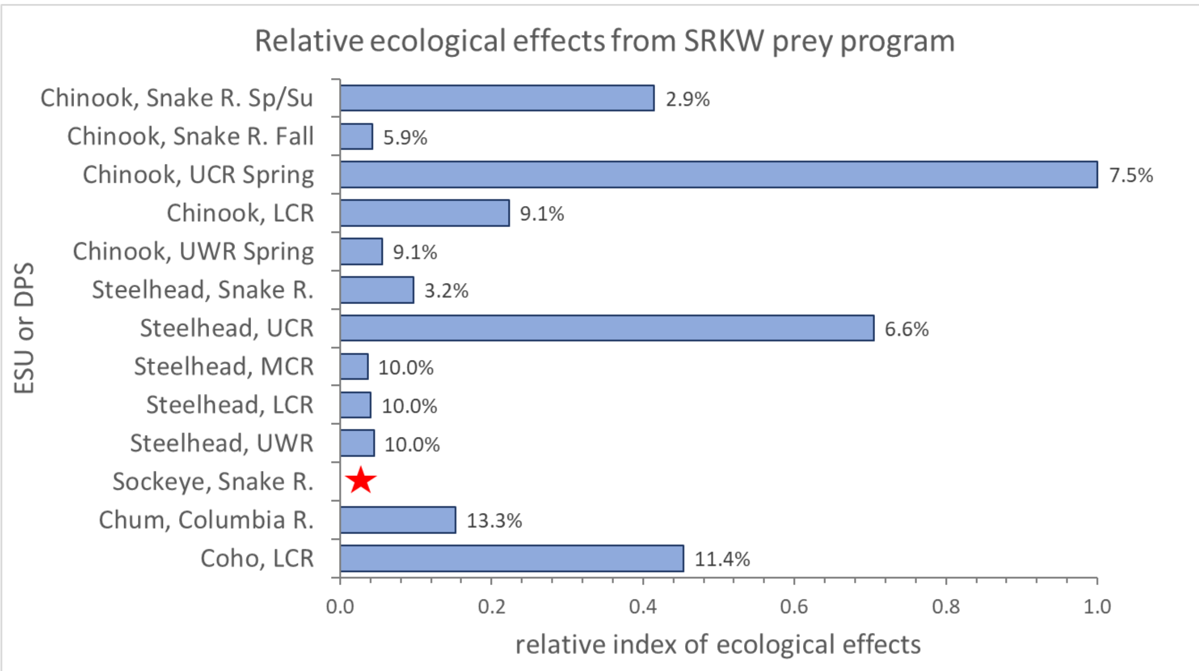


Figure 79. Modeled relative effects of competition and predation from using all available capacity to produce Chinook salmon smolts for SRKW prey to Columbia River basin ESUs and DPSs in freshwater (release to Columbia River mouth). Higher index scores indicate greater effects. See text for methods used in calculating the relative index of ecological effects. Percentages next to each bar represent increase in effects relative to those determined for hatchery releases associated with the 2018–2027 *U.S. v. Oregon* agreement (NMFS 2018e). An index score was not calculated for Snake River sockeye salmon; the model was not expected to yield reliable results because of this ESUs extremely low abundance (see text for additional explanation).

It is informative to consider potential SRKW prey production impacts relative to those from the *U.S. v. Oregon* hatchery releases given that the latter make up a large proportion of hatchery releases across the Columbia River basin. To do this, we calculated abundance-based impact metrics for *U.S. v. Oregon* hatchery releases by dividing the ESU- and DPS-specific *U.S. v. Oregon* AE mortalities reported in NMFS (2018e) by their 2015–2019 geometric mean natural spawner abundances (Ford 2022). We then added these to the SRKW prey production abundance-based impact metrics, and calculated the percent increase in the impact metric scores represented by using all available capacity to produce Chinook salmon smolts for SRKW prey. By this measure, using all available capacity to produce Chinook salmon smolts for SRKW prey would increase effects by 2.9–13.3% relative to those estimated for *U.S. v. Oregon* hatchery releases, depending on ESU and DPS (Figure 79). Using all available capacity to produce Chinook salmon smolts for SRKW prey would increase effects by 7.5% and 6.6% for the Upper Columbia Spring Chinook ESU and Upper Columbia Steelhead DPS, respectively, the two ESUs/DPSs most affected by the SRKW program. The Columbia River basin capacity-based SRKW prey production evaluated here—10.758 million smolts—represents a 15.5% increase relative to modeled *U.S. v. Oregon* Chinook salmon smolt releases. Increases in estimated impacts are in most cases much less than this likely because available capacity is skewed toward the middle and lower parts of the basin relative to *U.S. v. Oregon* releases (Table 78).

As discussed in more detail in Appendix B in NMFS (2018e), outputs from the PCD Risk model should not be considered estimates of the actual predation and competition impact on natural-origin salmon and steelhead from hatchery-origin juveniles because the PCD Risk model is not a total simulation of ecological interactions between hatchery and wild fish. Nonetheless, the simulations are useful in that they give an example of the magnitude of interactions that could occur under a certain set of assumptions.

2.5.1.2.3.3 Competition and Predation in Salish Sea Natal Inner Estuaries

Effects of competition and predation in Puget Sound natal inner estuaries (tidal deltas) operate at localized scales. That is, hatchery fish in these areas are primarily or exclusively from hatcheries within the corresponding river basin (Beamer et al. 2016; Hayes et al. 2019). Thus, competition and predation in Salish Sea natal inner estuaries are evaluated at a general level here. The exact scope and magnitude of effects to specific affected populations is evaluated in site-specific Biological Opinions.

Puget Sound steelhead, upon exiting freshwater, migrate rapidly through marine waters of the Salish Sea, making little to no use of natal inner estuaries (Pearsall et al. 2021, and references therein). The proposed action thus presents a negligible risk to Puget Sound steelhead from competition and predation in Salish Sea natal inner estuaries.

Subyearling Puget Sound Chinook salmon make extensive use of natal inner estuaries until they are about 70–75 mm FL, at which point they disperse to other habitats (e.g., outer estuary, epipelagic, intertidal nearshore) (Healey 1980; Greene et al. 2021). Hatchery subyearling Chinook salmon are typically released at a larger size (i.e., greater than 70–75 mm FL), and thus would be expected to make little use of and have short residence times in natal inner estuary habitat. In addition, hatchery Chinook salmon are often released later in the year after many natural Chinook salmon have left natal inner estuary habitats for other areas. Many Puget Sound river estuaries are substantially diminished in size and habitat quality as a result of historical diking and other forms of degradation (see Section 2.4.1, Environmental Baseline). Thus, even moderate release abundances of hatchery fish may have negative effects in natal inner estuary areas, though these effects would be tempered by the limited residence time and limited temporal overlap of hatchery fish in these areas.

Greene et al. (2021) evaluated the potential for density-dependence in the inner estuaries (tidal deltas) of four large Puget Sound rivers (Nisqually, Nooksack, Skagit, and Snohomish Rivers). Subyearling Chinook salmon make extensive use of natal inner estuaries until they are about 70–75 mm FL, at which point they disperse to other habitats (e.g., outer estuary, epipelagic, intertidal nearshore) (Healey 1980; Greene et al. 2021). One part of the study examined 6–22 years (depending on river) of data on juvenile Chinook salmon outmigration abundance (stock) and their densities in inner estuary habitat (recruit) at fine spatiotemporal scales. Results showed that exceedances of estimated capacity were driven almost entirely by natural-origin fish in three of the river deltas examined, though there was substantial variability in the data used to estimate capacity. Hatchery fish were a minor to nearly non-existent contributor to exceedances of estimated capacity. Another part of the study evaluated bioenergetic demand of juvenile Chinook salmon in these habitats relative to prey availability during one year (2014). In general, forage resources did not appear to be limiting during times when hatchery fish were present in more than minor proportions.

In regards to Hood Canal summer chum salmon, competition risk from hatchery Chinook salmon may be low to moderate depending on release size and timing. Both chum salmon and subyearling Chinook salmon make extensive use of natal inner estuaries. Subyearling Chinook salmon make extensive use of these areas until they are about 70–75 mm FL, at which point they disperse to other habitats (e.g., outer estuary, epipelagic, intertidal nearshore) (Healey 1980; Greene et al. 2021). Hatchery subyearling Chinook salmon are typically released at a larger size (i.e., greater than 70–75 mm FL), and thus would be expected to make little use of and have short residence times in natal inner estuary habitat. Further, Hood Canal summer chum salmon outmigrate to estuaries early in the year, allowing them several weeks to grow and complete the estuary-reliant part of their life history prior to hatchery Chinook salmon releases, which help to minimize effects. Many Puget Sound river estuaries are substantially diminished in size and habitat quality as a result of historical diking and other forms of degradation (see Section 2.4, Environmental Baseline). Thus, even moderate release abundances of hatchery fish may have negative effects in natal inner estuary areas, though these effects would be tempered by the limited residence time and limited temporal overlap of hatchery fish in these areas.

Juvenile salmonids may comprise an extremely small proportion of juvenile Chinook salmon diets in Salish Sea estuaries (e.g., Duffy et al. 2010). Because of this, and the very limited use of natal inner estuaries by hatchery-origin Chinook salmon, predation risk to both Puget Sound Chinook Salmon and Hood Canal summer chum salmon is considered low.

Federal prey program hatchery releases may occur throughout the Puget Sound. The degree of risk to individual ESA-listed populations in natal inner estuary areas will vary depending on many factors, including but not limited to the following: the abundance of the affected population(s); the abundance, body size, and timing of hatchery fish released within the watershed; and, the quantity and quality of inner estuary habitat available. Because the proposed action is programmatic in nature, we cannot identify the exact natal inner estuaries or populations that will be affected, nor the exact scope and magnitude of effects. NMFS evaluates these population-level effects in detail in site-specific ESA consultations, which are required for programs to be eligible to use SRKW prey program funds.

For the reasons described above, we expect that risk from competition and predation in Salish Sea natal inner estuaries may range from negligible to moderate for affected populations of Puget Sound Chinook salmon and Hood Canal summer chum. Moderate risk to a population from competition and predation in natal inner estuaries is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. At the ESU scale[44], risk will be negligible to low because not all populations (Chinook salmon) or spawning aggregation (chum salmon) will be affected, and because few, if any, populations (Chinook salmon) or spawning aggregations (chum salmon) are anticipated to be exposed to moderate risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). That is, release abundances and release size and timing of hatchery fish are expected to keep risk at negligible or low levels in most affected areas by minimizing hatchery fish presence and spatiotemporal overlap with natural fish. For Puget Sound steelhead, risk to affected populations and the DPS as a whole will be negligible.

2.5.1.2.3.4 Competition and Predation in Marine Areas of the Salish Sea & the Columbia River Estuary

Federal prey program Chinook salmon are expected to distribute across the Salish Sea and the Columbia River estuary. Based on this distribution, we expect that competition and predation in these marine areas may affect ESA-listed salmon and steelhead from the following Recovery Domains and ESUs/DPSs:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs

Salmon and steelhead from Recovery Domains or ESUs/DPSs not listed above are not expected to occur in marine areas of the Salish Sea & the Columbia River estuary.

Regarding predation, adult, immature, and large juvenile Chinook salmon in marine waters feed heavily on fish, particularly forage fish, and are large enough to prey on younger juvenile

[44] Risk at the ESU scale means risk to the ESU as a whole considering all affected populations, including the degree of risk presented to them and their conservation importance.

salmonids (Riddell et al. 2018, and references therein). However, there is substantial available information showing that predation on juvenile salmonids by Chinook salmon in marine waters is rare. Many diet studies of adult, immature, and large juvenile Chinook salmon in marine waters only identify specific taxa that made up more than about 1–5% of the Chinook's diet (i.e., "common" prey taxa), and do not mention specific taxa that were consumed at lower levels (e.g., Silliman 1941; Beacham 1986; Brodeur et al. 2007; Daly et al. 2009; Daly et al. 2012; Brodeur et al. 2014; Thayer et al. 2014; Hertz et al. 2015; Osgood et al. 2016; Daly et al. 2017; Hertz et al. 2017). Juvenile salmonids are not identified as common prey taxa in these studies. Of studies that have identified all consumed taxa regardless of their prevalence in the diet, the substantial majority have found no juvenile salmonids in Chinook salmon stomach contents (e.g., Reid 1961; Prakash 1962; Wing 1985; Brodeur et al. 1987; Brodeur et al. 1990; Landingham et al. 1998; Hunt et al. 1999; Kaeriyama et al. 2004; Weitkamp et al. 2008; Daly et al. 2019; Beauchamp et al. 2020; Chamberlin 2021; Weitkamp et al. 2022). Where juvenile salmonids have been consumed (Fresh et al. 1981; Duffy et al. 2010; Sturdevant et al. 2012), they have been a rare component of the diet, and they have been consumed almost exclusively at times and in places where large densities of juvenile salmonids are present (i.e., in Puget Sound and near the mouth of the Columbia River during early summer after large pulses of hatchery-origin fish have entered these areas). Outside of these areas, we are aware of only one survey that found juvenile salmonid predation by Chinook salmon: one salmonid individual (unidentified species) was consumed among 490 immature and adult Chinook salmon sampled in southeast Alaska coastal and inner waters from 1997 to 2011 (Sturdevant et al. 2012). These findings indicate that predation by Chinook salmon on salmonids in marine waters is exceedingly rare, particularly outside of times and places where large densities of recent marine-entrant juveniles are present.

Hatchery-origin Chinook salmon that remain in Puget Sound as residents (or transients) may prey upon juvenile salmonids. However, recent sampling efforts have found that resident Chinook salmon prey largely on forage fish (especially herring and to some extent sand lance), amphipods, and larval crab (Beauchamp et al. 2020; Chamberlin 2021). Beauchamp et al. (2020) found no salmonids in the stomachs of resident Chinook salmon (n=232) sampled in Puget Sound during May–September, 2018–2019. Similarly, Chamberlin (2021) found no juvenile Chinook salmon or steelhead in the stomachs of resident Chinook salmon (n=419) sampled in Puget Sound during November–April, 2015–2019. Conversely, previous sampling efforts (Duffy et al. 2010; Beauchamp et al. 2011) found some instances of cannibalism by resident Chinook salmon in Puget Sound. These researchers initially estimated that predation rates on juvenile Chinook salmon could be quite high based on these data. However, the later work (i.e., Beauchamp et al. 2020) noted that "…the limited sample sizes, suboptimal timing and temporal resolution of sampling the predators' diets infused considerable uncertainty into the [2011] predation estimates." The Beauchamp et al. (2020) study was performed in a more rigorous manner to address these shortcomings.

For the reasons discussed herewith in this section, we expect very low levels of predation on some ESA-listed salmonids in Puget Sound (estuaries and offshore areas), and in the Columbia River estuary.

Salish Sea Marine Areas

This subsection considers competition effects in marine areas of the Salish Sea, not including natal inner estuaries (effects in natal inner estuaries are discussed in a separate subsection above).

Competition among Puget Sound Chinook salmon in Puget Sound marine areas has been investigated perhaps more so than anywhere else. For Chinook salmon, the time spent rearing in Puget Sound is one of the most critical periods impacting their fitness and survival (Greene et al. 2005; Sobocinski et al. 2020; Pearsall et al. 2021). However, assessment of the effects of hatchery fish on natural-origin Chinook salmon in Puget Sound marine areas is problematic because relevant scientific knowledge is incomplete, albeit rapidly evolving (Pearsall et al. 2021). In their 2021 comprehensive review of the available science, the Synthesis Committee of the Salish Sea Marine Survival Project[45] (SCSSMSP) noted that the following factors appear to be most influential to Chinook mortality in Puget Sound: predator abundance (particularly seals), contaminants, water quality, prey availability, and growth during the early marine "critical period" (Pearsall et al. 2021). With regards to effects from hatchery fish, competitive interactions that negatively affect natural Chinook salmon (e.g., depleting prey resources and negatively impacting growth) are of particular concern. The SCSSMPS concluded that: 1) there is some evidence that intra- and inter-specific competition during some time periods and in some places of the Salish Sea impacts Chinook salmon marine survival; 2) study results are mixed; and, 3) if competition does occur, it is most likely dictated by factors other than Chinook abundance that deplete or limit prey availability or habitat (e.g., dynamic environmental variables, ecosystem productivity, and food web interactions involving natural-origin species such as pink salmon, herring, and crab) (Pearsall et al. 2021). Therefore, hatchery releases could exacerbate density-dependent effects during years of low productivity in Puget Sound.

Sobocinski et al. (2021) evaluated the influence of a wide array of variables and groupings of variables (e.g., density-dependence, predator buffering, water quality) on smolt-to-adult return rate (SAR) of 25 Puget Sound subyearling and yearling Chinook salmon hatchery stocks for ocean entry years 1975–2012. Chinook and coho salmon hatchery release abundances and release dates were included among the variables evaluated. Models performed poorly for Chinook salmon released as yearlings. For subyearling releases, SAR was best explained by three regional-scale (Salish Sea) variables: sea surface temperature (positive), hatchery coho salmon release date (negative), and seal abundance (negative). The best performing models only explained about 30% of the variability in SAR, suggesting that variables other than the ones considered were more important, or the data used to represent the evaluated variables were

[45] The Salish Sea Marine Survival Project, launched in 2013, describes itself as follows (Pearsall et al. 2021): "[The Salish Sea Marine Survival Project is] a US-Canada research collaboration to identify the primary factors affecting the survival of juvenile Chinook, Coho, and steelhead in the Salish Sea marine environment. From 2014–2018, this international collaborative of over 60 federal, state, tribal, nonprofit, academic, and private entities implemented a coordinated research effort that encompassed all major hypothesized impacts on Chinook, Coho, and steelhead as they entered and transited the Salish Sea. Ultimately, several hundred scientists collaborated to implement over 90 studies…[The Synthesis Report (i.e., Pearsall et al. (2021)] synthesizes the work to date and provides [the Synthesis Committee's] perspectives regarding the primary factors affecting survival and the next steps in research and management."

flawed. None of the best performing models included hatchery Chinook (or coho) release abundance, pink salmon abundance in Puget Sound, or ocean salmon abundance (pink, chum, and sockeye only). Release date of hatchery Chinook (and coho) salmon had a weak effect on survival of hatchery-origin Chinook salmon.

Sobocinski et al. (2021) also evaluated density-dependent indicators in isolation from other groupings of indicators (e.g., predator buffering, water quality). Ocean salmon abundance (pink, chum, and sockeye only) was one of the two strongest predictors of Chinook SAR, the other being Salish Sea sea surface temperature. A weak positive relationship was observed with yearling hatchery Chinook abundance, suggesting possible predator buffering effects even though predator buffering wasn't specifically assessed in this part of the analysis. A weak and variable relationship was observed with subyearling hatchery Chinook abundance, whereby SAR increased with increasing hatchery Chinook abundance to a point, then declined as hatchery Chinook abundance increased further. This relationship was only about one-fifth as strong as the strongest density-dependent metrics (sea surface temperature and ocean salmon abundance) and was absent from the 7 best performing density-dependence models. The best performing density-dependence models explained no more than 24% of the variation in Chinook SAR.

Kendall et al. (2020) evaluated the influence of pink salmon presence and hatchery Chinook salmon abundance, among a few other variables, on survival (smolt to ocean age 1) of 33 Salish Sea yearling and subyearling Chinook salmon hatchery stocks for ocean entry years 1983–2012[46]. The best performing model explained 41% of the variation in survival. There was a strong relationship observed between survival and region of origin (e.g., northern Washington, south Puget Sound). The interaction of pink salmon presence and hatchery Chinook salmon abundance had significant explanatory power. That is, in even-numbered years (pink salmon present), hatchery Chinook salmon survival from some regions decreased with increasing release abundances, suggesting that pink salmon were mediating ecosystem dynamics and triggering negative density-dependent interactions in hatchery Chinook salmon. Conversely, in odd-numbered years (pink salmon absent), hatchery Chinook salmon survival in some regions increased with increasing release abundances, suggesting possible predator buffering effects. Hatchery-released fry, which have extremely high mortality immediately after release, were a substantial proportion of the hatchery fish included in the early part of the time series, potentially biasing results and leading to spurious findings.

Ruggerone et al. (2004) evaluated influence of the even-odd year pink salmon cycle for its influence on smolt-to-adult survival (SAR) of 22 hatchery Chinook salmon populations from the Salish Sea and Washington coast for hatchery release years 1972–1997. During the latter part of the time series (1984–1997), pink salmon presence (even-numbered years) was associated with lower Chinook salmon growth during early marine residence, delayed maturity, and lower survival (SAR) in Salish Sea Chinook salmon stocks. This suggested that pink salmon were mediating ecosystem food-web dynamics and triggering negative density-dependent interactions in hatchery Chinook salmon during their first ocean year. However, during the early part of the time series (1972–1983), Chinook salmon survival was greater during years of pink salmon presence, suggesting predator buffering effects. The authors provide evidence of an El Niño-

[46] Data for most stocks did not encompass this entire time span.

based "regime shift" that occurred around 1982–1983, whereby abundances of many predators shifted in Puget Sound, altering the influence of pink salmon within the ecosystem generally, and on hatchery Chinook salmon specifically. The Salish Sea hatchery populations included in the study were, with only one exception, Green River-derivative. Thus, the findings may not be broadly applicable to other Salish Sea natural- or hatchery-origin populations.

Losee et al. (2019) evaluated changes in adult body size, abundance, and survival (SAR) of Puget Sound salmon and steelhead from 1970 to 2015. Correlations between species and origin (hatchery or natural) were evaluated, though correlations were reported in a color-coded format making it difficult to interpret in the strength of the correlation in many cases. In addition, statistical significance of correlations were not provided for most pairings. In evaluating the relationship between hatchery- and natural-origin Chinook salmon, weak negative correlations were observed in both abundance and survival (statistical significance was not reported). Pink and natural-origin Chinook salmon abundance was strongly negatively correlated ($p < 0.0.5$), but survival was positively correlated (weak to moderate). Conversely, for both abundance and survival, pink and hatchery-origin Chinook salmon were positively correlated either weakly (survival) or weak to moderately (abundance).

Claiborne et al. (2021) evaluated the influence of pink salmon abundance in Puget Sound on early marine growth and survival of three Puget Sound natural fall Chinook salmon populations from 7 outmigration years with contrasting survival rates. There was a moderate to strong correlation observed between early marine growth and survival in all three populations (Pearson Correlation Coefficients, $r = 0.60, 0.89, 0.96$). There was a strong negative correlation between growth and Puget Sound pink salmon abundance in one population ($r = -0.89$), and a weak negative correlation in the other two ($r = -0.29, -0.33$).

Nelson et al. (2019a) evaluated the influence of seal density and hatchery Chinook salmon abundance on productivity (spawner to ocean age 2) of 20 Salish Sea and Washington coast naturally-spawning Chinook salmon stocks for brood years 1972–2008[47]. The best models explained 67–69% of the variation in productivity, the substantial majority of which was explained by seal density. They found little evidence of any wide-spread negative relationships between regional-scale hatchery Chinook release abundances and natural-origin productivity, concluding that "…effects of hatchery abundance on wild stock productivity were mixed and weak in most populations...." One stock (Stillaguamish) showed a positive relationship between hatchery release abundance and natural stock productivity, perhaps due to predator swamping effects. In contrast, seal density was found to have a strong negative influence on productivity in 14 of the 20 stocks evaluated.

By not accounting for pink salmon, it is possible that effects of hatchery release abundances were obscured in the Nelson et al. (2019a) study. However, it is also possible that hatchery release abundances are more negatively influential on survival of hatchery-, but not natural-origin fish. Relative to natural-origin Chinook salmon, hatchery Chinook salmon enter Puget Sound over a condensed time period, at a larger fish size, and with less fish size variability (Nelson et al.

[47] Data for most stocks did not encompass this entire time span.

2019b). Thus, intra-specific competitive effects on survival may be more acute among hatchery-origin fish themselves.

Greene et al. (2023) evaluated the influence of prey availability and foraging demand of 12 prominent planktivorous taxa on subyearling natural- and hatchery-origin Chinook salmon in Puget Sound epipelagic waters during June–August, a time when both: 1) most juvenile Chinook salmon have entered these areas from nearshore and estuary habitat and forage heavily on zooplankton; and, 2) juvenile Chinook salmon grow very rapidly. One part of the study (spatially extensive) evaluated effects on Chinook salmon growth (as measured by IGF-1[48]) across Puget Sound in 2011. Another part of the study (temporally extensive) evaluated effects on Chinook salmon estimated growth (represented by monthly size change) within one focal area (Skagit Bay) during 2014–2021. A third part of the study evaluated effects of estimated total annual foraging demand by epipelagic planktivores during 2001–2017 on survival (SAR) of Skagit River natural Chinook salmon. Results showed that hatchery- and natural-origin Chinook salmon generally placed a relatively low demand on forage resources compared to other consumers, such as stickleback, herring, and chum salmon. The authors further found that forage resources were generally sufficient to support demand in 8 of the 9 years evaluated. Evaluation of the 17-year SAR time series indicated a weak correlation of SAR with total estimated foraging demand[49] by all planktivores (Pearson $r = 0.386$), and no correlation with either natural (unmarked) juvenile Chinook salmon density (Pearson $r = 0.017$) or total juvenile Chinook salmon density (Pearson $r = 0.052$).

Davis et al. (2020) sampled IGF-1 from juvenile Chinook salmon in nearshore and pelagic areas across Puget Sound during June–August, 2014–2015, two of the years that Greene et al. (2023) found no evidence of forage limitations. These years, 2015 and 2014, had the second and fourth lowest estimated foraging demand, respectively, and highest and fifth highest SAR, respectively, in the 17-year SAR time series evaluated by Greene et al. (2023). IGF-1 was about 45–50 ng/mL for 101–125 mm FL fish in pelagic areas during these years (Davis et al. 2020). In contrast, the one year that Greene et al. (2023) observed likely forage resource limitations (2011), juvenile Chinook salmon experienced lower growth during the June–August time period than in 2014–2015: in 2011, IGF-1 was 32–45 ng/mL for comparable size fish in comparable areas, with some exceptions (Chamberlin et al. 2017). The year 2011 had the third largest estimated foraging demand and was one of two years with the lowest SARs in the 17-year time series evaluated by Greene et al. (2023).

Rice et al. (2011) evaluated the influence of location (Puget Sound sub-basins) and juvenile Chinook salmon density (hatchery- and natural-origin) on their growth (represented by residual fish lengths) in Puget Sound epipelagic waters adjacent to shore from April to November, 2003. Models that included sub-basin effects and any one of three juvenile Chinook salmon density metrics (hatchery-origin only, natural-origin only, hatchery- plus natural-origin combined) explained 51–54% of the variation in natural Chinook salmon growth. A model that included only sub-basin effects without the Chinook salmon density metrics explained 36% of the

[48] IGF-1 is plasma concentration of insulin-like growth factor 1. It provides a measure of growth during the 2 weeks prior to sampling.
[49] Greene et al. (2023) used the term “predation pressure” rather than “foraging demand.”

variation. Thus, sub-basin appeared to be the dominant factor, with the various metrics of Chinook salmon density explaining an additional 15–18% of the variation in growth. Interestingly, the one year (2003) evaluated by Rice et al. (2011) had the second largest estimated foraging demand by pelagic planktivores of the 17-year time series evaluated by Greene et al. (2023). The third largest was 2011, the only year of the 9 years evaluated by Greene et al. (2023) that showed evidence of limited pelagic foraging resources with concomitant negative consequences to Chinook salmon growth. Thus, in the context of observations by Greene et al. (2023), it appears that Rice et al. (2011) sampled during a year when competition for foraging resources among the epipelagic planktivore community was particularly intense, and that the observed density-dependent effects, though relatively minor, were uncommonly large.

The above evidence suggests that intra- and inter-specific competition occurs at some times and in some places of Puget Sound marine waters. To the extent that competition does occur, hatchery Chinook salmon abundance does not appear to be a primary driver. Rather, ocean conditions and abundance of other species (e.g., pink salmon) are the dominant factors influencing forage availability and competitive effects. In years of high competitor abundance and/or unfavorable ocean conditions, forage resources for salmonids may become limited. Though it is possible that this may trigger negative density-dependent inter- and intra-specific competition among salmon species that utilize similar habitats and forage resources, effects are likely small relative to those from other non-salmonid competitors.

In regards to hatchery Chinook salmon in particular, their competitive effects to natural-origin ESA-listed salmonids in Puget Sound are indirect in nature (i.e., indirect competition[50]); that is, consumption of prey by hatchery Chinook salmon makes less prey available to other organisms. Such competitive effects thus occur specifically via effects to the pool of prey resources available to all individuals of species that eat the same prey types in the same areas at the same times, broadly speaking. Thus, the degree of competitive effects to natural-origin ESA-listed species is dictated by the amount of prey that hatchery Chinook salmon consume relative to the total amount of prey available. For example, under occasional conditions when resources are limiting (i.e., low marine productivity and/or high abundance of competitors other than Chinook salmon), if hatchery Chinook salmon consume 1% of all prey available, the effect to natural-origin ESA-listed salmonids is correspondingly small. As described above, the pool of prey resources in the action area supports large abundances of individuals of species other than natural- and hatchery-origin Chinook salmon. In fact, as described above, hatchery- and natural-origin Chinook salmon comprise a small proportion of consumers within Puget Sound. Because of this, competitive effects of hatchery-origin Chinook salmon to natural-origin ESA-listed fish in Puget Sound are likely to be small.

Available knowledge and research abilities are insufficient, at the present time, to discern the precise contribution of hatchery Chinook salmon to any density-dependent interactions affecting salmonid growth and survival in the Salish Sea. Our review of the relevant scientific literature described above leads us to conclude that the influence of density-dependent interactions on

[50] Indirect competition is in contrast to direct competition, whereby one individual physically interferes with the ability of another individual to consume prey (Rensel et al. 1984).

growth and survival is likely very small compared with the effects of large scale and regional environmental conditions. The evidence described above indicates that salmonid survival and size may be reduced during years of limited food supply, but that hatchery Chinook salmon are not a primary driver of nor substantial contributor to these effects. Federal prey program Chinook salmon could exacerbate density-dependent effects in the Salish Sea during years of low marine productivity and/or high competitor abundance. However, there are no studies that demonstrate or suggest the magnitude of hatchery salmon smolt release numbers that might be associated with adverse changes in natural salmonid population survival rates in marine areas. For the reasons discussed in this section, we expect competitive interactions from federal prey program hatchery-released Chinook salmon to have a small effect on the survival of ESA-listed natural-origin Chinook and summer chum salmon in the Salish Sea during years of low marine productivity and/or high abundance of other competitor species (e.g., pink salmon). During years when marine productivity is closer to or higher than average and/or abundance of other competitor species is lower, we expect any competitive interactions from federal prey program hatchery Chinook salmon to be negligible.

The federal prey program may result in up to 15.125 million Puget Sound hatchery Chinook salmon smolts released on average annually (14.405 million smolt total production goal with 5% overage). This represents an approximate 34–37% increase in hatchery smolt production over recent averages (depending on specific time periods compared), exclusive of federal prey program-funded production. This increased smolt production is expected to yield an increase in average abundance of 3- to 5-year-old Chinook salmon in Puget Sound of up to 1.7% during the summer months and up to 7.2% averaged across all seasons relative to the 2009–2018 time period (Table 79 and Appendix A). Risk to ESA-listed natural Chinook salmon in Puget Sound marine waters may thus increase accordingly. However, based on the evidence described above, the increased risk is likely to be greatest during years of low marine productivity and/or high abundance of other competitor species (e.g., pink salmon) because these are the times when food is most likely to be scarce[51] Greene et al. (2023) observed that forage resources were adequate to support epipelagic fish planktivores in most years, including pink salmon years. Greene et al. (2023) further indicated that Chinook salmon are a relatively minor component of the planktivorous epipelagic fish community, though fish prey—which become more important to juvenile Chinook salmon as they grow larger—were not evaluated. Nonetheless, the weight of evidence suggests that at recent historical hatchery release abundances, negative competitive interactions are minimal and driven by marine environmental conditions and other competitors. When these minimal effects occur, the federal prey program may exacerbate them. Federal prey program effects will cease approximately five years after the last release of fish produced with program funding.

[51] Negative density-dependence occurs when there is not enough food to support the number of individuals present, thereby reducing their growth and survival. The amount of food available to salmonids in marine environments is influenced by both ecosystem productivity and competitor abundance, both of which are variable and often fluctuate annually. Low marine productivity means that less biomass, and thus less food, is being produced by the marine ecosystem compared to average conditions. Larger-than-average numbers of competitors may consume large quantities of forage reesources, leaving less food available for salmon. When ecosystem productivity is not low and/or when competitor abundance is not high, negative density-dependence is less likely because more food is available.

Puget Sound steelhead populations experience extremely high mortality during their short residence in Puget Sound (Moore et al. 2010; Moore et al. 2015), much more so than during their time in the Pacific Ocean (Kendall et al. 2017; Sobocinski et al. 2020). There is strong evidence that predation—particularly though not exclusively by harbor seals—is the most dominant cause of mortality (PSSMSW 2018, and references therein; Sobocinski et al. 2020; Pearsall et al. 2021). Though recent reviews and investigations do not rule out ecological interactions from hatchery fish as one potential source of reduced fitness and mortality, they do indicate that any such causes are probably minor. This is likely due to the fast transit time of juvenile Puget Sound steelhead through the marine waters of Puget Sound and the Strait of Juan de Fuca, on the order of 6–12 days (Moore et al. 2010; Moore et al. 2015). The Synthesis Committee of the Salish Sea Marine Survival Project[52] (SCSSMSP) recently concluded that competition (intra- and inter-specific) and foraging opportunities are likely not factors or not very important for steelhead survival in Puget Sound (Pearsall et al. 2021).

Sobocinski et al. (2020) evaluated effects from Chinook salmon hatchery practices and a variety of other potential drivers of Puget Sound steelhead marine survival over a recent 30-year time series. The authors found a positive correlation between steelhead marine survival and hatchery Chinook salmon abundance in Puget Sound, suggesting that ecological interactions from hatchery Chinook salmon were at the very least not detrimental, and potentially beneficial to steelhead trout. Similarly, Malick et al. (2022) observed that hatchery Chinook salmon releases into south and middle Puget Sound watersheds did not affect early marine mortality of juvenile steelhead trout from the Nisqually River, a south Puget Sound watershed.

Juvenile steelhead in Puget Sound are too large to be preyed upon by hatchery-released Chinook salmon, except for those that may remain as residents or transients in Puget Sound. However, Beauchamp et al. (2020) found no steelhead trout in the stomachs of resident Chinook salmon (n=232) sampled in Puget Sound during May–September, 2018–2019. Similarly, Chamberlin (2021) found no steelhead trout in the stomachs of resident Chinook salmon (n=419) sampled in Puget Sound during November–April, 2015–2019. These results suggest that resident hatchery-origin Chinook salmon present a low risk of predation to steelhead trout.

Regarding Hood Canal summer chum salmon, both juvenile Chinook (subyearling) and chum salmon may comprise a large proportion of the planktivore fish community in Hood Canal during May (Greene et al. 2023). By this time, many Hood Canal summer chum salmon have likely outmigrated from Hood Canal to Admiralty Inlet or beyond. Greene et al. (2023) indicated that forage resources in Hood Canal may have been limiting to both species in 2011, when primary productivity and forage resources were low across Puget Sound. Within that same year,

[52] The Salish Sea Marine Survival Project, launched in 2013, describes itself as follows (Pearsall et al. 2021): "[The Salish Sea Marine Survival Project is] a US-Canada research collaboration to identify the primary factors affecting the survival of juvenile Chinook, Coho, and steelhead in the Salish Sea marine environment. From 2014–2018, this international collaborative of over 60 federal, state, tribal, nonprofit, academic, and private entities implemented a coordinated research effort that encompassed all major hypothesized impacts on Chinook, Coho, and steelhead as they entered and transited the Salish Sea. Ultimately, several hundred scientists collaborated to implement over 90 studies…[The Synthesis Report (i.e., Pearsall et al. (2021)] synthesizes the work to date and provides [the Synthesis Committee's] perspectives regarding the primary factors affecting survival and the next steps in research and management."

Admiralty Inlet, where Hood Canal summer chum and hatchery Chinook salmon may also overlap, showed a lower degree of potential forage resource limitations. Better productivity and little to no evidence of forage resource limitations were observed during eight other years evaluated (2014–2021), indicating that marine ecological interactions between the species may occur infrequently. Though Hood Canal was not a part of the study area in these years, conditions in Hood Canal were likely similar given that productivity across Puget Sound is generally driven by broad-scale factors such as climate and sea surface temperature. Based on the relative infrequence of low-productivity years and the somewhat limited temporal overlap in Hood Canal, we conclude that hatchery-origin Chinook salmon may present a low risk of negative interspecific competitive effects to Hood Canal summer chum salmon in Hood Canal.

To summarize, we expect the following:

- For the Puget Sound Chinook Salmon ESU, we expect low risk from competitive interactions, and low risk from predation. Overall risk from competition and predation in marine areas of the Salish Sea (other than natal inner estuaries) is therefore low.
- For the Puget Sound steelhead DPS, we expect negligible risk from competitive interactions, and low risk from predation. Overall risk from competition and predation in marine areas of the Salish Sea (other than natal inner estuaries) is therefore low.
- For the Hood Canal Summer Chum Salmon ESU, we expect low risk from competitive interactions, and low risk from predation. Overall risk from competition and predation in marine areas of the Salish Sea (other than natal inner estuaries) is therefore low.

Columbia River Estuary

This subsection considers competition effects in the Columbia River estuary. Juvenile salmonid residence time in the Columbia River estuary differs by species and life history. Longer hatchery fish residence times allow for potentially longer periods of interactions with natural-origin fish. Weitkamp et al. (2012) noted periods of time when each species and life history of salmonid (91–100% of which were of hatchery-origin) were caught in the estuary, an indication of residence time. Chum and sockeye salmon were typically caught during a two- to four-week period, yearling Chinook salmon, steelhead, and coho salmon were caught for a six- to eight-week period, and subyearling Chinook salmon were present for at least two months (but possibly longer due to the end of sampling in July, when subyearling Chinook salmon were still being caught) (Weitkamp et al. 2012). Another study by Bottom et al. (2008) found that Chinook salmon estuary residence time (time of first contact with salt water) ranged from 10–219 days, averaging 73 days. However, almost half of the Chinook salmon sampled were less than 60 mm FL, much smaller than Chinook salmon released from hatchery programs. Estimates from marked hatchery groups indicated that Chinook salmon yearling outmigrants had residency periods of about one week (Dawley et al. 1986; Bottom et al. 2008). Subyearling Chinook salmon were not sampled, but are generally known in other areas to have longer estuary residence times when they enter the estuary at less than about 70–75 mm FL (Healey 1980; Greene et al. 2021). Subyearling hatchery Chinook salmon enter the estuary at sizes larger than this, and therefore likely have much shorter residence times than those observed by Bottom et al. (2008).

Data suggest that overlap between natural-origin subyearling Chinook salmon and hatchery-origin yearling Chinook salmon is minimal, and that natural-origin subyearling Chinook salmon are likely insulated from ecological effects through both habitat partitioning and temporal variations in outmigration timing. Subyearling Chinook salmon tend to occupy shallower habitats than natural- or hatchery-origin yearlings (Weitkamp et al. 2014). For example, subyearlings accounted for 97.4% of all Chinook salmon sampled in shallow-water estuary habitat (Roegner et al. 2012). Chinook salmon less than 90 mm (i.e., subyearlings), are the primary users of Columbia River wetlands (Bottom et al. 2008). In addition, subyearlings can be found throughout the year, although abundance is low from October through January. Peak abundance differed depending on estuary zone: April–June in the tidal freshwater zone, peaks in May and July in the middle estuary zone, and a single July peak in the lower estuary zone. Weitkamp et al. (2012) also found peak subyearling abundance in June and early July. During the winter and early spring, fry comprised 25% of the samples, with the highest percentage of fry in the tidal freshwater zone. Most of the Chinook salmon fry (85%) were natural-origin fish from the Lower Columbia River ESU (Western Cascade Fall and Spring Creek Fall).

For steelhead and yearling Chinook salmon smolts, Weitkamp et al. (2022) observed that these fish actively fed and grew during April–June, 2016–2017, as they transited the Columbia River estuary, despite their relatively rapid transit time. Levels of IGF-1 and fish size increased from just below Bonneville Dam to the river mouth during this period. For steelhead, IGF-1 levels were greater than a previous study in the estuary (i.e., Daly et al. 2014), perhaps indicating better foraging conditions and/or less competition during the Weitkamp et al. (2022) investigation. For Chinook salmon, IGF-1 levels were intermediate between levels observed in Puget Sound Chinook salmon when foraging conditions appeared to be limiting (i.e., Chamberlin et al. 2017; Greene et al. 2023), and when foraging conditions appeared more favorable (i.e., Davis et al. 2020; Greene et al. 2023) (see further discussion on these Puget Sound findings in the Puget Sound subsection above).

Chum salmon fry and subyearling hatchery- and natural-origin Chinook salmon predominate in shallow tidal freshwater and estuary sites from March to May (Roegner et al. 2012). However, in the estuary, chum salmon fry are small, ≤ 60 mm FL, compared to hatchery-origin subyearling Chinook salmon, which are mostly ≥ 80 mm FL and almost exclusively ≥ 70 mm FL (Bottom et al. 2021). Therefore, chum salmon fry are expected to use shallower water and forage on smaller prey items than subyearling hatchery Chinook salmon, limiting extent of any competitive interactions in the estuary.

Peak sockeye salmon abundance in the estuary occurs in late May and early June, whereas the maximum abundance of hatchery yearling Chinook salmon occurs prior to this (Weitkamp et al. 2012). Thus, sockeye salmon are not likely to interact to a large degree with yearling hatchery fish in the estuary because their peak in abundance occurs after yearling hatchery Chinook salmon have likely moved offshore. Further, sockeye salmon are believed to make minimal use of estuarine areas, instead moving through these areas quickly to more off shore areas (Farley et al. 2018; Quinn 2018). Thus, any interaction with subyearling hatchery Chinook salmon in the estuary is minimal.

Spatiotemporal overlap between hatchery- and natural-origin subyearling Chinook salmon can be assessed based on work by the Lower Columbia River Estuary Partnership (LCREP) (Sagar et al. 2015). The LCREP found partial spatial segregation between hatchery- and natural-origin subyearling Chinook, with the former being found in higher densities in more upstream areas of the estuary, whereas the latter were found in higher densities lower in the estuary. The LCREP also observed partial temporal segregation. Although hatchery- and natural-origin subyearling Chinook salmon abundance peaked during the same time (May–June), natural-origin Chinook salmon were present in moderate densities in the months prior to the peak, whereas hatchery Chinook salmon were present in lower densities during this time. Hatchery- and natural-origin juvenile spring Chinook salmon had similar spatial distributions in the marine environment, but peak abundance occurred earlier for hatchery fish (May) than for natural fish (June). One caveat is that small-scale spatial overlap is unknown due to sampling of fish using trawls that sample a large volume of water (Daly et al. 2012), which is not informative for vertical or dispersed/aggregated patterns. Also, decreases in the proportions of hatchery-origin fish from the estuary to the ocean observed during sampling in 2010 and 2011 suggested that hatchery-origin fish had lower survival relative to natural-origin fish during early marine residence (Claiborne et al. 2014). Interestingly, there was no evidence for selective mortality of smaller salmonids, which the authors believe was because of favorable ocean conditions during the time period studied (e.g., cooler temperatures, plenty of food).

The ISAB (2015) concluded there is little direct evidence of density dependent interactions between hatchery- and natural-origin juvenile salmonids in the Columbia River estuary because of the lack of carefully designed experimental studies. The lack of scientific knowledge about density dependence of Columbia River salmonids during their time in the estuary and ocean is an important information gap, as understanding density dependence might help explain abundance patterns of natural salmonid resources in the Columbia River Basin. However, between 2012 and 2016, the Columbia River basin saw a substantial increase in abundance of many salmon species (WDFW 2020) with higher returns than those observed during the 1970s when hatchery production was less than or equivalent to current levels. This suggests that any density dependent interactions between hatchery- and natural-origin juvenile salmonids in the Columbia River estuary, and elsewhere in the marine environment, may not have had a substantial influence on productivity. Density dependence is not included as a limiting factor in the Columbia River estuary ESA recovery plan module for salmon and steelhead because of uncertainty about the mechanisms and effects of density dependence in the estuary (NMFS 2011e).

Other researchers have expressed similar sentiments about the lack of information needed to appropriately assess density dependence. Daly et al. (2012) stated that competition for food resources could not be determined due to the lack of an estimate of prey availability and whether or not it is limiting. However, other researchers found that the amount of food in juvenile salmon stomachs was less than 1% of body weight (Dawley et al. 1986; Weitkamp et al. 2014), which is generally lower than that found in studies of other estuary systems. This could be an indicator of competition with hatchery fish or an exceedance of system carrying capacity. However, hatchery-origin fish had less full stomachs than natural-origin fish. In addition, for both juvenile steelhead and juvenile spring Chinook salmon, unmarked (presumed mostly natural origin) fish had smaller lengths, but better body condition, fuller stomachs and higher IGF-1 levels than their hatchery-origin counterparts (Daly et al. 2012; Daly et al. 2014). This suggests that the natural-origin fish were faring better in the marine environment during the time period studied than hatchery-origin fish, and thus may be better competitors in the marine environment.

The proposed action will, on average, increase hatchery Chinook salmon releases into the Columbia River basin by up to 11.3%[53] relative to average releases during 2016–2022[54] (excluding federal prey program releases). During 2016–2022, the average annual basin-wide Chinook salmon smolt release abundance was 91.1 million smolts. It is reasonable to assume that this production level will remain largely constant, if not decline somewhat, for the duration of this consultation due to capacity limitations and funding constraints. As described in Section 2.4.1, Environmental Baseline (see Figure 74), annual basin-wide Chinook salmon smolt releases have declined from about 122.2 million smolts per year during the 1980s and 1990s. During the 2000s and early 2010s, annual average smolt production was about 100.0 million smolts. Thus, total release abundances from all hatchery Chinook salmon programs combined (up to about 101.4 million smolts), including the federal prey program (up to 9.8 million smolts plus up to a 5% production overage), would remain well below those during the 1980s and 1990s (122.2 million smolts), and would be approximately equivalent to, though slightly above, those from the 2000s and early 2010s (100.0 million smolts)[55].

Available knowledge and research abilities are insufficient, at the present time, to discern the precise contribution of hatchery Chinook salmon to any density-dependent interactions affecting salmonid growth and survival in the Columbia River estuary. From the scientific literature, the conclusion seems to be that the influence of density-dependent interactions on growth and survival is likely very small compared with the effects of large scale and regional environmental conditions. The evidence described above indicates that salmonid survival and size may be reduced during years of limited food supply, but that hatchery Chinook salmon are not a primary driver of nor substantial contributor to these effects. Federal prey program Chinook salmon could exacerbate density-dependent effects in the Columbia River estuary during years of low marine productivity and/or high competitor abundance. However, there are no studies that demonstrate or suggest the magnitude of hatchery salmon smolt release numbers that might be associated with adverse changes in natural salmonid population survival rates in marine areas. For the reasons discussed in this section, we expect competition from federal prey program hatchery-released Chinook salmon to have a small effect on the survival of ESA-listed natural-origin Chinook and chum salmon in the Columbia River estuary during years of low marine productivity and/or high abundance of competitors other than Chinook salmon. During other years, we expect any competitive interactions from federal prey program hatchery Chinook salmon to be negligible.

[53] Considers production overages of up to 5% on a running 5-year average, equivalent to a 5-year running average of 21 million smolts released.
[54] This time period was selected as a reference because there was a noticeable shift in release abundances from the Columbia River during this time relative to preceding time periods. See Figure 72.
[55] This assumes that hatchery releases from sources other than the federal prey program do not exceed their 2016–2022 average by more than 1.5 million fish, which they are not expected to due to the factors underpinning these recent and anticipated near-term production levels.

To summarize, we expect the following:

- For all Chinook Salmon ESUs within the Interior Columbia River and Willamette/Lower Columbia River Recovery Domains, we expect low risk from competition and negligible risk from predation in the Columbia River estuary, resulting in an overall low risk from competition and predation combined. Competition risk from federal prey program Chinook salmon released as subyearlings will likely be the greatest in the estuary due to their longer residence time compared to yearling Chinook salmon. However, differences in body size, residence time, and partial spatiotemporal separation between natural- and hatchery-origin subyearling Chinook salmon in the estuary help to ameliorate risk. In addition, federal prey program releases will be a minor proportion of hatchery- and natural-origin Chinook salmon in the estuary.
- For all steelhead DPSs within the Interior Columbia River and Willamette/Lower Columbia River Recovery Domains, we expect negligible risk from competition and negligible risk from predation in the Columbia River estuary, resulting in an overall negligible risk from competition and predation combined. Risks to steelhead in the estuary are extremely minor given their very short residence time here, on the order of 3–5 days during normal flow conditions (Weitkamp et al. 2022, and references therein). The most risk is likely to come from federal prey program Chinook salmon released as yearlings, as these fish are closer in size to steelhead and may share more similarities in habitat selection and diet (e.g., Weitkamp et al. 2022). Federal prey program yearling Chinook salmon will make up no more than a small proportion of hatchery- and natural-origin yearlings transiting the estuary, further diminishing risk to steelhead.
- For the Snake River Sockeye Salmon ESU (Upper Columbia River Recovery Domain), we expect negligible risk from competition and negligible risk from predation in the Columbia River estuary, resulting in an overall negligible risk from competition and predation combined. Risks to sockeye salmon in the estuary are extremely minor given that they likely make very minimal use of estuarine areas, instead moving through these areas quickly to more off shore areas (Farley et al. 2018; Quinn 2018). In addition, federal prey program releases will be a minor proportion of hatchery- and natural-origin Chinook salmon in the estuary.
- For the Lower Columbia Chum Salmon ESU (Willamette/Lower Columbia River Recovery Domains), we expect low risk from competition and low risk from predation in the Columbia River estuary, resulting in an overall low risk from competition and predation combined. Risks from federal prey program Chinook salmon released as subyearlings further upstream from the Columbia River mouth will likely have the greatest affect in the estuary due to their longer residence time compared to yearling Chinook salmon. However, differences in residence time, body size, and habitat segregation between chum salmon and hatchery subyearling Chinook salmon in the estuary help to ameliorate risk. In addition, federal prey program releases will be a minor proportion of hatchery- and natural-origin Chinook salmon in the estuary.
- For the Lower Columbia Coho Salmon ESU (Willamette/Lower Columbia River Recovery Domains), we expect negligible risk from competition and negligible risk from predation in the Columbia River estuary, resulting in an overall negligible risk from competition and predation combined. Risks to coho salmon in the estuary are extremely

minor given that they likely spend little time here. Coho salmon generally use estuaries as migratory corridors rather than extended rearing habitat (e.g., Quinn 2018), similar to yearling Chinook salmon and steelhead. Coho salmon show similarly narrow peaks in abundance in the Columbia River estuary as yearling Chinook salmon and steelhead (Weitkamp et al. 2012), suggesting equivalent transit times. Outmigrating yearling Chinook salmon and steelhead trout transit the Columbia River estuary in 3–5 days under normal flow conditions (Weitkamp et al. 2022, and references therein). Coho salmon transit times are likely similar. The most risk to coho salmon in the estuary is likely to come from federal prey program Chinook salmon released as yearlings, as these fish are closer in size to coho salmon and may share more similarities in habitat selection and diet. Federal prey program yearling Chinook salmon will make up no more than a small proportion of hatchery- and natural-origin yearlings transiting the estuary, further diminishing risk to coho salmon.

2.5.1.2.3.5 Competition and Predation in the Pacific Ocean

Federal prey program Chinook salmon are expected to distribute across a broad area of the Pacific Ocean, described in Section 2.2.10, Action Area. Based on this distribution, we expect that competition and predation in marine areas may affect ESA-listed salmon and steelhead from the following Recovery Domains and ESUs/DPSs:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs
- North Central California Coast: California Coastal Chinook Salmon
- Central Valley: Central Valley Spring-Run Chinook Salmon

Salmon and steelhead from Recovery Domains or ESUs/DPSs not listed above are not expected to occur in the action area or are not expected to experience adverse effects.

The proposed action will, on average, increase hatchery Chinook releases from Puget Sound, the Columbia River basin, and the Washington coast by up to 14.5%[56] relative to average releases during 2016–2022[57] (excluding federal prey program releases). During 2016–2022, the average annual smolt release abundance from all these areas combined was 145.4 million smolts. It is reasonable to assume that this production level will remain largely constant, if not decline somewhat, for the duration of the proposed action due to capacity limitations and funding constraints. As described in the Section 2.4.1, Environmental Baseline (see Figure 74), Chinook salmon smolt releases have declined from about 186.8 million smolts per year during the 1980s and 1990s. During the 2000s and early 2010s, annual average smolt production was about 153.7 million smolts. Thus, total release abundances from all hatchery Chinook programs combined (up to about 166.4 million smolts), including the federal prey program (up to 20 million smolts

[56] Considers production overages of up to 5% on a running 5-year average, equivalent to a 5-year running average of 21 million smolts released.
[57] This time period was selected as a reference because there was a noticeable shift in release abundances from the Columbia River and Puget Sound during this time relative to preceding time periods. See Figure 72.

plus up to a 5% production overage), would remain well below those during the 1980s and 1990s (186.8 million smolts), and would be about 8.2% greater those from the 2000s and early 2010s (153.7 million smolts)[58].

The analysis of competition and predation in the ocean is presented below in four subsections, as follows:

- Subsection 2.5.1.2.3.5.1, Ocean Distribution and Abundance of Federal Prey Program Chinook Salmon. The anticipated ocean distribution and abundance of prey program fish is described.
- Subsection 2.5.1.2.3.5.2, Evidence for Competition in the Pacific Ocean. General evidence for salmonid forage resource limitation and competition is described in the Pacific Ocean.
- Subsection 2.5.1.2.3.5.3, Evidence for Predation in the Pacific Ocean. Evidence for predation on salmonids by Chinook salmon in the Pacific Ocean is described.
- Subsection 2.5.1.2.3.5.4. The information and evidence described in the preceding subsections (2.5.1.2.3.5.1 through 2.5.1.2.3.5.3) is applied to assess risk of the prey program to fish from ESA-listed ESUs and DPSs, by Recovery Domain, likely to occur in the Pacific Ocean portion of the action area.

2.5.1.2.3.5.1 Ocean Distribution and Abundance of Federal Prey Program Chinook Salmon

Federal prey program funding may be used to produce Chinook salmon of varying life history types (i.e., spring-, summer-, and fall-runs). In terms of their marine distribution, these life history types can, with some exceptions, be divided into two primary categories: 1) those that remain mostly or entirely on the continental shelf as juveniles, subadults, and adults (i.e., summer and fall Chinook salmon; spring Chinook salmon from areas other than the upper Columbia River and the Snake River); and, 2) those that, after a relatively brief time on the shelf as recent outmigrants, distribute to and remain in open ocean areas off the shelf until maturing (i.e., spring Chinook salmon from the upper Columbia River and the Snake River). All marine life history stages of federal prey program fall Chinook salmon (juvenile, subadults, and adult) are expected to occur along the continental shelf, primarily from northern Oregon (north of Cape Falcon) to southeast Alaska, as well as within the Salish Sea (Puget Sound releases only). This is based on coastwide juvenile survey data (Trudel et al. 2009; Tucker et al. 2012; Trudel et al. 2013; Fisher et al. 2014; Teel et al. 2015; Hassrick et al. 2016), and immature and adult coded-wire tag and genetic stock identification data (Quinn 2018; Riddell et al. 2018, and references therein; Shelton et al. 2019; Shelton et al. 2021).

For spring Chinook salmon from the upper Columbia River and the Snake River, juveniles during their first ocean year are expected to show a similar distribution along the continental shelf as that described above for other Chinook salmon (Trudel et al. 2009; Sharma et al. 2012; Fisher et al. 2014; Teel et al. 2015). However, rather than remaining on the continental shelf,

[58] This assumes that hatchery releases from sources other than the federal prey program do not exceed their 2016–2022 average by more than 1.5 million fish, which they are not expected to due to the factors underpinning these recent and anticipated near-term production levels.

subadult and adult Chinook salmon from these populations typically utilize more offshore, open ocean areas off the continental shelf, generally north of 45° N latitude (Healey 1983; Sharma et al. 2012; Fisher et al. 2014; Quinn 2018; Shelton 2024b). This inference is based mainly on the absence of these fish in continental shelf fisheries, which is the primary data source for deducing population-specific Chinook salmon ocean distribution because fisheries and research in the open ocean are extremely limited (e.g., Sharma et al. 2012). Although the precise oceanic range and distribution of hatchery fish from upper Columbia and Snake River spring-run populations is not known, these fish would primarily only have effects in the open ocean to listed natural spring-run Chinook salmon originating from the same area. That is, for Chinook salmon populations whose distributions are known (i.e., those that remain largely on the continental shelf), hatchery- and natural-origin fish originating from the same geographic area use the same areas of the ocean, where they may interact (Weitkamp 2010; Tucker et al. 2011). We thus extend this finding to Chinook salmon populations that use the open ocean (off shelf) and whose exact range and distributions are not known, assuming that federal prey program Chinook salmon that use the open ocean will overlap with natural Chinook salmon from the same geographic area and run-type.

The exact distribution of other ESA-listed salmonids that use the open ocean (e.g., steelhead, sockeye salmon, chum salmon) is unknown. However, it is unlikely that these species would overlap with federal prey program Chinook salmon in the open ocean at a spatiotemporal scale sufficient to induce any detectable effects given the length of time these species spend in the ocean, the very broad areas over which they may range, and the much larger abundance of other salmonid and non-salmonid competitors.

NMFS used the FRAM-Shelton model (Appendix A) to estimate the increase in ocean abundance of Chinook salmon that may be expected from the federal prey program. Modelling was based on smolt releases comprising 94–97% (depending on model run[59]) from hatchery stocks that remain on the continental shelf, and 3–6% from stocks that distribute to the open ocean off the shelf (i.e., Upper and Middle Columbia River spring Chinook; Snake River spring/summer Chinook) (Appendix A). Results indicate that the federal prey program will increase ocean abundance of 3- to 5-year-old Chinook salmon substantially more north of Cape Falcon, Oregon relative to areas south of here (Table 3). Increased abundances north of Cape Falcon, Oregon would be 8–10 times greater during the summer (when most growth occurs and competitive effects may be most severe), and 5–6 times greater averaged across the year, compared to southern areas.

On average, less than 5.0% of fall Chinook salmon from the combined regions of the Columbia River, Washington coast, and Puget Sound move to areas south of Cape Falcon, Oregon (Shelton 2024a). Even fewer spring and summer Chinook salmon do, based on preliminary evidence

[59] Two models were run: one with maximum anticipated Puget Sound production (i.e., 14.4 million smolts from Puget Sound and 5.6 million smolts from the Columbia River and Washington Coast), and one with maximum anticipated Columbia River and Washington coast production maximized (i.e., 13.9 million smolts from the Columbia River and Washington coast, and 6.1 million smolts from Puget Sound), as described in the proposed action. Puget Sound and Columbia River figures were based on HGMPs submitted to NMFS and, where completed, in site-specific Biological Opinions (see Table 72 in the Environmental Baseline section). Washington coast projection was based on verbal and written communication from hatchery operators.

(Shelton 2024b), with upper Columbia River and Snake River spring Chinook salmon having the least distribution along the continental shelf. Along the southern coasts (Cape Falcon, Oregon to southern California), the proposed action may increase ocean abundance of 3- to 5-year-old Chinook salmon by up to 0.7% during the summer months and up to 1.0% averaged across all seasons (Table 79). Because of the very small abundance and projected increases in southern areas, we expect that the federal prey program will have no effects to ESA-listed salmonids in these areas (south of Cape Falcon, Oregon), based on the evidence for competition and predation in marine areas described below.

Table 79. Increase in marine abundance of age 3–5-year-old Chinook salmon under two possible hatchery release scenarios and accounting for hatchery production variables, as described in the proposed action[a]. The percent increase shown is relative to all adult Chinook salmon, hatchery- and natural-origin combined.

Region	Time period[b]	Modeled increase in age 3–5-year-old Chinook salmon			
		Puget Sound capacity maximized		Columbia R. and Washington coast capacity maximized	
		single year	5-year mean	single year	5-year mean
Salish Sea	summer	1.8%	1.7%	1.3%	1.2%
	full year	7.5%	7.2%	3.7%	3.5%
Southwest portion of the west coast of Vancouver Island	summer	6.1%	5.8%	4.0%	3.8%
	full year	6.6%	6.3%	5.9%	5.6%
Washington coast (north of Cape Falcon, OR)	summer	3.2%	3.0%	6.4%	6.1%
	full year	3.7%	3.5%	4.9%	4.7%
Oregon coast (south of Cape Falcon, OR)	summer	0.4%	0.4%	0.7%	0.6%
	full year	0.6%	0.6%	1.0%	1.0%
California coast	summer	0.3%	0.3%	0.2%	0.2%
	full year	0.7%	0.6%	1.0%	1.0%

[a] The proposed action describes that up to 20 million smolts annually will meet the overall goal for the program, but that up to 10% more (22 million smolts) may be released in any given year due to variables associated with hatchery production, and that up to 5% more (21 million smolts) may be released, on average, during any 5-year period. These 10% and 5% figures were applied to the FRAM-Shelton model results shown in Table 3 and described in Appendix A, which were based on release of 20 million smolts, to arrive at the figures shown in this table.
[b] Summer time period is represented by July–September.

2.5.1.2.3.5.2 Evidence for Competition in the Pacific Ocean

Federal prey program hatchery Chinook salmon have the potential to adversely affect natural populations of ESA-listed salmon and steelhead through competition in marine areas. As juvenile federal prey program Chinook salmon arrive in the estuaries, they may compete with other salmon and steelhead in areas where they co-occur, if shared resources are limiting. Effects may be more pronounced in estuaries and nearshore marine waters adjacent to river mouths where hatchery-origin salmon may initially be concentrated. Interactions and effects likely diminish as the fish disperse into more offshore areas.

The main limiting resource for salmon and steelhead that could be affected through competition posed by hatchery-origin fish is food. The early estuarine and nearshore marine life stage, when juvenile fish have recently entered the estuary and populations are concentrated in a relatively small area, is a critical life history period during which there may be short term instances where food is in short supply, and growth and survival declines as a result (e.g., Duffy 2003; Pearcy et al. 2007). The degree to which food is limiting depends upon the density of prey species. This does not discount limitations in available food resources in more seaward areas as a result of competition, as data are available that suggest that marine survival rates for salmon are density dependent, and thus possibly a reflection of the amount of food available (e.g., Brodeur 1991; Holt et al. 2008). Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival (e.g., Beamish et al. 1997; HSRG 2004a; Ruggerone et al. 2023). Some evidence suggests density-dependence in the abundance of returning adult salmonids (Emlen et al. 1990; Lichatowich et al. 1993; Bradford 1995), associated with cyclic ocean productivity (Nickelson 1986; Beamish et al. 1993; Beamish et al. 1997). Collectively, these studies indicate that competition for limited food resources in the marine environment may affect survival (also see Brodeur et al. 2003). The possibility that large-scale hatchery production could exacerbate density dependent effects in the ocean, particularly when ocean productivity is low, deserves consideration. For example, Puget Sound origin salmon survival may be intermittently limited by competition with almost entirely natural-origin odd-year pink salmon originating from Puget Sound and the Fraser River watersheds (Ruggerone et al. 2004), particularly when ocean productivity is low (Nickelson 1986; Beamish et al. 1993; Beamish et al. 1997; Mahnken et al. 1998). Evidence for competition in marine areas, and the potential role of federal prey program Chinook salmon, is described below.

Ecological interactions from hatchery-origin Chinook salmon may occur on the continental shelf, where juveniles of most species (all except steelhead trout) rear for at least several months. The first year at sea is a critical period for juvenile salmonids, when negative density-dependent interactions are more likely to occur than at later life history stages (Beamish 2018). Along the North American continental shelf, there is some limited, and in some cases equivocal, evidence of competition and negative density-dependent interactions occurring within some groups or populations of Chinook salmon (Riddell et al. 2018). Hatchery-origin salmon may contribute to density-dependent effects in areas where hatchery fish occur in relatively high abundances and densities. However, available data are insufficient to be able to predict precisely where such areas may occur, other than that they may occur at some level within certain broad geographic regions. On the continental shelf, the substantial majority of hatchery-origin Chinook salmon from the proposed action (≥ 95%) inhabit and migrate through marine waters along the North American continental shelf, from Cape Falcon, Oregon in the south to Yakutat Bay, Alaska in the north, where they may interact with ESA-listed salmonids from Puget Sound and the Columbia River (Fisher et al. 2014; Quinn 2018; Riddell et al. 2018, and references therein; Shelton et al. 2019; Van Doornik et al. 2019a; Shelton et al. 2021).

Ruggerone et al. (2022) and Ruggerone et al. (2023) provide evidence that pink salmon is a primary driver of ecosystem dynamics in the Pacific Ocean, affecting a multitude of species, including other salmonids. In short, correlative evidence suggests that pink salmon have negative consequences to other salmon species in marine habitats, including Chinook, coho, chum, and sockeye salmon and steelhead. Such negative consequences are presumed to arise via food web interactions. That is, large numbers of pink salmon may: 1) overconsume the same prey that other salmonids rely on; and/or, 2) overconsume prey at lower trophic levels (e.g., plankton) leading to less abundances of prey at the higher levels (e.g., fish) that other salmonids, such as Chinook and coho salmon, rely on (i.e., a "trophic cascade"). Further, evidence is presented that climate change has benefitted pink salmon to the detriment of other salmon species, contributing to a steady increase in ocean-wide pink salmon abundance from the mid-20th century to now. Ruggerone et al. (2022) note that 5.5 billion juvenile hatchery salmon were released into the Pacific Ocean in 2019 (citing NPAFC data), and that approximately 40% of the total salmon biomass in the Pacific Ocean during 1990–2015 was made up of hatchery salmon, especially chum and pink salmon (citing Ruggerone and Irvine 2018). The implication is that hatchery fish deepen the negative competition and density-dependent effects triggered by climate change and pink salmon.

At the scale considered by Ruggerone et al. (2022)—the entire north Pacific Ocean—hatchery- and natural-origin Chinook salmon contribute very little to overall salmon foraging demand. Chinook salmon make up a small proportion of salmon in the Pacific Ocean, approximated to be less than 1.3% by Ruggerone et al. (2018) based on NPAFC catch weight data (1992–2015). Also, hatchery Chinook salmon make up a small proportion of hatchery salmon releases, averaging just 4.8% annually (range: 4.6–5.1%) of all Pacific Ocean hatchery salmon releases from 2013 to 2022 (NPAFC 2023). For context, hatchery Chinook salmon from the federal prey program would increase hatchery salmon releases into the Pacific Ocean by up to 0.4% over 2013–2022 levels.

Though not addressed by Ruggerone et al. (2022), Ruggerone et al. (2023) acknowledge that regional differences may exist whereby researchers in some regions (western Bering Sea and western North Pacific Ocean) argue that the oceanic salmonid prey base is plentiful, but that much of the research providing evidence of the opposite (i.e., negative competitive effects) is from other regions of the ocean. For example, the substantial majority of the evidence presented by Ruggerone et al. (2023) of negative pink salmon effects to Chinook salmon is from two regions: Alaska and the Salish Sea. For the Alaska-based evidence, negative pink salmon effects to Chinook salmon occurred after the Chinook salmon first ocean year, whereas that presented for Salish Sea Chinook salmon occurred earlier, during the first ocean year. This difference in timing of apparent negative effects may be related to several factors. Both species—Chinook and pink salmon—spend their first ocean year in continental shelf areas (Radchenko et al. 2018; Riddell et al. 2018). However, Alaskan Chinook salmon are "stream-type" fish, meaning they outmigrate to marine habitats as yearlings after spending one year in freshwater. Thus, they are substantially larger during shelf residence than pink salmon, which outmigrate to marine waters as fry, likely limiting potential for competitive interactions between the species. That is, larger juvenile Chinook salmon the size of yearling migrants are generally piscivorous (Hertz et al. 2015; Riddell et al. 2018), while juvenile pink salmon during their first ocean year are planktivores (Radchenko et al. 2018). After their first ocean year, both species move to open ocean habitats off the continental shelf until they mature (Healey 1983; Healey et al. 1987). This is the time when the Alaskan-based studies have detected competitive effects to Chinook salmon (i.e., during the years they overlap with pink salmon in the open ocean).

In contrast to the "stream-type" Alaskan Chinook salmon described in the preceding paragraph, most Salish Sea Chinook salmon are "ocean-type", meaning they outmigrate to marine waters as subyearlings rather than spending a full year of life in freshwater. Thus, when they enter marine waters in late spring, they are comparable in size to the pink salmon that outmigrated several months earlier as fry but grew while the Chinook were rearing in freshwater (Duffy et al. 2005). The comparable size lends itself to greater competition, as subyearling Chinook salmon feed heavily on zooplankton while rearing in Puget Sound (Duffy et al. 2010). Further, fall Chinook salmon comprise the majority of Chinook salmon in Puget Sound. Puget Sound fall Chinook salmon are known to remain mostly or entirely on the continental shelf during the entirety of their marine residence (Shelton et al. 2019), where overlap with pink salmon after their first ocean year would be minimal. This may be why Sobocinski et al. (2021) observed only very weak effects of ocean salmon abundance on Puget Sound Chinook salmon SARs (see additional discussion below).

The Alaskan studies that have specifically investigated pink salmon effects to Chinook salmon have found relatively minor effects with weak support (Cunningham et al. 2018; Oke et al. 2020). (Cunningham et al. 2018) found that Japanese hatchery chum salmon abundance had a notably larger and more supported effect on Yukon River Chinook salmon than pink salmon. Japanese hatchery chum salmon typically make up about 30% of all salmon hatchery releases into the Pacific Ocean, and would not affect Chinook salmon from the continental United States. Oke et al. (2020) evaluated the continuous decline in body size of 202 Alaskan Chinook salmon populations from 1975 to 2018. Both climate and competition variables were evaluated for their effects. Competition from pink and sockeye salmon were negatively correlated with Chinook salmon body size. The combined effects of climate and competition explained only 29% of the variation in Chinook salmon body size, indicating that the combined effects from unexplored factors were more influential. In contrast to Cunningham et al. (2018), Oke et al. (2020) observed a positive correlation between chum salmon abundance and Chinook salmon body size.

Buckner et al. (2023) evaluated the effects of climate and oceanographic variables and pink salmon abundance on growth to adult stage (length-at-age) of 48 hatchery Chinook salmon stocks from the Columbia River basin, coastal Washington and Oregon, and Puget Sound. They found a negative correlation between Chinook salmon growth and North American pink salmon abundance for Chinook stocks that have a more northerly distribution (north of Vancouver Island). Chinook salmon growth trends have been declining as pink salmon abundance has been increasing. Thus, Buckner et al. (2023) acknowledge that their observations may be the result of the match of these long-run trends rather than an underlying causal relationship. Nonetheless, juvenile pink salmon abundance on the continental shelf is lowest along the Washington-to-California coast, moderate along the west coast of Vancouver Island, and highest to the north of Vancouver Island (Fisher et al. 2007a). Further, some far northerly migrating Chinook salmon populations from the continental United States move to the open ocean after their first ocean year (i.e., upper Columbia River and Snake River spring Chinook salmon) (Shelton 2024b), where immature and adult pink salmon are also found. In contrast, populations that do not migrate far north remain mostly or entirely on the continental shelf (i.e., fall-, summer-, and spring-run populations other than upper Columbia River and Snake River spring Chinook salmon) (Shelton et al. 2019; Shelton 2024b), where overlap with immature and adult pink salmon is minimal. Thus, the difference in spatial overlap with pink salmon between the more northerly and southerly distributed groups may at least partially explain why the more northerly migrating stocks showed evidence of pink salmon effects.

The above evidence suggests that pink salmon may have a negative effect on growth of other salmon species when they overlap in marine areas. In years of high pink salmon abundance and/or unfavorable ocean conditions, forage resources for other salmon species may become limited. Though it is possible that this may trigger negative density-dependent inter- and intra-specific competition among salmon species that utilize similar habitats and forage resources, effects are likely small relative to those from pink salmon. There is no direct evidence that competition from hatchery Chinook salmon negatively affects natural Chinook salmon or other salmon species in these areas. This is likely due to the fact that Chinook salmon make up a relatively small proportion of salmon in the North Pacific Ocean, and hatchery Chinook salmon make up a very small proportion of hatchery fish released into the ocean.

Evidence for competition along the North American continental shelf is limited and equivocal. Spawning populations of pink salmon do not occur along the Washington coast, in the Columbia River, or in areas to the south (Hard et al. 1996). Pink salmon are therefore relatively rare in Washington and Oregon coastal waters (Fisher et al. 2007a). This likely at least partially explains why Ruggerone et al. (2004) did not observe any odd-even year patterns in survival of Chinook salmon populations that spawn in Washington coastal rivers. Thus, to the extent that pink salmon is a primary driver of marine food web interactions, these effects are extremely minor, if nonexistent, along the Washington and Oregon coast.

Early studies suggested that juvenile Chinook and coho salmon along the Washington and Oregon coast were not food-limited during their early marine residence (Peterson et al. 1982; Brodeur 1990b, cited in Brodeur 1992; Brodeur 1992). These studies occurred during times when Columbia River Chinook salmon releases were at their peak (Figure 74). However, Daly et al. (2009) found that the percent of empty stomachs in both juvenile Chinook and coho salmon along the Oregon and Washington coast increased by 63% and 69%, respectively, from the 1980s to the early 2000s, despite 25% fewer Columbia River hatchery Chinook salmon being released during the latter time period. The authors noted that oceanographic conditions changed during this time, affecting the fish community and potentially the quantity of food available. Thus, the changing ocean conditions may have triggered forage limitations that outweighed the reduction in hatchery production, and induced competitive effects that previously did not exist or were more minor.

Brodeur et al. (2007) evaluated juvenile salmon feeding patterns (stomach contents) in coastal waters from northern California to the western Gulf of Alaska during April–November, 2000–2002. For Chinook and coho salmon, there were proportionally more empty stomachs along the Oregon and Washington coast (about 5–15% of sampled fish), than in more northerly areas (about 0–3% of sampled fish). With some exceptions, feeding intensity (prey consumed as a percent of predator body weight) was also lower for both species along the Oregon and Washington coast. These findings suggest that competition may have been more intense along the Oregon and Washington coast during the few years studied, although feeding intensity may not be correlated with prey availability (e.g., Brodeur 1990b, cited in Brodeur 1990b; 1990a).

Trudel et al. (2007) evaluated regional variation in summer marine growth (millimeters per day) of juvenile coho salmon and subyearling and yearling Chinook salmon along the North American west coast during 2002–2004. There were no apparent differences in growth of subyearling Chinook salmon (about 0.7–1.0 mm/day) along the Washington-Oregon coast in comparison to the other regions sampled. Coho salmon growth along the Washington-Oregon coast (1.2–1.3 mm/day) was slightly lower than in southeast Alaska (about 1.3–1.4 mm/day). Similarly, yearling Chinook salmon growth was lower along the Washington-Oregon coast (about 0.7–0.9 mm/day) than in southeast Alaska (about 1.0–1.3 mm/day). The authors speculated that the lower growth along the Washington-Oregon coast was likely due in part to more intense interspecific competition here relative to the more northern areas (e.g., southeast Alaska) citing Orsi et al. (2007) and Brodeur et al. (2007).

Daly et al. (2012) evaluated early marine characteristics of hatchery- and natural-origin juvenile Chinook salmon yearling outmigrants from five Columbia River spring Chinook populations during May and June across 11 years (1999–2009) along the Washington and northern Oregon coast. The authors found extensive spatial and dietary overlap between the hatchery- and natural-origin fish. Each group of fish had similar feeding intensities and growth rates, despite the natural-origin fish being consistently smaller, suggesting that neither group was outcompeting the other. Growth rates (IGF-1) were sampled in May (4 years) and June (2 years). For May, the two years with the highest growth (2007 and 2008) had the highest CPUE, suggesting that ocean conditions or other variables were more important than intraspecific competition in determining fish growth. Similar results were apparent in June. The two low-growth years (2006 and 2007) corresponded with low adult returns two years later. Feeding intensity was comparable across years, indicating that feeding intensity had no bearing on growth or survival.

Orsi et al. (2007) observed that, along the continental shelf, juvenile Chinook salmon density was 31–44 times greater and adult Chinook salmon density was 1.7–3.0 times greater in the south (California to Vancouver Island) compared to the north (northern southeast Alaska to the western Gulf of Alaska). Areas between the northern tip of Vancouver Island and northern southeast Alaska were not sampled. Epipelagic fish abundance was about 10 times greater in the south (California to Vancouver Island) than the north (northern southeast Alaska to the western Gulf of Alaska), with much of the abundance in the south consisting of Pacific herring, Pacific sardines, and northern anchovies. These species may compete with juvenile Chinook and coho salmon during their early marine residence, but may provide a forage resource as the salmon grow larger. In the southern areas (California to Vancouver Island), juvenile and immature/adult Chinook salmon comprised only 0.6–0.7% and 0.1–0.2% of the catch, respectively, indicating that Chinook salmon are a minor component of the continental shelf epipelagic fish assemblage. However, their greater densities and the greater abundance of competitors may increase the likelihood of both interspecific and intraspecific competition relative to that in Alaskan waters

Miller et al. (2013) evaluated survival (SAR) of upper Columbia River summer-fall Chinook salmon subyearling outmigrants during an 11-year time series (outmigration years 1998–2008). Variables that were evaluated for their effect on survival included river and ocean environmental conditions, and fish size, condition (length-weight relationship), growth, and abundance[60] during early ocean residence (June and September) along the Washington and Oregon coast. Unexpectedly, the authors found that survival was negatively related to September juvenile condition indices, and that these condition indices were the best individual predictors of survival. That is, years with smaller, slower-growing, "poorer" condition fish in September had better survival than years with larger, faster-growing, and better condition September fish. Similar results were observed along the California coast for Central Valley fall Chinook salmon (Sabal et al. 2016). No density-dependent response was observed in juvenile attributes (length, weight, condition factor, growth), which the authors thought may have been due to the absence of intraspecific competition or inadequate spatial coverage of ocean sampling (Miller et al. 2013). Nonetheless, competition or size-selective mortality could have led to the findings of smaller yet better surviving fish during years of more productive ocean conditions (Miller et al. 2013; Sabal et al. 2016).

Daly et al. (2009) noted a near doubling in the percentage of empty Chinook and coho salmon stomachs along the Oregon and Washington coast from the 1980s (observed by Brodeur 1992) to the late 1990s and early 2000s. The authors suggest that changes in oceanographic conditions and the pelagic nekton community were likely responsible. This suggests that forage resources are more limiting and competition more intense now as compared to the recent past.

The above evidence suggests that intra- and inter-specific competition likely occurs at some times along the continental shelf. To the extent that competition does occur, hatchery Chinook salmon abundance does not appear to be a primary driver. Rather, ocean conditions and abundance of other competitors are likely the dominant factors influencing forage availability and competitive effects. In years of high competitor abundance and/or unfavorable ocean conditions, forage resources for salmonids may become limited. Though it is possible that this may trigger negative density-dependent inter- and intra-specific competition among salmon species that utilize similar habitats and forage resources, as indicated in the evidence described above, competition effects are likely small both in absolute terms and relative to those from other non-salmonid competitors.

In regards to hatchery Chinook salmon in particular, their competitive effects to natural-origin ESA-listed salmonids in marine environments are indirect in nature (i.e., indirect competition[61]); that is, consumption of prey by hatchery Chinook salmon makes less prey available to other organisms. Such competitive effects thus occur specifically via effects to the pool of prey resources available to all individuals of species that eat the same prey types in the same areas at the same times, broadly speaking. Thus, the degree of competitive effects to natural-origin ESA-listed species is dictated by the amount of prey that hatchery Chinook salmon consume relative to the total amount of prey available. For example, under occasional conditions when resources are limiting (i.e., low marine productivity and/or high abundance of competitors other than Chinook salmon), if hatchery Chinook salmon consume 1% of all available prey, the effect to natural-origin ESA-listed salmonids is correspondingly small. As described above, the pool of

[60] The abundance metric included all subyearling Chinook salmon regardless of origin.
[61] Indirect competition is in contrast to direct competition, whereby one individual physically interferes with the ability of another individual to consume prey (Rensel et al. 1984).

prey resources in the action area supports large abundances of individuals of species other than natural- and hatchery-origin Chinook salmon. In fact, as described above, hatchery- and natural-origin Chinook salmon comprise a small, albeit indeterminate, proportion of consumers throughout the marine portions of the action area. Because of this, marine competitive effects of hatchery-origin Chinook salmon to natural-origin ESA-listed fish are likely to be small.

Available knowledge and research abilities are insufficient, at the present time, to discern the precise contribution of hatchery Chinook salmon to any density-dependent interactions affecting salmon and steelhead growth and survival in marine areas. From the scientific literature described above, we conclude that the influence of density-dependent interactions on growth and survival is likely very small compared with the effects of large scale and regional environmental conditions. The evidence described above indicates that salmonid survival and size may be reduced during years of limited food supply, but that hatchery Chinook salmon are not a primary driver of nor substantial contributor to these effects. Federal prey program Chinook salmon could exacerbate density-dependent effects in some parts of the action area during years of low marine productivity and/or high competitor abundance. However, there are no studies that demonstrate or suggest the magnitude of hatchery salmon smolt release numbers that might be associated with adverse changes in natural salmonid population survival rates in marine areas. For the reasons discussed in this section, we expect competition from federal prey program hatchery-released Chinook salmon to have a small effect on the survival of ESA-listed natural-origin Chinook salmon in the action area during years of low ocean productivity and/or high abundance of competitors other than Chinook salmon. During other years, we expect any competitive interactions from federal prey program hatchery Chinook salmon to be negligible.

2.5.1.2.3.5.3 Evidence of Predation in the Pacific Ocean

Adult, immature, and large juvenile Chinook salmon in marine waters feed heavily on fish, particularly forage fish, and are large enough to prey on younger juvenile salmonids (Riddell et al. 2018, and references therein). However, there is substantial available information showing that predation on juvenile salmonids by Chinook salmon in marine waters is rare. Many diet studies of adult, immature, and large juvenile Chinook salmon in marine waters only identify specific taxa that made up more than about 1–5% of the Chinook's diet (i.e., "common" prey taxa), and do not mention specific taxa that were consumed at lower levels (e.g., Silliman 1941; Beacham 1986; Brodeur et al. 2007; Daly et al. 2009; Daly et al. 2012; Brodeur et al. 2014; Thayer et al. 2014; Hertz et al. 2015; Osgood et al. 2016; Daly et al. 2017; Hertz et al. 2017). Juvenile salmonids are not identified as common prey taxa in these studies. Of studies that have identified all consumed taxa regardless of their prevalence in the diet, the substantial majority have found no juvenile salmonids in Chinook salmon stomach contents (e.g., Reid 1961; Prakash 1962; Wing 1985; Brodeur et al. 1987; Brodeur et al. 1990; Landingham et al. 1998; Hunt et al. 1999; Kaeriyama et al. 2004; Weitkamp et al. 2008; Daly et al. 2019; Beauchamp et al. 2020; Chamberlin 2021; Weitkamp et al. 2022).

Where juvenile salmonids have been consumed by Chinook salmon (Fresh et al. 1981; Duffy et al. 2010; Sturdevant et al. 2012), they have been a rare component of the diet, and they have been consumed almost exclusively at times and in places where large densities of juvenile salmonids are present (i.e., in Puget Sound and near the mouth of the Columbia River during early summer after large pulses of hatchery-origin fish have entered these areas). Outside of these areas, we are aware of only one survey that found juvenile salmonid predation by Chinook salmon: one salmonid individual (unidentified species) was consumed among 490 immature and adult Chinook salmon sampled in southeast Alaska coastal and inner waters from 1997 to 2011 (Sturdevant et al. 2012). These findings indicate that predation by Chinook salmon on salmonids in marine waters is exceedingly rare, particularly outside of times and places where large densities of recent marine-entrant juveniles are present. For the reasons discussed in this section, we expect very low levels of predation on some ESA-listed salmonids in Puget Sound (estuaries and offshore areas), and in the Columbia River estuary and plume, but not in other marine areas.

2.5.1.2.3.5.4 Effects of Competition and Predation in the Ocean to Listed ESUs and DPSs in the Action Area

Puget Sound Recovery Domain

<u>Puget Sound Chinook Salmon ESU</u>

Risk from competition to Puget Sound Chinook salmon in the Pacific Ocean is low. The evidence described above suggests that low-level negative intraspecific density-dependent competitive effects to Chinook salmon may occur at some times and in some places along the continental shelf depending primarily on ocean conditions and interspecific competitor abundance. The addition of hatchery Chinook salmon via the federal prey program may have a small affect in exacerbating these effects. However, the federal prey program would not be a primary driver of or substantial contributor to these effects due to the much larger abundance of other salmonid and non-salmonid competitors, including other hatchery- and natural-origin Chinook salmon. For example, even in areas where the federal prey program is expected to increase Chinook salmon abundance the most, the federal prey program is expected to increase total Chinook salmon abundance by no more than 6.4% during the summer (Table 79) when most growth occurs and competition may be most detrimental. Available information is insufficient to be able to quantify a relationship between hatchery Chinook salmon abundance and adverse competitive effects to natural listed Chinook salmon (e.g., identifying rates of slower growth by population, decreased survival estimates by ESU). However, NMFS has determined that the available information does show risk from adverse competitive effects to listed species in a qualitative manner.

Risk from predation to Puget Sound Chinook salmon in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Puget Sound Chinook salmon in the Pacific Ocean is low because risk from competition is low and risk of predation is negligible, as described above.

Puget Sound Steelhead DPS

Risk from competition to Puget Sound steelhead in the Pacific Ocean is negligible. Though direct observations of juvenile Puget Sound steelhead transit time across the continental shelf are lacking, there are no indications that their behavior would be any different from that of steelhead from the Columbia River or other areas, which show a rapid transit across the continental shelf to open ocean areas. For example, Columbia River basin steelhead migrate rapidly from the river mouth to the outer edge of the continental shelf. Based on 13–14 years of sampling along the Washington and northern Oregon coast, including the Columbia River plume, Daly et al. (2014) determined that juvenile steelhead from the Columbia River basin reached the western edge of the continental shelf in just a few days, and spent about 10 days in continental shelf waters before moving to open ocean areas off the shelf. Juvenile Puget Sound steelhead's rapid migration through Puget Sound (described above) further supports the likelihood of a short continental shelf residence.

In open ocean areas (off the continental shelf), Puget Sound steelhead may overlap at a very broad spatial scale with immature and adult spring Chinook salmon from the upper Columbia River and the Snake River, including any from the federal prey program. The exact distribution and overlap in the open ocean of Puget Sound steelhead and these spring Chinook salmon stocks is unknown. However, it is unlikely that these fish overlap at a spatiotemporal range sufficient to induce any detectable effects to steelhead trout given the length of time both species spend in the ocean, the very broad area over which they may range, and the much larger abundance of other salmonid and non-salmonid competitors. Steelhead generally remain in open ocean waters until they mature and migrate back across the shelf as adults, likely making an equally rapid transit across the shelf and through Puget Sound to the river mouths of their origin (Hayes et al. 2011). For these reasons, any competitive effects to Puget Sound basin steelhead from upper Columbia River and Snake the River federal prey program spring Chinook salmon are expected to be insignificant.

Risk from predation to Puget Sound steelhead in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Puget Sound steelhead in the Pacific Ocean is negligible because risk from competition is negligible and risk of predation is negligible, as described above.

Hood Canal Summer Chum Salmon ESU

Risk from competition to Hood Canal summer chum in the Pacific Ocean is negligible. Juvenile Chinook salmon (subyearlings and yearlings) are typically found in shallower water than juvenile chum salmon during their first ocean year on the continental shelf (Fisher et al. 2007a; Riddell et al. 2018; Urawa et al. 2018). In addition, juvenile chum salmon typically feed at a lower trophic level than juvenile Chinook salmon during this time, with the former consuming mostly zooplankton while the latter transitions to a mostly fish-based diet (Brodeur et al. 2007;

Riddell et al. 2018; Urawa et al. 2018). During their first ocean year, chum salmon migrate north and westward off the continental shelf to open ocean areas where they remain until maturing. At this stage (off-shelf open ocean), they may overlap at a very broad spatial scale with immature and adult spring Chinook salmon from the upper Columbia River and Snake River, including those from the federal prey program. However, the exact distribution and overlap in the open ocean of ESA-listed chum salmon and these spring Chinook salmon stocks is unknown. Similar to juveniles, dietary overlap between the two species at their immature and adult stages is minimal, with Chinook salmon continuing to feed at higher tropic levels than chum salmon (e.g., Johnson et al. 2009; Riddell et al. 2018; Urawa et al. 2018). Risk from predation to Hood Canal summer chum in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Hood Canal summer chum salmon in the Pacific Ocean is negligible because risk from competition is negligible and risk of predation is negligible, as described above.

Interior Columbia and Willamette/Lower Columbia Recovery Domains

<u>Chinook Salmon ESUs</u>

Risk from competition to all Interior Columbia and Willamette/Lower Columbia Recovery Domain Chinook salmon ESUs in the Pacific Ocean is low. Low-level negative intraspecific density-dependent effects to Chinook salmon may occur at some times and in some places depending primarily on ocean conditions and interspecific competitor abundance, as described above. The addition of hatchery Chinook salmon via the federal prey program may have a small affect in exacerbating these effects. The areas where these effects may occur include the following: 1) continental shelf portions of the action area; and, 2) open ocean (off shelf) areas where ESA-listed Chinook salmon from interior spring populations (i.e., Upper Columbia River Spring-run Chinook salmon and Snake River Spring/Summer Run Chinook Salmon ESUs) may overlap with federal prey program fish originating from the same interior areas. The federal prey program would not be a primary driver of or substantial contributor to density-dependent competitive effects in these areas due to the much larger abundance of other salmonid and non-salmonid competitors, including other hatchery- and natural-origin Chinook salmon. For example, even in areas where the federal prey program is expected to increase Chinook salmon abundance the most, the federal prey program is expected to increase total Chinook salmon abundance by no more than 6.4% during the summer (Table 79) when most growth occurs and competition may be most detrimental. Available information is insufficient to be able to quantify a relationship between hatchery Chinook salmon abundance and adverse competitive effects to natural listed Chinook salmon (e.g., slower growth, decreased survival).

Risk from predation to all Interior Columbia and Willamette/Lower Columbia Recovery Domain Chinook salmon ESUs in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program

Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Interior Columbia and Willamette/Lower Columbia Recovery Domain Chinook salmon in the Pacific Ocean is low because risk from competition is low and risk of predation is negligible, as described above.

Steelhead DPSs

Risk from competition to all Interior Columbia and Willamette/Lower Columbia Recovery Domain steelhead DPSs in the Pacific Ocean is negligible. Columbia River basin steelhead migrate rapidly from the river mouth to the outer edge of the continental shelf. Based on 13–14 years of sampling along the Washington and northern Oregon coast, including the Columbia River plume, Daly et al. (2014) determined that juvenile steelhead from the Columbia River basin reached the western edge of the continental shelf in just a few days, and spent about 10 days in continental shelf waters before moving to open ocean areas off the shelf. In open ocean areas (off the continental shelf), they may overlap at a very broad spatial scale with immature and adult spring Chinook salmon from the upper Columbia River and the Snake River, including those from the federal prey program. The exact distribution and overlap in the open ocean of Columbia River basin steelhead and these spring Chinook salmon stocks is unknown. However, it is unlikely that these fish overlap at a spatiotemporal range sufficient to induce any detectable effects to steelhead trout given the length of time both species spend in the ocean, the very broad area over which they may range, and the much larger abundance of other salmonid and non-salmonid competitors. Steelhead generally remain in open ocean waters until they mature and migrate back across the shelf as adults, seemingly making an equally rapid transit across the shelf to the mouth of the Columbia River, as evidenced by their very rare capture in continental shelf fisheries (NMFS 2001a; 2018d).

Risk from predation to all Interior Columbia and Willamette/Lower Columbia Recovery Domain steelhead DPSs in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Interior Columbia and Willamette/Lower Columbia Recovery Domain steelhead in the Pacific Ocean is negligible because risk from competition is negligible and risk of predation is negligible, as described above.

Columbia River Chum Salmon ESU

Risk from competition to Columbia River chum salmon in the Pacific Ocean is negligible. Juvenile Chinook salmon (subyearlings and yearlings) are typically found in shallower water than juvenile chum salmon during their first ocean year on the continental shelf (Fisher et al. 2007a; Riddell et al. 2018; Urawa et al. 2018). In addition, juvenile chum salmon typically feed at a lower trophic level than juvenile Chinook salmon during this time, with the former consuming mostly zooplankton while the latter transitions to a mostly fish-based diet (Brodeur et al. 2007; Riddell et al. 2018; Urawa et al. 2018). During their first ocean year, chum salmon migrate north and westward off the continental shelf to open ocean areas where they remain until maturing. In open ocean areas (off the continental shelf), they may overlap at a very broad spatial scale with immature and adult spring Chinook salmon from the upper Columbia River and the Snake River, including those from the federal prey program. The exact distribution and overlap in the open ocean of Columbia River chum salmon and these spring Chinook salmon stocks is unknown. However, it is unlikely that these fish overlap at a spatiotemporal range sufficient to induce any detectable effects to steelhead trout given the length of time both species spend in the ocean, the very broad area over which they may range, and the much larger abundance of other salmonid and non-salmonid competitors. In addition, similar to juveniles, dietary overlap between the two species at their immature and adult stages is minimal, with Chinook salmon continuing to feed at higher tropic levels than chum salmon (e.g., Johnson et al. 2009; Riddell et al. 2018; Urawa et al. 2018).

Risk from predation to Columbia River chum salmon in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Columbia River chum salmon in the Pacific Ocean is negligible because risk from competition is negligible and risk of predation is negligible, as described above.

<u>Lower Columbia River Coho Salmon ESU</u>

Risk from competition to Lower Columbia River coho salmon in the Pacific Ocean is negligible. Juvenile Columbia River coho salmon disperse broadly on the continental shelf during their first ocean year, from northern Oregon to Kodiak Island, Alaska (Fisher et al. 2014), where they may overlap at broad geographic scales with federal prey program Chinook salmon. At a broad scale, Chinook and coho salmon utilize somewhat similar habitat and forage resources in marine areas, including along the Washington and Oregon coast. Similarities in general spatial distribution (e.g., Bi et al. 2008) and depth selection (e.g., Fisher et al. 2007a) have been observed. Though data are limited, there is evidence that Chinook and coho salmon occur in loose aggregations or patches at large spatial scales (e.g., Peterson et al. 2010; Berdahl et al. 2016). Pearcy et al. (1990a) evaluated the distribution and abundance of juvenile salmonids along Washington and Oregon coastal areas during May–September, 1981–1985. They observed a high degree of co-occurrence of juvenile Chinook and coho salmon. That is, the two species were frequently captured in the same purse seine sets. The number of sets with both species was significantly greater than the expected number if co-occurrence was random ($p < 0.05$). Conversely, Pool et al. (2012) observed that juvenile Chinook and coho salmon along the Oregon coast selected different habitat types. Studies have documented a moderate to high degree of dietary overlap between coho and Chinook salmon juveniles (e.g., Peterson et al. 1982; Brodeur et al. 1990; Schabetsberger et al. 2003; Brodeur et al. 2007; Miller et al. 2007; Weitkamp et al. 2008; Daly et al. 2009; Brodeur et al. 2013) and adults (e.g., Brodeur et al. 1987; Brodeur et al. 2014) along the west coast of North America, including coastal Washington and Oregon and the Columbia River plume. However, there do not appear to be any indications that coho salmon suffer from density dependence within the action area (Beamish et al. 2018), perhaps owing in part to the lack of full overlap in habitat selection and diet described above. For these reasons, it is unlikely that hatchery Chinook salmon from the federal prey program will have a measurable impact on the growth and survival of coho salmon within the action area.

Risk from predation to Lower Columbia River coho salmon in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Lower Columbia River coho salmon in the Pacific Ocean is negligible because risk from competition is negligible and risk of predation is negligible, as described above.

Snake River Sockeye Salmon ESU

Risk from competition to Snake River sockeye salmon in the Pacific Ocean is negligible. There is no stock-specific ocean distribution information available for Snake River sockeye salmon. Juvenile sockeye salmon stocks from Puget Sound and the Columbia River migrate north on the continental shelf during the summer (Tucker et al. 2009; Beacham et al. 2014) where they may overlap with juvenile Chinook salmon released as part of the federal prey program (Tucker et al. 2011; 2012). Juvenile Chinook salmon (subyearlings and yearlings) are typically found in shallower water than juvenile sockeye salmon during their first ocean year on the continental shelf (Fisher et al. 2007a; Farley et al. 2018; Riddell et al. 2018). Researchers have found very little overlap in diet between juveniles of the two species in these areas (Brodeur et al. 1990; Landingham et al. 1998; Brodeur et al. 2007; Farley et al. 2018; Riddell et al. 2018). These studies found that juvenile Chinook salmon feed at a higher trophic level than sockeye salmon. That is, juvenile Chinook salmon in the ocean are primarily piscivores, whereas juvenile sockeye salmon are largely planktivores (Brodeur et al. 2007; Farley et al. 2018; Riddell et al. 2018). For these reasons, any potential competitive effects during this time are discountable.

By winter, most juvenile sockeye salmon move off the continental shelf to the open ocean (Tucker et al. 2009; Beacham et al. 2014; Farley et al. 2018). At this stage (off shelf, open ocean), they may overlap at a very broad spatial scale with immature and adult spring Chinook salmon from the upper Columbia River and the Snake River, including those from the federal prey program. The exact distribution and overlap in the open ocean of Snake River sockeye salmon and these spring Chinook salmon stocks is unknown. However, it is unlikely that these fish overlap at a spatiotemporal range sufficient to induce any detectable effects to sockeye salmon given the length of time both species spend in the ocean, the very broad areas over which they may range, and the much larger abundance of other salmonid and non-salmonid competitors. Similar to juveniles, dietary overlap between the two species at their immature and adult stages is minimal, with Chinook salmon continuing to feed at higher tropic levels than sockeye salmon (e.g., Johnson et al. 2009; Farley et al. 2018; Riddell et al. 2018). For these reasons, risks to Snake River sockeye salmon on the continental shelf and in open ocean are minimal to non-existent.

Risk from predation to Snake River sockeye salmon in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, ESA-listed juvenile Snake River sockeye salmon are expected to occur in very low abundances relative to preferred prey taxa and other juvenile salmonids in the broad spatial areas where they may overlap with federal prey program Chinook salmon. Federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Snake River sockeye salmon in the Pacific Ocean is negligible because risk from competition is negligible and risk of predation is negligible, as described above.

North Central California Coast Recovery Domain

<u>California Coastal Chinook Salmon ESU</u>

Risk from competition to California Coastal Chinook salmon in the Pacific Ocean is low. Low-level negative intraspecific density-dependent effects to Chinook salmon may occur at some times and in some places depending primarily on ocean conditions and interspecific competitor abundance, as described above. The addition of hatchery Chinook salmon via the federal prey program may have a small affect in exacerbating these effects. However, the federal prey program would not be a primary driver of or substantial contributor to these effects due to the much larger abundance of other salmonid and non-salmonid competitors, including other hatchery- and natural-origin Chinook salmon. For example, even in areas where the federal prey program is expected to increase Chinook salmon abundance the most, the federal prey program is expected to increase total Chinook salmon abundance by no more than 6.4% during the summer when most growth occurs and competition may be most detrimental. Based on the information described above in the subsection entitled Evidence for Competition in the Pacific Ocean, the small, incremental increase in Chinook salmon marine abundance represented by the federal prey program will not present any more than a low risk to ESA-listed natural salmonids in the marine portion of the action area. Available information, described above in the subsection entitled Evidence for Competition in the Pacific Ocean, is insufficient to be able to quantify a relationship between hatchery Chinook salmon abundance and adverse competitive effects to natural listed Chinook salmon (e.g., slower growth, decreased survival). Our analysis is thus largely qualitative nature.

On average, less than 6.7% of Chinook salmon from the California Coastal Chinook ESU are likely to occur along the Washington coast to Cape Falcon, Oregon (Shelton et al. 2019) where the federal prey program may increase Chinook salmon abundance by up to 6.4% during the summer (Table 79) when most growth occurs and competition may be most detrimental. North of Washington, less than 1.5% of California Coastal Chinook salmon are likely to occur, some of which may occur in areas where the federal prey program may increase Chinook abundance by up to 6.1% during the summer. Chinook salmon from the California Coastal Chinook ESUs may experience negative density dependent effects in these areas during some years depending on ocean productivity and abundance of other salmonid and non-salmonid competitors. The federal prey program may exacerbate these effects to a small degree, but would not be a primary driver of or substantial contributor to them due to the much larger abundance of other salmonid and non-salmonid competitors. Risk at the scale of the ESUs is particularly low given the relatively small proportion of fish from these ESUs expected to occur in these areas.

Risk from predation to California Coastal Chinook salmon in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, ESA-listed juvenile California coastal Chinook salmon are expected to occur in very low abundances relative to preferred prey taxa and other juvenile salmonids in the broad spatial areas where they may overlap with federal prey program Chinook salmon. Federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to California Coastal Chinook salmon in the Pacific Ocean is low because risk from competition is low and risk of predation is negligible, as described above.

Central Valley Recovery Domain

Central Valley Spring-run Chinook Salmon ESU

Risk from competition to Central Valley Spring-run Chinook salmon in the Pacific Ocean is low. Low-level negative intraspecific density-dependent effects to Chinook salmon may occur at some times and in some places of the action area depending primarily on ocean conditions and interspecific competitor abundance, as described above. The addition of hatchery Chinook salmon via the federal prey program may have a small affect in exacerbating these effects. However, the federal prey program would not be a primary driver of or substantial contributor to these effects due to the much larger abundance of other salmonid and non-salmonid competitors, including other hatchery- and natural-origin Chinook salmon. For example, even in areas where the federal prey program is expected to increase Chinook salmon abundance the most, the federal prey program is expected to increase total Chinook salmon abundance by no more than 6.4% during the summer (Table 79) when most growth occurs and competition may be most detrimental. Based on the information described above in the subsection entitled Evidence for Competition in the Pacific Ocean, the small, incremental increase in Chinook salmon marine abundance represented by the federal prey program will not present any more than a low risk to ESA-listed natural salmonids in the marine portion of the action area. Available information, described above in the subsection entitled Evidence for Competition in the Pacific Ocean, is insufficient to be able to quantify a relationship between hatchery Chinook salmon abundance and adverse competitive effects to natural listed Chinook salmon (e.g., slower growth, decreased survival). Our analysis is thus largely qualitative nature.

Ocean distribution of Central Valley spring Chinook salmon is inferred from CWT recoveries of fish originating from only two populations (Shelton 2024c), which are the only populations that are tagged: Feather River and Butte Creek[62]. The Feather River population is represented by fish

[62] Feather River CWT data is represented by 23 brood years (1977–2011), a total of 21.7 million tagged fish, with an average of over 940,000 fish tagged per year. Butte Creek CWT data is represented by 14 brood years (1995–2007),

from the Feather River Hatchery. Feather River fish have regularly occurred throughout the action area, from its southern extent to northern Vancouver Island, albeit in low numbers. Butte Creek fish, on the other hand, have never been observed in the action area. This discrepancy could be related to the lower numbers of tagged fish released from Butte Creek: if Central Valley spring Chinook salmon are relatively rare in the action area, as suggested by the Feather River recoveries, it follows that many tagged fish need to be released to generate any recoveries. This appears to be an unlikely cause for the lack of Butte Creek recoveries in the action area, though, because even Feather River brood years represented by relatively few tagged fish (9 brood years; 41,000–314,000 tagged fish released per brood year) generated recoveries in the action area, often multiple recoveries per brood year. If Butte Creek exhibited a similar oceanic distribution as Feather River, the cumulative release of 1.8 million tagged Butte Creek fish should have generated at least a few recoveries in the action area.

A more plausible explanation lies in the ancestral origins of the Feather River fish. Ocean distribution is largely genetically programmed, and researchers have remarked on the consistency with which genetically related populations from specific geographic areas and run-timings use the same areas of the ocean year after year despite fluctuating ocean conditions (citations). Though the ancestral origins of the Feather River Hatchery stock are not known with certainty, evidence suggests the hatchery lineage has been heavily introgressed with fall Chinook salmon (NMFS 2016t; SWFSC 2022). Fall Chinook salmon from the Central Valley are known to use the action area at similar proportions and with a similar distribution as the Feather River Hatchery spring Chinook salmon (Shelton et al. 2019). Genetic studies and other evidence suggest that other Central Valley spring Chinook salmon populations, including Butte Creek, have not been affected by introgression from Feather River Hatchery fish or fall Chinook salmon (SWFSC 2022). Thus, it appears likely that Feather River Hatchery spring Chinook salmon occur in the action area because it is an expression of their ancestral hybridization with fall Chinook salmon. It further appears likely that Butte Creek spring Chinook salmon, unaffected by such hybridization, are more representative of the rest of the Central Valley spring Chinook salmon populations in terms of their ocean distribution.

Central Valley spring Chinook salmon that occur in the action area may experience negative density dependent effects during some years depending on ocean productivity and abundance of other salmonid and non-salmonid competitors. The federal prey program may exacerbate these effects to a small degree, but would not be a primary driver of or substantial contributor to them due to the much larger abundance of other salmonid and non-salmonid competitors. Risk at the scale of the ESU is negligible because only fish from the Feather River population are likely to be affected, and only a small proportion of fish from the Feather River population would be affected.

Risk from predation to Central Valley Spring-run Chinook salmon in the Pacific Ocean is negligible. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas, as described above. Further, ESA-listed juvenile Central Valley spring Chinook salmon are expected to occur in very low abundances relative to preferred prey taxa and other juvenile salmonids in the broad spatial

a total of 1.8 million tagged fish, with an average of over 126,000 fish tagged per year.

areas where they may overlap with federal prey program Chinook salmon. Federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas.

The combined risk from competition and predation to Central Valley Spring-run Chinook salmon in the Pacific Ocean is low because risk from competition is low and risk of predation is negligible, as described above.

2.5.1.2.3.6 Effects of progeny of hatchery-origin fish that spawn naturally

Because naturally-produced progeny of hatchery-origin fish are expected to have broadly similar distribution as that described above for hatchery-origin fish themselves in freshwater and marine areas (including Salish Sea natal inner estuaries and mainstem Columbia and Snake Rivers), the same Recovery Domains and ESUs/DPSs described in those sections may be affected. These include the following:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs
- North Central California Coast: California Coastal Chinook Salmon ESU
- Central Valley: Central Valley Spring-Run Chinook Salmon ESU

Salmon and steelhead from Recovery Domains or ESUs/DPSs not listed above are not expected to occur in the action area.

Naturally spawning hatchery-origin salmon may be less efficient at reproduction than their natural-origin counterparts (Christie et al. 2014). However, the progeny of such hatchery-origin spawners may comprise a sizable proportion of the juvenile fish assemblage depending on the abundance of hatchery-origin spawners relative to the affected natural population(s). This added natural production may contribute to density-dependent responses of decreased growth and exceedance of habitat capacity, as well as other ecological effects, described in the preceding subsections on competition and predation in freshwater and marine areas (including Salish Sea natal inner estuaries and mainstem Columbia and Snake Rivers). Hatchery fish from integrated and stepping stone programs may replace, to a certain extent, natural fish removed for broodstock (see discussions in Factor 1 and Factor 2, Genetic Effects). Thus, effects from these fish are expected to be reasonably close to what would be expected if no natural-origin fish were removed for broodstock. Conversely, natural spawning of fish from isolated programs is generally undesirable and not intended. Effects of naturally-produced progeny from these hatchery-origin fish from isolated programs may thus present a greater risk.

Progeny of naturally spawning hatchery-origin salmon will have similar ecological effects as those described in the preceding subsections on competition and predation in freshwater and marine areas (including Salish Sea natal inner estuaries and mainstem Columbia and Snake Rivers). Effects of naturally-produced progeny would likely be most acute in freshwater rearing areas and in delta and Salish Sea natal inner estuary areas. These watershed-scale effects are evaluated at a general level here. The exact scope and magnitude of these effects to specific affected populations are evaluated in site-specific Biological Opinions. Combined effects from federal prey program hatchery production in the mainstem Columbia and Snake Rivers, including the Columbia River estuary, and in marine areas are evaluated here.

At a population scale, risk from progeny of hatchery-origin fish that spawn naturally may range from negligible to moderately negative depending on a variety of factors, including but not limited to the degree of spatial and temporal overlap between hatchery- and natural-origin fish, and amount of available rearing space and forage resources, among other factors. In site-specific Biological Opinions, NMFS ensures that progeny of hatchery-origin fish that spawn naturally do not pose an unacceptable risk to natural populations. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the precise effects on natural populations.

To assess combined effects, we estimated potential natural juvenile production resulting from the proposed action; that is, natural juvenile production from federal prey program-funded hatchery-origin fish that spawn in the wild after eluding all sources of mortality and capture. The abundance of hatchery-origin fish that spawn in the wild and thus produce progeny may vary considerably across hatchery programs that receive federal prey program funding. There are many program-specific variables that contribute to this, including but not limited to the following: hatchery fish release abundance, post-release fish survival rates, harvest rates, the genetic management strategy employed (which can affect reproductive success in the wild), and hatchery adult management strategies (e.g., whether or not a weir is used to limit hatchery-origin spawner abundance). For this analysis, we assumed that the programs identified as having available space (production capacity) to produce Chinook salmon smolts for SRKW forage provide a reasonable representation of programs likely to be funded (Table 69). We thus used these programs as the basis of our analysis.

We used 2010–2019 average abundance of hatchery-origin spawners from these programs (Ford 2022). Most fish contributing to these abundances were released during 2007–2016. The federal prey program may increase hatchery release abundances by up to 36.1% and 10.2% across Puget Sound and the Columbia River basin, respectively, relative to this 2007–2016 time period. Thus, we applied these percent increases to the 2010–2019 average hatchery-origin spawner abundances to determine the additional number of hatchery-origin spawners resulting from the increased hatchery production, making the simplifying assumption that hatchery-origin spawner abundances will increase at the same rate as hatchery smolt releases. This yielded 3,948 hatchery-origin spawners across Puget Sound and 400 hatchery-origin spawners across the Columbia River basin Next, we applied a 50:50 sex ratio and a 4,200 eggs per female fecundity (Malick et al. 2023) to these estimates of hatchery-origin spawner abundances. We also applied an egg-to-smolt survival (exclusive of fry outmigrants) of 4.27% (Zimmerman et al. 2015), which is based on data from six Skagit River populations for 13 brood years (BYs 1996–2008). This likely provides a high estimate of survival, not only for the reasons described above (i.e., first generation hatchery fish often have lower reproductive success than naturally-produced fish), but also because Skagit River populations have some of the best, if not the best, productivity of any natural Chinook salmon populations across the region (Ford 2022). Applying these factors to the 3,948 Puget Sound and 400 Columbia River hatchery-origin spawners resulting from the proposed action yields a total of 354,025 Puget Sound and 35,876 Columbia

River Chinook salmon smolts. This represents an additional 2.4% smolts relative to the Puget Sound portion of the proposed action (i.e., up to 14.4 million smolt production goal and up to 5% average production overage), and up to an additional 0.3% smolts relative to the Columbia River portion of the proposed action (i.e., up to 9.8 million smolt production goal and up to 5% average production overage).

The analysis above indicates the following:

- In Puget Sound marine areas, the abundance of progeny of naturally-spawning hatchery-origin fish from the proposed action is likely to be very small, estimated to be up to 354,025 smolts (assuming 5% average hatchery production overage). Risk from these fish is therefore negligible.
- In the mainstem Columbia and Snake Rivers and the Columbia River estuary, the abundance of progeny of naturally-spawning hatchery origin fish from the proposed action is likely to be very small, estimated to be up to 35,876 smolts (assuming 5% average hatchery production overage). Risk from these fish is therefore negligible.
- In other marine areas, the abundance of progeny of naturally-spawning hatchery origin fish from the proposed action is likely to be very small, based on the Puget Sound and Columbia River estimates. Although we did not calculate an estimate for the Washington coast, this area is expected to produce the fewest federal prey program-funded hatchery smolts because it has less available capacity. Therefore, abundance of progeny of naturally-spawning hatchery origin fish in marine areas is expected to be equivalent to or less than those from the Columbia River and Puget Sound. Risk in marine areas is thus negligible

2.5.1.2.3.7 Disease

Pathogens may be transmitted from the hatchery to the natural environment by the release of hatchery fish, the discharge of hatchery effluent, or the rearing of juvenile fish in net pens. In addition, hatchery effluent may contain contaminants and have other properties (e.g., may be warmer with less dissolved oxygen) that may contribute to disease outbreaks. Pathogen transmission between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Steward et al. 1990; Naish et al. 2007). This lack of reporting is because both hatchery and natural-origin salmon and trout are susceptible to the same pathogens (Noakes et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum*, the cause of Bacterial Kidney Disease).

When implemented, best management practices, as well as state, Federal, and tribal fish health policies, limit the disease risks associated with hatchery programs (e.g., IHOT 1995; ODFW 2003; USFWS 2022; NWIFC 2006; NWIFC and WDFW 2006). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic reportable pathogens. For all reportable and non-reportable pathogens, pathogen spread and amplification are minimized through regular monitoring (typically monthly), removing mortalities, and disinfecting eggs. When available, vaccines may provide additional protection from certain pathogens (e.g., *Vibrio anguillarum*). If a pathogen is found to be present, treatments (e.g., antibiotics) are used to limit further pathogen transmission and amplification. Some pathogens, such as infectious hematopoietic necrosis virus (IHNV), have no known treatment. Thus, if an epizootic occurs for those pathogens, the only way to control pathogen amplification is to cull infected individuals or terminate all susceptible fish. In addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

Hatchery programs typically implement policies and practices for preventing, monitoring, and controlling pathogens in the hatchery environment (e.g., IHOT 1995; ODFW 2003; USFWS 2022; NWIFC 2006; NWIFC and WDFW 2006). These protocols and practices help contain pathogen outbreaks at hatchery facilities, minimize release of infected fish from hatcheries, and reduce the risk of fish pathogen transfer and amplification to natural origin fish (e.g., Naish et al. 2008; also see Appendix A). Frequent inspections and fish health monitoring allow for rapid detection and treatment of pathogens and disease. Treatments for nearly all commonly encountered pathogens are usually effective within hours to weeks, minimizing the length of time pathogens may be shed and amplified in the hatchery. High egg-to-smolt survival rates are common, providing further evidence that pathogen management protocols are effective. The risk of any pathogen amplification effects is often further reduced because the sizes of the primary receiving waterbodies (i.e., large rivers) are usually much larger than the effluent outflow, rapidly diluting the concentrations of any infectious agents in the hatchery effluent.

Based on the factors described above, disease risk associated with hatchery programs are highest near hatchery facilities and in areas where large concentrations of hatchery fish are present (i.e., shortly after release in freshwater habitats). However, there is no evidence showing that hatchery programs meaningfully elevate pathogen risks beyond baseline levels (i.e., that present naturally from natural-origin fish). Based on these factors, we conclude that the risk of disease amplification and transmission is low in freshwater watersheds where hatchery facilities operate, and declines to negligible in larger bodies of water (e.g., mainstem Columbia River and Snake River; marine areas) where hatchery fish become more dispersed and hatchery effluent becomes extremely diluted.

During site-specific consultations, NMFS evaluates whether safeguards proposed by hatchery operators are sufficient for minimizing disease risk to natural populations. If they are not sufficient, NMFS imposes Terms and Conditions so that risk is sufficiently minimized. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the precise effects on natural populations. Not all populations within a given ESU or DPS may be affected by disease in freshwater. This is because federal prey program-funded hatchery smolts will be released in areas with existing hatchery facilities, and some populations exist in areas without hatchery facilities. Thus, only natural populations affected by existing programs may be affected by the federal prey program in freshwater. Risk to individual affected populations in freshwater areas other than the Columbia and Snake River mainstems is expected to range from negligible to low based on our experience completing site-specific consultations (see Environmental Baseline and Appendix B). In all other areas, disease risk is negligible. For these reasons, we expect that disease risk will be negligible at the ESU and DPS scale.

2.5.1.2.4 Factor 4: Research, monitoring, and evaluation that exists because of the hatchery program

Research, monitoring, and evaluation (RM&E) focused on federal prey program fish may occur in freshwater, estuarine, and adjacent nearshore marine areas within and near the watersheds that federal prey program fish are released into. Federal prey program fish will be released exclusively within Puget Sound, the Columbia River basin, and the Washington coast. Therefore, ESA-listed salmon and steelhead from the following Recovery Domains may be affected:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

Salmon and steelhead from other Recovery Domains are not expected to occur in the areas described above. Therefore, salmon and steelhead from other Recovery Domains will not be affected by RM&E.

Effects of RM&E occur solely at the watershed scale (i.e., they are watershed-scale effects) and are thus considered at a general level here. The exact scope and magnitude of effects to specific affected populations are evaluated in site-specific Biological Opinions.

RM&E of hatchery programs often include one or more of the following activities:

- Observational surveys (in-water or from the bank)
- Collecting and handling (purposeful or inadvertent)
- Sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping, and observing the fish (in-water or from the bank)

RM&E for adults often include foot and boat spawning ground surveys that count spawning fish and may include sampling carcasses for scales, otoliths, tissues for DNA analysis, and other similar types of carcass biosampling. The same level and types of biological sampling would occur for some species escaping to the hatcheries and collected as broodstock. Surveyor presence is temporary and infrequent, on the order of minutes within a given stream reach, occurring once or twice per week. The effects of these activities on ESA-listed adult salmon and steelhead are confined to avoidance behavior and temporary displacement from preferred areas until surveyors move through a stream reach. Fish frightened by disturbance, turbulence, and/or noise are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors. Therefore, we do not anticipate RM&E actions to result in a decrease in the likelihood of survival and recovery of the listed species.

Other RM&E activities, such as juvenile outmigrant trapping, are typically covered under separate NMFS ESA authorizations because they are usually more broadly focused and would occur in the absence of any hatchery programs. That is, data collected from these efforts are incidental to or only one aspect of efforts to monitor and study natural populations. Data collected through these efforts aids in monitoring and assessing hatchery effects. Data collected may include fish size, origin (based on mark and tag presence/absence), and other biological data (e.g., tissues sampled for genetic analyses).

During site-specific consultations, NMFS evaluates whether safeguards proposed by hatchery operators are sufficient for minimizing risk of RM&E to affected natural populations. If they are not sufficient, NMFS imposes Terms and Conditions so that risk is sufficiently minimized. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the precise effects on natural populations. Only RM&E actions that are specific to the hatchery program—not the more broadly focused RM&E that would occur absent the hatchery program—are evaluated in the site-specific consultations.

Not all populations within a given ESU or DPS may be affected by RM&E. This is because federal prey program-funded hatchery smolts will be released from existing hatchery facilities, and some populations exist in areas without hatchery facilities. Thus, only natural populations affected by RM&E associated with these existing programs may be affected by the federal prey program. At a population scale, risk from RM&E may range from beneficial to low negative depending on a variety of factors, including but not limited to the proportion of the population exposed to RM&E effects. Beneficial effects may accrue from the information that is generated from RM&E that aids in managing hatcheries to benefit natural populations (e.g., conservation programs). For these reasons, we expect that risk from RM&E will be negligible at the ESU and DPS scale.

2.5.1.2.5 Factor 5: Operation and maintenance of hatchery facilities

Hatchery facilities associated with the federal prey program will operate exclusively within Puget Sound (freshwater, estuarine, and marine areas), the Columbia River basin (freshwater and estuarine areas), and the Washington coast (freshwater areas). Therefore, ESA-listed salmon and steelhead from the following Recovery Domains may be affected:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

Salmon and steelhead from other Recovery Domains are not expected to occur in the areas described above. Therefore, salmon and steelhead from other Recovery Domains will not be affected by federal prey program hatchery facilities.

Effects of operation and maintenance of hatchery facilities occur solely at the watershed scale (i.e., they are watershed-scale effects) and are thus considered at a general level here. The exact scope and magnitude of effects to specific affected populations are evaluated in site-specific Biological Opinions.

Most hatchery facilities use surface water from adjacent rivers and streams, the withdrawal of which risks entraining fish into water intakes and/or impinging fish on intake infrastructure such as screening. Intake structures and screening that are designed and operated in accordance with current NMFS screening criteria (NMFS 2022c) substantially minimize this risk. Structures that meet previous NMFS criteria (NMFS 1995; 1996a; 2011g) may also reduce risk. Structures that do not meet criteria may present a high risk at the scale of the individual animal, but may present a negligible or low risk at the population scale if intake is small relative to the size of the waterbody and/or it is located in an area where few ESA-listed fish are likely to occur. Hatchery water use is typically non-consumptive, though the relative quantity of surface water withdrawn and relative locations of withdrawal and discharge points may present risks to migration, spawning, and rearing habitat to listed fish. Facilities that withdraw a small proportion of total stream discharge, and/or that discharge near the point(s) of withdrawal, minimize risks.

Hatchery water discharge into adjacent surface waters may affect several water quality parameters in the aquatic system. Hatchery facility waste products may include uneaten food, fish waste products (i.e., fecal matter, mucus excretions, proteins, soluble metabolites such as ammonia), chemotherapeutic agents (e.g., Formalin), cleaning agents (e.g., chlorine), drugs and antibiotics, nutrients (e.g., various forms of nitrogen and phosphorus), bacterial, viral, or parasitic microorganisms, and algae[63]. Some of these waste products are in the form of suspended solids and settleable solids, while others are dissolved in the water. Water temperature may increase and dissolved oxygen decrease as water flows through hatchery raceways and holding ponds. Maintenance activities, such as vacuuming and removal of accumulated sediment on the bottoms of hatchery ponds and raceways, may temporarily elevate the concentration of some contaminants in the hatchery water system.

The direct discharge of hatchery facility effluent is regulated by the Environmental Protection Agency (EPA) under the Clean Water Act through NPDES permits. For discharges from hatcheries not located on federal or tribal lands within Washington, the EPA has delegated its regulatory oversight to the State. Washington Department of Ecology is responsible for issuing and enforcing NPDES permits that ensure water quality standards for surface and marine waters remain consistent with public health and enjoyment, and the propagation and protection of fish, shellfish, and wildlife (WAC 173-201A). In Oregon, the Oregon Department of Environmental Quality (DEQ) is the agency responsible for issuing and enforcing NPDES, while in Idaho the Idaho Department of Environmental Quality (IDEQ) is the authority for issuing and enforcing NPDES. NPDES permits are not required for hatchery facilities that release less than 20,000 pounds of fish per year or that feed less than 5,000 pounds of fish food during any calendar month. Additionally, Native American tribes may adopt their own water quality standards for permits on tribal lands (i.e., tribal wastewater plans). Many hatcheries operate pollution

[63] Risk of pathogens from effluent discharge is addressed as part of Factor 3.

abatement ponds to remove suspended solids and settleable solids from effluent prior to discharge.

Most, if not all, chemicals used at hatcheries are used periodically (not constantly) and in relatively low volumes. This is particularly true for chemotherapeutic agents (e.g., formaldehyde, sodium chloride, iodine, potassium permanganate, hydrogen peroxide, antibiotics), which must be used at levels that will not appreciably affect the fitness or survival of juvenile salmonids rearing at the hatchery. In addition, many of these agents break down quickly in the water and/or are not likely to bioaccumulate in the environment. For example, formaldehyde readily biodegrades within 30 to 40 hours in stagnant waters. Similarly, potassium permanganate would be reduced to compounds of low toxicity within minutes. Aquatic organisms are also capable of transforming formaldehyde through various metabolic pathways into non-toxic substances, preventing bioaccumulation in organisms (EPA 2015). Although potentially more harmful, cleaning agents may be used periodically, but are diluted prior to being discharged resulting in extremely diminutive levels of discharge to any receiving waterbody.

Hatchery discharge volumes are typically a relatively small proportion of the receiving waterbody’s flow. Thus, hatchery effluent is often rapidly diluted near the point of discharge to the receiving waterbody. The likelihood of injury to listed salmonids from exposure to effluent is related to the frequency of occurrence, length of time they are exposed (e.g., how long they remain in the immediate vicinity of the effluent discharge points), and concentration of substances within the effluent water. Due to the periodic nature of chemical and chemotherapeutic use, and the low concentrations that are commonly achieved at or very near the point of discharge, we do not expect any deleterious effects to ESA-listed salmon and steelhead.

Compliance with NPDES requirements is not an assurance that effects on ESA-listed salmonids will not occur. However, the hatchery facilities use water specifically for the purpose of incubating and rearing juvenile salmon. Survival of eggs and juveniles in hatcheries are typically much higher than those in the natural environment. Egg and juvenile survival of the programs included in this consultation are indicative of generally good water quality. Chemicals are used periodically and diluted prior to discharge. Effluent discharge volumes are relatively small compared to the volumes of the receiving waters. Therefore, pollutants in the effluent are expected to be rapidly diluted near the point of discharge. In addition, any increase in temperature or decrease in dissolved oxygen that may have occurred in the hatchery would quickly return to background levels. For these reasons, effluent from the facilities included in this consultation are believed to present minimal risk to ESA-listed salmonids.

Maintenance of hatchery equipment and infrastructure (e.g., weirs, fish ladders, holding ponds, raceways) occurs intermittently and for short time periods. Such maintenance may generate disturbance from noise (equipment operation) and resuspension of fine sediments localized near the operation. Adult and larger juvenile salmonids are highly mobile and able to detect and avoid areas of disturbance. Salmonids in these age classes can easily move around or pass through sediment plumes. Individuals that may pass through a sediment plume will be exposed to elevated levels of turbidity for brief periods (less than 1 hour), and are not expected to be measurably affected. Noise from heavy equipment is not expected to reach levels that would be harmful. Therefore, direct effects associated with short-term exposure to elevated levels of turbidity and/or noise from maintenance activities are not expected to be meaningful.

Operation of net pens may affect water quality, native substrates, and benthos in the immediate vicinity of the operation. Effects are typically small in scale, localized near the facility, and do not have any measurable effects on listed species.

Herbicides (primarily glyphosate-based chemicals) are used at many hatchery facilities to maintain landscaping and lawns. Herbicides are used in accordance with the manufacturer's label guidelines, and are applied during dry weather conditions (i.e., not raining or expected to rain) to prevent runoff into surface waters. Roundup is often used around buildings and landscaped areas, and is not applied within 300 feet of water. Rodeo is often used for applications closer to water. Backpack sprayers or equivalent are often used for application. Herbicide use is typically relatively low and conservation measures are implemented to prevent chemicals from entering the water.

NMFS ensures that safeguards are in place so that operation and maintenance of hatchery facilities does not pose an unacceptable risk to natural populations. During site-specific consultations, NMFS evaluates whether safeguards proposed by hatchery operators are sufficient for minimizing risk. If they are not sufficient, NMFS imposes Terms and Conditions so that risk is sufficiently minimized. Such safeguards may include but not be limited to timelines on when hatchery operators must complete infrastructure upgrades to bring water intake structures and screening into compliance with current NMFS standards, and establishing and implementing flow criteria for safe fish passage in stream reaches partially dewatered by hatchery surface water withdrawal. The site-specific evaluations that must occur before federal prey program funding is distributed to the operators (criterion 6) assess the specific situation and determine the precise effects on natural populations.

Not all populations within a given ESU or DPS may be affected by hatchery operations and maintenance. This is because federal prey program-funded hatchery smolts will be released from existing hatchery facilities, and some populations exist in areas without hatchery facilities. Thus, only natural populations affected by these existing programs may be affected by the federal prey program. At a population scale, risk from hatchery operations and maintenance may range from negligible to moderately negative depending on a variety of factors, including but not limited to the extent of facility compliance with current NMFS safe fish passage and screening criteria, and the proportion of the population exposed to hatchery facility effects. Moderate risk to a population from hatchery operations and maintenance is generally only appropriate when these and other risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance, consistent with recovery plans. Most, if not all, populations are likely to incur only negligible or low risk based on our extensive experience completing site-specific hatchery consultations for all purposes (e.g., harvest, salmonid conservation) across the Columbia River basin and Puget Sound (see Environmental Baseline and Appendix B for a detailed accounting of all NMFS hatchery consultations completed across the Columbia River basin and Puget Sound). For these reasons, we expect risk from hatchery operations and maintenance will result in negligible to low negative risk at the ESU and DPS scale.

2.5.1.2.6 Factor 6: Fisheries that exist because of the hatchery program

There are no fisheries that exist because of the federal prey program. The federal prey program is intended to mitigate for removal of prey by fisheries subject to the PST, and provide additional prey for Southern Resident Killer Whales. Salmon fisheries off Alaska, Canada, Washington, and Oregon are managed under the PST and applicable domestic regulations. The Treaty has annex agreements that provide detailed implementation provisions that are renegotiated periodically for multi-year periods ("PST Agreement"). The 2019–2028 PST Agreement currently in effect (Pacific Salmon Commission 2022) includes provisions limiting harvest impacts in all Chinook salmon fisheries and refining the management of coho, sockeye, chum, and pink salmon within its scope. This PST Agreement includes reductions in the allowable annual catch of Chinook salmon in the SEAK and Canadian West Coast of Vancouver Island and Northern British Columbia fisheries by up to 7.5% and 12.5%, respectively, compared to the previous (2009–2018) PST Agreement. The level of reduction depends on the Chinook salmon abundance in a particular year. This comes on top of the reductions of 15% and 30% for those same fisheries that occurred as a result of the 2009–2018 PST Agreement. These reductions result in more salmon returning to the more southerly U.S. Pacific Coast portion of the EEZ than under prior PST Agreements. Therefore, under the new PST Agreement, the fisheries should have a smaller effect in terms of reducing SRKW prey than under the previous PST Agreement, and the federal prey program decreases the likelihood that the abundance of fish in SRKW forage areas will be very low in a given year. (NMFS 2024c).

2.5.1.2.7 Summary of Effects to Salmon and Steelhead

Table 80 below summarizes the anticipated effects from the federal prey program described in the preceding sections.

Table 80. Summary of the ranges of possible risk presented by the proposed action for each factor of analysis and effect element to affected ESA-listed salmon ESUs and steelhead DPSs from affected Recovery Domains. Abbreviations are as follows: N = none or negligible risk; L = low risk. Maximum potential level of risk is indicated by highlighting color: dark green (none or negligible risk), light green (low risk).

Factor	Effect element[a]	Combined effects?	Recovery Domains[b] and ESUs/DPSs[c] potentially affected by the proposed action											
			Puget Sound			Interior Columbia River			Willamette / Lower Columbia River				NC CC	CV
			PS CHK	PS STH	HC SC	CHK (all)	STH (all)	SR SOC	CHK (all)	STH (all)	CR chum	LCR coho	CCC	CV SpC
Factor 1	NO fish used for broodstock	no	N–L			N–L			N–L					
Factor 2 (HO fish on spawning grounds; broodstock collection)	Genetic effects	no	N–L			N–L			N–L					
	Ecological effects[d]	no	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L		
	Adult collection	no	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L		
Factor 3 (Hatchery fish in juvenile rearing areas, the estuary, and ocean)	C&P: Freshwater (except mainstem CR & SR)	no	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L		
	C&P: mainstem CR & SR	yes				N–L	N–L	N–L	N–L	N–L	N–L	N–L		
	C&P: SS natal inner estuaries	no	N–L	N	N–L									
	C&P: SS & CR estuary marine[e]	yes	L	L	L	L	N	N	L	N	L	N		
	C&P: Pacific Ocean	yes	L	N	N	L	N	N	L	N	N	N	L	L
	Disease	yes	N	N	N	N	N	N	N	N	N	N	N	N
	Progeny of HOS	yes	N	N	N	N	N	N	N	N	N	N	N	N
Factor 4	RM&E	no	N	N	N	N	N	N	N	N	N	N		
Factor 5	Hatchery O&M	no	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L	N–L		
Factor 6	Fisheries	n/a	n/a											

[a] NO = natural origin; C&P = competition and predation; CR = Columbia River; SR = Snake River; SS = Salish Sea; HOS = hatchery-origin spawners; RM&E = research, monitoring, and evaluation; O&M = operations and maintenance.
[b] NCCC = North-Central California Coast; CV = Central Valley
[c] CCC = California Coastal Chinook; CHK (all) = all Chinook ESUs in the Recovery Domain; CR chum = Columbia River Chum; CV SpC = Central Valley Spring Chinook; HCCS = Hood Canal Summer Chum; LCR coho = Lower Columbia River Coho; PS CHK = Puget Sound Chinook; PS STH = Puget Sound

Steelhead; SR SOC = Snake River Sockeye; STH (all) = all steelhead DPSs in the Recovery Domain.
[d] Marine-derived nutrients and ecological services; Spawning site competition and redd superimposition; Disease
[e] Not including Salish Sea natal inner estuaries.

2.5.2 Salmon and steelhead Critical Habitat

Designated critical habitat occurs in the action area for listed salmonids from the following Recovery Domains:

- Puget Sound: all salmon ESUs and steelhead DPSs
- Willamette/Lower Columbia River: all salmon ESUs and steelhead DPSs
- Interior Columbia River: all salmon ESUs and steelhead DPSs

Most effects to critical habitat occur solely at the watershed scale (i.e., they are watershed-scale effects) and are thus considered at a general level here. The exact scope and magnitude of watershed-scale effects to specific PBFs and components of PBFs are evaluated in site-specific Biological Opinions. The proposed action will have combined effects on the following critical habitat PBFs (physical or biological features)[64]: 1) PBF 2 as it pertains to forage supporting juvenile development in the mainstem Columbia and Snake Rivers; 2) PBF 4 as it pertains to predation and forage in the Columbia River estuary and estuarine areas of the Salish Sea (other than natal inner estuaries); and, PBF 6 as it pertains to forage in those portions of Puget Sound nearshore marine areas that are designated critical habitat. Effects to these PBFs are described below.

Effects to PBFs are as follows:

PBF 1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.

Effects to PBF 1 occur solely at the watershed scale (i.e., they are watershed-scale effects). Hatchery water use is typically non-consumptive, though the relative quantity of surface water withdrawn and relative locations of withdrawal and discharge points may present risks to this PBF. Facilities that withdraw a small proportion of total stream discharge, and/or that discharge near the point(s) of withdrawal, minimize risks. Hatchery effluent may be discharged into or near critical habitat, decreasing water quality in a localized area near the discharge point. Chemicals and other hatchery-related pollutants in the effluent, slightly reduced dissolved oxygen levels, and minor increases in temperature typically do not alter water quality downstream of the facilities to a degree that would inhibit or measurably affect reproduction, growth or survival of listed salmonids downstream of any of the facilities. In addition, the discharge volumes are often relatively small compared to the volumes of the receiving waterbodies in critical habitat. Compliance with applicable NPDES permits helps ensure that water quality in downstream critical habitat areas is not degraded or adversely affecting this PBF. In-water broodstock collection efforts may result in minor, localized, and temporary disturbances to water quality in critical habitat.

Hatchery facilities and hatchery activities are generally not expected to have more than insignificant effects to spawning substrate quantity or quality. Any work in or near surface waters that are included in critical habitat will be done in compliance with applicable state and

[64] PBFs are habitat features that are essential to the conservation of the listed species because they support one or more of the species' life stages. See Section 2.2.7 for additional information.

federal permits (e.g., WDFW Hydraulic Project Approval) that specifies allowable in-water work windows and Best Management Practices. Any affects to spawning substrates would be minor, temporary, and limited in area. In-water broodstock collection efforts may result in minor, localized, and temporary disturbances to critical habitat substrates.

PBF 2. Freshwater rearing sites with: (i) Water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) Water quality and forage supporting juvenile development; and (iii) Natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

In freshwater areas, except for the mainstem Columbia River and Snake River, effects to water quality and quantity related to this PBF occur solely at the watershed scale (i.e., they are watershed-scale effects) and are the same as those described for PBF 1. At many hatchery facilities, weirs, water intake infrastructure and affiliated structures, and bank armoring diminish habitat complexity. However, their effects are relatively small and localized, and are not expected to affect the functioning of this PBF at the scale of the watershed or spatial extent of the populations. There may be minor effects to cover as a result of needing to keep hatchery infrastructure such as surface water intakes clear of debris such as large wood, rocks, and aquatic vegetation. However, these areas are expected to be very small relative to available critical habitat throughout the watershed. Floodplain connectivity and access to side channels may be impaired, though these areas are expected to be a small proportion of critical habitat in the watershed. Hatchery fish may consume forage resources that would otherwise be available to natural fish, as described in Section 2.5.1.2.3 (Factor 3). These effects are expected to be minor for the reasons described therein.

The proposed action will have combined effects to forage supporting juvenile development in the mainstem Columbia and Snake Rivers, as federal prey program-funded hatchery fish from across the basin move through these areas. Hatchery fish may consume forage resources that would otherwise be available to natural fish, as described in Section 2.5.1.2.3 (Factor 3). These effects are expected to be minor for the reasons described therein.

PBF 3. Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

Effects to PBF 3 occur solely at the watershed scale (i.e., they are watershed-scale effects). Effects to water quality and quantity related to this PBF are the same as those described for PBF 1. Effects to cover related to this PBF are the same as those described for PBF 2. Surface water usage is generally non-consumptive. However, hatchery water withdrawal may affect critical habitat in the stream or river reach between the withdrawal and discharge points, depending on the relative volumes of withdrawal and stream or river flow. Hatchery water withdrawal may degrade passage conditions through this partially dewatered reach, potentially affecting juvenile and adult mobility and survival. Fish mobility may be temporarily impaired and made more strenuous due to the challenges of navigating riffles that are shallower than they otherwise would be without the water withdrawals. Effects are usually temporary (only occurring during lower-flow periods), and passage is generally not precluded.

PBF 4. Estuarine areas free of obstruction and excessive predation with: (i) Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and (iii) Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

For Salish Sea natal inner estuaries, effects to PBF 4 occur solely at the watershed scale (i.e., they are watershed-scale effects). Released hatchery fish that enter the estuary may directly and indirectly compete with listed salmonids for forage resources, as described in Section 2.5.1.2.3 (see Factor 3 subsections pertaining to Competition and Predation in Salish Sea Natal Inner Estuaries). As described in Section 2.5.1.2.3, these effects are expected to vary by location, but are expected to be mostly negligible or minor for the reasons described therein.

For the Columbia River estuary and estuarine areas of the Salish Sea (other than natal inner estuaries), the proposed action will have combined effects to forage resources. Released hatchery fish that enter these areas may directly and indirectly compete with listed salmonids for forage resources, as described in Section 2.5.1.2.3 (see Factor 3 subsections pertaining to Competition and Predation in Marine Areas of the Salish Sea & the Columbia River Estuary). These effects are expected to be minor for the reasons described therein.

PBF 5. Nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

Effects to this PBF are the same as those described for PBF 4.

PBF 6. Offshore marine areas with water-quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Released hatchery fish that enter marine areas may directly and indirectly compete with listed salmonids for forage resources, as described above for PBF 4 and in Section 2.5.1.2.3. These effects are expected to be minor for the reasons described therein.

2.5.3 Eulachon

2.5.3.1 Effects of Predation

For purposes of this analysis, we first examined the likelihood that the production and release of hatchery-produced Chinook salmon would be expected to co-occur in space and time in the action area with eulachon. With co-occurrence and exposure established, we then examined the extent to which hatchery-produced and released Chinook salmon may affect eulachon. The three effect pathways we considered in this analysis were predation, competition, and the potential for hatchery-produced and released Chinook salmon to transmit diseases to adult, juvenile, sub-adult, and larval eulachon.

Based on the temporal distribution of emigrating/migrating eulachon and salmonid fishes in Table 67, Table 68, and Table 81, there is extensive spatial and temporal co-occurrence of eulachon and hatchery-produced and released Chinook salmon throughout the action area. Therefore, since eulachon will be exposed to hatchery-produced and released Chinook salmon for multiple generations,[65] we expect hatchery-produced Chinook salmon to prey on adult, juvenile, sub-adult, and larval eulachon. However, the magnitude, severity, and duration (number of eulachon generations) of predation on eulachon as a result of an annual production and release of up to 22 million Chinook salmon smolts will depend on the duration of effects, and the spatial and temporal overlap of eulachon and hatchery-produced Chinook salmon throughout the action area.

Salmon are piscivorous and are known to feed on other fishes, including eulachon (Osgood et al. 2016). Predation, either direct (direct consumption) or indirect (increases in predation by another predator species due to enhanced attraction) can result from hatchery fish released into the wild.

As a general matter, hatchery fish released at a later stage (yearlings) tend to emigrate quickly to the ocean, but depending on timing, they are likely to encounter, and therefore prey, on larval eulachon — eulachon larval production in the Columbia River can number in the trillions — in freshwater environments during their downstream drift-migration to the ocean. Sub-yearling hatchery produced and released Chinook salmon (i.e., ocean-type Chinook salmon) tend to take longer than yearling Chinook salmon (i.e. stream-type Chinook salmon) to migrate through the freshwater-estuarine portions of rivers, as they tend to utilize off-channel and marsh habitats for extended periods prior to emigrating to the ocean, thus their impact on eulachon in terms of predation is likely larger. Once hatchery-produced and released fish reach the ocean, it is likely they would continue to prey on larval eulachon in the nearshore-ocean environment, as well as juvenile, sub-adult, and adult eulachon that are encountered during their residence (years) in the nearshore and open ocean environments. In addition to hatchery-produced and released Chinook salmon that the emigrate to the ocean, some of these hatchery-produced and released fish may not emigrate and instead take up residence in the freshwater environments (residuals) where predation intensity on larval and adult eulachon may increase due to an increase in exposure potential.

Under the proposed action, both sub-yearling and yearling hatchery-produced Chinook salmon would continue to be released. Adults from these releases would continue to return to rivers and streams that are accessible to anadromous salmonids in the action area; however, the effects (predation) are likely to persist well beyond the return of these adults as offspring of these hatchery-produced and released Chinook salmon will continue to spawn and produce offspring that then return as adults and produce progeny. While the specific number of generations that these hatchery-produced Chinook salmon will persist in the wild are unknown, management

[65] For eulachon, we use age-3 fish as a generation, as they typically represent greater than 50% of the spawners in the Columbia River and Fraser River.

Table 81. Seasonal patterns of occurrence for ESA-listed salmonid stocks in the lower Columbia River. Black regions indicate times of peak abundance.

Adult Salmonids	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook												
Snake River Fall												
Snake River Spring/Summer												
Upper Columbia River Spring												
Lower Columbia River												
Upper Willamette												
Sockeye												
Snake River												
Chum												
Lower Columbia River												
Coho												
Lower Columbia River												
Steelhead												
Upper Columbia River												
Snake River												
Middle Columbia												
Upper Willamette												
Lower Columbia River												
Juvenile Salmonids												
Chinook												
Snake River Fall												
Snake River Spring/Summer												
Upper Columbia River Spring												
Lower Columbia River												
Upper Willamette												
Sockeye												
Snake River												
Chum												
Lower Columbia River												
Coho												
Lower Columbia River												
Steelhead												

Adult Salmonids	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Columbia River												
Snake River												
Middle Columbia												
Upper Willamette												
Lower Columbia River												

efforts, such as removal of these hatchery-produced fish at weirs, fishing, and natural attrition, etc., will further diminish the presence of hatchery-produced fish in the wild over time reducing the effects of predation on eulachon.

As noted above, eulachon occur throughout the action area in space and time with the production and release of hatchery-produced Chinook salmon under the proposed action. The proposed increases in hatchery-produced and released Chinook salmon are likely to have direct effects that will adversely affect eulachon. Although the amounts of larval, juvenile, sub-adult, and adult eulachon consumed by these hatchery-produced and released Chinook salmon under the proposed action cannot be quantified, we do not expect the duration and magnitude of predation to meaningfully affect eulachon productivity and abundance at the subpopulation or DPS level as Chinook salmon (wild and hatchery-produced), while predators of eulachon, are not know to selectively prey on eulachon, and therefore this increase in hatchery-produced Chinook salmon is not likely to have a significant impact on the survival and recovery of eulachon.

2.5.3.2 Effects of Competition and Disease

The potential effects of the proposed action considered here include competition for space, and the likelihood that these hatchery-produced Chinook salmon would act as a disease vector for eulachon. Adult eulachon typically spawn in the lower reaches of larger rivers fed by snowmelt (Hay et al. 2000). Spawning substrates can range from silt, sand, or gravel to cobble and detritus (Barrett et al. (1984), Vincent-Lang and Queral (1984); as cited in NMFS (2017i)), but sand appears to be most common (Langer et al. (1977) and Lewis et al. (2002); as cited in NMFS (2017i)).

We do not expect hatchery-produced Chinook salmon that return as adults to the spawning grounds to compete for space with eulachon as they generally utilize different substrates and have limited overlap in run timing. Eulachon larvae are carried downstream and are dispersed to the ocean by river, estuarine, and tidal currents, and are generally distributed throughout the water column. Yearling hatchery-produced Chinook salmon smolts generally migrate rapidly through the Columbia River estuary and tend to be more surface oriented. Sub-yearling hatchery produced Chinook salmon tend to take longer to migrate through the freshwater and estuarine portions of rivers, and tend to utilize off-channel and marsh habitats prior to emigrating to the ocean. Therefore, we do not expect the effects of the proposed action on competition for space to be too dissimilar from natural conditions, and what effects for space may occur are likely to be minor.

We are not aware of disease transmission between salmonids and eulachon. Therefore, we expect the effects of the proposed action to transmit diseases to eulachon to be minor.

2.5.4 Puget Sound/Georgia Basin Rockfish

The proposed action is likely to impact listed yelloweye rockfish and bocaccio in Puget Sound because juvenile Chinook salmon are predators of certain life stages of rockfish, which varies depending on their habitat use patterns. Rockfish have a complex life history that spans multiple seasons and years, across several habitat types. In order to determine the effects of the proposed action, we reviewed what is known about the spatiotemporal distribution and abundance of various life stages of both rockfishes and salmonids. While the overlap of ESA-listed rockfish and hatchery salmon released as part of this action are primarily in Puget Sound, we draw on available data about how these species interact outside of Puget Sound as well. This same evaluation was conducted as part of our 2020 consultation on salmon and steelhead hatchery operations in Puget Sound (NMFS 2020d), and in presented in brief here. Our 2020 analysis developed a bioenergetic model to predict how many listed rockfish (i.e., yelloweye rockfish and bocaccio) larvae these hatchery fish were likely to consume (Beauchamp et al. 2020; NMFS 2020d). This model incorporated data on the frequency of occurrence of rockfish larvae in juvenile Chinook stomach contents (e.g., Duffy et al. 2005), the relative abundance of ESA-listed rockfish compared to total rockfish abundance in Puget Sound (e.g., Pacunski et al. 2013; Blaine et al. 2020; Pacunski et al. 2020), and the fecundity of listed rockfish (Love et al. 2002). We concluded that, even under this high release scenario, impacts would result in minimal losses of the equivalent of approximately 3.72 adult yelloweye rockfish (0.003% of the population) and approximately 7.18 adult bocaccio (0.156% of the population) annually (NMFS 2020d). The full version is incorporated by reference here (NMFS 2020d).

Natural- and hatchery-origin Chinook salmon juveniles exhibited distinct habitat use patterns during emigration, with natural-origin fish captured more frequently in tidally influenced freshwater and mesohaline emergent marsh areas, and hatchery-origin fish caught more often in the nearshore intertidal zone (Davis et al. 2018b). Chinook salmon off the coasts of Oregon and Washington ate primarily the same prey in May and June (Brodeur et al. 2011), with their diet consisting of adult krill, and juvenile sand lance (*Ammodytes personatus*), rockfish (*Sebastes* spp.), and greenling (*Hexagrammos* spp.). In Puget Sound, a proportion of the Chinook salmon juveniles leave freshwater but remain in the semi-estuarine waters of Puget Sound until they mature, at which time they return to freshwater to spawn; these fish are referred to as residents (Chamberlin et al. 2011). For hatchery-origin individuals, about 24% of the fish were classified as residents. Release location was identified as the strongest factor in determining if hatchery-origin fish displayed the residency life history type, with higher residency proportions in South Sound, Central Sound, and Hood Canal than in the Strait of Juan de Fuca and Nooksack River regions (Chamberlin et al. 2011). A second study using the Fishery Regulation and Assessment Model (FRAM) found that residency was correlated with the age at which Chinook salmon emigrated from freshwater. Hatchery-origin salmon enter marine waters feeding on plankton and small fish, depending on their size, and Chinook salmon prey on larval rockfish in both coastal waters of Washington and Puget Sound (Daly et al. 2015; Dale et al. 2016; Litz et al. 2017). Only the larval rockfish in the pelagic zone during summer months will coincide with young salmon (Greene et al. 2012). As young salmon leave Puget Sound, larval rockfish also become too large to eat and settle onto nearshore bottom habitats, and the two species become separated by size and habitat type. Once rockfish reach a larger size they also develop physical features, such as dorsal fin spines, that protect them from predation and there is no documentation of salmon predation on non-larval rockfish.

Ichthyoplankton data are sparse in Puget Sound. They are difficult to capture, are digested quickly as prey, experience high natural mortality, and many species are difficult to distinguish from each other during larval stages. Because of the paucity of comprehensive local data, and the inability to effectively measure larval predation from monitoring, we determined the best way to measure effects of the proposed action was to use a model initially formalized from 2018–20 by Dave Beauchamp and his team at the United States Geological Society (USGS), who specialize in regional fish diet studies and the production of bioenergetic models, in collaboration with NWFSC and WDFW researchers (Beauchamp et al. 2020; NMFS 2020d). Several components of rockfish and salmon life history were reviewed to evaluate the population-level impacts on rockfish from the proposed action, including available information on larval rockfish life history in the range of the DPS and elsewhere, data on salmon consumption rates and bioenergetic needs, estimates of spatiotemporal overlap in salmon and rockfish occurrence, and the reproductive output of listed rockfish. Data gaps and uncertainties were also identified, as were assumptions based on the best available science. This model was previously used to assess existing hatchery programs for Chinook salmon in Puget Sound (NMFS 2020d), as noted in section 1.2 Consultation History, and its formulation is presented here in brief.

2.5.4.1 Larval Rockfish Data

Rockfish mate via internal fertilization and, after a period of internal brooding, females release millions of free-swimming larvae. Very few of these larvae reach the juvenile life history stage, and even fewer survive to reach maturity. Rockfish offset losses from high early mortality by living several decades and relying on episodic years with good climatic conditions and food availability to maintain the population over time (Tolimieri et al. 2005; Drake et al. 2010; NMFS 2017s). Yelloweye rockfish can produce between 1.2 and 2.7 million larvae per year per female, and bocaccio produce between 20 thousand and 2.3 million larvae per year per female (Love et al. 2002). While very little is known about larval survival in the pelagic habitats of the Action Area, in a laboratory setting rockfish larvae experienced up to 70% mortality 7–12 days after birth (Canino et al. 1989), and we can infer from stock assessment models of yelloweye rockfish along the outer Pacific coast that only a small fraction of individuals survives to reach the juvenile life history stage (Gertseva et al. 2017).

Timing of larval release varies among rockfish species and regions. Within the Action Area that overlaps the DPSs, there are 28 species of rockfish, and many have similar larval periods. Yelloweye rockfish in the Salish Sea appear in pelagic habitats from April through September, with the highest numbers in May and June (Washington et al. 1978; Yamanaka et al. 2006), while bocaccio along the outer Washington State coast first appear as early as January and April (Love et al. 2002). Greene et al. (2012) found peak abundance in Puget Sound from July to September across basins (Figure 80), and Chamberlin et al. (2004) and Weis (2004) documented larval rockfish in the San Juan Islands from April to July. Yelloweye rockfish larvae grow and develop over the course of about 120 days before settling into benthic habitats (Shanks et al. 2005), while bocaccio may stay in pelagic habitats for upwards of 150 to 170 days (Shanks et al. 2003). The timing of larvae present in the action area coincides with known outmigration of salmon through the region.

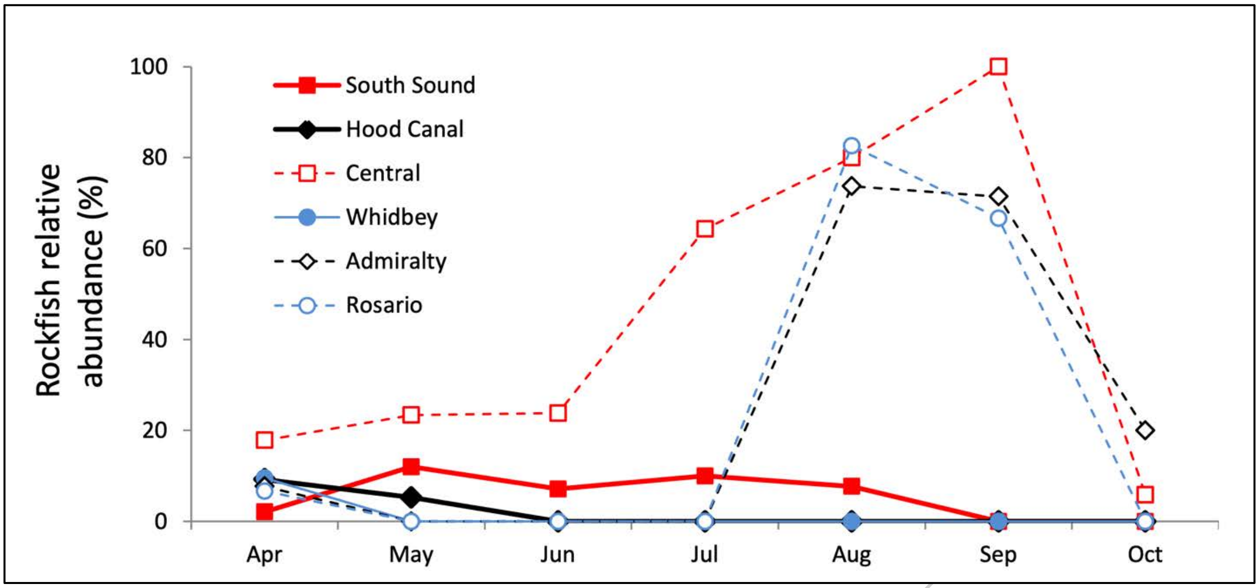


Figure 80. Relative abundance of rockfish at a subset of index sites from April through October. Image from Greene et al. (2012).

In order to determine the proportion of ESA-listed rockfish larvae in the pelagic zone, we used data from WDFW ROV, hook and line, and scuba surveys on adult populations to estimate the percentage of yelloweye rockfish and bocaccio larvae present relative to total rockfish abundance for all species (Pacunski et al. 2013; Pacunski et al. 2020; Lowry et al. 2022; Lowry et al. 2024). The total abundance estimate for bocaccio is currently based on observations only from the San Juan Islands, and little is known of their abundance in Central Puget Sound, other than anecdotal fishing records (NMFS 2017s; Lowry et al. 2024). Yelloweye rockfish in Hood Canal are genetically divergent from the rest of the DPS (Andrews et al. 2018), and addressed as a separate population in the recovery plan (NMFS 2017s). Despite these regional variations in adults, little is known about the mixing of larvae between Puget Sound basins, though simulations predict considerable movement under proper wind and current conditions (Andrews et al. 2021). Based on best available data for all species of adult rockfish populations in the DPS, and assuming the same relative fraction are present for larval populations, the ESA-listed species fraction of rockfish larvae was determined to be between 0.25 and 3.20% (yelloweye rockfish and bocaccio combined). Given that this range is based on the best available scientific information and that there is uncertainty regarding the specific fraction, we use the 3.2% value here for analysis to ensure we do not erroneously underestimate the effects of the action. Based on the population estimates for the two species, yelloweye rockfish comprise 96.9% of that fraction, and bocaccio account for 3.1%.

2.5.4.2 Salmon Diet and Rockfish Consumption

While salmon can be found at depths greater than 120 feet in the nearshore, they are not considered benthic fish, and instead feed in the pelagic water column of nearshore habitats. As such, their diets consist primarily of invertebrate and ichthyoplankton upon first entering marine waters, and they become piscivorous as they grow (Duffy et al. 2010; Beauchamp et al. 2011). Chinook consumption of larval rockfish during the spring and summer months varies annually, with some years comprising as much as 40.8% of their total diet during peak seasons along the California coast (Brodeur et al. 2011; Daly et al. 2013). Within Puget Sound, hatchery-origin Chinook salmon enter the Action Area as early as May, and leave the area by October, with peak marine entry in June and most emigrating to the ocean in September (Beauchamp et al. 2020). While a small fraction of salmon may stay in Puget Sound as residents, they no longer feed on larval rockfish due to larvae settling onto benthic habitats in the early fall. There is no data for second-year resident salmon predation on larval rockfish, but it is also not likely based on diet shifts in salmon targeting larger prey to meet their growth needs.

2.5.4.2.1 Salmon Diet Surveys in Puget Sound

To estimate relative consumption of listed rockfish by juvenile Chinook salmon for a prior consultation (NMFS 2020d), we evaluated existing data on salmon diet composition and developed a framework to model likely impacts (Beauchamp et al. 2020). This model was also applied here, and included: 1) identifying presence of larval rockfish in salmon diets within the pelagic habitats of Puget Sound across years, and dividing observed predation into estimates of monthly diet composition; 2) estimating monthly, size-structured, population-level biomass of larval rockfish consumed; and 3) employing a maximum hatchery production scenario to estimate salmon predation on ESA-listed rockfish based on assumptions of the proportion of ESA-listed rockfish in the pool of all pelagic larval rockfish, and the size and body weight of rockfish that correspond to the estimated periods of predation by salmon. By comparing the estimated number of larvae consumed to rockfish fecundity, we were able to estimate an adult equivalent for purposes of quantifying take. To best avoid underestimating effects given the uncertainties involved in estimating the parameters used, the analysis included the *high* levels of proposed salmon hatchery releases, the *low* levels of rockfish larval production, the *high* estimates for percent mortality for each DPS, and the *high* estimates for rockfish adult equivalents to estimate impacts.

Existing data and archived samples were analyzed to determine seasonal and size-dependent diet composition of juvenile Chinook from pelagic habitats in Puget Sound. There were three primary sources of data from 2001–19, as detailed in NMFS (2020d). First was depth-stratified, midwater trawling cruises of the *R/V Ricker* by Fisheries and Oceans Canada (DFO), in collaboration with the WDFW and University of Washington. These surveys were conducted in mid-late July and late September/early October from Admiralty Inlet and the Central Basin of Puget Sound, and infrequently sampled South Puget Sound. The *Ricker* cruises continued from 2010–16 with less frequency, but with additional tows in the Whidbey Basin and Saratoga Passage. Seasonal coverage was also expanded in select years when ship time was available, with tows occurring in March 2008, February 2010, and November 2015. The second major source of pelagic diet samples provided finer-resolution temporal coverage as part of the Salish Sea Marine Survival Project (Connelly et al. 2018; Gamble et al. 2018). Surveys were conducted twice monthly by purse seine, from mid-May through mid-August in 2014 and 2015. The purse seine was deployed in marine waters within estuarine deltas for four watersheds (the Nisqually, Snohomish, Skagit, and Nooksack rivers) and along Rosario Strait. The final source of salmon diet data came from microtrolling surveys (e.g., Duguid et al. 2017; Beauchamp et al. 2020) conducted weekly from late May through mid-September in 2018 and 2019. Sampling locations in 2018 were limited to Possession Bar south of Whidbey Island and at Jefferson Head in Central Sound. In 2019, sites including Duwamish Head (from May–June) and Shilshole (sampled throughout the season) were added.

Stomach contents were collected either via dissection or gastric lavage. Invertebrate prey were identified to functional group, whereas all fish prey were identified to species whenever possible. Partially digested remains were identified using diagnostic bones or other calcified hard parts. The proportional weight of prey species (Beauchamp et al. 2020) to the diets of individual salmon were measured as blotted wet weights or visually approximated as biovolumes (for on-board processing from *R/V Ricker* cruises).

2.5.4.3 Predation Estimates and Effects on Abundance

Given the diets of Chinook salmon in Puget Sound coinciding with availability of larval rockfish in the water column, it is likely that a small fraction of the total rockfish biomass is consumed in any given year, and that a very small proportion of those larvae will be yelloweye rockfish or bocaccio.

For data sets from sub-yearling salmon surveys that included observations of larval rockfish predation, we calculated monthly mean diet composition for the species, size classes, and years corresponding with the highest level of predation to avoid underestimation given the uncertainty involved in the survey methods. Data for monthly prey was then quantified using a bioenergetics model combining timing, diet composition, age, growth estimates, water temperatures, and energy requirements for the consumer (Beauchamp et al. 2007; Beauchamp et al. 2020; NMFS 2020d). The model results provide an energy balance equation based on the amount of food needed by juvenile Chinook salmon to satisfy growth rates over the season (Beauchamp 2009). To determine the quantity of predation on rockfish, we used the bioenergetic simulations constructed for sub-yearling Chinook salmon cohorts described in Beauchamp et al. (2011).

Model simulations were run for a year from May 1 to April 30, to fit annual growth increments. However, the only evidence for predation on larval rockfish was observed in from the *R/V Ricker* midwater trawl surveys in July and September. Therefore, prey consumption estimates were only examined for June through October, marking peak entry of Chinook to pelagic marine habitats, through the end of ocean-bound migration, also representing the period that was relevant to rockfish larval presence. The estimated biomass of larval rockfish consumed each month was divided by the mean individual body mass of larval rockfish, converting biomass of total rockfish consumed to a numerical estimate of ESA-listed larval rockfish consumption.

In 2020, this model was run for current numbers, a low scenario, and a proposed high hatchery release scenario for Chinook salmon into Puget Sound (NMFS 2020d). The high release number (88,090,625 individuals) represented maximum facility capacity, and was described in the proposed action as increasing incrementally over a number of years. For analysis, however, it was used as the maximum hatchery release and predation scenario. The high hatchery release levels have not occurred in recent years due to the global COVID-19 pandemic and a variety of other logistical factors (Table 82). In 2023, total juvenile Chinook hatchery releases into Puget Sound were 52,147,431, only moderately above the long-term annual average of 44,536,201 (see Table 3, (NMFS 2024e)). As such, our analysis for the proposed action here (i.e., increasing prey availability for SRKW) incorporates the 2020 analysis by reference to demonstrate that the release of up to 14.4 million additional Chinook salmon smolts into Puget Sound annually will have minimal impacts on populations of listed rockfish.

With the potential of up to 14.4 million proposed additional hatchery releases above 2023 release levels, the population-level monthly estimates for sub-yearling salmon were structured to account for survival from hatchery to marine entry (50%), then a marine survival from marine entry to adult return (1% total or daily mortality of 0.0056). The per capita caloric needs (in grams) for individual fish were than multiplied by the observed proportion of rockfish in the diet surveys, times the monthly salmon population estimates to produce the estimated total grams of rockfish consumed per month. The estimated biomass of all species of larval rockfish consumed was then multiplied by the fraction of the larval rockfish population estimated to be ESA-listed species (0.032), and the monthly mean body mass of larval rockfish (1.55 grams) was used to estimate the total number of ESA-listed rockfish larvae consumed by smolts generated specifically to increase SRKW prey resources (Table 83). The total estimated annual larval rockfish consumption of these fish (584,355) was then separated into the fraction of yelloweye rockfish and bocaccio based on adult abundance estimates (Table 84).

Through consumption of larval rockfish, hatchery-origin Chinook released as part of the proposed action are expected to remove an adult equivalent of less than one yelloweye rockfish and less than one bocaccio annually, whether the lower or upper bound of species-specific rockfish fecundity is used. For both species, this represents less than 0.02% of the best estimates of adult abundance. Furthermore, even when combined with the current running average of slightly over 44.5 million hatchery-origin Chinook annually, up to an additional 14.4 million fish in Puget Sound associated with the proposed action falls well short (58.9 million) of the 88 million fish used in the high release estimate evaluated in 2020 (NMFS 2020d). This demonstrates that consumption of larval rockfish by hatchery-origin Chinook in Puget Sound will have minor population-level impacts now, or into future, even if all existing hatchery production capacity should be brought online.

Table 82. Total regional hatchery juvenile Chinook salmon releases from 2008 through 2023. Data from Regional Mark Information System (https://www.rmpc.org/).

Release Year	Salish Sea	WA Coast	OR Coast	Columbia River
2008	44,930,915	10,125,788	6,176,199	94,901,003
2009	43,336,852	10,330,852	5,629,442	103,057,567
2010	41,836,569	9,202,126	6,675,993	107,783,568
2011	43,863,472	11,197,030	5,983,922	102,170,533
2012	41,907,618	11,248,489	6,312,472	103,798,265
2013	41,006,628	9,872,485	6,079,183	103,748,801
2014	41,275,967	11,422,843	7,252,409	101,376,847
2015	42,486,682	11,311,230	5,987,165	99,083,861
2016	41,392,329	8,842,142	5,878,639	93,116,623
2017	41,502,620	10,059,269	5,461,163	95,083,272
2018	46,089,539	9,696,522	5,895,970	97,087,901
2019	49,758,060	11,044,692	4,067,665	92,635,747
2020	50,178,052	8,791,100	5,920,781	91,357,510
2021	40,609,889	12,506,266	5,662,594	97,874,041
2022	50,256,589	13,033,163	4,597,875	87,761,462
2023	52,147,431	9,042,426	4,597,875*	76,963,674
Average by Area	**44,536,201**	**10,482,901**	**5,761,209**	**96,737,542**

Table 83. Monthly population-level consumption of ESA-listed rockfish larvae by hatchery-origin Chinook released into Puget Sound above 2023 release levels, using potential production increase of up to 14.4 million smolts in Puget Sound annually.

Month	Day of Marine Life	Population Estimate	Caloric needs (g) per fish	Proportion of RF in diet	Total Predation (g) of Rockfish	ESA-listed Predation (g) of Rockfish	# ESA-listed Rockfish Larvae
Marine Entry	0	7,200,000	87.7	-	-	-	-
June	15	6,619,159	104.0	-	-	-	-
July	45	5,594,270	121.7	0.0001	61,503	1,968	1,270
August	75	4,728,072	139.8	0.0120	7,959,674	254,710	164,329
September	105	3,995,993	154.2	0.0290	17,871,903	571,901	368,968
October	135	1,013,180	164.2	0.0145	2,411,607	77,171	49,788
TOTAL	-	-	-	-	28,304,687	905,750	584,355

Table 84. Monthly population-level consumption of ESA-listed rockfish, using the maximum planned production increase of 14.4 million smolts annually in Puget Sound. Low and high estimates are based on species-specific fecundity ranges.

Species	Adult Abundance Scenario	Number Larval Mortalities	Adult Equivalence of DPS killed (low estimate)	Adult Equivalence of DPS killed (high estimate)	Low Estimated Percent Mortality	High Estimated Percent Mortality
Yelloweye	143,086	566,131	0.21	0.47	0.000%	0.000%
Bocaccio	4,606	18,224	0.01	0.91	0.000%	0.020%

2.6 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation (50 CFR 402.02). Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to Section 7 of the ESA.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in Section 2.4.1.5, Climate Change.

2.6.1 Salmon and Steelhead

Some types of human activities that contribute to cumulative effects are expected to have adverse impacts on listed fish and PBFs, many of which are activities that have occurred in the recent past and had an effect on the environmental baseline. These can be considered reasonably certain to occur in the future because they occurred frequently in the recent past, especially if authorizations or permits have not yet expired. Within the freshwater portion of the action area, non-Federal actions are likely to include those associated with human population growth (e.g., expansion of the built environment; conversion of forests and open space to residential, commercial, and industrial uses; increased effluent discharge from municipal wastewater treatment), water withdrawals (i.e., those pursuant to senior state water rights), and land use practices (e.g., forestry, agriculture), the effects of which are described in the Environmental Baseline. In marine waters within the action area, state, tribal, and local government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, shoreline growth management, and resource permitting. Private activities include continued resource extraction, vessel traffic, development, and other activities which contribute to poor water quality and continued vessel and construction noise in the freshwater and marine environments of Puget

Sound and the Columbia River basin. Although these activities and their effects are ongoing to some extent and likely to continue in the future, past occurrence is not a guarantee of a continuing level of activity. That will depend on the pace at which human population growth and its corresponding environmental ramifications continues, as well as the emergence, adoption, implementation, and/or effectiveness of economic, administrative, and legal impediments to activities with adverse effects, and safeguards to minimize or prevent adverse effects. Therefore, NMFS finds it likely that the cumulative effects of these activities will have adverse effects commensurate to those of similar past activities, as described in the Environmental Baseline. These effects may occur at somewhat higher or lower levels than those described in the Baseline. These are discussed in more detail below.

Activities occurring in the Puget Sound area were considered in the discussion of cumulative effects in several broad-scale section 7 consultations, including the following:

- Salish Sea Nearshore Programmatic Consultation (NMFS 2022b)
- Issuance of Permits for Projects under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act for Actions related to Structures in the Nearshore Environment of Puget Sound (NMFS 2020e; 2021i; 2022h)
- Puget Sound Harvest Resource Management Plan (NMFS 2024a)
- Washington State Department of Transportation Preservation, Improvement, and Maintenance Activities (NMFS 2013b)
- Washington State Water Quality Standards (NMFS 2008c)
- National Flood Insurance Program (NMFS 2008a)

Activities occurring in the Columbia River basin were considered in the discussion of cumulative effects in several broad-scale section 7 consultations, including the following:

- Issuance of NPDES Permits for Eight Federal Dams on the Lower Columbia and Lower Snake Rivers (NMFS 2021k)
- Operations and Maintenance Dredging of the Federal Navigation Channel at Tongue Point, Clatsop County, Oregon; Elochoman Slough, Wahkiakum County, Washington; Lake River, Clark County, Washington; and Oregon Slough, Multnomah County, Oregon (NMFS 2021j)
- Continued Operation and Maintenance of the Columbia River System (NMFS 2020c)
- 2018-2027 *U.S. v. Oregon* Management Agreement (NMFS 2018e)
- Willamette River Basin Flood Control Project (NMFS 2008i)
- Washington State Department of Transportation Preservation, Improvement, and Maintenance Activities (NMFS 2013b)
- Washington State Water Quality Standards (NMFS 2008c)
- National Flood Insurance Program (NMFS 2008a)

As discussed in the above-cited Biological Opinions, we expect spawning and rearing habitat, foraging and migration habitat, and water quality to continue to be negatively affected by the following: forestry; agriculture and grazing; channel and bank modifications; road building and maintenance; urbanization; sand and gravel mining; dams; irrigation impoundments and withdrawals; boat traffic in rivers, estuaries, and the ocean; wetland loss; forage fish/species harvest; and, climate change. We anticipate that the effects described in these previous analyses will continue into the future and therefore we incorporate those discussions by reference here. Those Opinions discussed the types of actions taken to protect listed species through habitat protection and restoration, hatchery and harvest reforms, and management of activities that affect aquatic resources.

Most hatchery programs throughout the action area have completed ESA consultation, and are thus considered in the Environmental Baseline. At the beginning of FY23, NMFS had approved the following HGMPs by geographic areas: 1) of 100 HGMPs in Puget Sound, 53 (53%) were authorized and the remaining 47 (47%) were in progress; 2) of 160 HGMPs in the Columbia River Basin, 145 (90%) had been authorized and an additional 15 (10%) were in progress. Washington coast hatchery programs do not require HGMP ESA review by the NMFS because they operate in areas (freshwater) where there are no ESA-listed salmon and steelhead under NMFS jurisdiction. Most Puget Sound and Columbia River programs that have not had HGMP ESA review, as well as Washington coast programs, are established, ongoing programs producing fish for harvest or other needs of the operators (e.g., harvest management, salmonid conservation and recovery).

Effects of past operations of State or tribal programs that are ongoing that have not yet completed consultation are included in the Environmental Baseline. We expect these programs to continue to release similar species in similar or lower abundances for the duration of this consultation, understanding that there may be some changes arising from shifting demands on hatchery production due to changes in conservation needs or harvest regime changes. Though we have not analyzed effects of these programs, and cannot therefore be certain what those effects are, it is reasonable to assume that those programs have many, most, or all of the same adverse effects as those described in the Environmental Baseline.

While past effects from ongoing programs currently lacking ESA consultation are in our environmental baseline, and future effects are included here, we do expect reductions in effects on listed salmon are likely to occur through changes in some or all of the following as the science of hatchery effects continues to evolve, as more hatchery programs go through the ESA consultation process, as RM&E and adaptive management of hatchery programs continue, and as hatchery programs continue to evolve and reform to align with respective recovery plans:

- Hatchery monitoring information and best available science.
- Times and locations of fish releases to reduce risks of competition and predation.
- Management of overlap in hatchery- and natural-origin spawners to meet gene flow objectives.
- Decreased use of isolated hatchery programs.
- Increased use of integrated hatchery programs for conservation purposes.
- Incorporation of new research results and improved best management practices for hatchery operations.
- Creation of wild fish only areas.

- Changes in the species propagated and released into streams and rivers and in hatchery production levels.
- Termination of programs.
- Increased use of marking of hatchery-origin fish.
- More accurate estimates of natural-origin salmon and steelhead abundance for abundance-based fishery management approaches.

Overall, we anticipate that projects to restore and protect habitat, restore access and recolonize the former range of salmon and steelhead, and improve fish survival throughout their ranges will result in a beneficial effect on salmon compared to the current conditions. We also expect that future harvest, hatchery, and development activities will continue to have adverse effects on listed species in the action area; however, we anticipate these activities will be conducted in a manner that considers the effects on ESA-listed species and will perhaps be less harmful than would have otherwise occurred in the absence of the current body of scientific work that has been established for anadromous fish. In general, we think the level of adverse effects will be lower than those in the recent past, and much lower than those in the more distant past. NMFS anticipates that available scientific information will continue to grow and tribal, public, and private support for salmon recovery will remain high. This will continue to fuel state and local habitat restoration and protection actions as well as hatchery, harvest, and other reforms that are likely to result in improvements in fish survival.

2.6.2 Eulachon

The contribution of non-federal activities to the current status of eulachon include agriculture, forest management, mining, road construction, urbanization, water development, and river restoration. Those actions were driven by a combination of economic conditions that characterized traditional natural resource-based industries, general resource demands associated with settlement of local and regional population centers, and the efforts of social groups dedicated to river restoration and use of natural amenities, such as cultural inspiration and recreational experiences.

Resource-based industries caused many long-lasting environmental changes that harmed eulachon and their critical habitat, such as state-wide loss or degradation of stream channel morphology, spawning substrates, instream roughness and cover, estuarine rearing habitats, wetlands, riparian areas, water quality (e.g., temperature, sediment, dissolved oxygen, contaminants), fish passage, and habitat refugia. Those changes reduced the ability of subpopulations to sustain themselves in the natural environment by altering or interfering with their behavior in ways that reduce their survival throughout their life cycle. The environmental changes also reduced the quality and function of critical habitat PBFs that are necessary for successful spawning, production of offspring, and migratory access necessary for adult fish to swim upstream to reach spawning areas and for juvenile fish to proceed downstream and reach the ocean. Without those features, the species cannot successfully spawn and produce offspring. However, the declining level of resource-based industrial activity and rapidly rising industry standards for resource protection are likely to reduce the intensity and severity of those impacts in the future.

The adverse effects of non-Federal actions stimulated by general resource demands are likely to continue in the future driven by changes in human population density and standards of living. These effects are likely to continue to a similar or reduced extent in the rural areas in the action area. Areas of growing population in the action area are likely to experience greater resource demands, and therefore more adverse environmental effects. Land use laws and progressive policies related to long-range planning will help to limit those impacts by ensuring that concern for a healthy economy that generates jobs and business opportunities is balanced by concern for protection of farms, forests, rivers, streams and natural areas. In addition to careful land use planning to minimize adverse environmental impacts, larger population centers may also partly offset the adverse effects of their growing resource demands with more river restoration projects designed to provide ecosystem-based cultural amenities, although the geographic distribution of those actions, and therefore any benefits to eulachon or their critical habitat, may occur far from the centers of human populations.

It is not possible to predict the future intensity of specific non-federal actions related to resource-based industries at this program scale due to uncertainties about the economy, funding levels for restoration actions, and individual investment decisions. However, the adverse effects of resource-based industries in the action area are likely to continue in the future, although their net adverse effect is likely to decline slowly as beneficial effects spread from the adoption of industry-wide standards for more protective management practices. These effects, both negative and positive, will be expressed most strongly in rural areas where these industries occur, and therefore somewhat in contrast to human population density. The future effects of river restoration are also unpredictable for the same reasons, but their net beneficial effects may grow with the increased sophistication and size of projects completed and the additive effects of completing multiple projects in some watersheds.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area’s future environmental conditions caused by global climate change that are properly part of the environmental baseline vs. cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline.
In summary, resource-based activities such as timber harvest, agriculture, mining, shipping, and energy development are likely to continue to exert an influence on the quality of freshwater and estuarine habitat in the action area. The intensity of this influence is difficult to predict and is dependent on many social and economic factors. However, the adoption of industry-wide standards to reduce environmental impacts and the shift away from resource extraction to a mixed manufacturing and technology-based economy should result in a gradual decrease in influence over time. Additional residential and commercial development and a general increase in human activities are expected to cause localized degradation of freshwater and estuarine habitat.

Non-federal habitat and hydropower actions are supported by state and local agencies, tribes, environmental organizations, and private communities. Projects supported by these entities focus on improving general habitat and ecosystem function or species-specific conservation objectives.

These projects address the protection of adequately functioning habitat and the restoration of degraded salmonid habitat, including improvements to instream flows, water quality, fish passage and access, pollution reduction, and watershed or floodplain conditions that affect downstream habitat and mainstem habitat that may also yield incremental benefits for eulachon. Significant actions and programs contributing to these benefits include growth management programs (planning and regulation), various stream and riparian habitat projects, watershed planning and implementation, acquisition of water rights for instream purposes and sensitive areas, instream flow rules, stormwater and discharge regulation, TMDL implementation to achieve water-quality standards, hydraulic project permitting, and increased spill and bypass operations at hydropower facilities. NMFS has determined that many of these actions would have positive effects on the viability (abundance, productivity, spatial structure, and/or diversity) of listed salmon and steelhead populations and the functioning of PBFs in designated critical habitat. Although these actions target salmon and steelhead habitat, they may also yield incremental beneficial cumulative effects for eulachon.

NMFS has also noted that some types of human activities, such as development and harvest, contribute to cumulative effects and are generally expected to have adverse effects on populations and PBFs. Many of these effects are activities that occurred in the recent past and are included in the environmental baseline. Some of these activities are considered reasonably certain to occur in the future because they occurred frequently in the recent past (especially if authorizations or permits have not yet expired), and are addressed as cumulative effects. Within the action area, non-federal actions are likely to include human population growth, water withdrawals (i.e., those pursuant to senior state water rights), and land use practices. Continuing commercial and sport fisheries, which have some incidental catch of listed species, will have adverse impacts through removal of fish that would contribute to spawning populations. Attaching LED lights to the fishing lines of ocean shrimp trawls appears to greatly reduce the number of eulachon bycatch for this commercial fishery (Hannah et al. 2015; Lomeli et al. 2018).

Overall, we anticipate that projects to restore and protect salmon and steelhead habitat may result in minor beneficial effects for eulachon compared to the current conditions. We also expect that future harvest and development activities will continue to have adverse effects on eulachon in the action area.

2.6.3 Puget Sound/Georgia Basin Rockfish

Future state, tribal, and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives. Government and private actions may include changes in land and water uses, including ownership and intensity, any of which could impact listed species or their habitat. Government actions are subject to political, legislative, and fiscal uncertainties. These realities, added to the geographic scope of the action area, which encompasses numerous government entities exercising various authorities, make any analysis of cumulative effects difficult and speculative.

A final recovery plan for listed rockfish in the Puget Sound/Georgia basin was released in 2017 (NMFS 2017s). In early 2010, WDFW adopted a series of measures to reduce rockfish mortality from non-tribal fisheries within the Puget Sound/Georgia Basin. These measures include the following:

1. closure of the entire Puget Sound to the retention of any rockfish species;
2. prohibition of fishing for bottom fish deeper than 120 feet (36.6 m); and,
3. closure of the non-tribal commercial fisheries listed in Section 2.4.2.

These measures have eliminated future direct harvest of rockfish, and reduced or prevented bycatch from future non-tribal recreational and commercial fisheries within the U.S. portion of the Puget Sound/Georgia Basin. These fishery restrictions are unlikely to be lifted until recovery of ESA-listed rockfishes occurs, given the WDFW's commitment to broadscale ecosystem conservation. Furthermore, in 2014 the WDFW implemented a rule that requires all anglers targeting halibut and bottomfish to have a descending device onboard, rigged, and ready for use to help ameliorate impacts of barotrauma on captured rockfishes of all species. This conservation measure reduces sublethal and lethal impacts from capture, decreasing individual and population-level stress.

In addition, there are ongoing recovery programs for other ESA-listed species that may benefit rockfish. For more information on the various efforts being made at the local, tribal, state, and national levels to conserve ESA-listed species within the action area, see any of the recent status reviews, Federal Register notices of listings, and recovery planning documents, as well as recent consultations on issuance of section 10(a)(1)(A) research permits, including the Puget Sound Salmon Recovery Plan (SSDC 2007), the Summer Chum Salmon Conservation Initiative (WDFW et al. 2000), the Southern Resident Killer Whale Recovery Plan (NMFS 2008d), the Southern Oregon/Northern California Coast Coho Salmon Recovery Plan (79 FR 58750, September 30, 2014).

NMFS finds it reasonably certain that state-managed fisheries that affect ESA-listed rockfish will continue into the future, including the recreational bottomfish and shrimp trawl fisheries in Puget Sound. Section 2.4, Environmental Baseline, of this opinion briefly summarizes these fisheries and their effects on ESA-listed rockfish. The take of ESA-listed rockfish in the recreational bottomfish and shrimp trawl fisheries in Puget Sound was addressed in an incidental take permit issued to WDFW in 2012 and WDFW is working on a new incidental take permit application (WDFW 2017).

NMFS also finds it reasonably certain that state and private actions associated with marine pollution will continue into the future (e.g., state permits for effluent discharges and the status of currently contaminated sites). Although the Puget Sound Partnership may make progress toward reducing marine pollution (Sanga 2015), measurable change is not reasonably certain to occur in the near term.

Some types of human activities that contribute to cumulative effects are expected to have adverse impacts on populations and habitat features, many of which are activities that have occurred in the recent past and had an effect on the environmental baseline. These can be considered reasonably certain to occur in the future because they occurred frequently in the recent past, especially if authorizations or permits have not yet expired. In marine waters within the action area, state, tribal, and local government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, shoreline growth management, and resource permitting. Private activities include continued resource extraction, vessel traffic, development, and other activities that contribute to non-point source pollution and stormwater run-off.

Non-federal actions are likely to continue affecting listed species. The cumulative effects in the action area are difficult to analyze because of this opinion's geographic scope, the different resource authorities in the action area, the uncertainties associated with government and private actions, and the changing economies of the region. Whether these effects will increase or decrease is a matter of speculation; however, based on the trends identified in the baseline, the adverse cumulative effects are likely to increase. Although state, tribal, and local governments have developed plans and initiatives to benefit listed fish, they must be applied and sustained in a comprehensive way before NMFS can consider them "reasonably foreseeable" in its analysis of cumulative effects.

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed actions. In this section, we add the Effects of the Action (Section 2.5) to the Environmental Baseline (Section 2.4) and the Cumulative Effects (Section 2.6), taking into account the Status of the Species and Critical Habitat (Section 2.2), to formulate the agency's Opinion as to whether the proposed actions are likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminishes the value of designated or proposed critical habitat for the conservation of the species.

2.7.1 Salmon and Steelhead

The action area is used by the listed species shown in Table 80. These species are all listed as threatened except for Snake River sockeye salmon and Upper Columbia River spring-run Chinook salmon, which are listed as endangered. These species are ESA-listed due to a combination of low abundance and productivity, reduced spatial structure, and/or decreased genetic and life history diversity, reviewed in each respective status of the species section above. Individuals from most of the ESA-listed component populations occur in parts of the action area at some point during their life history. Many of the component populations of these ESUs and DPSs are at low levels of abundance or productivity; in many cases, decreases in the last few years are associated with poor environmental conditions, be it ocean conditions or poor freshwater outmigration conditions. Several species have lost some of their historical population structure due to human activities, and the populations that remain in the available habitat face multiple limiting factors. Among the salmon and steelhead species, factors limiting recovery continue to include the following: blocked habitat; hydropower projects affecting mainstem habitat and fish passage; tributary (and for Snake River sockeye, natal lake) habitat conditions; estuary habitat conditions; harvest; hatcheries; predation; and, additional factors (e.g., exposure to toxic contaminants and the effects of climate change including elevated river temperature and ocean conditions).

The environmental baseline is characterized by widespread and persistent habitat degradation, altered water quality and temperature, altered hydrographs, and altered fish passage due to dams and reservoirs. In addition, salmon and steelhead are exposed to high rates of natural predation during all life stages from fish, birds, and marine mammals. With regard to the effects of hatcheries in the action area, in the Environmental Baseline section, we detail our completion of more than one hundred Section 7 consultations on hatchery programs in numerous Biological Opinions. A detailed description of the effects of these hatchery programs can be found in the site-specific Biological Opinions referenced in Appendix B. These effects are further described in Appendix C. All of the completed analyses have determined that the hatchery programs will not jeopardize listed salmonids. In many cases, these conclusions were reached because the hatchery programs under consideration have been modified to reduce their adverse effects on listed species based on the best available scientific information, resulting in an environmental baseline that continues to improve over time with regard to hatchery activities at a broad scale across the action area. As described in the Cumulative Effects section, state and private actions within the action area are anticipated to continue to have negative effects on ESA-listed salmonids, however those may be offset to some extent by state and private efforts to protect and recover these fish.

In Section 2.4.4, Effects Analysis and summarized in Table 80, we evaluated both watershed-scale effects at a general level and combined effects of the proposed action. These are summarized below.

Watershed-scale effects

Many effects of the federal prey program-funded production and releases occur solely at the watershed scale (i.e., they are watershed-scale effects), including the following (Table 80):

- Use of natural-origin fish for broodstock
- Genetic effects
- Ecological effects resulting from hatchery-origin fish spawning naturally (i.e., delivery of marine-derived nutrients and ecological services; spawning site competition and redd superimposition; disease)
- Collection of adults for broodstock
- Competition and predation in freshwater areas (exclusive of the Columbia River and Snake River mainstems)
- Competition and predation in Salish Sea natal inner estuaries
- Research, monitoring and evaluation
- Operation and maintenance of hatchery facilities

In general, these effects are limited to the river basin where a hatchery is operating, including areas at or relatively near the hatchery, and downstream areas to the point where the affected watershed meets a larger body of water (e.g., Puget Sound marine; Columbia River mainstem).

The proposed action may fund hatchery facilities and operations throughout multiple Recovery Domains across the action area described above. The degree of risk from watershed-scale effects to individual ESA-listed populations within these Recovery Domains will vary depending on a variety of factors including but not limited to the following: the abundance of the affected population(s); the number, size, and location(s) of released hatchery fish; unique features of hatchery infrastructure and operations within the particular riverscape setting; and, unique features of the watershed(s) where fish are released. Because the proposed action is programmatic in nature, we cannot identify the exact population(s) that will be affected, nor the exact scope and magnitude of effects. Some populations in most ESUs and DPSs are in areas where there are no hatchery facilities and thus would not be affected by hatchery production. Based on our assessment, some watershed-scale effects may present up to moderately negative risk to some affected populations (Table 80). However, the substantial majority of affected populations are expected to face no more than a negligible to low level of risk from most or all watershed-scale effects, based on our extensive experience conducting hatchery consultations across the region. Moderate risk to a population from hatchery effects are generally only appropriate when these risks are outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance.

The proposed action requires NMFS to have evaluated the programs in detail in site-specific ESA consultations prior to providing federal prey program funding, which is an integral component of the proposed action. This requirement provides assurance that the effects of funding additional production will not jeopardize listed species or adversely modify their critical habitat. Hatchery operators typically employ best management practices that minimize adverse effects to locally affected listed species, and this is especially the case where NMFS has evaluated a program and issued a Biological Opinion concluding it is not likely to jeopardize any listed species or adversely modify critical habitat. In addition, in its Biological Opinions addressing hatchery programs, where a no jeopardy determination is reached, NMFS includes an ITS with reasonable and prudent measures (RPMs) or terms and conditions (T&Cs). These measures are intended to minimize the impact of take of listed species. Where a proposed action is found to jeopardize listed species or adversely modify critical habitat, NMFS issues Reasonable and Prudent Alternatives that, when implemented, avoid jeopardy or adverse modification and minimize impact of take. In such situations, NMFS would not issue federal prey program funding unless and until the RPAs were implemented by the hatchery operator.

<u>Combined effects</u>

Combined effects of the proposed action are likely to accrue from ecological interactions in the mainstem Columbia and Snake Rivers and in certain marine areas (Table 80). Many or all populations from ESUs and DPSs from particular Recovery Domains will be affected (except for the Central Valley Spring Chinook ESU). The exact degree of risk to affected ESUs and DPSs will vary depending largely on the regional distribution of released hatchery fish, and on the relative composition in life history types (spring-, summer-, fall-run) and life history stages (subyearling, yearling) of hatchery Chinook releases. Here, as described in the proposed action, NMFS will annually verify and document the regional distribution of released fish by modeling the total annual proposed release, using the same method in our analysis within this Opinion to confirm effects analyzed within this Opinion remain valid. However, regardless of these factors, the overall level of risk to all potentially affected ESUs and DPSs is expected to be either negligible or low for the reasons described in Section 2.5.1 (Effects of the Action, Salmon and Steelhead), and summarized below.

In the Columbia River and Snake River mainstems, we could not find direct evidence that competition and predation from hatchery Chinook salmon presents any more than a low risk to listed ESUs and DPSs present in these areas (Table 80 and Section 2.5.1.2.3, subsection Competition and Predation in the Mainstem Columbia and Snake Rivers). Chinook salmon from the proposed action will comprise a relatively small proportion of juvenile hatchery- and natural-origin salmonids migrating through these areas. Residence times of juvenile hatchery Chinook salmon within these areas will be relatively short because they will be released at a physiological stage where rapid seaward migration is both expected and verified from past releases. Predation from hatchery-origin fish on natural-origin fish is expected to be minor for these same reasons and because the spatiotemporal overlap of potentially piscivorous hatchery Chinook salmon and life history stages of vulnerable ESA-listed salmon and steelhead is expected to be small. For these reasons, risk from competition and predation in the Columbia River and Snake River mainstems is expected to be no more than low for all Columbia River basin salmon and steelhead ESUs and DPSs (Interior Columbia River and Willamette/Lower Columbia River Recovery Domains).

In Salish Sea marine areas (not including natal inner estuaries[66]), hatchery Chinook salmon from the proposed action will compete for forage resources with ESA-listed salmonids. We determined in Section 2.5.1.2.3 (subsection Competition and Predation in Marine Areas of the Salish Sea and the Columbia River Estuary), that forage resources for juvenile salmonids in the Salish Sea may be limited during periodic years of low marine productivity and/or high interspecific competitor abundance, but not during other years when productivity is nearer to or above average and/or competitor abundance is not particularly high. Low productivity years appear to occur somewhat infrequently. We also determined that forage resource competition is likely driven by species other than juvenile hatchery Chinook salmon (i.e., other planktivores—such as pink and chum salmon, herring, and stickleback—consume substantially more forage resources than hatchery- and natural-origin Chinook salmon). We expect the proposed action to increase hatchery Chinook salmon releases into Puget Sound by no more than 36% (relative to 2013–2022 average), though juvenile hatchery Chinook salmon would continue to comprise a small proportion of the epipelagic fish community that may compete for forage resources. Thus, hatchery Chinook salmon will continue to consume a small proportion of the available forage resources, having a correspondingly small effect on natural-origin ESA-listed species. Effects of competition are expected to be minor given the minor role that hatchery Chinook salmon play in resource competition and the relatively infrequent occurrence of low marine productivity years.

Risk of predation from hatchery origin fish on natural origin fish will be very minor for the following reasons: 1) sizes of juvenile ESA-listed salmon and steelhead present in these areas are

[66] We determined that there are no combined effects of the proposed action in Salish Sea natal inner estuaries. Specific effects in these areas are described in detail in the relevant site-specific Biological Opinions.

generally too large to be preyed upon by juvenile hatchery Chinook salmon; and, 2) resident subadult and adult Chinook salmon rarely prey on juvenile salmonids.

Fish from the Puget Sound Chinook salmon ESU would be most affected by competition and predation in the Salish Sea because of their extensive spatiotemporal overlap with hatchery Chinook salmon. Fish from the Hood Canal summer chum salmon ESU would be less affected because of their more limited spatial overlap. Fish from the Puget Sound steelhead DPS would be least affected because of their very short residence time in Salish Sea marine waters. For the reasons described above and in the preceding two paragraphs, risk from competition and predation in Salish Sea marine areas (not including natal inner estuaries) is expected to be no more than low for all Puget Sound Recovery Domain ESUs and DPSs.

In the Columbia River estuary, hatchery Chinook salmon from the proposed action may compete for forage resources with ESA-listed salmonids from the Interior Columbia River and Willamette/Lower Columbia River Recovery Domains. We expect the proposed action will increase hatchery Chinook releases into the Columbia River basin by no more than 12.0%[67] relative to 2016–2022[68] average of hatchery releases exclusive of those funded by the federal prey program. However, total release abundances from all hatchery Chinook programs combined (up to about 101.4 million smolts), including the federal prey program (up to 9.8 million smolts plus up to a 5% production overage), would remain well below those during the 1980s and 1990s (122.2 million smolts), and would be approximately equivalent to, though slightly above, those from the 2000s and early 2010s (100.0 million smolts)[69]. There are no data indicating that hatchery Chinook salmon of the sizes and life history stages to be released as part of the proposed action (large subyearlings and yearlings) have substantively contributed to any forage resource limitations in the estuary, even during the times of larger Chinook salmon hatchery release abundances, though research in this area is incomplete and continuing to evolve. Regardless of origin (natural or hatchery), yearling Chinook salmon make little use of the estuary, moving through in about a week, whereas subyearling Chinook salmon less than 90 mm FL use the estuary more extensively. However, hatchery subyearling Chinook salmon are either released larger than 90 mm FL, or generally achieve this size prior to encountering the estuary, thus suggesting that they move through the estuary quickly as well. These factors—the relatively small increase in Chinook salmon release abundances and the short expected residence time in the estuary—minimize risk of competitive effects to all ESA-listed salmonids in the estuary.

For the reasons described in both the preceding paragraph and this one, risk to all listed species in the Columbia River estuary is expected to be no more than low. The lowest risk is to species and life history types that move through the estuary quickly, namely steelhead and coho, sockeye, and yearling Chinook salmon. The greatest potential risk, albeit still a low one, is to

[67] Considers production overages of up to 5% on a running 5-year average, equivalent to a 5-year running average of 21 million smolts released.
[68] We use the 2016–2022 period as a reference range here because hatchery Chinook production levels produced from funding sources other than the federal prey program appeared to shift starting in 2016 relative to previous years (Figure 74), and because 2023 data may not be complete due to hatchery operator lag time in reporting release data to the Regional Mark Information System (https://www.rmpc.org/data-selection/rmis-queries/).
[69] This assumes that hatchery releases from sources other than the federal prey program do not appreciably increase, which they are not expected to due to the factors underpinning recent and anticipated near-term production levels.

natural subyearling Chinook salmon and juvenile chum salmon because these fish rear in the estuary for extended periods. These fish may therefore be present while multiple pulses of hatchery fish move through the estuary. Thus, Chinook salmon ESUs with large proportions of subyearling outmigrants, such as the Lower Columbia Chinook Salmon and Snake River Fall Chinook Salmon ESUs, would be most affected, as would the Columbia River Chum Salmon ESU. However, due to their smaller size, natural subyearling Chinook salmon and chum salmon in the estuary typically occur in shallower water than hatchery yearling and subyearling Chinook salmon. This spatial segregation means that most natural-origin fish are not exposed to effects from hatchery-origin fish, and that relatively few hatchery-origin fish interact with natural-origin fish. In combination with the rapid transit time of hatchery-origin Chinook salmon through the estuary, this minimizes risk of competitive effects, and minimizes risk of predation, in the estuary from fish released from the federal prey program. All other listed entities from the Interior Columbia River and Willamette/Lower Columbia River Recovery Domains—that is, the other four Chinook salmon ESUs, the Lower Columbia Coho Salmon ESU, the Snake River Sockeye Salmon ESU, and all six steelhead DPSs—would be considerably less affected given the short transit time through the estuary of fish from these ESUs and DPSs that is expected, on the order of about one week. There will be no predation risk to fish from these ESUs and DPSs because of their large size in the estuary. For these reasons, risk from competition and predation in the Columbia River estuary is expected to be no more than low for all Interior Columbia River and Willamette/Lower Columbia River Recovery Domains ESUs and DPSs.

In marine areas outside of the Salish Sea and the Columbia River estuary, hatchery Chinook salmon from the proposed action are expected to compete for forage resources with ESA-listed salmonids. We determined in Section 2.5.1.2.3 (subsection Competition and Predation in the Pacific Ocean) that forage resources in the Pacific Ocean are limited during periodic years of low marine productivity, but not during other years when productivity is nearer to or above average. We also determined that forage resource competition, to the extent that it occurs, is driven by species other than hatchery Chinook salmon, meaning that hatchery Chinook salmon have a minor effect on the pool of available prey resources and thus concomitantly minor effect on natural-origin ESA-listed salmonids. We expect the proposed action to increase hatchery Chinook releases from Puget Sound, the Columbia River, and the Washington coast by no more than 14.5%[70] relative to 2016–2022 average of hatchery releases exclusive of those funded by the federal prey program. Total release abundances from all hatchery Chinook programs combined (up to about 166.4 million smolts), including the federal prey program (up to 20 million smolts plus up to a 5% average production overage), would remain well below those during the 1980s and 1990s (186.8 million smolts), but would exceed those from the 2000s and early 2010s (153.7 million smolts)[71] by 8.2%. Along continental shelf areas of the action area, the proposed action is expected to increase subadult and adult abundance of Chinook salmon by 3.0–6.1% during summer months, and 3.5–6.3% averaged across the year. Risk from competition in marine areas due to the proposed action is expected to be minor for the following reasons: 1) hatchery Chinook salmon play a minor role in oceanic resource competition; 2) the proposed

[70] Considers production overages of up to 5% on a running 5-year average, equivalent to a 5-year running average of 21 million smolts released.
[71] This assumes that hatchery releases from sources other than the federal prey program do not appreciably increase, which they are not expected to due to the factors underpinning recent and anticipated near-term production levels.

action represents a relatively small increase in hatchery Chinook salmon abundance; and, 3) competition is expected to be periodic, occurring only during years of low marine productivity and/or high abundance of competitors other than Chinook salmon. Predation risk will be very minor for the following reasons: 1) sizes of juvenile ESA-listed salmon and steelhead present in these areas are too large to be preyed upon by juvenile hatchery Chinook salmon; and, 2) subadult and adult Chinook salmon rarely prey on juvenile salmonids in the ocean.

For the reasons described in the preceding paragraph, risk to all listed species in marine areas outside of the Salish Sea and Columbia River estuary is expected to be no more than low. Competitive interactions from federal prey program Chinook salmon would present the greatest risk, albeit still no more than a low one, to ESA-listed Chinook salmon relative to other listed salmonid species. This is because we expect federal prey program hatchery Chinook salmon to have the greatest degree of spatiotemporal and dietary overlap with other Chinook salmon. Coupled with this, we expect ESA-listed Chinook salmon originating from the same geographic areas as federal prey program Chinook salmon would have the most spatiotemporal overlap in the ocean, and thus would be most affected. This includes Chinook salmon ESUs from the Puget Sound, Interior Columbia River, and Willamette/Lower Columbia River Recovery Domains. Some Chinook salmon originating from other areas (i.e., California) may use the action area, and thus be affected. This includes Chinook salmon from the following two ESUs: California Coastal Chinook Salmon (North-Central California Coast Recovery Domain) and Central Valley Spring Chinook Salmon (Central Valley Recovery Domain). However, for both, risk at the ESU scale is negligible because low proportions of fish from these ESUs are expected in the action area.

ESA-listed coho salmon in the marine portion of the action area may also be affected because of their broad-scale spatiotemporal overlap and typically high degree of dietary overlap with Chinook salmon. However, effects would be less than those for Chinook salmon because of the lower degree of spatiotemporal and dietary overlap. For the Lower Columbia River Coho Salmon ESU (Willamette/Lower Columbia River Recovery Domain), risk at the scale of the ESU is further minimized because only about 25–60% of these coho salmon are expected to remain in the action area throughout their marine life history stage.

Spatiotemporal and dietary overlap of all marine life history stages of hatchery Chinook salmon and natural steelhead and chum and sockeye salmon is extremely minor. Thus, any competitive effects to the following ESUs and DPSs in marine areas outside of the Salish Sea and the Columbia River estuary are negligible:

- Puget Sound Recovery Domain: Hood Canal Summer Chum ESU, Puget Sound Steelhead DPS
- Interior Columbia River Recovery Domain: Snake River Sockeye Salmon ESU, all steelhead DPSs
- Willamette/Lower Columbia River Recovery Domain: Lower Columbia Coho Salmon ESU, all steelhead DPSs

Cumulative effects from future non-Federal activities are expected to perpetuate current effects on all ESUs and DPSs. Within the action area, non-Federal actions are likely to include activities associated with human population growth, water withdrawals (i.e., those pursuant to state water rights), and land use practices. Continuing commercial and sport fisheries, which have some incidental catch of listed species, will have adverse impacts through removal of fish that would otherwise contribute to spawning populations. Cumulative effects also include any non-federal restoration activities that result in increased abundance and quality of freshwater, estuarine, and nearshore habitat, in cooler water and thermal refugia, and reduced pollutants in the action area. These have occurred in the past and are likely to continue in the future, although most restoration actions have some federal component and thus are not considered cumulative effects. Climate change is a substantial threat to all ESUs and DPSs, especially during the marine rearing phase of their life cycles. We expect climate change and other environmentally related factors will affect the abundance of salmon and steelhead in the future, and we expect that the direction of that change will ultimately be negative.

Considering the current status of the threatened and endangered species and the current state of the environmental baseline within the action area, the proposed action's effects are characterized as follows:

- Chinook salmon ESUs in the Puget Sound, Willamette/Lower Columbia River, and Interior Columbia River Recovery Domains: Watershed-scale effects will usually present negligible to low risk to affected populations. It is possible, though not certain, that some watershed-scale effects may present a moderate risk to some populations depending on the specific hatchery programs receiving funding. Site-specific Biological Opinions and associated ITSs determine acceptable levels of risk based on the conservation needs and importance of the affected populations, among other factors, and will exempt take accordingly. Combined effects could affect many or all populations, but risk from these effects will be negligible to low in all cases and will not substantively add to the risk presented by watershed-scale effects. Negative effects to VSP parameters are therefore considered low.
- All other salmon ESUs and steelhead DPSs in the Puget Sound, Willamette/Lower Columbia, and Interior Columbia River Recovery Domains: Watershed-scale effects will present negligible to low risk to affected populations with some possible exceptions. It is possible, though not certain, that some watershed-scale effects may present a moderate risk to some populations depending on the specific hatchery programs receiving funding. Site-specific Biological Opinions and associated ITSs determine acceptable levels of risk based on the conservation needs and importance of the affected populations, among other factors, and will exempt take accordingly. Combined effects could affect many or all populations, but risk from these effects will be negligible to low in all cases and will not substantively add to the risk presented by watershed-scale effects. Negative effects to VSP parameters are therefore considered low.
- California Coastal Chinook Salmon ESU (North-Central California Coast Recovery Domain), Central Valley Spring Chinook Salmon (Central Valley Recovery Domain) ESU: Fish from these ESUs will not be affected by watershed-scale effects. Combined effects could affect many or all populations, but risk from these effects will be negligible to low in all cases. Negative effects to VSP parameters are therefore considered low.

To summarize, Section 2.4, Environmental Baseline, describes in detail actions that have been implemented over the course of the last several decades that have substantially improved the environmental baseline, including but not limited to the following: hatchery reform efforts and NMFS hatchery ESA consultations on the majority of hatchery programs and facilities operating across Puget Sound and the Columbia River basin; harvest reductions, NMFS ESA consultations on harvest management plans, and implementation of monitoring and management of incidental by-catch of non-target ESA-listed species; widespread habitat protection and restoration actions in freshwater and estuarine habitats; restoration of fish passage in many previously-blocked areas and, in some areas, managed reintroduction of ESA-listed anadromous salmonids; and, improved management of hydropower operations, particularly in the areas of safe fish passage around hydropower projects and improved flow management that reduces risk to spawning, incubating, rearing, and migrating salmonids in areas downstream from hydropower projects. Although the environmental baseline is still degraded, it is substantially improved over recent decades. Section 2.6, Cumulative Effects, describes in detail future actions that are likely to either help or impair ESA-listed salmonids, concluding that: 1) the level of adverse effects will be lower than those in the recent past, and much lower than those in the more distant past; and, 2) state and local habitat restoration and protection actions, and further improvements in hatchery, harvest, and hydropower operations, are likely to result in improvements in fish survival. Section 2.5, Effects of the Action, describes in detail risks from the proposed action. All risks were found to be low, with the exception of some watershed-scale effects that were found to present a moderate risk. However, moderate risks from some effects were only indicated for either: 1) populations with the lowest conservation importance (consistent with recovery plans) where a moderate risk from ongoing (base) hatchery operations was already present and the proposed action will not increase that risk; or, 2) low-abundance, at-risk populations where the benefits of hatchery propagation (e.g., increased spawner abundance, maintenance of genetic lineage) outweigh the moderate risk(s) necessary to implement that propagation (e.g., removing natural-origin fish for broodstock)[72]. The status of each affected listed entity (Section 2.2) indicates that: 1) Puget Sound and Columbia River hatchery programs operating in accordance with NMFS site-specific consultations—which describes the substantial majority of hatchery programs across Puget Sound and the Columbia River basin, and is also a requirement for prey program funding—are not a substantive limiting factor to recovery; and, 2) combined effects of hatchery programs in marine waters of the action area also is not a substantive factor limiting recovery. Based on the status and limiting factors of each affected listed entity (Section 2.2), the generally improved and improving baseline (Section 2.4), and future improvements in many conditions affecting listed salmonids and their habitat (Section 2.6), we conclude that the limited risks presented by the proposed action (Section 2.5) will not impair the survival or recovery of any listed ESU/DPS or

[72] Recall that most or all hatchery programs anticipated to be federally funded have ongoing, or "base", programs that propagate Chinook salmon for purposes other than SRKW forage. That is, hatcheries operating base programs for purposes such as harvest or recovery may have capacity to produce more fish for SRKW forage. Such facilities may apply for and receive federal prey program funding to produce more fish, presuming that all 6 criteria described in the proposed action are met. Production for SRKW forage is thus simply an extension of the base program. Where a previous NMFS site-specific ESA consultation has found acceptable moderate risk from one or more elements of the base program, we confer that moderate risk to the federal prey program-funded portion of the production. However, we do not anticipate that producing more fish for SRKW forage will present a moderate risk in and of itself, nor elevate risk from low to moderate when added to the base program.

critical habitat. For these reasons, the viability of the respective ESUs and DPSs are also not likely to be affected. We do not think that the effects of the proposed action will reduce the likelihood of recovery or impede implementation of recovery actions identified in the recovery plans.

After reviewing and analyzing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS's biological opinion that the proposed action is not likely to appreciably reduce the likelihood of both survival and recovery of the listed species shown in Table 80.

2.7.2 Salmon and Steelhead Designated Critical Habitat

Critical habitat for ESA-listed salmon and steelhead is described in Section 2.2.7. In reviewing the proposed action and evaluating its effects, NMFS has determined that the proposed action will, at small spatial scales, incrementally degrade designated salmon and steelhead critical habitat, but will not preclude its functioning or intended conservation role (Section 2.5.2).

Historical and persistent habitat degradation associated with human activities other than hatchery facilities and operations are the dominant and primary factors contributing to degraded habitat conditions and PBFs throughout the action area. Further degradation is likely due to the persistence of these factors, population growth, and climate change. The effects of the proposed action are likely to subtlety exacerbate these, but would represent only incremental declines at small spatial scales, and would not preclude salmon or steelhead from migrating, spawning, and rearing within the action area.

Most effects to critical habitat from the proposed action occur solely at the watershed scale (i.e., they are watershed-scale effects) and affect PBFs 1–5. In general, these effects primarily affect critical habitat within the river basin that any specific hatchery is operating within, including areas at or relatively near the hatchery, and downstream areas to the point where the affected stream or river meets a larger body of water (e.g., Puget Sound marine; Columbia River mainstem). The proposed action may fund hatchery operations throughout the Puget Sound, Interior Columbia River, and Willamette/Lower Columbia River Recovery Domains. The degree of risk from watershed-scale effects to critical habitat for individual ESA-listed populations within these Recovery Domains will vary depending on a variety of factors including but not limited to the following: the condition of critical habitat within the affected watershed(s); unique features of hatchery infrastructure and operations within the particular riverscape setting; and, unique features of the watershed. In general, watershed-scale effects to critical habitat are expected to be small and localized in most cases. It is possible, though not certain, that some watershed-scale effects may have a larger effect on some PBFs in some areas depending on the specific hatchery programs receiving funding.

Because the proposed action is programmatic in nature, we cannot identify the exact locations or amount of critical habitat that will be affected, nor the exact scope and magnitude of effects. Instead, we are informed here by the detail in the environmental baseline for adverse effects that NMFS has previously consulted on for critical habitat through site-specific Section 7 consultations. As part of the proposed action, under Criterion 6, NMFS will need to have evaluated the hatchery programs in detail in site-specific ESA consultations prior to providing federal prey program funding, which is an integral component of the proposed action. This requirement provides assurance that the effects of funding additional production will not jeopardize listed species or adversely modify their critical habitat. Hatchery operators typically employ best management practices that minimize adverse effects to critical habitat, and this is especially the case where NMFS has evaluated a program and issued a biological opinion concluding it is not likely to jeopardize any listed species or adversely modify critical habitat. Where a proposed action is found to jeopardize listed species or adversely modify critical habitat, NMFS issues Reasonable and Prudent Alternatives that, when implemented, avoid jeopardy or adverse modification and minimize impact of take. In such situations, NMFS would not issue federal prey program funding unless and until the RPAs were implemented by the hatchery operator.

Combined effects of the proposed action on critical habitat are likely to be incurred in the mainstem Columbia and Snake Rivers, in the Columbia River estuary, and in certain marine areas. Affected PBFs include the following: 1) PBF 2 as it pertains to forage supporting juvenile development in the mainstem Columbia and Snake Rivers; 2) PBF 4 as it pertains to predation and forage in the Columbia River estuary and estuarine areas of the Salish Sea (other than natal inner estuaries); and, PBF 6 as it pertains to forage in those portions of Puget Sound nearshore marine areas that are designated critical habitat. Our analysis indicates that combined effects to these PBFs will be minor in all cases.

For these reasons, we conclude that the proposed action will not preclude critical habitat from establishing and maintaining functioning PBFs. The proposed action will not impair or prohibit critical habitat within the action area from serving the intended conservation role for any of the species at the scale of the population, watershed, or listed entity.

After reviewing and analyzing the current status of critical habitat, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS's biological opinion that the proposed action is not likely to destroy or adversely modify designated critical habitat of the species shown in Table 80 within the Puget Sound, Interior Columbia River, and Willamette/Lower Columbia River Recovery Domains.

2.7.3 Eulachon

Predation by salmonids on eulachon was identified as a threat to eulachon recovery as outlined in the "Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*)" (NMFS 2017i). As noted above (Section 2.5.2), eulachon occur throughout the action area and overlap in space and time with hatchery-produced Chinook salmon that would be produced and released under the proposed action. These increases in hatchery-produced and released Chinook salmon are likely to have direct effects (predation) that will have an effect on eulachon abundance (reduction). Although the quantities of larval, juvenile, sub-adult, and adult eulachon consumed by these hatchery-produced and released Chinook salmon under the proposed action cannot be directly quantified, we do not expect the magnitude of predation to meaningfully affect eulachon productivity and abundance at the subpopulation or DPS level as Chinook salmon (wild and hatchery-produced) are not known to selectively prey on eulachon (Osgood et al. 2016), therefore there we do n ot expect that will be a detectable reduction in eulachon abundance at the subpopulation or DPS level that can be linked to the proposed action, and given that eulachon abundance is driven largely by positive ocean conditions, any decrease is likely to be masked by unfavorable ocean conditions, e.g., low biomass of northern copepods in the California Current.

While the proposed action may have some small effect on the species' abundance (by killing a relatively small proportion of eulachon), it is not likely to have an appreciable effect on their productivity, diversity, or structure. In summary, the effects of the Proposed Action (Section 2.5), when added to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), and taking into account the status of the species and critical habitat (Section 2.2), would not reduce appreciably the likelihood of either the survival or recovery of eulachon.

2.7.1 Puget Sound/Georgia Basin Rockfish

As described above in Section 2.2, Rangewide Status of the Species and Critical Habitat, we conclude that the Puget Sound/Georgia Basin DPSs of yelloweye rockfish and bocaccio are at moderate and high risk of extinction, respectively. Low estimated adult abundance, reduced productivity as a consequence of historical removal of large adults, and a lack of recent recruitment events contribute to this risk in both species. For yelloweye rockfish, genetic evidence has validated the DPS boundaries and regular observation of both juveniles and adults in waters of both the U.S. and Canada suggest that populations are slowly rebuilding (Min et al. 2023; Lowry et al. 2024). For bocaccio, however, encounter rates have remained near zero and connectivity to coastal populations is poorly understood. With the major threat of fishery impacts minimized since 2010, management practices for both species now focus on researching and minimizing other threats to promote successful recruitment and retention over coming decades as newly settled juveniles mature to reproductive age (NMFS 2017s).

2.7.1.1 Effects on Abundance

Bycatch in fisheries is likely a limiting factor for yelloweye rockfish and bocaccio, though there is uncertainty regarding the degree to which it impacts population recovery (NMFS 2017s). As detailed in Section 2.4, Environmental Baseline, yelloweye rockfish and bocaccio can be caught by anglers targeting salmon and bottomfish, and in the shrimp trawl fishery. To assess if the increase in release of hatchery Chinook proposed here to increase prey for SRKW may adversely limit the viability of each rockfish species, we consider the proposed action in the context of the population-level impact from all fisheries and research combined. Thus, we compare the number of individual fish affected by known sources of mortality/injury (fisheries and scientific research) to the overall size of the population.

To conduct this analysis, we consider effects on the overall population of the rockfish DPSs for both species. However, as described above in Section 2.2, Rangewide Status of the Species and Critical Habitat, there are no reliable estimates of the abundance of either of the ESA-listed rockfish DPSs, which is particularly acute for bocaccio. The best available abundance data for each species come from the WDFW ROV surveys (Pacunski et al. 2013; WDFW 2017; Pacunski et al. 2020; Lowry et al. 2022), and we use these surveys as a fundamental source to understand the total abundance of the U.S. portion of the DPSs. The structure of this analysis likely underestimates the total abundance of each species within the U.S. portion of the DPS because:

1) we use the lower confidence interval population estimates available for yelloweye rockfish; and 2) we use the WDFW population estimate of bocaccio for the San Juan Island and Eastern Strait of Juan de Fuca area and note that it is generated within only 46% of the estimated habitat of bocaccio within the U.S. portion of the DPS. The rest of the area, including the Main Basin, South Sound, and Hood Canal, were likely the most historically common area used by bocaccio (Drake et al. 2010). The structure of these assessments likely underestimates the total abundance of each DPS, resulting in a minimum abundance scenario and evaluation of cumulative fishery bycatch mortality for each species.

To assess potential population-level effects on yelloweye rockfish and bocaccio from the proposed increase in hatchery Chinook releases, we calculated the adult equivalent of estimated larval consumption and determined that less than one yelloweye rockfish and less than one bocaccio will be impacted annually by this action, amounting to less than 0.02% of either population (Table 84). We rounded these values to one yelloweye rockfish and one bocaccio, then added this to expected impacts from activities within the environmental baseline (Table 85).

Table 85. Total annual lethal catches for fisheries and research within the U.S. portion of the DPS.

Species	Total Lethal Take in Baseline (plus halibut fishery estimate)	Abundance Estimate	Proportion of DPS Killed
Bocaccio	157[a] (+1) = 158	4,606	0.034
Yelloweye Rockfish	477[b] (+1) = 478	143,086	0.003

[a] This includes the following estimated bocaccio mortalities: 77 from the salmon fishery, 45 during research, 17 in other fisheries (recreational bottomfish and shrimp trawl), and 18 in halibut fisheries.
[b] This includes the following estimated yelloweye rockfish mortalities: 66 from the salmon fisheries, 54 during research, 87 in other fisheries (recreational bottomfish and shrimp trawl), and 270 in halibut fisheries.

To assess the effect of these mortalities on population viability, we adopted the methodology used by the Pacific Fishery Management Council for rockfish species, which has identified precautionary harvest rates of 0.5 to 0.7 (50% to 70%) of natural mortality for rockfish species (Walters et al. 1996; PFMC 2000). Annual natural mortality rates for yelloweye rockfish range from 2–4.6% (as detailed in Section 2.2.1, Status of Listed Species) (Yamanaka et al. 1997; Wallace 2007); thus, the precautionary level of fishing and research mortality would be 1–2.3%. For yelloweye rockfish, total lethal impacts from the proposed action and activities considered in the Environmental Baseline would be 0.3%, which is well below the precautionary level of 1–2.3%. Annual natural mortality rate for bocaccio is approximately 8% (as detailed in Section 2.2.1, Status of Listed Species) (Palsson et al. 2009); thus, the precautionary level of fishing and research mortality would be 4%. For bocaccio, total lethal impacts would be 3.4%, which is close to the precautionary level of 4%. We note, however, that the population estimate for bocaccio is from one area of the DPS, the San Juan Island area, which represents approximately 46% of bocaccio habitat in the U.S. portion of the DPS. Bocaccio exist in the rest of the DPS area (they were recently documented in the Main Basin in fisheries and research efforts; Lowry et al. (2024)) and the population estimate used here is an underestimate for which better science does not exist. The percent of the DPS killed would, therefore, be less than calculated and reported in Table 85.

Potential bycatch and research effects in the environmental baseline are also determined using estimates that have exceeded the actual effects, and the actual impacts on each species would very likely be less. For the previously analyzed research projects, the actual catches of yelloweye rockfish and bocaccio is well below the permitted take. As an example, since bocaccio were listed in 2010, only four fish have been caught in research projects (compared to the permitted take of 58 fish, and 27 mortalities in 2017 alone) within the U.S. portion of the DPS area. Similarly, estimates of catches in some fisheries may also be an underestimate as no yelloweye rockfish or bocaccio were reported as caught in the shrimp trawl fishery from 2012 to 2017 (WDFW 2017).

While the proposed action may have some small effect on the species' abundance (by killing a relatively small proportion of larvae), it is not likely to have an appreciable effect on their productivity, diversity, or structure within the Puget Sound/Georgia Basin. In summary, the effects of the Proposed Action (Section 2.5), when added to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), and taking into account the status of the species and critical habitat (Section 2.2), would not reduce appreciably the likelihood of either the survival or recovery of yelloweye rockfish or bocaccio of the Puget Sound/Georgia Basin DPSs.

2.8 Conclusion

2.8.1 Salmon and steelhead and their designated critical habitat

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of the listed species shown in Table 1. or destroy or adversely modify their designated critical habitat.

2.8.2 Eulachon

Based on the analysis herein, NMFS has determined that the proposed action is not likely to jeopardize the continued existence of the southern DPS of eulachon.

2.8.3 Puget Sound/Georgia Basin Rockfish

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of Puget Sound/Georgia Basin DPSs of yelloweye rockfish and bocaccio. We reach this conclusion because the mortality resulting from the proposed action, when combined with the mortality from other fishing and research within the environmental baseline, is unlikely to exceed levels that would hinder population viability.

2.9 Incidental Take Statement

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

The NMFS has not yet promulgated an ESA section 4(d) rule prohibiting take of threatened eulachon. Anticipating that such a rule may be issued in the future, we have included a prospective incidental take exemption for eulachon. The elements of this ITS for eulachon would become effective on the date on which any future 4(d) rule prohibiting take of eulachon becomes effective. Nevertheless, the amount and extent of eulachon incidental take, as specified in this statement, will serve as one of the criteria for reinitiation of consultation pursuant to 50 C.F.R. §402.16(a), if exceeded.

This incidental take statement addresses program actions that are reasonably certain to cause take and are not subject to further section 7 consultation (50 CFR 402.14(i)(7)). The actions in this latter category are related solely to the federal funding of en masse region-wide hatchery releases of Chinook salmon smolts for the specific purpose of increasing the preferred forage base of the ESA-endangered SRKW, thereby mitigating for the effects of prey removal in fisheries subject to the 2019–2028 PST Agreement. These federal funding actions are reasonably certain to cause take via combined effects (see beginning of Section 2.5 for description of combined effects) and will occur without further consultation. Conversely, the particular hatchery programs that are funded and their watershed-scale effects are subject to further section 7 consultation.

2.9.1 Amount or Extent of Take

In this Opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

2.9.1.1 Salmon and Steelhead

Hatchery operations are likely to cause take, and those forms of take have been or will be analyzed and addressed in site-specific ITSs. Individual hatchery operators are held to the terms and conditions of their site-specific ITSs. On an annual basis, NMFS will review the annual reports associated with the site-specific consultations, and document they are still in effect during the funding decision process, to ensure compliance with the site-specific ITSs prior to issuing funds from the federal prey program.

Combined effects from competition, predation, and pathogen transmission, collectively referred to as ecological interactions, by federal prey program hatchery Chinook salmon are expected to result in take of listed salmon and steelhead. This type of take is difficult, if not impossible, to quantify because it cannot be observed, and, therefore, cannot be directly or reliably measured. However, as described in Section 2.5.1.2.3, ecological interactions are the direct result of hatchery releases, and the magnitude of interactions will increase as more fish are released from hatcheries. Therefore, NMFS will rely on the following two surrogates as take indicators for take associated with combined effects from ecological interactions caused by federal prey program hatchery Chinook salmon: 1) the annual abundance of federal prey program hatchery Chinook salmon smolts released; and, 2) the projected increase in ocean Chinook salmon abundance from federal prey program hatchery production, as estimated by the most current FRAM-Shelton model version available at the time model runs are expected to be produced. These are described in more detail below. These are reliable surrogate take indicators because we expect that the extent of ecological interactions is largely a function of hatchery Chinook salmon abundance, such that greater numbers of hatchery Chinook salmon would yield greater magnitude of ecological interactions.

For take surrogate 1 (annual abundance of federal prey program hatchery Chinook salmon smolts released), NMFS expects some annual variability in release numbers due to the level of unpredictability inherent in hatchery operations. Therefore, we expect that release abundances will not exceed the following values, as described in the proposed action:

- Total federal prey program release abundance from Puget Sound, Columbia River, and Washington coast not to exceed 22 million smolts in any given year, and running 5-year average not to exceed 21 million smolts.
- Total federal prey program release abundance from Puget Sound not to exceed 15.9 million smolts in any given year, and running 5-year average not to exceed 15.2 million smolts.
- Total federal prey program release abundance from Columbia River not to exceed 10.8 million smolts in any given year, and running 5-year average not to exceed 10.3 million smolts.

For take surrogate 2 (projected increase in ocean Chinook salmon abundance from the federal prey program hatchery production), NMFS expects annual variability due to the expected variability in release abundances described above arising from unpredictability inherent in hatchery operations. Therefore, we expect that increases in marine abundance will not exceed the following values, as described in the proposed action:

- Increase in modeled age 3–5-year-old Chinook salmon abundance in any continental shelf area (outside of the Salish Sea) not to exceed: 1) for a full calendar year, 6.6% for any given year, and running 5-year average not to exceed 6.3%; and, 2) for summer months (July–September), 6.4% for any given year, and running 5-year average not to exceed 6.1%.
- Increase in modeled age 3–5-year-old Chinook salmon abundance in the Salish Sea not to exceed: 1) for a full calendar year, 7.5% for any given year, and running 5-year average not to exceed 7.2%; and, 2) for summer months (July–September), 1.8% for any given year, and running 5-year average not to exceed 1.7%.

2.9.1.2 Eulachon

Under the proposed action, hatchery-produced and released Chinook salmon will take place within habitats that are occupied by eulachon. Therefore, the proposed is likely to cause incidental take (killing, via predation) of adult, juvenile, sub-adult, and larval eulachon by hatchery-produced and released Chinook salmon throughout their life cycle.

Take caused by the production and release of hatchery-produced Chinook salmon cannot be directly quantified because the distribution and abundance of eulachon that occur within the action area are affected by habitat quality, competition, predation, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, the distribution and abundance of eulachon within the action area cannot be attributed entirely to predation caused by the production and release of hatchery-produced Chinook salmon under the proposed action. In such circumstances, NMFS uses a surrogate to describe the extent of take. Here, the best available indicator for the extent of take is the annual production and release of up to 22 million hatchery-produced Chinook salmon smolts.

2.9.1.3 Puget Sound/Georgia Basin Rockfish

We anticipate that take of yelloweye rockfish and bocaccio of the Puget Sound/Georgia Basin DPSs will occur as a result of the proposed operation of Chinook salmon hatcheries to increase prey resources for SRKW. Incidental take of each species is expected to occur in the form of fatal injury through consumption of larvae of either species. Incidental take of each species under the proposed operations is not expected to exceed an adult equivalent of 1 yelloweye rockfish and 2 bocaccio annually. Take cannot be comprehensively monitored because it requires lethal gut content sampling of juvenile salmonids, but hatchery release data will inform bioenergetic models as a surrogate for direct observation. Here, the best available indicator for the extent of take is annual production and release of up to 22 million hatchery-produced Chinook salmon smolts.

2.9.2 Effect of the Take

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

2.9.2.1 Reasonable and Prudent Measures

"Reasonable and prudent measures" refer to those actions the Director considers necessary or appropriate to minimize the impact of the incidental take on the species(50 CFR 402.02).

2.9.2.1.1 Salmon and Steelhead

1. NMFS shall monitor and report annually information pertaining to the take surrogates identified in Section 2.9.1.1 above.

2.9.2.1.2 Eulachon

1. NMFS shall monitor and report annually information pertaining to the take surrogates identified in Section 2.9.1.2 above.

2.9.2.1.3 Puget Sound/Georgia Basin Rockfish

1. NMFS shall monitor and report annually information pertaining to the take surrogates identified in Section 2.9.1.3 above.

2.9.2.2 Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. NMFS or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

These terms and conditions constitute no more than a minor change to the proposed action because they are consistent with the basic design of the proposed action.

2.9.2.2.1 Salmon and Steelhead

The following terms and conditions implement reasonable and prudent measure 1:

1. NMFS shall produce two annual reports for all activities and monitoring occurring that calendar year. Reports shall include the following information:

    a. For each fiscal year of proposed prey program funding, and prior to final funding distribution, a report complete with the following:

i. The number of federal prey program funded Chinook salmon smolts planned to be released with that fiscal year of funding, by calendar year of proposed smolt release and by region (Puget Sound, Columbia River, Washington coast).
ii. The running 5-year average—including the proposed releases for the fiscal year under consideration—of federal prey program Chinook salmon smolts released and proposed to be released in total (all regions combined), and for each region separately (Puget Sound, Columbia River, Washington coast).
iii. The anticipated percent increase in ocean abundance of age 3–5-year-old Chinook salmon in the Salish Sea and continental shelf areas resulting from the following calendar years federal prey program hatchery Chinook releases, based on FRAM-Shelton modelling.
iv. The running 5-year average—including the planned releases for the calendar year following the one the report is completed within—modeled percent increase in ocean abundance of age 3–5-year-old Chinook salmon in the Salish Sea and continental shelf areas resulting from federal prey program hatchery Chinook releases (actual and planned), based on FRAM-Shelton modelling.
v. Documentation that each hatchery program expected to receive funds meets criterion 6 and is in compliance with their site-specific Biological Opinion and associated ITS.

b. For each calendar year that smolts are released, a report submitted within 4 months after the last federal prey program-funded hatchery smolt release of the calendar year complete with the following:

i. The number of federal prey program funded Chinook salmon smolts actually released in that calendar year, in total (all regions combined) and by region (Puget Sound, Columbia River, Washington coast).
ii. The running 5-year average—including the calendar year of the report's completion—of federal prey program Chinook salmon smolts released in total (all regions combined) and for each region separately (Puget Sound, Columbia River, Washington coast).
iii. The anticipated percent increase in marine abundance of age 3–5-year-old Chinook salmon in the Salish Sea and continental shelf areas resulting from the current year's federal prey program hatchery Chinook salmon smolt releases, based on FRAM-Shelton modelling.
iv. The running 5-year average—including the calendar year of the report's completion—modeled percent increase in ocean abundance of age 3–5-year-old Chinook salmon in the Salish Sea and continental shelf areas resulting from federal prey program hatchery Chinook releases, based on FRAM-Shelton modelling.

2. NMFS shall annually monitor emerging science regarding ecological interactions as they relate to hatchery science, including but not limited to density-dependent competitive interactions, relevant to parts of the action area affected by combined effects of the proposed action (i.e., marine and estuarine areas, and Columbia and Snake River mainstems). This annual review will evaluate emerging science to ensure that the scientific understanding of the nature, scope, and magnitude with which hatchery-origin Chinook salmon ecologically interact with listed natural salmonids does not meaningfully change from that which underpins this Opinion's analysis and conclusions. This review shall include, but not be limited to, relevant peer-reviewed journal publications and agency reports that document results of scientific investigations specific to density-dependent competitive interactions between hatchery- and natural-origin salmonids. Reports of monitoring activities that document routine data collections would not constitute emerging science unless accompanied by a scientific analysis.

3. NMFS shall evaluate the feasibility of directing a portion of the annual funding towards monitoring indicators of forage resource limitation and competition in marine areas affected by the funding decision. Indicators to be considered shall include, but not be limited to, the following: a) hatchery- and natural-origin juvenile Chinook salmon growth during the summer; b) forage resource availability; and, c) forage resource demand by hatchery- and natural-origin juvenile Chinook salmon and other species that prey on similar taxa. NMFS shall document the conclusions of this feasibility assessment within one year of this Opinion's signature.

   NMFS shall implement any monitoring deemed feasible, to begin as soon as practicable once the feasibility assessment is completed. Reports documenting monitoring results shall be produced by May 1 for the previous calendar year's monitoring.

2.9.2.2.2 Eulachon

NMFS shall submit an annual report on the total production and release of hatchery-produced Chinook salmon throughout the action area under the proposed action.

2.9.2.2.3 Puget Sound/Georgia Basin Rockfish

Terms and conditions specific to the above identified reasonable and prudent measures for rockfish are identified below.

1. NMFS shall coordinate with the relevant entities to implement consistent methods to monitor, document, and report release of hatchery Chinook salmon into Puget Sound and adjacent waters.

2.10 Conservation Recommendations

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

NMFS believes the following conservation recommendations are consistent with these obligations, and therefore should be implemented by NMFS.

2.10.1 Salmon and Steelhead

1. Ecological interactions involving hatchery Chinook salmon in the mainstem Columbia and Snake Rivers (outmigrating juveniles) and in marine waters of the Salish Sea and the continental shelf (juveniles, subadults, and adults) are not well understood. NMFS should endeavor to continue to assess beneficial and detrimental interactions involving hatchery Chinook salmon in these habitats to better understand how hatchery programs can be managed to aid in the recovery of listed salmonids across the region. NMFS should support, financially or otherwise, studies to address critical research needs in these areas.

2.10.2 Listed Rockfish

The following conservation recommendation is provided to better understand the incidental take of listed rockfish in the proposed fishery and its effects.

1. NMFS should work with the appropriate entities to collect additional information on the spatiotemporal overlap of larval rockfish and juvenile salmon, including conducting dedicated diet studies that employ genetic interrogation tools to determine the proportional representation of ESA-listed rockfish in gut contents.

2.11 Reinitiation of Consultation

This concludes formal consultation for the NMFS Preferred Alternative for Expenditure of Pacific Salmon Treaty Funds to Increase Prey Availability for Southern Resident Killer Whales.

Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the federal agency, where discretionary federal involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action."

2.12 "Not Likely to Adversely Affect" Determinations

NMFS concludes that the proposed actions are not likely to adversely affect species or critical habitat of the species listed in Table 2. The applicable standard to find that a proposed action is "not likely to adversely affect" ESA listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects on the species. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are extremely unlikely to occur. The information NMFS considered in making these determinations is summarized below.

2.12.1 Salmon and Steelhead

The entirety of the action area described for salmon and steelhead in Section 2.3.1 was assessed in order to determine potential effects to ESA-listed salmon and steelhead. In this assessment the following ESUs and DPSs were determined to incur discountable or insignificant effects as a result of the proposed action within the action area. All of the following ESUs and DPSs are only affected by the proposed action in the marine waters portion of the action area, as they are outside the impacted freshwater areas described in Section 2.3.1.

2.12.1.1 Coho Salmon (Oregon Coast, Southern Oregon/Northern California Coast, and North-Central California Coast Recovery Domains)

Coho salmon from the Oregon Coast Coho Salmon ESU (Oregon Coast Recovery Domain) occur from the Oregon coast to the west coast of Vancouver during April–June, and from Oregon to Alaska later in the year (Morris et al. 2007; Beacham et al. 2016). Van Doornik et al. (2007) determined the origin of 2,344 juvenile coho salmon collected along the Washington and Oregon coasts during June and September, 1998–2005. Oregon coast coho was found in approximately equivalent abundances along both coasts in both months. Immature and adult Oregon coast coho salmon are known to occur from northern Oregon to Vancouver Island, although higher proportions are likely to occur in more southerly areas (Weitkamp et al. 2002). Based on coded wire tag recoveries, fewer than 20% of adult Oregon Coast Coho Salmon are expected to occur in the action areas (Weitkamp et al. 2002),

Coho salmon from ESA-listed California ESUs in the Southern Oregon/Northern California Coast and North-Central California Coast Recovery Domains—including the Southern Oregon/Northern California Coast Coho Salmon ESU, and the Central California Coast Coho Salmon ESU—very rarely occur in the action area (Weitkamp et al. 2002; Van Doornik et al. 2007; Beacham et al. 2016).

At a broad scale, Chinook and coho salmon utilize somewhat similar habitat and forage resources in marine areas, including along the Washington and Oregon coast. Similarities in general spatial distribution (e.g., Bi et al. 2008) and depth selection (e.g., Fisher et al. 2007a) have been observed. Though data are limited, there is evidence that Chinook and coho salmon occur in loose aggregations or patches at large spatial scales (e.g., Peterson et al. 2010; Berdahl et al. 2016). Pearcy et al. (1990a) evaluated the distribution and abundance of juvenile salmonids along Washington and Oregon coastal areas during May–September, 1981–1985. They observed a high degree of co-occurrence of juvenile Chinook and coho salmon. That is, the two species were frequently captured in the same purse seine sets. The number of sets with both species was significantly greater than the expected number if co-occurrence was random ($p < 0.05$). Conversely, Pool et al. (2012) observed that juvenile Chinook and coho salmon along the Oregon coast selected different habitat types. Studies have documented a moderate to high degree of dietary overlap between coho and Chinook salmon juveniles (e.g., Peterson et al. 1982; Brodeur et al. 1990; Schabetsberger et al. 2003; Brodeur et al. 2007; Miller et al. 2007; Weitkamp et al. 2008; Daly et al. 2009; Brodeur et al. 2013) and adults (e.g., Brodeur et al. 1987; Brodeur et al. 2014) along the west coast of North America, including coastal Washington and Oregon and the Columbia River plume. However, there do not appear to be any indications that coho salmon suffer from density dependence within the action area (Beamish et al. 2018), perhaps owing in part to the lack of full overlap in habitat selection and diet described above. For these reasons, it is unlikely that hatchery Chinook salmon from the federal prey program will have a measurable impact on the growth and survival of coho salmon within the action area.

Adult, immature, and large juvenile Chinook salmon in marine waters feed heavily on fish, particularly forage fish, and are large enough to prey on younger juvenile salmonids (Riddell et al. 2018, and references therein). However, predation on juvenile salmonids by Chinook salmon in marine waters is rare. Many diet studies of adult, immature, and large juvenile Chinook salmon in marine waters only identify specific taxa that made up more than about 1–5% of the Chinook's diet (i.e., "common" prey taxa), and do not mention specific taxa that were consumed at lower levels (e.g., Silliman 1941; Beacham 1986; Brodeur et al. 2007; Daly et al. 2009; Daly et al. 2012; Brodeur et al. 2014; Thayer et al. 2014; Hertz et al. 2015; Daly et al. 2017; Hertz et al. 2017). Juvenile salmonids are not identified as common prey taxa in these studies. Of studies that have identified all consumed taxa regardless of their prevalence in the diet, the substantial majority have found no juvenile salmonids in Chinook salmon stomach contents (e.g., Reid 1961; Prakash 1962; Wing 1985; Brodeur et al. 1987; Brodeur et al. 1990; Landingham et al. 1998; Hunt et al. 1999; Kaeriyama et al. 2004; Weitkamp et al. 2008; Daly et al. 2019; Beauchamp et al. 2020; Chamberlin 2021; Weitkamp et al. 2022). Where juvenile salmonids have been consumed (Fresh et al. 1981; Duffy et al. 2010; Sturdevant et al. 2012), they have been a rare component of the diet, and they have been consumed almost exclusively at times and in places where large densities of juvenile salmonids are present (i.e., in Puget Sound and near the mouth of the Columbia River during early summer after large pulses of hatchery-origin fish have entered these areas). Outside of these areas, we are aware of only one survey that found juvenile salmonid predation by Chinook salmon: one salmonid individual (unidentified species) was consumed among 490 immature and adult Chinook salmon sampled in southeast Alaska coastal and inner waters from 1997 to 2011 (Sturdevant et al. 2012). These findings indicate that predation by Chinook salmon on salmonids in marine waters is extraordinarily rare, particularly outside of times and places where large densities of recent marine-entrant juveniles are present.

ESA-listed juvenile coho salmon from the coho salmon ESUs listed above are expected to occur in very low abundances relative to preferred prey taxa and other juvenile salmonids in the broad spatial areas where they may overlap with federal prey program Chinook salmon. Further, as described above, ESA-listed juvenile salmonids in coastal areas are typically spatially segregated both vertically and horizontally from the sizes of Chinook salmon (immature and adults) large enough to forage on them. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas. For these reasons, we conclude that predation by federal prey program Chinook salmon on coho salmon from the ESUs listed above is extremely unlikely to occur, and is therefore discountable.

Designated critical habitat for the ESA-listed coho salmon ESUs listed above includes specified freshwater areas and the adjacent estuaries. These are all located outside of the action area. Therefore, no effects to critical habitat are expected as part of the proposed action.

2.12.1.2 Sockeye Salmon (Washington Coast Recovery Domain)

Lake Ozette sockeye salmon are the only sockeye salmon species within the Washington Coast Recovery Domain. There is very little stock-specific information available for Lake Ozette sockeye salmon. Distribution and migration patterns for Lake Ozette sockeye salmon are not well understood, and no marine harvest data for Lake Ozette sockeye salmon exist (Haggerty et al. 2009). However, juvenile sockeye from neighboring Puget Sound and the Columbia River migrate north on the continental shelf during the summer (Tucker et al. 2009; Beacham et al. 2014), where they may overlap with juvenile Chinook salmon released as part of the federal prey program (Tucker et al. 2011; 2012). Researchers have found very little overlap in diet between juveniles of the two species in these areas (Brodeur et al. 1990; Landingham et al. 1998; Brodeur et al. 2007). These studies found that juvenile Chinook salmon feed at a higher trophic level than sockeye salmon. That is, juvenile Chinook salmon in the ocean are primarily piscivores, whereas juvenile sockeye salmon are largely planktivores (NMFS 2009a). Given the extent of information available, and for these aforementioned reasons, we’ve determined that any potential competitive effects during this time are discountable.

By winter, most juvenile sockeye salmon move off the continental shelf as smolts to the open ocean (Haggerty et al. 2009; Tucker et al. 2009; Beacham et al. 2014; Farley et al. 2018), where they are unlikely to interact with Chinook salmon released as part of the federal prey program. Typically, they return as adults in mid-April to mid-August (NMFS 2009a).

Adult, immature, and large juvenile Chinook salmon in marine waters feed heavily on fish, particularly forage fish, and are large enough to prey on younger juvenile salmonids (Riddell et al. 2018, and references therein). However, predation on juvenile salmonids by Chinook salmon in marine waters is rare. Many diet studies of adult, immature, and large juvenile Chinook salmon in marine waters only identify specific taxa that made up more than about 1–5% of the Chinook’s diet (i.e., “common” prey taxa), and do not mention specific taxa that were consumed at lower levels (e.g., Silliman 1941; Beacham 1986; Brodeur et al. 2007; Daly et al. 2009; Daly et al. 2012; Brodeur et al. 2014; Thayer et al. 2014; Hertz et al. 2015; Daly et al. 2017; Hertz et al. 2017). Juvenile salmonids are not identified as common prey taxa in these studies. Of studies that have identified all consumed taxa regardless of their prevalence in the diet, the substantial majority have found no juvenile salmonids in Chinook salmon stomach contents (e.g., Reid 1961; Prakash 1962; Wing 1985; Brodeur et al. 1987; Brodeur et al. 1990; Landingham et al. 1998; Hunt et al. 1999; Kaeriyama et al. 2004; Weitkamp et al. 2008; Daly et al. 2019;

Beauchamp et al. 2020; Chamberlin 2021; Weitkamp et al. 2022). Where juvenile salmonids have been consumed (Fresh et al. 1981; Duffy et al. 2010; Sturdevant et al. 2012), they have been a rare component of the diet, and they have been consumed almost exclusively at times and in places where large densities of juvenile salmonids are present (i.e., in Puget Sound and near the mouth of the Columbia River during early summer after large pulses of hatchery-origin fish have entered these areas). Outside of these areas, we are aware of only one survey that found juvenile salmonid predation by Chinook salmon: one salmonid individual (unidentified species) was consumed among 490 immature and adult Chinook salmon sampled in southeast Alaska coastal and inner waters from 1997 to 2011 (Sturdevant et al. 2012). These findings indicate that predation by Chinook salmon on salmonids in marine waters is extraordinarily rare, particularly outside of times and places where large densities of recent marine-entrant juveniles are present.

ESA-listed juvenile sockeye from the Lake Ozette Sockeye Salmon ESU are expected to occur in very low abundances relative to preferred prey taxa, and other juvenile salmonids, in the broad spatial areas where they may overlap with federal prey program Chinook salmon. Federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas. Further, as described above, ESA-listed juvenile salmonids in coastal areas are typically spatially segregated both vertically and horizontally from the sizes of Chinook salmon (immature and adults) large enough to forage on them. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas. For these reasons, we conclude that predation by federal prey program Chinook salmon on ESA-listed Lake Ozette sockeye salmon is extremely unlikely to occur, and is therefore discountable.

Critical habitat for Lake Ozette sockeye salmon does not exist within the action area for the proposed action and there is therefore no effect to Lake Ozette sockeye salmon critical habitat.

2.12.1.3 Steelhead (North-Central California Coast, Central Valley, and South-Central/Southern California Coast Recovery Domains)

Steelhead from ESA-listed California DPSs in the North-Central California Coast, Central Valley, and South-Central/Southern California Coast Recovery Domains—including Northern California steelhead, Central California Coast steelhead, South-Central California steelhead, Southern California steelhead, and California Central Valley steelhead—rarely occur in the action area.

A very small but indeterminate proportion of juvenile steelhead from ESA-listed California DPSs may remain near the outer edge of the continental shelf as they move northward to common steelhead open ocean ranges (Myers 2018). For example, Van Doornik et al. (2019b) identified 1 California-origin (Central Valley) juvenile steelhead among 490 juvenile steelhead captured along the Washington and northern Oregon coast during sampling in May, 2006–2012. Other findings also demonstrate that some steelhead individuals from stocks south of the Columbia River migrate north along the continental shelf as they move west toward the open ocean. For example, Brodeur et al. (2014) estimated that 28% of steelhead captured during June and August, 2000, along the southern Oregon coast (south of Newport, Oregon) were of

California origin, with 3% originating from the Central and South California Coast. Similarly, 2% of juvenile steelhead (11 of 490 individuals) captured by Van Doornik et al. (2019b) along the Washington and northern Oregon coast were from Oregon stocks south of the sampling area, some potentially as far as 300 km. Because the catch per unit effort (CPUE) of those southern stocks was very low, the authors speculated that the majority of fish originating from those areas were already in the open ocean outside the sample area by the time they reached the sample area latitude.

The presence of any juvenile steelhead from ESA-listed California DPSs along within the action area is expected to be very small, transitory, and farther from shore than most federal prey program Chinook salmon. Juvenile steelhead presence along the coast of Washington and Oregon diminishes during the summer and becomes very rare by September (Pearcy et al. 1990b; Daly et al. 2014). When juvenile steelhead are present, they are mostly found farther from shore in deeper water than juvenile Chinook salmon, similar to the observations of Hayes et al. (2016) along the California coast noted above. Most juvenile steelhead along Washington and Oregon are in waters greater than 100 m deep (Daly et al. 2014; Van Doornik et al. 2019b). Conversely, juvenile Chinook salmon in these areas are typically closer to shore in waters less than 70 m deep (Fisher et al. 2007a; Peterson et al. 2010), except for yearlings in the immediate vicinity of the Columbia River plume which tend to extend into deeper water (Teel et al. 2015). For these reasons, any competitive effects to juvenile steelhead from ESA-listed California DPSs along the coasts of Oregon and Washington are expected to be extremely small, undetectable, and therefore insignificant.

Adult, immature, and large juvenile Chinook salmon in marine waters feed heavily on fish, particularly forage fish, and are large enough to prey on younger juvenile salmonids (Riddell et al. 2018, and references therein). However, predation on juvenile salmonids by Chinook salmon in marine waters is rare. Many diet studies of adult, immature, and large juvenile Chinook salmon in marine waters only identify specific taxa that made up more than about 1–5% of the Chinook's diet (i.e., "common" prey taxa), and do not mention specific taxa that were consumed at lower levels (e.g., Silliman 1941; Beacham 1986; Brodeur et al. 2007; Daly et al. 2009; Daly et al. 2012; Brodeur et al. 2014; Thayer et al. 2014; Hertz et al. 2015; Daly et al. 2017; Hertz et al. 2017). Juvenile salmonids are not identified as common prey taxa in these studies. Of studies that have identified all consumed taxa regardless of their prevalence in the diet, the substantial majority have found no juvenile salmonids in Chinook salmon stomach contents (e.g., Reid 1961; Prakash 1962; Wing 1985; Brodeur et al. 1987; Brodeur et al. 1990; Landingham et al. 1998; Hunt et al. 1999; Kaeriyama et al. 2004; Weitkamp et al. 2008; Daly et al. 2019; Beauchamp et al. 2020; Chamberlin 2021; Weitkamp et al. 2022). Where juvenile salmonids have been consumed (Fresh et al. 1981; Duffy et al. 2010; Sturdevant et al. 2012), they have been a rare component of the diet, and they have been consumed almost exclusively at times and in places where large densities of juvenile salmonids are present (i.e., in Puget Sound and near the mouth of the Columbia River during early summer after large pulses of hatchery-origin fish have entered these areas). Outside of these areas, we are aware of only one survey that found juvenile salmonid predation by Chinook salmon: one salmonid individual (unidentified species) was consumed among 490 immature and adult Chinook salmon sampled in southeast Alaska coastal and inner waters from 1997 to 2011 (Sturdevant et al. 2012). These findings indicate that predation by Chinook salmon on salmonids in marine waters is exceedingly rare, particularly outside of times and places where large densities of recent marine-entrant juveniles are present.

ESA-listed juvenile steelhead from all the California steelhead DPSs listed above are expected to occur in very low abundances relative to preferred prey taxa and other juvenile salmonids in the broad spatial areas where they may overlap with federal prey program Chinook salmon. Federal prey program Chinook salmon are expected to be a relatively small proportion of the piscivorous Chinook salmon in these areas. Further, as described above, ESA-listed juvenile salmonids in coastal areas are typically spatially segregated both vertically and horizontally from the sizes of Chinook salmon (immature and adults) large enough to forage on them. Numerous diet surveys have demonstrated the extreme rarity of predation on juvenile salmonids by Chinook salmon in marine waters, particularly in coastal areas. For these reasons, we conclude that predation by federal prey program Chinook salmon on ESA-listed steelhead from the California steelhead DPSs listed above is extremely unlikely to occur, and is therefore discountable.

Designated critical habitat for the ESA-listed DPSs includes specified freshwater areas and the adjacent estuaries. These are all located outside of the action area. Therefore, no effects to critical habitat are expected as part of the proposed action.

2.12.2 Marine Mammals

We assessed potential effects to ESA-listed marine mammals from this action. In this assessment the following DPS was determined to incur beneficial effects as a result of the proposed action. The following DPS is affected by the proposed action in marine waters, as the species does not occur in freshwater areas.

2.12.2.1 Southern Resident Killer Whales

2.12.2.1.1 Status and Occurrence

The SRKW DPS was listed as endangered under the ESA in 2005 (70 FR 69903, November 18, 2005) and the final recovery plan was completed in 2008 (NMFS 2008d). Several factors identified in the recovery plan for SRKWs may be limiting their recovery. The primary threats include quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. It is likely that multiple threats are acting together to impact the whales. Although it is not clear which threat or threats are most significant to the survival and recovery of SRKWs, all of the threats identified are potential limiting factors in their population dynamics (NMFS 2008d). A 5-year review under the ESA completed in 2021 concluded that SRKWs should remain listed as endangered and includes recent information on the population, threats, and new research results and publications (NMFS 2021a).

The SRKW DPS consists of three pods (J, K, and L) that inhabit coastal waters off Washington, Oregon, and Vancouver Island, Canada, and are known to travel as far south as central California and as far north as Southeast Alaska (NMFS 2008d; Hanson et al. 2013; Carretta et al. 2023). Seasonal movements are likely tied to migration of their primary prey, salmon. During the spring, summer, and fall months, SRKWs spend a substantial amount of time in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982; Ford et al. 2000; Krahn et al. 2002; Hauser et al. 2007; Olson et al. 2018; NMFS 2021a; Ettinger et al. 2022; Thornton et al. 2022). During fall and early winter, SRKWs, and J pod in particular, expand their routine movements into Puget Sound, likely to take advantage of chum, coho, and Chinook salmon runs (Osborne 1999; Hanson et al. 2010; Ford et al. 2016b; Olson et al. 2018). Although seasonal movements are somewhat predictable, there can be large inter-annual variability in arrival time and days present in inland waters from spring through fall, with late arrivals and fewer days present in recent years (NMFS 2021a; Ettinger et al. 2022).

Land- and vessel-based opportunistic and survey-based visual sightings, satellite tracking, and passive acoustic research have provided an updated estimate of the whales' coastal range. In recent years, several sightings and acoustic detections of SRKWs have been obtained off the Washington, Oregon, and California coasts in the winter and spring (Hanson et al. 2010; Hanson et al. 2013; Hanson et al. 2017; Emmons et al. 2021; NMFS 2021d). Satellite-linked tag deployments in the winter indicate that K and L pods use the coastal waters along Washington, Oregon, and California during non-summer months (Hanson et al. 2017; NMFS 2021d), while J pod occurred frequently near the western entrance of the Strait of Juan de Fuca but spent relatively little time in other outer coastal areas. A full description of the geographic area occupied by SRKW can be found in the biological report that accompanies the final critical habitat rule (NMFS 2021d).

SRKWs consume a variety of fish species (22 species) and one species of squid (Ford et al. 1998; Ford et al. 2000; Ford et al. 2006a; Hanson et al. 2010; Ford et al. 2016b), but salmon are identified as their primary prey. The diet of SRKWs is the subject of ongoing research, including direct observation of feeding, scale and tissue sampling of prey remains, and fecal sampling. The diet data suggest that SRKWs are consuming mostly larger (i.e., generally age 3 and up) Chinook salmon (Ford et al. 2006a). Chinook salmon is their primary prey despite the much lower abundance in comparison to other salmonids in some areas and during certain time periods. Scale and tissue sampling from May to September in inland waters of Washington and British Columbia, Canada, indicate that their diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90%) (Hanson et al. 2010; Ford et al. 2016b). Ford et al. (2016b) confirmed the importance of Chinook salmon to SRKWs in the summer months using DNA sequencing from whale feces. Salmon and steelhead made up to 98% of the inferred diet, of which almost 80% were Chinook salmon. Coho salmon and steelhead are also found in the diet in inland waters in spring and fall months when Chinook salmon are less abundant (Ford et al. 1998; Ford et al. 2006a; Hanson et al. 2010; Ford et al. 2016b).

Prey remains and fecal samples collected in inland and coastal waters during October through May indicate Chinook salmon and chum salmon are primary contributors of the whale's diet during the fall, winter, and spring months as well, including hatchery salmon (Hanson et al. 2021). Analysis of prey remains and fecal samples sampled during the winter and spring in coastal waters indicated the majority of prey samples were Chinook salmon (approximately 80% of prey remains and 67% of fecal samples were Chinook salmon), with a smaller number of steelhead, chum salmon, and halibut detected in prey remain samples and foraging on coho, chum, steelhead, big skate, and lingcod detected in fecal samples (Hanson et al. 2021). The occurrence of K and L pods off the Columbia River in March suggests the importance of

Columbia River spring runs of Chinook salmon in their diet (Hanson et al. 2013). Chinook salmon genetic stock identification from samples collected in winter and spring in coastal waters included 12 U.S. west coast stocks, and over half the Chinook salmon consumed originated in the Columbia River (Hanson et al. 2021).

At the time of the 2023 population census, there were 75 SRKWs counted in the population (CWR 2023), including three calves born in 2023. The abundance estimate for this stock of killer whales is a direct count of individually identifiable animals, and as such serves as both a best estimate of abundance and a minimum estimate of abundance. The NWFSC continues to evaluate changes in fecundity and mortality rates. Population projections using survival and fecundity rates from a recent five-year period (2017–2021) project a downward trend over the next 25 years (NMFS 2021a). Recent genomic analyses indicate that the SRKW population has greater inbreeding and carries a higher load of deleterious mutations than do Alaska resident or transient killer whales, and that inbreeding depression is likely impacting the survival and growth of the population (Kardos et al. 2023). These factors likely contribute to the SRKW population's poor status.

The most recent potential biological removal[73] (PBR) level for this stock is 0.13 whales per year, which was based on the minimum population size of 74 whales from the 2021 July census. A recent examination of all killer whale ecotype strandings found that three whales, including one SRKW (L98 who was habituated to humans) died from vessel strikes (Raverty et al. 2020). The cause of death of L112 was determined to be blunt force trauma to the head, however the source of the trauma (vessel strike, intraspecific aggression, or other unknown source) could not be established (Carretta et al. 2023). Total observed fishery mortality and serious injury for this stock is zero; however, recovery of a SRKW carcass is rare and undetected mortality and serious injury may occur.

Critical Habitat

In November 2006, NMFS designated critical habitat for the SRKW DPS (71 FR 69054, November 29, 2006). This designation includes approximately 2,500 square miles of Puget Sound, including three specific areas: 1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca. Areas with water less than 20 feet deep are not included in the designation. Three physical or biological essential features were identified: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging.

In September 2021, NMFS revised the critical habitat designation for the SRKW DPS by designating six additional coastal critical habitat areas along the U.S. West Coast (86 FR 41668, August 2, 2021). The revision added to the existing critical habitat approximately 15,910 square

[73] Under the Marine Mammal Protection Act (MMPA), the PBR for a stock is defined as the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population size.

miles of marine waters between the 6.1-meter and 200-meter depth contours from the U.S.-Canada border to Point Sur, California. The same physical or biological essential features were identified for coastal critical habitat, and each coastal area contains all three physical or biological essential features identified in the 2006 designation.

2.12.2.1.2 Potential for Proposed Action Effects

The proposed action is expected to increase the amount of Chinook salmon prey available to SRKWs in their critical habitat, which would positively affect the whales and their critical habitat. We do not expect any impacts to SRKWs via other effects pathways, such as vessel or noise disturbance, or water quality impacts.

As described in detail in the Environmental Baseline for salmon and steelhead (Section 2.4.1), hatchery production of salmonids has occurred for over a hundred years. There are over 300 hatchery programs in Washington, Oregon, California, and Idaho that produce and release juvenile salmon that migrate through coastal and inland waters of the action area. Many of these fish contribute to both fisheries and the SRKW prey base in coastal and inland waters of the action area.

NMFS has completed Section 7(a)(2) consultations on more than two hundred hatchery programs (Doremus et al. 2021); refer to Appendix B). A detailed description of the effects of these hatchery programs can be found in the site-specific ESA and NEPA documents for programs referenced in Appendix B. These effects are further described in Appendix C of NMFS (2018e), which is incorporated here by reference. Additionally, a description of the effects of hatchery production implemented with federal funds to increase SRKW prey is described above in Section 2.5.1, as well as in Alternative 2 of the prey program FEIS (NMFS 2024e). Currently, hatchery production is a significant component of the salmon prey base within the range of SRKWs (Barnett-Johnson et al. 2007; NMFS 2008h). Prey availability has been identified as a threat to SRKW recovery, and we expect the existing hatchery programs to continue benefiting SRKWs by contributing to their prey base.

As described in the proposed action, to date the federal prey increase program has funded an average of $6.2 million per year to increase prey for SRKW, with adult (age 3+) Chinook salmon returning starting in 2022 (Section 1.3). The program has resulted in the release of an additional 30.6 million Chinook salmon smolts from 2020–2024 when compared to releases prior to 2020 (NMFS 2024e), with adult (age 3+) Chinook salmon returning starting in 2022. NMFS has and will continue to work with hatchery operators and funders to ensure that all hatchery production to support SRKWs receiving federal prey program funds has been thoroughly reviewed under the ESA (and NEPA as applicable) to ensure that it does not jeopardize the survival and recovery of any ESA-listed species or adversely modify critical habitat. All of the completed analyses to date have determined that the hatchery programs will not jeopardize listed salmonids (see Appendix B for the list of programs).

The associated benefits to the SRKW prey base are expected to occur 3–5 years following implementation of each year of funding and production; namely, from 2022 for the following several years as those fish that have been released to date age into the SRKW prey base (age 3+).

For this analysis, we estimate Chinook salmon abundance increases in the action area by modeling hatchery production that has already been funded and released as part of the PST initiative (2020–2023). For a description of the methods used to estimate annual regional prey abundance increases as a result of the PST-funded hatchery program, please see Appendix A and NMFS (2024e). The annual projected benefit to the SRKW prey base is presented below based on a representative year of releases (2023), and this benefit is included in the analysis and expected to occur for at least three years following the release of fish from the program at 2023 release levels. We also considered the increases in Chinook salmon abundance that could result from the federal funding program if funding allows for production of the “goal” level of approximately 20 million juvenile Chinook salmon per year.

While increases in prey abundance from all areas in the SRKW range are of interest, we focus our attention on hatchery production benefits during times and places that are most likely to be important for SRKW foraging. Specifically, the Salish Sea and Soutwest West Coast of Vancouver Island (SWWCVI) (which includes Swiftsure Bank) are important foraging areas during the May–June and July–September time steps. The NOF region is an important area during the October–April time step, though in recent years is becoming more important in the summer months (see Status and Occurrence above).

Based on the current (2023) hatchery production that has been released as a result of the federal prey increase program, SRKW prey is expected to increase in various regions and seasons across their range (as compared to the post-season validation runs; see Figure 82), and at varying times throughout the year, for the next few years. As shown in Figure 81, during the October–April time step, SRKW prey is expected to increase by approximately 2%, on average, in the NOF region (also see Table 86). During the May–June time step, SRKW prey is expected to increase by approximately 2.2% on average, in the SWWCVI region, and in the July–September time step, prey is expected to increase by nearly 2% in the SWWCVI and NOF regions, and 0.5% in the Salish Sea, on average (Figure 81 and Table 86).

Under a scenario in which program goals are met (achieving release goals of approximately 20 million Chinook salmon smolts per year), SRKW prey is expected to increase by 3.8%, on average, in the NOF region during the October–April time step, approximately 5% in the SWWCVI region during the May–June and July–September time steps, and about 1.3% in the Salish Sea during the July–September time step (Figure 81). The greatest prey increases are expected to occur during the October–April time step in the SWWCVI region and the Salish Sea at 5.7% and 8%, respectively.

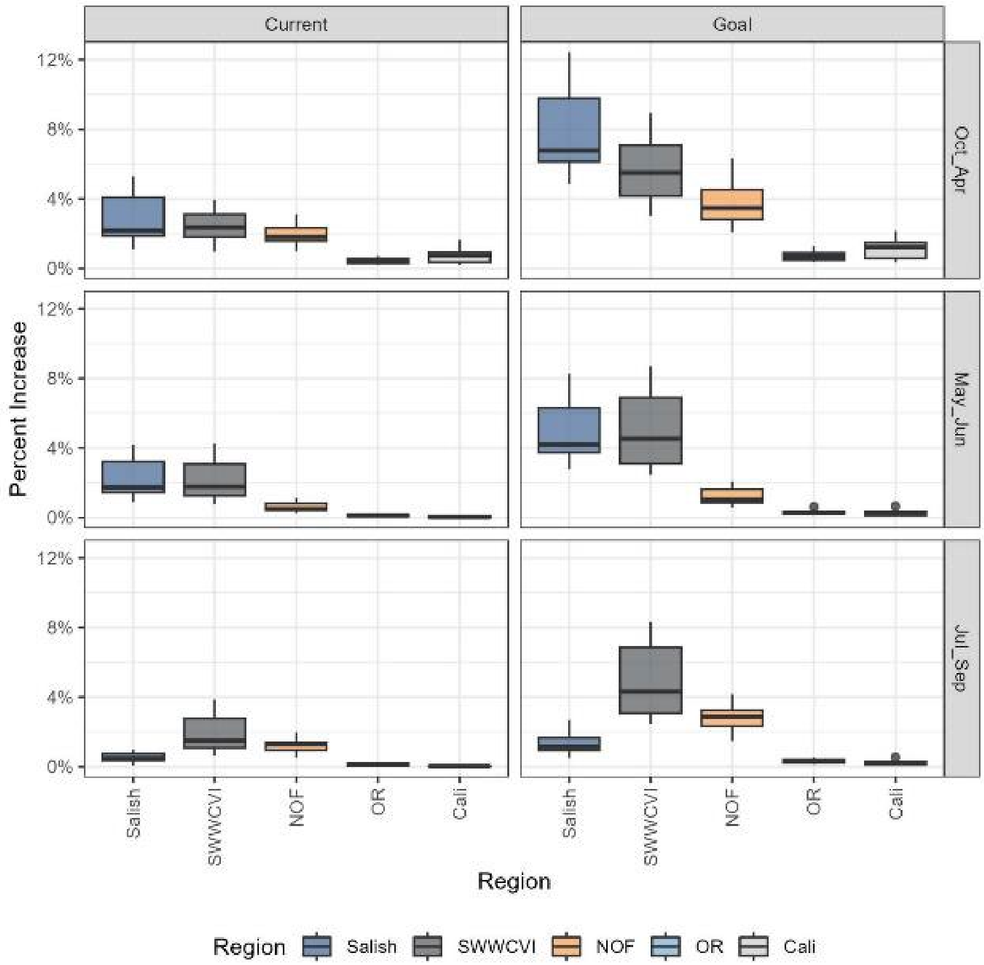
Table 86. Expected annual impact of the hatchery prey increase program funding under the Current (a) and Goal (20 million smolts) (b) scenarios as represented by the average expected percent increase of the SRKW prey base (age 3+ Chinook salmon) by spatial region and time step. Asterisks indicate the key times and areas of focus for SRKW.

a)

Hatchery Prey Program - Current Expected prey increase under current (2023) releases									
	Oct–Apr			May–Jun			Jul–Sep		
	Region		*	*			*	*	
Year	SWWCVI	Salish	NOF	SWWCVI	Salish	NOF	SWWCVI	Salish	NOF
2009	2.76%	2.39%	1.79%	2.12%	1.92%	0.62%	1.77%	0.48%	1.97%
2010	2.60%	1.86%	2.18%	1.66%	1.44%	0.52%	1.47%	0.46%	1.66%
2011	2.11%	1.86%	1.83%	1.52%	1.45%	0.47%	1.27%	0.07%	1.26%
2012	2.10%	2.74%	1.66%	1.89%	2.27%	0.48%	1.51%	0.77%	0.86%
2013	1.06%	1.65%	1.03%	0.89%	1.36%	0.31%	0.78%	0.34%	0.79%
2014	0.97%	1.11%	0.98%	0.75%	0.89%	0.24%	0.62%	0.21%	0.52%
2015	1.70%	1.97%	1.54%	1.15%	1.56%	0.40%	1.01%	0.43%	1.35%
2016	3.23%	5.21%	2.37%	3.39%	3.98%	0.87%	3.11%	0.97%	1.20%
2017	3.96%	5.28%	3.11%	4.24%	4.17%	1.13%	3.86%	0.77%	1.40%
2018	3.68%	4.51%	2.71%	4.01%	3.52%	1.03%	3.60%	0.66%	1.32%

b)

Hatchery Prey Program - Goal Expected prey increase under goal releases									
	Oct–Apr			May–Jun			Jul–Sep		
	Region		*	*			*	*	
Year	SWWCVI	Salish	NOF	SWWCVI	Salish	NOF	SWWCVI	Salish	NOF
2009	6.70%	7.29%	3.70%	5.31%	4.61%	1.30%	5.03%	1.03%	4.16%
2010	5.75%	6.25%	3.68%	4.18%	3.67%	1.02%	4.01%	0.96%	3.29%
2011	5.11%	6.11%	3.27%	3.94%	3.72%	0.98%	3.81%	0.50%	2.83%
2012	5.25%	8.21%	3.24%	4.88%	5.54%	1.04%	4.61%	1.50%	1.99%
2013	3.21%	6.23%	2.40%	2.72%	3.80%	0.78%	2.75%	0.93%	2.21%
2014	3.04%	4.86%	2.08%	2.47%	2.78%	0.59%	2.45%	0.82%	1.49%
2015	3.84%	5.82%	2.68%	2.82%	3.77%	0.81%	2.83%	1.24%	2.92%
2016	7.21%	12.42%	4.81%	7.43%	8.26%	1.75%	7.47%	2.68%	2.73%
2017	8.94%	12.34%	6.32%	8.69%	7.72%	2.07%	8.33%	1.83%	3.43%
2018	8.12%	10.30%	5.34%	8.14%	6.56%	1.87%	7.76%	1.72%	3.07%



Note: box-and-whisker plots display a box representing the first quartile, median, and third quartile as the lower bound, midline, and upper bound of the box, respectively, the whiskers representing the minimum and maximum values, and the dots representing outliers which are values beyond 1.5*IQR (interquartile range, or distance between the first and third quartiles).

Figure 81. Expected annual impact of the U.S. federal prey increase funding (based on number of fish released in 2023) as represented by the expected percent increase of the SRKW prey base (age 3+ Chinook salmon) by spatial region (x-axis) and time step (rows) based on a range of abundances from the retrospective time period of 2009–2018. The Current scenario is based on hatchery releases from 2023. The Goal scenario assumes approximately 20 million smolts released.

The ranges of increases presented in Figure 81 and Table 86 are estimates based on either the production that occurred in 2023 (Current scenario), or target production levels (Goal scenario). However, the percent prey increases depend on the overall abundance of Chinook salmon observed in that year. For example, variable ocean conditions are a major driver of ocean salmon abundances which can vary widely from year to year (see Figure 82). As such, percent prey increases due to the hatchery program may be smaller in years when ocean abundance is high (i.e., marine survival is high for salmon across all stocks). Accordingly, the benefits of the prey increase program (i.e., percent prey increases) may be much higher in low abundance years.

While the “current” (2023) release scenario described in Figure 81 is reasonably certain to occur as it is based on releases that occurred in the past, we recognize that there may be year-to-year variation in funding proposals, facility capacity, and the regional distribution of stocks produced with these funds in any given year. We also recognize that the goal of a 4–5% increase in SRKW prey could be achieved through many different scenarios (e.g., the location of funded production). As such, two additional scenarios were analyzed: maximizing Puget Sound production, and maximizing Columbia River and Washington Coast production, up to 20 million total smolts released (see Section 1.3). These scenarios represent approximate upper limits on SRKW prey program production from each of these regions.

As shown in Table 3 and Appendix A, in a scenario where Puget Sound capacity is maximized, adult Chinook salmon would increase by 1.6% in the Salish Sea during July–September, 5.9% and 5.5% in the SWWCVI region during May–June and July–September, respectively, and by 4% in the NOF region during October–April (Figure 82). By contrast, in a scenario where Columbia River and Washington Coast capacity is maximized, adult Chinook salmon would increase by 1.1% in the Salish Sea during July–September, 4.1% and 3.6% in the SWWCVI region during May–June and July–September, respectively, and by 4.6% in the NOF region during October–April (Table 3 and Figure 83).

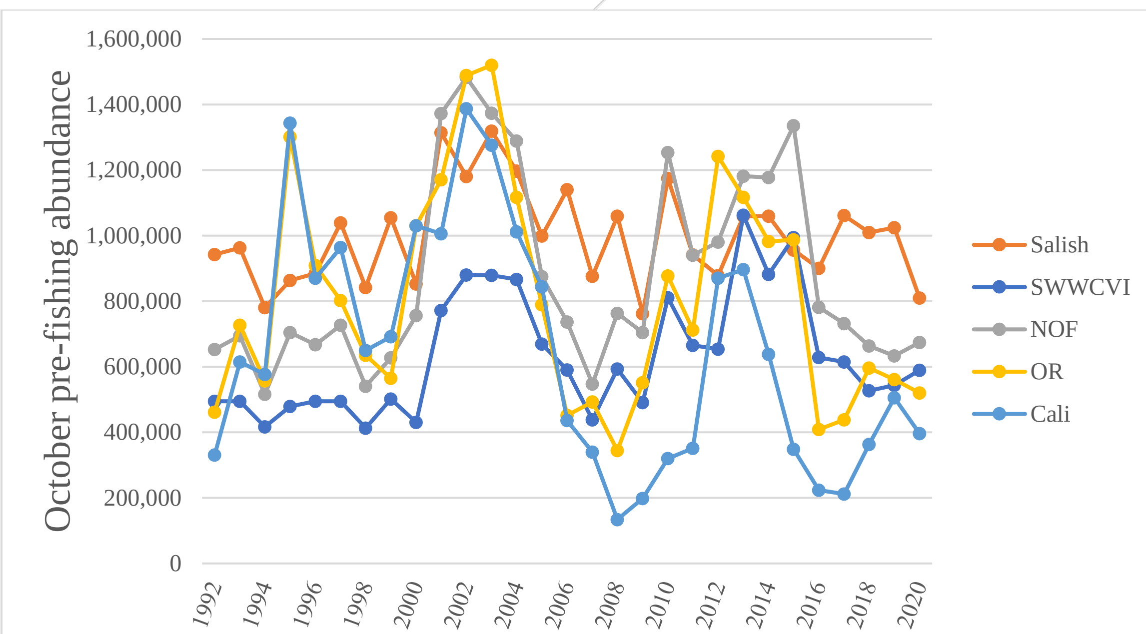
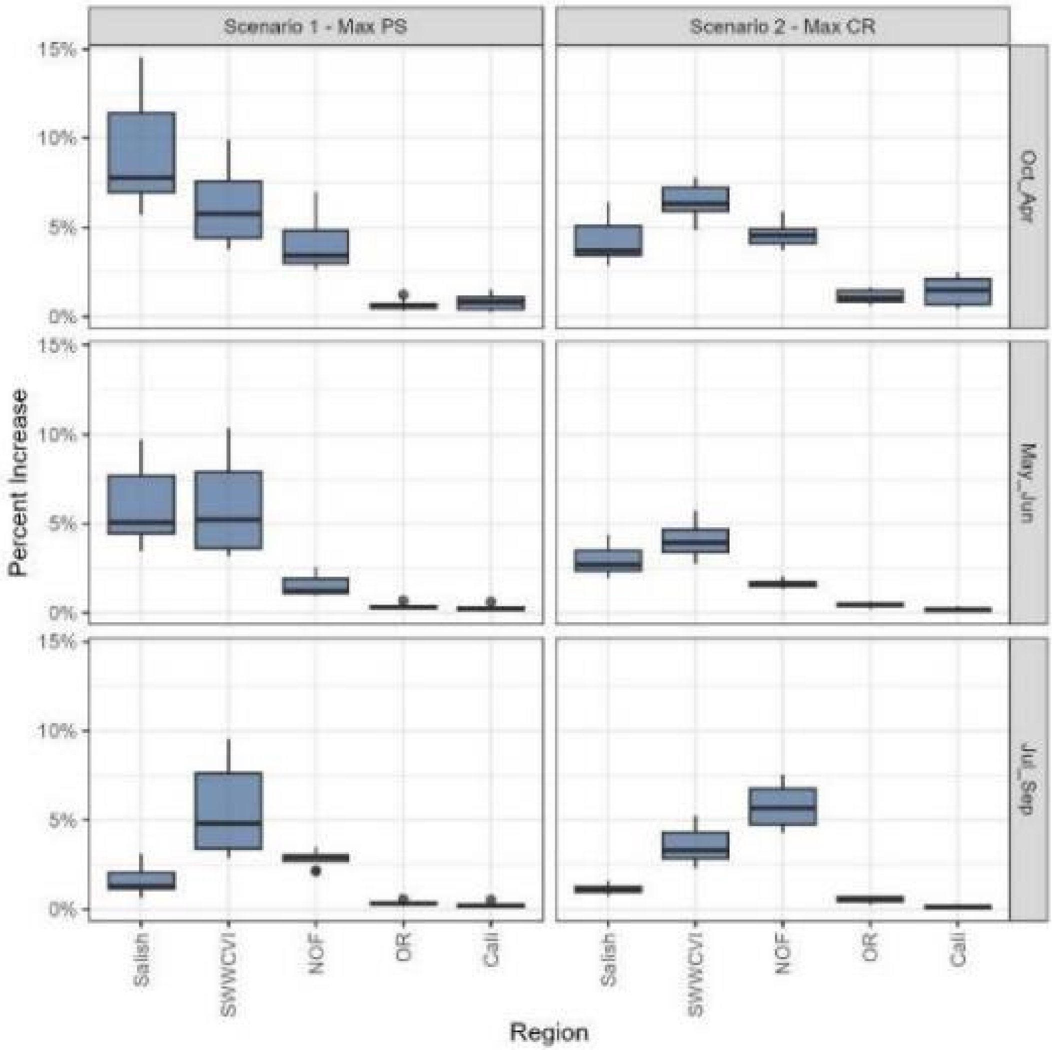


Figure 82. Post-season validation runs (FRAM 7.1.1) showing October pre-fishing Chinook salmon abundances by region in a retrospective analysis from 1992–2020.



Note: box-and-whisker plots display a box representing the first quartile, median, and third quartile as the lower bound, midline, and upper bound of the box, respectively, the whiskers representing the minimum and maximum values, and the dots representing outliers which are values beyond 1.5*IQR (interquartile range, or distance between the first and third quartiles).

Figure 83. Expected annual impact of the U.S. federal prey increase funding in two scenarios: (1) max Puget Sound (PS) wherein modeled releases were 14.4 million smolts from PS hatcheries and 5.6 million smolts from the Columbia River (CR) and Washington Coast hatcheries, and (2) max CR and Washington coast wherein modeled releases were 6.1 million smolts from PS hatcheries and 13.9 million smolts from CR and Washington Coast hatcheries. Boxplots represent the expected percent increase of the SRKW prey base (age 3+ Chinook salmon) by spatial region (x-axis) and time step (rows) based on a range of abundances from the retrospective time period of 2009–2018.

Under the three scenarios analyzed, the hatchery program provides benefits to SRKWs through improving the abundance and availability of prey in various regions and seasons, and is expected to occur year-round. These results also suggest that program goals could be met in a variety of scenarios, and we expect future production using these funds to approximate the range of benefits described in Figure 81 and Figure 82.

Chinook salmon aged 3+ are the preferred prey of SRKWs year-round (Ford et al. 1998; Ford et al. 2006a; Hanson et al. 2010; Ford et al. 2016b; Hanson et al. 2021). Genetic studies from fecal and predation event remains have identified Chinook salmon stocks consumed by SRKWs during different seasons in inland and coastal portions of their range (Hanson et al. 2010; Ford et al. 2016b; Hanson et al. 2021). These studies have informed a list of priority prey stocks that are important to SRKWs (NOAA Fisheries and WDFW 2018). While these studies have not assessed whether the fish consumed come from wild or hatchery populations, all available evidence suggests that SRKWs consume both wild and hatchery Chinook salmon given the high proportion of hatchery-origin fish in the priority stocks that were identified. The abundance of the Puget Sound Chinook salmon ESU, the top priority prey stocks for SRKW, comprises a minimum[74] of 77% hatchery produced fish, on average (Appendix E). In the Columbia River, a minimum of 50% of the abundance is made up of hatchery fish (Appendix E). Based on the contribution of hatchery fish to these preferred prey stock groups, it is extremely likely that hatchery fish are a main component of the SRKW diet.

Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (O'Neill et al. 2014), likely the reason for their preference in the SRKW diet. Studies have identified a trend in declining body size and age structure in Chinook salmon along the west coast (Ohlberger et al. 2018; Ohlberger et al. 2019). This trend is evident in both hatchery- and natural-origin fish, and is evident even in natural Chinook salmon populations that are not exposed to hatchery fish, such as in western Alaska (Ohlberger et al. 2018). Given that smaller fish have a lower total energy value than larger ones (O'Neill et al. 2014), this trend suggests that SRKWs may need to eat more Chinook salmon – hatchery- and natural-origin – to meet their daily metabolic needs as compared to historically. The cause of this trend is uncertain, but several hypotheses include climate change, size-selective removals from predation or fishing practices, or evolutionary shifts. Given all of this information, we do not expect any negative effects to SRKWs from the proposed action in terms of changes to the proportion of hatchery- and natural-origin fish or priority prey stock composition, or the size of Chinook salmon available as prey.

Importantly, as described in Section 2.5.1, the expected increases in Chinook salmon abundance due to the proposed action (all three scenarios discussed above) are not expected to jeopardize listed Chinook salmon ESUs. The primary risks of the proposed action to natural-origin Chinook salmon include genetic and ecological effects and broodstock collection. The degree/severity of each of these risks by recovery domain is summarized in Table 80. At a population scale,

[74] These percentages are based on the percentage of marked versus unmarked fish from FRAM validation runs 2009-2020. While mass marking is largely in effect in these areas, there are several unclipped hatchery programs (and a couple wild marking programs in the Columbia), leading these percentages to be underestimates of the proportion of hatchery fish.

moderate risk to a population is generally only appropriate when the risk is outweighed by the demographic benefits of increased spawner abundance (i.e., for small populations at risk of extirpation), or when risk level is not expected to change for populations of low conservation importance. Anywhere from beneficial effects to low risk of effects is expected in a majority of the factors analyzed. Additionally, hatchery facilities typically employ best management practices to minimize risks to natural-origin salmon. At the ESU scale, anywhere from negligible effects to low risk of effects is expected for all factors analyzed (Table 80). Our assessment of these risks at the program and site-specific levels support our conclusion that the effects of the proposed action on natural-origin Chinook salmon is sufficiently low that no adverse effects to SRKW in terms of reduced quantity or quality of Chinook prey over the long term are expected.

In summary, given that the proposed action is beneficial to SRKWs in that more prey is expected to be available throughout the range of SRKWs, including in important times and areas for foraging, there are no negative effects expected to SRKWs, and that listed Chinook salmon ESUs are not jeopardized, the proposed action is therefore not likely to adversely affect SRKWs.

<u>Critical Habitat</u>

In addition to the effects to the DPS discussed above, the proposed action affects critical habitat designated for SRKWs. We do not expect the proposed action to impact the water quality or passage features of critical habitat because hatchery production occurs in-river and does not affect the water quality or passage conditions within SRKW critical habitat. The proposed action has the potential to affect the quantity and availability of prey in critical habitat.

The expected prey increases due to the proposed action are shown in Figure 81. The percent prey increases presented are estimates based on either the production that has occurred in 2023 (current scenario), or goal production (20 million smolts), but depend on the level of Chinook salmon observed in that year. For example, variable ocean conditions are a major driver of ocean salmon abundances which can vary widely from year to year. As such, percent prey increases due to the hatchery program may be smaller in years when ocean abundance is high (i.e., marine survival is high for salmon across all stocks). Accordingly, the benefits of the prey increase program (i.e., percent prey increases) may be much higher in low abundance years.

We would not expect any impacts from the proposed action on prey quality with respect to levels of harmful contaminants. We also do not expect any impacts on prey quality with respect to size of Chinook salmon. As discussed above, size and age structure of Chinook salmon has substantially changed across the Northeast Pacific Ocean since the 1970s (Ohlberger et al. 2018). Therefore, SRKWs would need to consume more salmon in order to meet their caloric needs as a result of a decrease in average size of older Chinook salmon, as compared to previous years when Chinook salmon were larger. Across most of the west coast, adult Chinook salmon (ocean ages 4 and 5) are becoming smaller, the size of age 2 fish are generally increasing, and most of the Chinook salmon populations from Oregon to Alaska have shown declines in the proportions of age 4- and 5-year-olds and an increase in the proportion of 2-year-olds (i.e., the mean age in populations has declined over time) (Ohlberger et al. 2018). Strength of trends varied by region. Ohlberger et al. (2019) found that reasons for this shift may be largely due to direct effects from size-selective removal by resident killer whales and fisheries, followed by evolutionary changes toward these smaller sizes and early maturation. Therefore, we would not expect the current level of hatchery production to appreciably decrease Chinook salmon size (i.e., quality) thereby reducing the conservation value of the prey feature.

As described above and in Section 2.5.1, the increase in Chinook salmon abundance due to the proposed action is not expected to jeopardize listed Chinook salmon ESUs. There are also no negative effects to SRKW critical habitat expected due to the proposed action. As such, the proposed action is beneficial to SRKW prey in both coastal and inland critical habitat, and therefore is not likely to adversely affect SRKW critical habitat.

2.12.3 Other Species

The entirety of the action area described in Section 2.2.10 was assessed in order to determine potential effects to ESA-listed species. In this assessment the following DPSs were determined to incur discountable or insignificant effects as a result of the proposed action within the action area. All of the following DPSs are only affected by the proposed action in the marine waters portion of the action area, as they are outside the impacted freshwater areas described in Section 2.2.10.

2.12.3.1 Green Sturgeon

The action area for the proposed federal SRKW prey program overlaps with the range of the threatened Southern DPS of North American green sturgeon (*Acipenser medirostris*) in the following areas: Puget Sound, including the Strait of Juan de Fuca, the lower Columbia River estuary, coastal estuaries in Washington (including Grays Harbor and Willapa Bay), and coastal marine waters from Alaska to Monterey Bay, California. Thus, the increase in hatchery production and release of Chinook salmon under the proposed federal SRKW prey program may affect Southern DPS green sturgeon and their habitat within the action area.

Green sturgeon are broadly distributed in nearshore marine areas from Mexico to the Bering Sea. Green sturgeon consist of two DPSs that co-occur throughout much of their range, but use different river systems for spawning. The Southern DPS consists of all naturally-spawned populations of green sturgeon originating from coastal watersheds south of the Eel River in California, and the Northern DPS consists of populations originating from coastal watersheds north of and including the Eel River. On April 7, 2006, NMFS listed Southern DPS green sturgeon as a threatened species and maintained the Northern DPS as a NMFS Species of Concern (71 FR 17757).

Subadults and adults of both the Southern DPS and Northern DPS migrate seasonally along the West Coast, congregating in bays and estuaries in Washington, Oregon, and California during the summer and fall months, including the lower Columbia river estuary, Grays Harbor, and Willapa Bay (Moser et al. 2007; Lindley et al. 2008). During winter and spring months, they congregate off of northern Vancouver Island, B.C., Canada (Lindley et al. 2008).

Tagged Southern DPS green sturgeon have been detected in the Strait of Juan de Fuca, likely entering and migrating some distance into the Strait (Lindley et al. 2008; NMFS 2009b). Some migrate through the Strait and into Puget Sound. Green sturgeon do not appear to use Puget

Sound very extensively. Observations of green sturgeon in Puget Sound are much less common compared to other estuaries in Washington. A few green sturgeon adults and/or subadults have been incidentally captured in Puget Sound fisheries, mostly in trawl fisheries (Adams et al. 2002). Monitoring data for tagged green sturgeon show few detections in Puget Sound (Moser 2018).

The proposed increases in hatchery production and release of Chinook salmon into the action area are not likely to have measurable effects on Southern DPS green sturgeon or their habitat. We are not aware of disease transmission between salmonids and sturgeon, and do not expect competition for food resources. Within Puget Sound and coastal estuaries (including the lower Columbia River estuary, Grays Harbor, and Willapa Bay), there is limited overlap in prey species between salmon and green sturgeon. The primary prey consumed by salmon in tidal fresh, brackish, and estuarine waters include aquatic and terrestrial insects, amphipods, mysids, copepods, krill, freshwater crustaceans, and larval and juvenile fish (Weitkamp et al. 2014). The primary prey consumed by green sturgeon in freshwater, bays, and estuaries include benthic invertebrates and fishes, such as crangonid shrimp, burrowing shrimp, amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies (Moyle et al. 1995; Erickson et al. 2002; Moser et al. 2007; Dumbauld et al. 2008).

In the Strait of Juan de Fuca and coastal marine waters, green sturgeon are primarily migrating, but may also be feeding. We do not expect the increased hatchery production and release of Chinook salmon to affect the ability of green sturgeon to migrate through these areas. Green sturgeon are bottom-oriented, whereas salmon typically occupy the water column. We also expect limited, if any, competition for prey resources, given the limited overlap in prey species. Salmon in coastal marine waters primarily feed on adult krill, juvenile fish (sand lance, rockfish, greenling, sculpins), amphipods, and larval crab (Brodeur et al. 2011), whereas green sturgeon likely feed on benthic invertebrates and fish similar to those fed upon in bays and estuaries (e.g., shrimp, clams, crabs, anchovies, sand lances, as described above).

Overall, the proposed action would not affect Southern DPS green sturgeon and their habitat in a measurable way, and any potential effects would therefore be insignificant. We conclude that the proposed action may affect, but is not likely to adversely affect, Southern DPS green sturgeon.

Critical Habitat

The action area for the proposed federal SRKW prey program overlaps with designated critical habitat for Southern DPS green sturgeon within the following areas: the lower Columbia River estuary, Grays Harbor, Willapa Bay, the Strait of Juan de Fuca, and coastal marine waters from Cape Flattery, Washington, to Monterey Bay, California. Thus, the increase in hatchery production and release of Chinook salmon under the proposed federal SRKW prey program may affect the designated critical habitat within the action area.

NMFS designated critical habitat for Southern DPS green sturgeon on October 9, 2009 (74 FR 52300). Designated critical habitat for Southern DPS green sturgeon does not include Puget Sound or marine waters off the coast of Alaska, but does include the lower Columbia River estuary, Grays Harbor, Willapa Bay, and coastal marine waters within 60 fathoms depth from Cape Flattery, Washington, to Monterey Bay, California. Designated critical habitat also includes U.S. coastal marine waters in the Strait of Juan de Fuca, Washington, extending from the Tatoosh Island – Bonilla Point British Columbia line at the mouth to Admiralty Inlet, marking the boundary between the Strait and Puget Sound. The northern border is delineated by the U.S./Canada border drawn through the middle of the Strait and a line drawn along the base of the San Juan Islands. The designation extends north into Rosario Strait up to a line drawn across Rosario Strait from the northern tip of Lopez Island to Fidalgo Head.

Designated critical habitat within the Strait of Juan de Fuca and coastal marine waters off California, Oregon, and Washington contains all three essential habitat features for green sturgeon: water quality, food resources, and migratory corridors. In addition, designated critical habitat within the lower Columbia River estuary, Grays Harbor, and Willapa Bay contain the essential features for green sturgeon in estuarine habitats; food resources, water flow, water quality, depth, sediment quality, and migratory corridors.

We do not expect the proposed increase in hatchery production and release of Chinook salmon to have a measurable effect on these essential features.

First, we do not expect the increased hatchery production and release of Chinook salmon to reduce dissolved oxygen levels or increase contaminant levels within the action area. We also do not expect the increase in salmon to alter water flow, sediment quality, or the diversity of depths within coastal estuaries.

Second, there is limited overlap between the prey species for salmonids and green sturgeon. As discussed above, salmon primarily feed on aquatic and terrestrial insects, amphipods, mysids, copepods, krill, freshwater crustaceans, and larval and juvenile fish in tidal fresh, brackish, and estuarine waters (Weitkamp et al. 2014) and on adult krill, juvenile fish, amphipods, and larval crab in coastal marine waters (Brodeur et al. 2011). Green sturgeon feed on benthic invertebrates and fish in coastal bays and estuaries, and possibly also in marine waters (Moyle et al. 1995; Erickson et al. 2002; Moser et al. 2007; Dumbauld et al. 2008). We do not expect the increase in salmon to measurably reduce food resources for green sturgeon in the action area.

Third, we do not expect the increased hatchery production and release of Chinook salmon to affect the migration of green sturgeon through the action area. Green sturgeon are bottom-oriented, whereas salmon typically occupy the water column. Given their separation in space, we do not expect the increase in salmon within the action area to impede migration of green sturgeon.

Overall, the proposed increase in hatchery production and release of Chinook salmon under the proposed action would not affect designated critical habitat for Southern DPS green sturgeon in a measurable way, and any potential effects would therefore be insignificant. We conclude that the proposed action may affect, but is not likely to adversely affect, designated critical habitat for Southern DPS green sturgeon.

2.12.3.2 Eulachon Critical Habitat

2.12.3.2.1 Background

Critical habitat was designated for the southern DPS of eulachon on 2011 under section 4(a)(3)(A) of the ESA (76 FR 65324, October 20, 2011). The physical or biological features of eulachon habitat identified as essential to conservation are migration and spawning: (1) freshwater spawning and incubation sites with water flow, quality and temperature conditions and substrate supporting spawning and incubation, and with migratory access for adults; (2) Freshwater and estuarine migration corridors associated with spawning and incubation sites that are free of obstruction and with water flow, quality and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted; and (3) Nearshore and offshore marine foraging habitat with water quality and available prey, supporting juveniles and adult survival. Critical habitat includes portions of 13 (Table 87) rivers and streams in Oregon, and Washington (NMFS 2011a). We designated all of these areas as migration and spawning habitat for this species

Table 87. Rivers and streams designated as critical habitat for the southern DPS of eulachon.

Specific Area	River Miles Containing Features
Umpqua River	24.2
Tenmile Creek	0.2
Sandy River	12.4
Columbia River	143.2
Grays River	4.8
Skamokawa Creek	11.1
Elochoman River	5.2
Cowlitz River	50.2
Toutle River	6.6
Kalama River	7.8
Lewis River East Fork	19.3 5.7
Quinault River	3.0
Elwha River	4.7

2.12.3.2.2 Effects to Critical Habitat

The proposed action has the potential to affect designated critical habitat for the southern DPS of eulachon within the following areas: Sandy River, Columbia River, Grays River, Skamokawa Creek, Elochoman River, Cowlitz River, Toutle River, Kalama River, Lewis River, East Fork, Quinault River, and Elwha River. Thus, the increase in hatchery-produced and released Chinook salmon under the proposed action may affect designated critical habitat for eulachon.

Designated critical habitat contains the essential features for eulachon in freshwater and estuarine areas: (1) spawning and incubation sites (with water flow, quality and temperature conditions and substrate supporting spawning and incubation); and (2) migration corridors (free of obstruction and with water flow, quality and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding). Although they are separate features, spawning and incubation sites for eulachon cannot functionally exist without a migratory corridor to access them.

We do not expect the increase in hatchery-produced and released Chinook salmon to have measurable or detectable effects on these essential features based on the following considerations:

Spawning and Incubation Sites

- We do not expect the increase in hatchery-produced and released Chinook salmon to have a measurable effect on eulachon spawning and incubation sites in critical habitat as there is limited spatial and temporal overlap in spawn timing (Table 70, Table 71, and Table 76), and location — eulachon typically spawn in the lower reaches of rivers, and eulachon spawning habitat primarily consists of sand or pea-sized gravel; whereas Chinook salmon spawning, especially stream-type Chinook salmon, occurs further up-river, and spawning substrates primarily consists of gravel and cobble sized rock. As such, we do not expect hatchery-produced and released Chinook salmon that return to inland rivers to spawn to affect eulachon critical habitat for spawning and incubation (via competition for space) given these differences in spawn timing, location, and substrate preferences. Furthermore, the release of hatchery-produced fish into the environment will have no measurable or detectable affect on water flow, quality and temperature conditions and substrate supporting spawning and incubation as the release of hatchery-produced fish into the environment will have no physical impact on water flow, quality and temperature, and substrate.

Migration Corridors

- The increase in hatchery-produced and released Chinook salmon will not obstruct eulachon migration corridors as the release of hatchery-produced fish into the environment will have no physical effects on aquatic habitats or create in-water barriers that would obstruct the mobility of larval or adult eulachon.

- We do not expect the increase in hatchery-produced and released Chinook salmon to have any physical effects on migration corridors for adult eulachon that would obstruct their migration as there is limited spatial and temporal overlap of these two species in freshwater environments as adults (see Sections 2.2.8, 2.4.2, 2.5.3, 2.6.2, and 2.7.3).

- Even though there is an overlap in the timing of eulachon larvae as they drift downriver and juvenile/smolt Chinook salmon out-migration (see Sections 2.2.8, 2.4.2, 2.5.3, 2.6.2, and 2.7.3), we do not expect the increase in hatchery-produced and released Chinook salmon to impede larval eulachon as they drift downriver through estuaries to the ocean as eulachon larvae tend to be distributed throughout the water column, whereas juvenile/smolt Chinook salmon tend to be distributed in the upper 10-12 feet of the water column. Additionally, while there is overlap with the timing of larval eulachon and juvenile/smolt Chinook salmon, peak abundance of eulachon larval tends to occur in January through April, whereas peak abundance of juvenile/smolt Chinook salmon tends to occur in May through early August (stock-dependent). Therefore, we do not expect the release of hatchery-produced Chinook salmon to have any physical effects on migration corridors for larval eulachon that would obstruct their migration (passive drift) to the Pacific ocean based on these spatial and temporal differences in migration patterns.

- The release of hatchery-produced fish into the environment will have no measurable or detectable affect on water flow, quality, and temperature conditions that support eulachon larval and adult mobility as the release of hatchery-produced fish into the environment will have no physical impact on water flow, quality and temperature, and substrate.

- There is limited overlap in the prey species consumed by Chinook salmon eulachon, Chinook salmon, especially smolts, primarily feed on aquatic and terrestrial insects, amphipods, mysids, copepods, krill, freshwater crustaceans, and larval and juvenile fish in tidal fresh, brackish, and estuarine waters. Adult Choinook salmon feed primarily on other fishes, e.g., herring, whiting, and mackerel. Eulachon larvae and post-larvae eulachon eat a variety of prey items, including phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, and worm larvae (NMFS 2011a). Eulachon adults feed on zooplankton, chiefly eating crustaceans such as copepods and euphausiids (NMFS 2011a). Therefore, we do not expect the increase in hatchery-produced and released Chinook salmon to measurably reduce food resources for eulachon given these differences in prey species.

Overall, we expect the likelihood of effects on critical habitat PBFs for eulachon, to the extent they occur, would be too small to meaningfully measure, detect or evaluate and therefore are insignificant. Therefore, we conclude the proposed increase in hatchery production and release of Chinook salmon under the proposed action would not adversely affect designated critical habitat for southern DPS of eulachon.

2.12.3.3 Puget Sound/Georgia Basin Rockfish Critical Habitat

Critical habitat was designated for the Puget Sound/Georgia Basin yelloweye rockfish and bocaccio DPSs in 2014 under section 4(a)(3)(A) of the ESA (79 FR 68041, November 13, 2014). The physical or biological features of rockfish habitat identified as essential to conservation are: (1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities (juveniles and adults); (2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities (juveniles and adults); and (3) structure and rugosity to support feeding opportunities and predator avoidance (adults only). The hatchery fish produced in the proposed action will overlap with designated critical habitat for rockfish, but predation on larval rockfish occurs in the pelagic zone, which lies off bottom from designated critical habitats. As such, there are no anticipated impacts to water quality or habitat structure/rugosity features of critical habitat, and the action could increase availability of prey for juveniles and adults that may feed on hatchery fish. Therefore, we do not anticipate any adverse effect to critical habitat of either rockfish species to any measurable degree.

3 MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the associated physical, chemical, and biological properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects may result from actions occurring within EFH or outside of it and may include direct, indirect, site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH (50 CFR 600.905(b))].

The Proposed Action occurs within EFH that is described for the following federally managed fish species within fishery management plans (FMPs) developed by the Pacific Fisheries Management Council (PFMC) and approved by the Secretary of Commerce: Pacific coast salmon (PFMC 2024b), coastal pelagic species (CPS) (PFMC 2023a), highly migratory species (HMS) (PFMC 2023b), and Pacific coast groundfish (PFMC 2023c).

3.1 Essential Fish Habitat Affected by the Project

For this EFH consultation, the Proposed Action and Action Area are described in detail above in Sections 1.3 and 2.3, respectively. Briefly, the Proposed Action is federal funding of Chinook salmon smolt hatchery production from hatchery facilities in Puget Sound, the Columbia River basin, and the Washington coast to mitigate for harvest effects by increasing forage resources for the endangered Southern Resident Killer Whale. The Action Area includes freshwater and marine areas where the hatcheries operate and where the federally funded hatchery-origin Chinook salmon are anticipated to occur and cause ESA-defined adverse effects to listed salmonids. The freshwater, estuarine, and offshore marine waters are designated EFH for various life stages of Pacific coast salmon (PFMC 2024b). The estuarine and offshore marine waters are designated EFH for various life stages of coastal pelagic species, highly migratory species, and Pacific coast groundfish, and Pacific coast salmon (PFMC 2023a; 2023b; 2023c; 2024b).

Pursuant to the MSA, NMFS' approval of the most current FMPs includes designated EFH for three species of Pacific salmon (PFMC 2024b)—Chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), Puget Sound pink salmon (*O. gorbuscha*)—six coastal pelagic taxa (PFMC 2023a), 11 highly migratory species (PFMC 2023b), and over 90 species of groundfish (PFMC 2023c). Assessment of potential adverse effects to these species' EFH from the Proposed Action is based, in part, on the information described below. Federal waters are not managed for chum salmon (*O. keta*), sockeye salmon (*O. nerka*), or steelhead (*O. mykiss*). Therefore, EFH has not been designated for these species.

Marine EFH for Chinook, coho, and Puget Sound pink salmon in Washington, Oregon, and California includes all estuarine, nearshore and marine waters, from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the EEZ (PFMC 2014; 2024b). Freshwater EFH for Pacific salmon includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to Chinook, coho, and Puget Sound pink salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable man-made barriers, and longstanding, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years). Freshwater EFH for Chinook and coho salmon consists of four major components, (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors and adult holding habitat. Marine EFH for Chinook and coho salmon consists of three components, (1) estuarine rearing; (2) ocean rearing; and (3) juvenile and adult migration. Freshwater EFH for pink salmon consists of three components, (1) spawning and incubation; (2) juvenile migration corridors; and (3) adult migration corridors and adult holding habitat. Marine EFH for pink salmon consists of three components, (1) estuarine rearing; (2) early ocean rearing; and (3) juvenile and adult migration. A more detailed description and identification of EFH for salmon is found in Appendix A to the Pacific Coast Salmon Fishery Management Plan (PFMC 2014; 2024b).

EFH for coastal pelagic species includes all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10 °C to 26 °C (PFMC 2023a). A more detailed description and identification of EFH for coastal pelagic species is found in Appendix D of the Coastal Pelagic Species Fishery Management Plan as Amended Through Amendment 20 (PFMC 2023a).

EFH for highly migratory species range from vertical habitat within the upper ocean water column from the surface to depths generally not exceeding 200 meters to vertical habitat within the mid-depth ocean water column, from depths between 200 and 1000 meters (PFMC 2023). These range from coastal waters primarily over the continental shelf; generally over bottom depths equal to or less than 183 meters to the open sea, beyond continental and insular shelves. A more detailed description and identification of EFH for highly migratory species can be found in Section 7.2 of the Fishery Management Plan for U.S. West Coast Fisheries for Highly Migratory Species Amended Through Amendment 7 (PFMC 2023b), and in Appendix F of that same document.

EFH for groundfish includes all waters and substrate from the mean higher high water line, or the upriver extent of saltwater intrusion in river mouths, seaward to the 3,500 m depth contour plus specified areas of interest such as seamounts (PFMC 2023c). A more detailed description and identification of EFH for groundfish is found in Appendix B of the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery (PFMC 2023c).

3.2 Adverse Effects on Essential Fish Habitat

NMFS determined that the Proposed Action will adversely affect salmon EFH. Adverse effects to salmonid freshwater EFH are likely to occur as a result of facility operations (e.g., water withdrawal, effluent discharge, weir operations) and ecological interactions from released hatchery fish (e.g., juvenile competition and predation). Low-level adverse effects to salmonid marine EFH are likely to occur through ecological interactions, particularly to Chinook and coho salmon. These effects are described in more detail below. The Proposed Action will have negligible effects on EFH for all other species identified in Section 1.1, as described later in this section.

PFMC (2014) describes potential adverse effects to salmon EFH from artificial propagation of fish and shellfish. These activities have the potential to adversely affect salmon EFH by altering water quality, modifying physical habitat, and creating impediments to passage. Artificial propagation of finfish may also adversely impact salmon EFH by predation of native fish by introduced hatchery fish, competition between hatchery and native fish for food and habitat, exchange of diseases between hatchery and wild populations, the release of chemicals in natural habitat, and the establishment of non-native populations of salmonids and non-salmonids. These potential effects were considered in the context of the Proposed Action (i.e., Chinook salmon hatcheries and release of Chinook salmon smolts) to determine effects to salmon EFH, as described in the following paragraphs.

The Proposed Action is likely to affect freshwater EFH for Chinook, coho, and Puget Sound pink salmon through funding hatchery facilities that will withdraw surface water for use in the hatcheries. As described in the Biological Opinion's Effects Analysis—Sections 2.5.1.2.5 (Factor 5) and 2.5.2 (Salmon and Steelhead Critical Habitat)—hatchery water use is typically non-consumptive and withdrawn water is returned relatively near the point of withdrawal, limiting the spatial extent of impacts to relatively small, localized areas. Nonetheless, salmonid habitat, and thus EFH, may be adversely affected in the reach of the river or steam that is partially dewatered by the hatchery water withdrawal. The partially dewatered reach may experience reduced flow, degraded fish passage conditions, and diminished and degraded spawning and rearing habitat. The relative quantity of surface water withdrawn and relative locations of withdrawal and discharge points are important factors dictating level of impact. Facilities that withdraw a small proportion of total river or stream discharge, and/or that discharge near the point(s) of withdrawal, minimize risks. For specific hatcheries, site-specific consultations evaluate the precise effects of proposed hatchery water withdrawal on habitat conditions and EFH within the affected waterbodies.

The Proposed Action is likely to affect freshwater EFH for Chinook, coho, and Puget Sound pink salmon through the discharge of effluent from the hatchery facilities. As described in the Biological Opinion's Effects Analysis—Sections 2.5.1.2.5 (Factor 5) and 2.5.2 (Salmon and Steelhead Critical Habitat)—effluent discharge from hatchery facilities can adversely affect water quality by introducing contaminants, raising water temperatures, and reducing dissolved-oxygen levels. The proposed hatchery programs minimize each of these effects through compliance with the NPDES permits, where applicable. Effects are typically low-level and localized near the point of discharge. For specific hatcheries, site-specific consultations evaluate the precise effects of proposed hatchery effluent discharge on habitat conditions and EFH within the affected waterbodies.

The Proposed Action is likely to affect freshwater EFH for Chinook, coho, and Puget Sound pink salmon through the use of temporary and permanent weirs. As described in the Biological Opinion's Effects Analysis—Sections 2.5.1.2.2 (Factor 2) and 2.5.2 (Salmon and Steelhead Critical Habitat)—weirs present obstructions within migration corridors, potentially causing displaced spawning, migration delay, and increased mortality from handling of fish at the trap. Effects to EFH associated with weirs are minimized through implementation of one or more best management practices, including but not limited to the following: use of removable weir structures that rest on the river bottom and banks with minimal disruption of riverine habitat; placement and operation of removable weirs only when they are needed; continuous surveillance of weirs by staff residing on-site to ensure proper operation and to safeguard fish trapped; frequent sorting of fish from the trap to minimize trap holding times; and, implementation of fish capture and handling methods that protect the health of fish retained as broodstock or released back into the river. For specific hatcheries, site-specific consultations evaluate the precise effects of associated weirs.

The Proposed Action is likely to affect freshwater and marine EFH for Chinook, coho, and Puget Sound pink salmon through ecological interactions between hatchery and wild salmonids, including predation, competition, and disease, as described by PFMC (2014). Ecological interactions to natural Chinook and coho salmon from Chinook salmon hatchery programs are described in considerable detail in the Biological Opinion (see Sections 2.5.1.2.2 and 2.5.1.2.3, Factors 2 and 3, respectively). Additional detail on possible effects of hatchery programs can be found in Appendix C. Adverse effects from predation and disease on natural Chinook, coho, and Puget Sound pink salmon in freshwater will be minor because hatchery Chinook salmon are released as smolts and migrate rapidly to marine habitats after release. In addition, hatcheries maintain rigorous pathogen prevention, monitoring, and control programs that minimize risk of releasing large proportions of diseased fish. In marine areas, predation by Chinook salmon on salmonids is extremely rare. Adverse effects from competition will be greatest to Chinook salmon because they are the same species being propagated by the Proposed Action and thus will overlap the most in time and space, have the most dietary overlap, and face more intense (intra-specific) direct competition. Coho will be somewhat less affected because of partial spatial and temporal segregation in habitat selection, slight differences in diet, and less intense (inter-specific) direct competition. Puget Sound pink salmon will be minimally affected because spatiotemporal habitat and dietary overlap is minimal between the two species.

For specific hatcheries, site-specific consultations evaluate the precise effects of ecological interactions in freshwater from hatchery releases. In marine areas, as well as the mainstem Columbia and Snake Rivers, the Biological Opinion indicates that effects of ecological interactions from the Proposed Action are relatively minor, mainly because the Proposed Action will increase overall Chinook salmon abundance in affected areas by relatively small amounts, and because available evidence indicates that Chinook salmon make up a very small proportion of competitors in marine areas.

The Proposed Action is not likely to have adverse effects to EFH for coastal pelagic species or highly migratory species. Of the broad categories of activities listed in PFMC (2023a) and (PFMC 2023b) that can adversely affect these species' EFH, aquaculture provides a reasonable analog for Chinook salmon hatchery operations. In particular, discharge of organic waste (i.e., feces, unconsumed feed) and release of high levels of antibiotics, disease, and "escapees" are listed as primary concerns of aquaculture on EFH for coastal pelagic and highly migratory species. However, similar effects from Chinook salmon hatchery operations are not likely to adversely affect EFH for coastal pelagic species or highly migratory species for the following reasons: 1) all relevant facilities will have applicable NPDES permits that minimize effects of hatchery effluent; 2) most, if not all, chemicals used at hatcheries are used periodically (not constantly) and in relatively low volumes; 3) hatchery effluent is often rapidly diluted near the point of discharge because hatchery discharge volumes are typically a relatively small proportion of the receiving waterbody's flow; and, 4) most Chinook salmon hatchery facilities are in freshwater habitats and any discharged organic wastes and antibiotics would be highly diluted prior to reaching the marine environment. Disease transfer from hatchery Chinook salmon is unlikely because coastal pelagic species and highly migratory species are not closely related to Chinook salmon. Released hatchery Chinook salmon may function as competitors or as prey to some coastal pelagic and highly migratory species. However, hatchery Chinook salmon from the Proposed Action will comprise a small proportion of competitors or prey in EFH areas, thereby limiting any positive or negative effects to coastal pelagic species EFH and highly migratory species EFH.

The Proposed Action is not likely to have adverse effects to EFH for groundfish. Of the broad categories of activities listed in (PFMC 2019a) that can adversely affect groundfish EFH, aquaculture provides a reasonable analog for Chinook salmon hatchery operations. The potential adverse effects on EFH from aquaculture include the following: 1) escapes and releases; 2) introduction of pathogens; 3) release of contaminants; 4) water quality impacts; and, 5) benthic impacts. Chinook salmon hatchery operations are not likely to adversely affect groundfish EFH for the following reasons: 1) all relevant facilities will have applicable NPDES permits that minimize effects of hatchery effluent (contaminants, water quality); 2) most, if not all, chemicals used at hatcheries are used periodically (not constantly) and in relatively low volumes (contaminants, water quality); 3) hatchery effluent is often rapidly diluted near the point of discharge because hatchery discharge volumes are typically a relatively small proportion of the receiving waterbody's flow (pathogens, contaminants, water quality, benthic impacts); 4) most Chinook salmon hatchery facilities are in freshwater habitats and any discharged organic wastes and antibiotics would be highly diluted prior to reaching the marine environment (pathogens, contaminants, water quality, benthic impacts); and, 5) disease transfer from hatchery Chinook salmon is unlikely because groundfish are not closely related to Chinook salmon (pathogens).

3.3 Essential Fish Habitat Conservation Recommendations

For each of the potential adverse effects of the Proposed Action on EFH for Chinook, coho, and Puget Sound pink salmon, NMFS believes that the Proposed Action and the Biological Opinion's ITS (Section 2.9) include the best approaches to avoid or minimize those adverse effects. The Reasonable and Prudent Measures and Terms and Conditions included in the ITS constitute NMFS' recommendations to address potential EFH effects. NMFS shall ensure that the ITS, including Reasonable and Prudent Measures and implementing Terms and Conditions, are carried out. The Biological Opinion explicitly discusses the potential risks of hatcheries and hatchery fish to native salmonids and their habitat, and describes operation and monitoring appropriate to minimize these risks in the Action Area. In addition, many or all of these risk minimization measures directed at ESA-listed species will also confer similar benefits to unlisted salmonid species (e.g., Puget Sound coho salmon). Therefore, NMFS has no additional EFH conservation recommendations to provide at this time. This concludes the EFH consultation.

3.4 Supplemental Consultation

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

4 DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The DQA specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the Opinion addresses these DQA components, documents compliance with the DQA, and certifies that this Opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this consultation are the applicants and funding/action agencies listed on the first page. Other interested users could include the agencies, applicants, and the American public. Individual copies of this Opinion were provided to the NMFS. The document will be available within 2 weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adhere to conventional standards for style.

4.2 Integrity

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

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR part 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References Section. The analyses in this Opinion and EFH consultation contain more background on information sources and quality.

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

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

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6 APPENDICES

Appendix A

Modeling for SRKW Hatchery Prey Program Biological Opinion

December 15, 2023

Modeling the Prey Program

Scenario descriptions

To assess the effects of the prey program, we ran three model scenarios:

1. *S1_MaxPS* – this scenario represents the prey program at full implementation (approximately 20M smolts released each year) with the maximum possible number of smolts coming out of Puget Sound and the balance coming from facilities on the WA coast and in the Columbia River.
2. *S2_MaxCR* – this scenario represents the prey program at full implementation (approximately 20M smolts released each year) with the maximum possible number of smolts coming out of the Columbia River and WA coast and the balance coming from facilities in Puget Sound.
3. *S3_2023release* – this scenario represents the prey program at a level of production based on what was actually released under the program in 2023. This scenario was assessed at three different levels:
    - (1) only considering releases that were produced using Federal funding,
    - (2) only considering releases that were produced using WA State funding, and
    - (3) considering both Federally and WA State funded releases.

Approach

Table A-1 presents the levels of prey production modeled under each scenario, summarized by Fishery Regulation Assessment Model (FRAM) stock. For more detail on these releases, see below, TABLE X . Regional abundance increases resulting from this increased hatchery production were estimated by comparing the ending abundances between two sets of FRAM runs, one with and one without the prey production “turned on.” Regional abundance estimates were derived using the approach developed by the Pacific Fishery Management Council’s ad-hoc Southern Resident Killer Whale (SRKW) Workgroup (PFMC 2020) with modifications de- scribed in NMFS (2023). For all analyses in this document, we used distribution parameters from Shelton et al. (2021). The base model runs used in this assessment (i.e., without the prey program) used the FRAM Round 7.1.1 base period calibration and were from the “2019 PST” scenario completed for the NMFS (2024).

To estimate abundances that might occur with the increased prey program production, we developed a set of stock/brood year specific expansion factors to apply to the existing starting cohorts in the base model runs. To derive the expansion factors, we first needed to know the level of actual hatchery production that occurred for each stock. To determine this we conducted a series of queries of the Regional Mark Information System that returned the number of adipose fin-clipped (marked) Chinook released by brood year for each relevant FRAM stock (Table A-6 and A-7). These releases produced the subsequent age-specific cohorts contained in the postseason model runs; for example, the brood year 2010 marked releases of a given stock would produce the age 3 marked starting cohort in the 2013 postseason FRAM run and the age 4 marked starting cohort in the 2014 FRAM run. The stock and brood year-specific expansion factors were calculated by summing the actual production for a given stock/brood with the assumed increased production for that stock (from Table A-1) and dividing by the actual production. These expansions were then applied to the respective stock/age-specific starting cohort sizes in each model run to simulate the proportional increases in abundance that would be expected with the increased hatchery production relative to the production that actually occurred. All fishery inputs were converted to effort scalars to allow for increased catches that would be expected to occur with higher abundances under the same levels of effort.

Table A-1. Number of Chinook salmon released as part of the hatchery prey program, by scenarios and FRAM stock.

FRAM STOCK	SCENARIO 1 MAX PS	SCENARIO 2 MAX CR	SCENARIO 3 - 2023 RELEASES FEDERAL	WA STATE	TOTAL
PUGET SOUND					
Nooksack/Samish Fall	1,500,000	636,749	NA	1,563,464	1,563,464
Nooksack Spr Hatchery	2,000,000	848,999	NA	1,798,920	1,798,920
Skagit Spring Year	600,000	254,700	NA	703,483	703,483
Snohomish Fall Fing	1,200,000	509,399	NA	1,151,558	1,151,558
Snohomish Fall Year	250,000	106,125	NA	79,315	79,315
Tulalip Fall Fing	2,000,000	848,999	1,808,692	NA	1,808,692
Mid PS Fall Fing	5,255,200	2,230,830	3,137,191	1,061,249	4,198,440
South PS Fall Fing	900,000	382,050	NA	419,058	419,058
White River Spring Fing	700,000	297,150	NA	749,886	749,886
COLUMBIA RIVER/WA COAST					
WA North Coast Fall	201,469	500,000	NA	500,000	500,000
Willapa Bay	1,027,493	2,550,000	NA	1,910,660	1,910,660
Cowlitz River Spring	402,938	1,000,000	NA	290,165	290,165
Willamette River Spring	604,408	1,500,000	1,430,813	NA	1,430,813
CR Oregon Hatchery Tule	100,735	250,000	234,871	NA	234,871
CR Bonneville Pool Hatchery	805,877	2,000,000	NA	NA	NA
CR Upriver Bright	717,230	1,780,000	NA	154,835	154,835
CR Upriver Summer	805,877	2,000,000	623,952	514,075	1,138,027
Non-FRAM	928,773	2,305,000	1,065,673	712,010	1,777,683
Grand Total	20,000,000	20,000,000	8,301,192	11,608,678	19,909,870

For this exercise we focused only on the marked components of each stock because we know the number of releases that produced the estimated starting cohorts, whereas the total production that produced the un-clipped cohorts is generally unknown due to uncertainty regarding the number of naturally-produced Chinook. Consequently, we limited this analysis to a time frame that began with return year 2009, as mass-marking became less consistent for brood years that contributed to prior return years. Once these models with the simulated increased hatchery production were run, we calculated the pre- and post-fishing abundances by region using the FRAM/Shelton approach outlined in PFMC (2020) with the modifications described in NMFS (2023). For each region/year combination we calculated percent increases due to the increased hatchery production by subtracting the post-fishing abundances in the original runs without the prey increases from the runs with the simulated prey program then dividing by the starting abundance of the original runs.

Effects on Abundance

A summary of the percent increases resulting from each modeling scenario by region, time period, and funding source is presented in Table A-2, with additional detail provided in Appendices A4 and A5. Figure A-1 summarizes the estimated percent increases in abundance by region and time period for prey program production scenarios 1 (MaxPS) and 2 (MaxCR). Figure A-2 summarizes the estimated percent increases in abundance by region and time period and funding source for prey program production scenario 3 (actual 2023 releases).

Table A-2. Estimated mean 2009-2018 percent increases in adult (age 3-5) Chinook salmon abundance under each hatchery prey production scenario by region and time step.

		SCENARIO 1	SCENARIO 2	SCENARIO 3 - 2023 RELEASES		
REGION	TIME STEP	MAX PS	MAX CR	FEDERAL	WA STATE	TOTAL
Salish	Oct_Apr	9.21%	4.29%	2.86%	5.13%	7.98%
Salish	May_Jun	6.08%	2.99%	2.26%	2.79%	5.04%
Salish	Jul_Sep	1.59%	1.12%	0.52%	0.81%	1.32%
SWWCVI	Oct_Apr	6.18%	6.38%	2.42%	3.30%	5.72%
SWWCVI	May_Jun	5.92%	4.05%	2.16%	2.90%	5.06%
SWWCVI	Jul_Sep	5.50%	3.56%	1.90%	3.00%	4.90%
NOF	Oct_Apr	4.02%	4.57%	1.92%	1.83%	3.75%
NOF	May_Jun	1.52%	1.65%	0.61%	0.61%	1.22%
NOF	Jul_Sep	2.84%	5.78%	1.23%	1.58%	2.81%
OR	Oct_Apr	0.66%	1.12%	0.44%	0.29%	0.73%
OR	May_Jun	0.35%	0.45%	0.11%	0.19%	0.30%
OR	Jul_Sep	0.34%	0.56%	0.12%	0.19%	0.32%
Cali	Oct_Apr	0.80%	1.42%	0.72%	0.44%	1.16%
Cali	May_Jun	0.25%	0.18%	0.03%	0.23%	0.26%
Cali	Jul_Sep	0.21%	0.15%	0.03%	0.19%	0.22%

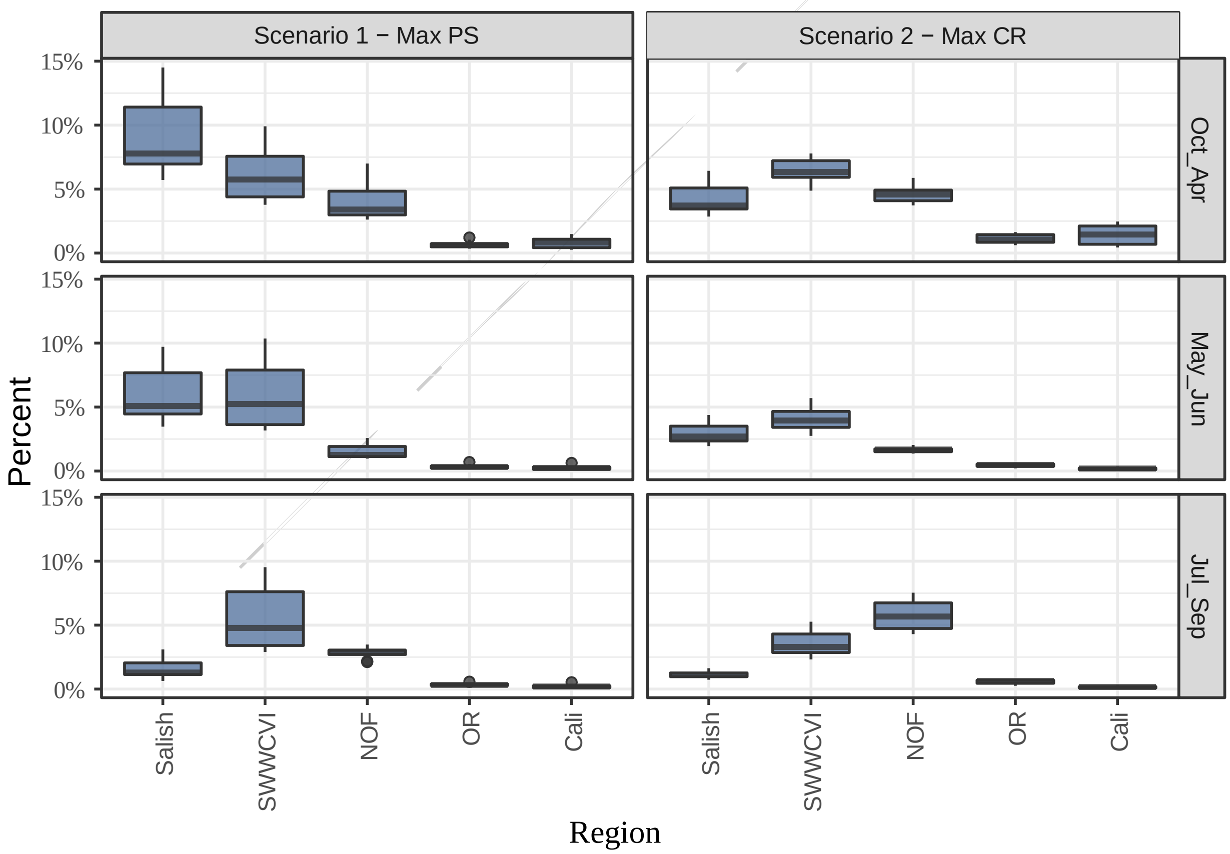

Figure A-1: Summary of estimated 2009-2018 percent increases in Chinook abundance for scenarios 1 and 2 by region and time step.

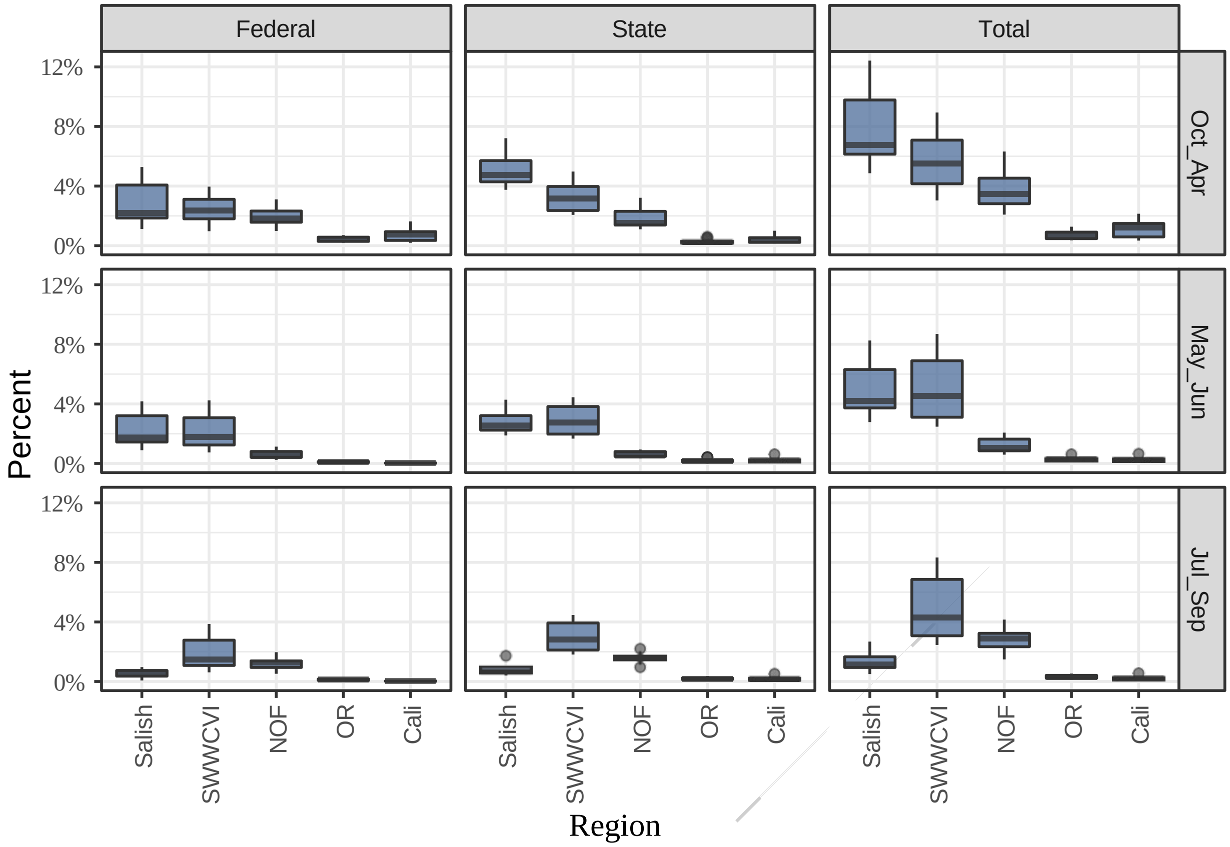

Figure A-2: Summary of estimated 2009-2018 percent increases in Chinook abundance for scenario 3 by region, time step, and funding source.

Effects on Escapement

Table A-3 shows the estimated mean annual increase in numbers of fish expected to return to the river under each prey program scenario. Table A-4 shows the percentage increase that the values in Table A-3 represent relative to the original abundances without the prey program. For all stocks with the exception of White River Spring, these are assumed to be 100% ad-clipped and the percentage increase is relative to only the ad-clipped component of the stock. It is important to note here that the numbers of fish reported represent returns to the river mouth, not fish on the spawning grounds. Of these additional fish returning to the river, some would be caught in freshwater fisheries and some would return to hatchery racks, while others would ultimately end up on the spawning grounds. All fisheries in the hatchery prey program Alternative were modeled to maintain the existing effort levels (i.e., if the abundance of a given stock doubled, then the fishery would catch twice as many of that stock). This is an important caveat to be aware of, and may not be a valid assumption in some cases, as the additional expected returns would likely be captured in annual forecasts, and certain fisheries, particularly those in more terminal areas, might be shaped differently as a result. Given this, it might be best to instead look at the percent increases and consider them as high bookends for the potential proportional increase in ad-clipped HOR spawners, acknowledging that fishery effort could be increased in some areas which would reduce the proportion of those additional fish that make it to escapement.

Table A-3. Estimated mean annual increase in returns to the river mouth by FRAM stock resulting from each hatchery prey program scenario.

FRAM STOCK	MEAN ANNUAL INCREASE IN RETURNS				
	S1_MAXPS	S2_MAXCR	S3_FEDERAL	S3_STATE	S3_TOTAL
Nooksack/Samish Fall	6,448	2,738	0	6,716	6,719
Nooksack Spr Hatchery	7,629	3,237	0	6,860	6,861
Skagit Spring Year	3,230	1,371	0	3,786	3,787
Snohomish Fall Fing	4,358	1,850	0	4,179	4,181
Snohomish Fall Year	1,849	785	0	587	588
Tulalip Fall Fing	1,088	461	983	0	983
Mid PS Fall Fing	19,728	8,375	11,769	3,988	15,760
South Puget Sound Fall Fing	4,290	1,825	0	1,996	2,007
White River Spring Fing	1,462	621	0	1,565	1,566
CR Oregon Hatchery Tule	237	583	546	0	548
CR Bonneville Pool Hatchery	4,888	12,108	0	0	3
Columbia R Upriver Summer	11,713	29,068	9,066	7,472	16,540
Columbia R Upriver Bright	7,107	17,626	0	1,567	1,576
Cowlitz River Spring	3,956	9,816	0	2,849	2,849
Willamette River Spring	7,576	18,802	17,931	0	17,933
WA North Coast Fall	1,169	2,902	0	2,896	2,898
Willapa Bay	3,920	9,731	0	7,283	7,286

Table A-4. Estimated mean annual percent increase in returns to the river mouth by FRAM stock resulting from each hatchery prey program scenario.

FRAM STOCK	MEAN PERCENT INCREASE IN RETURNS				
	S1_MAXPS	S2_MAXCR	S3_FEDERAL	S3_STATE	S3_TOTAL
Nooksack/Samish Fall	32%	13%	0%	33%	33%
Nooksack Spr Hatchery	295%	125%	0%	265%	265%
Skagit Spring Year	173%	73%	0%	203%	203%
Snohomish Fall Fing	131%	56%	0%	126%	126%
Snohomish Fall Year	98%	42%	0%	31%	31%
Tulalip Fall Fing	133%	56%	120%	0%	120%
Mid PS Fall Fing	63%	27%	38%	13%	50%
South Puget Sound Fall Fing	9%	4%	0%	4%	4%
White River Spring Fing	51%	22%	0%	54%	54%
CR Oregon Hatchery Tule	3%	8%	7%	0%	7%
CR Bonneville Pool Hatchery	7%	17%	0%	0%	0%
Columbia R Upriver Summer	31%	76%	24%	20%	43%
Columbia R Upriver Bright	5%	13%	0%	1%	1%
Cowlitz River Spring	14%	34%	0%	10%	10%
Willamette River Spring	8%	20%	19%	0%	19%
WA North Coast Fall	16%	39%	0%	39%	39%
Willapa Bay	18%	44%	0%	33%	33%

Figure A-3 and Table A-5 provide information on the amount of year-to-year variability in the number of fish returning to the river for the marked component of each FRAM stock that has a proposed increase under the prey program. Note that these values represent expected returns under the base model runs, not the model runs that include the additional production from the prey program.

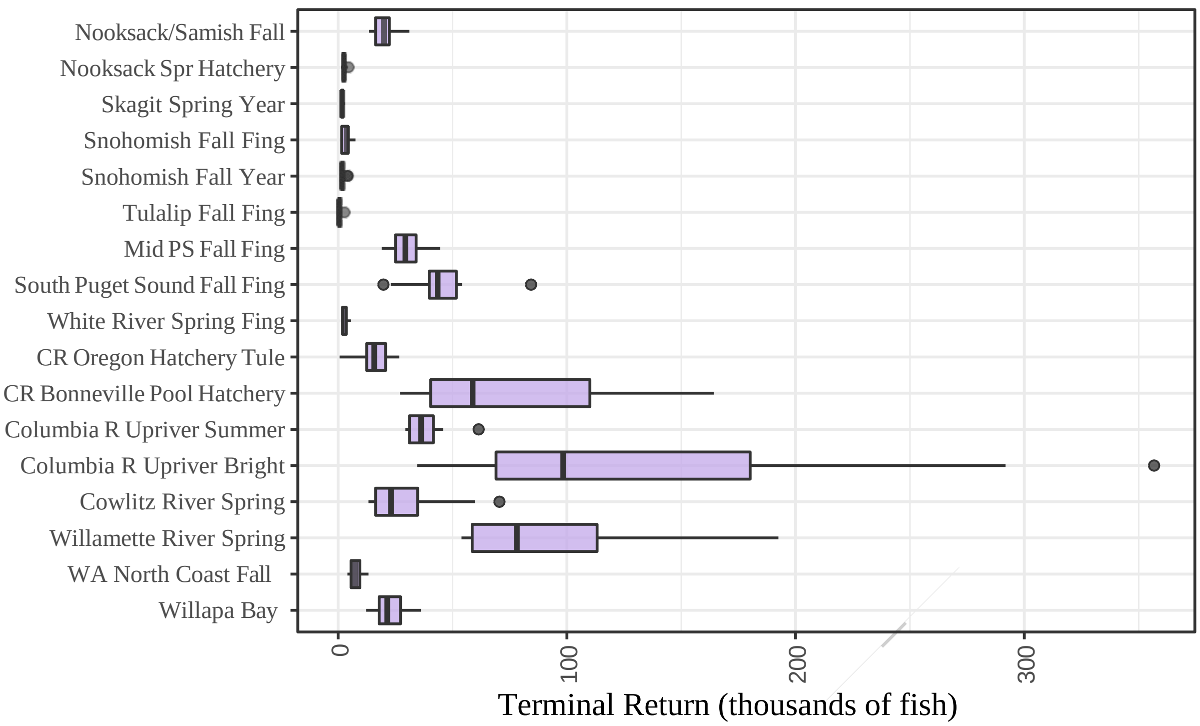

Figure A-3: Summary of projected 2009-2018 returns to the river for FRAM stocks with proposed hatchery increases. These projections are from the base '2019 PST' model runs withouth increased hatchery production and, with the exception of White River spring, represent only the marked component of each stock.

Table A-5. Minimum, maximum, mean, and standard deviation of projected returns to the river between 2009 and 2018 for FRAM stocks with proposed hatchery increases. These projections are from the bast '2019 PST' model runs without increased hatchery production and, with the exception of White River spring, represent only the marked component of each stock.

FRAM STOCK	2009-2018 RETURNS TO THE RIVER MOUTH			
	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
Nooksack/Samish Fall	13,401	31,149	20,603	5,631
Nooksack Spr Hatchery	1,239	4,497	2,697	1,041
Skagit Spring Year	1,303	3,122	1,906	580
Snohomish Fall Fing	1,042	7,578	3,411	2,063
Snohomish Fall Year	768	4,199	2,048	1,157
Tulalip Fall Fing	188	2,723	904	815
Mid PS Fall Fing	19,035	44,589	30,637	8,227
South Puget Sound Fall Fing	19,785	84,339	45,262	17,897
White River Spring Fing	1,346	5,517	2,946	1,471
CR Oregon Hatchery Tule	641	26,744	15,727	7,689
CR Bonneville Pool Hatchery	27,018	164,256	75,744	46,701
Columbia R Upriver Summer	29,384	61,411	38,337	9,769
Columbia R Upriver Bright	34,562	356,733	139,309	108,550
Cowlitz River Spring	13,254	70,506	30,659	19,755
Willamette River Spring	53,924	192,467	94,142	45,529
WA North Coast Fall	4,067	13,275	7,623	2,867
Willapa Bay	12,202	36,153	23,297	7,656

Table A-6. Number of Chinook salmon released by facility under each model scenario

FACILITY	BROOD SOURCE	RUN	STAGE	FRAM STOCK	S1_MAXPS	S2_MAXCR	S3_FEDERAL	S3_STATE
PUGET SOUND								
Skookum Creek	Skookum Creek	Spring	Sub-yearling	Nooksack Spr Hatchery	1,000,000	424,499	0	762,084
University of Washington Hatchery	NA	Fall	Sub-yearling	Mid PS Fall Fing	180,000	76,410	0	0
Puyallup	NA	Fall	Sub-yearling	Mid PS Fall Fing	1,000,000	424,499	0	0
Squaxin/South Sound Net Pens	NA	Fall	Sub-yearling	South PS Fall Fing	500,000	212,250	0	0
Clarks Creek	Clarks Creek	Fall	Sub-yearling	Mid PS Fall Fing	675,200	286,622	0	675,200
Wilkeson Creek	Clarks Creek	Fall	Sub-yearling	Mid PS Fall Fing	400,000	169,800	0	386,049
Issaquah Hatchery	Issaquah Hatchery	Fall	Sub-yearling	Mid PS Fall Fing	1,000,000	424,499	1,000,000	0
Soos Creek-Palmer Pond Hatchery Chinook	Green River	Fall	Sub-yearling	Mid PS Fall Fing	2,000,000	848,999	2,137,191	0
Lummi Bay Hatchery	Kendall	Spring	Sub-yearling	Nooksack Spr Hatchery	500,000	212,250	0	504,080
Kendall	Kendall	Spring	Sub-yearling	Nooksack Spr Hatchery	500,000	212,250	0	532,756
Samish	Samish	Fall	Sub-yearling	Nooksack/Samish Fall	1,000,000	424,499	0	1,042,50
Whatcom Cr.	Samish	Fall	Sub-yearling	Nooksack/Samish Fall	500,000	212,250	0	520,964
Marblemount	Marblemount	Spring	Sub-yearling	Skagit Spring Year	100,000	42,450	0	204,190
Marblemount	Marblemount	Spring	Yearling	Skagit Spring Year	500,000	212,250	0	499,293
Wallace River	Wallace River	Summer	Sub-yearling	Snohomish Fall Fing	1,200,000	509,399	0	1,151,55
Wallace River	Wallace River	Summer	Yearling	Snohomish Fall Year	250,000	106,125	0	79,315
Minter	Minter	Fall	Sub-yearling	South PS Fall Fing	400,000	169,800	0	419,058
Tulalip Bernie Gobin Hatchery	Wallace	Summer	Sub-yearling	Tulalip Fall Fing	2,000,000	848,999	1,808,692	0
White River	White River	Spring	Sub-yearling	White River Spring Fing	200,000	84,900	0	273,385
Hupp Springs	Minter	Spring	Sub-yearling	White River Spring Fing	500,000	212,250	0	476,501
WA COAST								
Sol Duc/Bear Springs	Sol Duc	Summer	Sub-yearling	NA	64,470	160,000	0	73,122
Sol Duc/Bear Springs	Sol Duc	Summer	Yearling	NA	30,220	75,000	0	20,170
Sol Duc	Sol Duc	Summer	Sub-yearling	NA	310,263	770,000	0	553,736
Sol Duc	Sol Duc	Summer	Yearling	NA	20,147	50,000	0	64,982
Quinault Lake	Quinault	Fall	Sub-yearling	WA North Coast Fall	201,469	500,000	0	500,000
Forks Creek	Forks Creek	Fall	Sub-yearling	Willapa Bay	20,147	50,000	0	84,308
Naselle	Naselle	Fall	Sub-yearling	Willapa Bay	1,007,346	2,500,000	0	1,826,35
COLUMBIA RIVER								
Dworshak NFH	Clearwater	Spring	Yearling	NA	201,469	500,000	493,858	0
Carson NFH	Carson	Spring	Yearling	NA	40,294	100,000	74,123	0
Little White/Willard NFH	NA	Fall (URB)	Sub-yearling	CR Upriver Bright	261,910	650,000	0	0
East Bank and Marion Drain Hatcheries	NA	Summer	Sub-yearling	CR Upriver Summer	201,469	500,000	0	0
East Bank and Marion Drain Hatcheries	Entiat/Chelan/Wells	Summer	Yearling	CR Upriver Summer	201,469	500,000	109,876	0
Lewis River	Lewis River	Spring	Sub-yearling	Cowlitz River Spring	402,938	1,000,000	0	290,165
Spring Creek NFH	NA	Fall (tule)	Sub-yearling	CR Bonneville Pool Hatchery	805,877	2,000,000	0	0
Bonneville Hatchery	Bonneville	Fall (tule)	Sub-yearling	CR Oregon Hatchery Tule	100,735	250,000	234,871	0
Umatilla and Bonneville Hatcheries	NA	Fall (URB)	Sub-yearling	CR Upriver Bright	52,382	130,000	0	0
Klickitat Hatchery	Klickitat/Little White	Fall	Sub-yearling	CR Upriver Bright	402,938	1,000,000	0	154,835
Wells Hatchery	Wells	Summer	Sub-yearling	CR Upriver Summer	402,938	1,000,000	514,076	514,075
Little White/Willard NFH	Little White	Spring	Yearling	NA	261,910	650,000	497,692	0
SAFE	Willamette Tribs	Spring	Yearling	Willamette River Spring	604,408	1,500,000	1,430,813	0

Table A-7. RMIS query results for adipose fin clipped hatchery releases by Puget Sound FRAM stock for brood years that contributed to the 2009-2018 return years.

BROOD YEAR	NOOKSACK/ SAMISH FALL	NOOKSACK SPRING	SKAGIT SPRING	SNOHOMISH FALL	TULALIP FALL	MID-PUGET SOUND FALL	SOUTH PUGET SOUND FALL	WHITE RIVER SPRING
2004	4,131,337	575,946	329,764	864,068	871,052	7,850,399	9,298,328	1,207,892
2005	3,076,746	644,700	453,274	665,931	631,876	8,029,038	10,325,435	943,587
2006	3,428,802	538,117	325,670	908,596	1,416,909	10,067,592	10,664,882	956,430
2007	4,725,746	649,793	279,957	813,010	1,454,572	8,725,073	11,143,657	1,615,426
2008	5,685,216	573,135	331,769	959,818	1,269,856	8,636,504	11,169,211	1,993,986
2009	5,215,421	619,980	349,117	1,050,308	1,212,932	8,576,246	8,691,804	1,244,325
2010	5,254,095	615,849	320,033	802,361	2,350,291	10,172,139	10,976,905	1,258,454
2011	5,039,573	611,457	293,714	1,562,009	2,400,654	9,020,533	8,626,100	879,573
2012	5,227,115	961,169	373,394	863,093	1,704,712	8,907,625	9,865,846	911,704
2013	5,116,893	845,678	370,591	841,453	2,069,986	5,408,199	9,031,590	1,475,086
2014	5,023,502	884,463	465,154	857,206	2,351,392	7,300,402	9,289,473	566,384
2015	5,391,056	871,655	443,600	891,121	2,260,025	8,961,833	7,515,973	783,585
2016	3,786,085	830,408	388,387	758,966	1,936,200	8,303,974	9,105,392	1,227,522

Table A-8. RMIS query results for adipose fin clipped hatchery releases by Columbia River and Washington Coastal FRAM stock for brood years that contributed to the 2009-2018 return years.

BROOD YEAR	COWLITZ SPRING	WILLAMETTE SPRING	COLUMBIA SUMMER	COLUMBIA UPRIVER BRIGHT	COLUMBIA OR TULE	COLUMBIA BONNEVILLE POOL HATCHERY	WASHINGTON NORTH COAST FALL	WILLAPA BAY FALL
2004	2,164,087	7,327,150	1,959,956	5,660,272	268,564	14,103,694	1,486,682	597,053
2005	2,530,768	7,109,765	1,166,611	11,015,277	234,079	14,790,728	1,025,323	2,438,315
2006	2,109,163	7,795,601	2,098,215	5,625,472	4,210,265	15,022,357	969,218	9,178,859
2007	2,651,585	6,990,827	1,960,353	11,565,752	4,018,254	14,448,272	1,288,519	7,205,850
2008	2,622,600	8,290,048	3,881,758	14,637,321	7,960,365	12,746,912	1,417,014	7,244,549
2009	2,268,888	8,130,635	4,266,996	15,880,918	8,573,093	12,147,017	1,090,685	4,630,642
2010	2,933,697	7,966,999	3,372,056	14,601,170	7,715,779	12,261,685	1,387,827	7,100,337
2011	2,999,836	7,792,413	3,628,913	15,455,031	7,901,326	12,352,339	1,904,334	5,993,346
2012	3,606,838	7,452,389	2,680,540	16,537,660	7,428,683	12,682,866	1,253,514	6,612,844
2013	3,713,648	7,080,269	3,812,867	16,418,912	8,644,922	10,336,664	1,035,603	6,923,821
2014	3,677,188	6,727,818	3,872,978	16,813,047	9,252,691	10,020,574	1,478,578	6,906,901
2015	3,043,928	6,799,252	3,236,338	15,657,840	9,096,236	9,765,769	1,781,165	4,126,030
2016	3,065,965	6,673,263	3,599,085	16,882,494	5,379,154	10,369,524	956,335	5,810,492

Table A-9. Annual estimates of percent increase in abundance for Scenarios 1 and 2 by region, and time step.

TIMESTEP	REGION	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	MEAN	MEDIAN
SCENARIO 1: MAXIMUM PUGET SOUND													
Oct_Apr	Salish	8.36%	6.99%	6.95%	9.58%	7.19%	5.71%	6.60%	14.15%	14.50%	12.02%	9.21%	7.78%
Oct_Apr	NOF	3.72%	3.41%	3.19%	3.44%	2.89%	2.62%	2.92%	5.21%	7.00%	5.80%	4.02%	3.42%
Oct_Apr	OR	0.58%	0.75%	0.58%	0.34%	0.40%	0.46%	0.64%	1.05%	1.21%	0.64%	0.66%	0.61%
Oct_Apr	Cali	0.92%	1.26%	0.69%	0.29%	0.26%	0.36%	1.00%	1.11%	1.48%	0.59%	0.80%	0.81%
Oct_Apr	SWWCVI	6.66%	5.69%	5.22%	5.83%	3.89%	3.77%	4.12%	7.87%	9.91%	8.89%	6.18%	5.76%
May_Jun	Salish	5.50%	4.31%	4.45%	6.75%	4.63%	3.47%	4.48%	9.71%	9.53%	8.00%	6.08%	5.06%
May_Jun	NOF	1.43%	1.18%	1.16%	1.31%	1.11%	0.97%	1.12%	2.08%	2.58%	2.25%	1.52%	1.24%
May_Jun	OR	0.34%	0.34%	0.28%	0.16%	0.24%	0.23%	0.28%	0.53%	0.70%	0.39%	0.35%	0.31%
May_Jun	Cali	0.31%	0.31%	0.18%	0.07%	0.10%	0.12%	0.19%	0.31%	0.63%	0.26%	0.25%	0.22%
May_Jun	SWWCVI	5.92%	4.65%	4.49%	5.80%	3.34%	3.17%	3.33%	8.55%	10.36%	9.57%	5.92%	5.23%
Jul_Sep	Salish	1.19%	1.12%	0.63%	1.91%	1.18%	1.03%	1.39%	3.10%	2.30%	2.10%	1.59%	1.29%
Jul_Sep	NOF	3.48%	2.99%	2.70%	2.18%	3.04%	2.11%	3.01%	2.71%	3.27%	2.89%	2.84%	2.94%
Jul_Sep	OR	0.38%	0.38%	0.30%	0.15%	0.27%	0.23%	0.33%	0.47%	0.57%	0.32%	0.34%	0.33%
Jul_Sep	Cali	0.26%	0.26%	0.15%	0.06%	0.08%	0.09%	0.15%	0.27%	0.53%	0.22%	0.21%	0.19%
Jul_Sep	SWWCVI	5.43%	4.29%	4.15%	5.28%	3.15%	2.89%	3.09%	8.35%	9.53%	8.82%	5.50%	4.79%
SCENARIO 2: MAXIMUM COLUMBIA RIVER & WA COAST													
Oct_Apr	Salish	3.93%	3.44%	3.34%	4.41%	3.47%	2.85%	3.47%	6.27%	6.43%	5.31%	4.29%	3.70%
Oct_Apr	NOF	4.40%	5.05%	4.27%	4.03%	3.73%	3.81%	4.95%	4.84%	5.87%	4.73%	4.57%	4.56%
Oct_Apr	OR	1.00%	1.47%	1.09%	0.62%	0.71%	0.87%	1.36%	1.64%	1.62%	0.83%	1.12%	1.04%
Oct_Apr	Cali	1.60%	2.47%	1.32%	0.58%	0.44%	0.63%	2.15%	2.05%	2.14%	0.84%	1.42%	1.46%
Oct_Apr	SWWCVI	7.79%	7.51%	6.39%	5.82%	4.88%	4.89%	6.24%	6.22%	7.41%	6.67%	6.38%	6.32%
May_Jun	Salish	2.73%	2.32%	2.29%	3.21%	2.43%	1.95%	2.64%	4.38%	4.31%	3.61%	2.99%	2.69%
May_Jun	NOF	1.70%	1.72%	1.51%	1.37%	1.51%	1.49%	1.84%	1.64%	2.04%	1.74%	1.65%	1.67%
May_Jun	OR	0.50%	0.55%	0.44%	0.21%	0.37%	0.37%	0.53%	0.56%	0.63%	0.36%	0.45%	0.47%
May_Jun	Cali	0.24%	0.26%	0.15%	0.06%	0.07%	0.09%	0.21%	0.22%	0.36%	0.15%	0.18%	0.18%
May_Jun	SWWCVI	4.44%	4.04%	3.56%	3.82%	2.75%	2.84%	3.36%	4.74%	5.70%	5.24%	4.05%	3.93%
Jul_Sep	Salish	1.01%	0.95%	0.73%	1.17%	1.05%	0.86%	1.29%	1.63%	1.33%	1.18%	1.12%	1.11%
Jul_Sep	NOF	7.54%	6.69%	5.90%	4.30%	6.76%	4.70%	6.92%	4.67%	5.48%	4.84%	5.78%	5.69%
Jul_Sep	OR	0.69%	0.73%	0.56%	0.25%	0.52%	0.42%	0.70%	0.66%	0.67%	0.39%	0.56%	0.61%
Jul_Sep	Cali	0.19%	0.21%	0.12%	0.04%	0.06%	0.07%	0.17%	0.18%	0.29%	0.12%	0.15%	0.14%
Jul_Sep	SWWCVI	3.84%	3.33%	3.09%	3.28%	2.44%	2.32%	2.77%	4.46%	5.27%	4.83%	3.56%	3.31%

Table A-10. Annual estimates of percent increase in abundance by funding source, region, and time step for the hatchery prey program based on 2023 releases.

TIMESTEP	REGION	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	MEAN	MEDIAN
FEDERAL													
Oct_Apr	Salish	2.39%	1.86%	1.86%	2.74%	1.65%	1.11%	1.97%	5.21%	5.28%	4.51%	2.86%	2.18%
Oct_Apr	NOF	1.79%	2.18%	1.83%	1.66%	1.03%	0.98%	1.54%	2.37%	3.11%	2.71%	1.92%	1.81%
Oct_Apr	OR	0.39%	0.71%	0.50%	0.24%	0.20%	0.25%	0.45%	0.59%	0.68%	0.39%	0.44%	0.42%
Oct_Apr	Cali	0.76%	1.63%	0.83%	0.27%	0.19%	0.32%	1.07%	0.74%	0.98%	0.43%	0.72%	0.75%
Oct_Apr	SWWCVI	2.76%	2.60%	2.11%	2.10%	1.06%	0.97%	1.70%	3.23%	3.96%	3.68%	2.42%	2.36%
May_Jun	Salish	1.92%	1.44%	1.45%	2.27%	1.36%	0.89%	1.56%	3.98%	4.17%	3.52%	2.26%	1.74%
May_Jun	NOF	0.62%	0.52%	0.47%	0.48%	0.31%	0.24%	0.40%	0.87%	1.13%	1.03%	0.61%	0.50%
May_Jun	OR	0.14%	0.13%	0.10%	0.05%	0.05%	0.04%	0.10%	0.18%	0.20%	0.12%	0.11%	0.11%
May_Jun	Cali	0.04%	0.07%	0.03%	0.01%	0.01%	0.01%	0.04%	0.02%	0.04%	0.02%	0.03%	0.03%
May_Jun	SWWCVI	2.12%	1.66%	1.52%	1.89%	0.89%	0.75%	1.15%	3.39%	4.24%	4.01%	2.16%	1.77%
Jul_Sep	Salish	0.48%	0.46%	0.07%	0.77%	0.34%	0.21%	0.43%	0.97%	0.77%	0.66%	0.52%	0.47%
Jul_Sep	NOF	1.97%	1.66%	1.26%	0.86%	0.79%	0.52%	1.35%	1.20%	1.40%	1.32%	1.23%	1.29%
Jul_Sep	OR	0.18%	0.18%	0.13%	0.05%	0.06%	0.05%	0.14%	0.17%	0.17%	0.11%	0.12%	0.13%
Jul_Sep	Cali	0.04%	0.06%	0.03%	0.01%	0.01%	0.01%	0.04%	0.03%	0.04%	0.02%	0.03%	0.03%
Jul_Sep	SWWCVI	1.77%	1.47%	1.27%	1.51%	0.78%	0.62%	1.01%	3.11%	3.86%	3.60%	1.90%	1.49%
STATE													
Oct_Apr	Salish	4.90%	4.40%	4.25%	5.47%	4.58%	3.75%	3.85%	7.21%	7.06%	5.79%	5.13%	4.74%
Oct_Apr	NOF	1.91%	1.50%	1.44%	1.58%	1.37%	1.10%	1.13%	2.44%	3.21%	2.62%	1.83%	1.54%
Oct_Apr	OR	0.29%	0.27%	0.22%	0.14%	0.17%	0.15%	0.21%	0.51%	0.59%	0.31%	0.29%	0.24%
Oct_Apr	Cali	0.55%	0.51%	0.31%	0.15%	0.15%	0.19%	0.44%	0.69%	1.00%	0.39%	0.44%	0.41%
Oct_Apr	SWWCVI	3.94%	3.15%	2.99%	3.14%	2.15%	2.06%	2.14%	3.98%	4.98%	4.44%	3.30%	3.15%
May_Jun	Salish	2.69%	2.23%	2.27%	3.27%	2.44%	1.89%	2.21%	4.28%	3.55%	3.04%	2.79%	2.57%
May_Jun	NOF	0.68%	0.50%	0.51%	0.56%	0.46%	0.35%	0.41%	0.88%	0.94%	0.84%	0.61%	0.53%
May_Jun	OR	0.21%	0.19%	0.16%	0.08%	0.12%	0.10%	0.13%	0.30%	0.42%	0.23%	0.19%	0.17%
May_Jun	Cali	0.29%	0.27%	0.17%	0.07%	0.09%	0.10%	0.16%	0.31%	0.62%	0.26%	0.23%	0.21%
May_Jun	SWWCVI	3.18%	2.52%	2.43%	2.99%	1.82%	1.72%	1.67%	4.04%	4.45%	4.13%	2.90%	2.76%
Jul_Sep	Salish	0.56%	0.50%	0.43%	0.73%	0.60%	0.61%	0.81%	1.72%	1.06%	1.06%	0.81%	0.67%
Jul_Sep	NOF	2.19%	1.63%	1.58%	1.13%	1.41%	0.97%	1.56%	1.52%	2.04%	1.74%	1.58%	1.57%
Jul_Sep	OR	0.23%	0.22%	0.17%	0.08%	0.13%	0.10%	0.16%	0.28%	0.36%	0.20%	0.19%	0.19%
Jul_Sep	Cali	0.24%	0.22%	0.13%	0.05%	0.07%	0.08%	0.13%	0.25%	0.50%	0.21%	0.19%	0.17%
Jul_Sep	SWWCVI	3.25%	2.54%	2.54%	3.10%	1.97%	1.84%	1.81%	4.35%	4.47%	4.16%	3.00%	2.82%
TOTAL													
Oct_Apr	Salish	7.29%	6.25%	6.11%	8.21%	6.23%	4.86%	5.82%	12.42%	12.34%	10.30%	7.98%	6.77%
Oct_Apr	NOF	3.70%	3.68%	3.27%	3.24%	2.40%	2.08%	2.68%	4.81%	6.32%	5.34%	3.75%	3.47%
Oct_Apr	OR	0.68%	0.97%	0.72%	0.38%	0.36%	0.41%	0.67%	1.10%	1.27%	0.69%	0.73%	0.69%
Oct_Apr	Cali	1.30%	2.14%	1.14%	0.42%	0.34%	0.51%	1.51%	1.43%	1.98%	0.82%	1.16%	1.22%
Oct_Apr	SWWCVI	6.70%	5.75%	5.11%	5.25%	3.21%	3.04%	3.84%	7.21%	8.94%	8.12%	5.72%	5.50%
May_Jun	Salish	4.61%	3.67%	3.72%	5.54%	3.80%	2.78%	3.77%	8.26%	7.72%	6.56%	5.04%	4.21%
May_Jun	NOF	1.30%	1.02%	0.98%	1.04%	0.78%	0.59%	0.81%	1.75%	2.07%	1.87%	1.22%	1.03%
May_Jun	OR	0.35%	0.32%	0.26%	0.14%	0.17%	0.15%	0.22%	0.48%	0.61%	0.35%	0.30%	0.29%
May_Jun	Cali	0.33%	0.34%	0.20%	0.08%	0.09%	0.12%	0.20%	0.33%	0.65%	0.28%	0.26%	0.24%
May_Jun	SWWCVI	5.31%	4.18%	3.94%	4.88%	2.72%	2.47%	2.82%	7.43%	8.69%	8.14%	5.06%	4.53%
Jul_Sep	Salish	1.03%	0.96%	0.50%	1.50%	0.93%	0.82%	1.24%	2.68%	1.83%	1.72%	1.32%	1.14%
Jul_Sep	NOF	4.16%	3.29%	2.83%	1.99%	2.21%	1.49%	2.92%	2.73%	3.43%	3.07%	2.81%	2.88%
Jul_Sep	OR	0.42%	0.40%	0.29%	0.13%	0.19%	0.15%	0.29%	0.45%	0.53%	0.31%	0.32%	0.30%
Jul_Sep	Cali	0.27%	0.29%	0.16%	0.06%	0.08%	0.09%	0.17%	0.28%	0.54%	0.23%	0.22%	0.20%
Jul_Sep	SWWCVI	5.03%	4.01%	3.81%	4.61%	2.75%	2.45%	2.83%	7.47%	8.33%	7.76%	4.90%	4.31%

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Appendix B

Puget Sound salmon and steelhead hatchery programs (ongoing and proposed), and ESA consultation status.

Watershed/ Bundle	Program	Program operator[a]	ESA consultation status[b]
Deep South Sound	Minter Creek Hatchery Coho	WDFW	NC
	Minter Creek Hatchery Chum	WDFW	
	Minter Creek Fall Chinook	WDFW	
	Tumwater Falls Chinook	WDFW	
	Chambers Creek Fall Chinook	WDFW	
	Squaxin/South Sound Net-Pens Coho	SqIT/WDFW	
	Squaxin/South Sound Net-Pens Chinook	SqIT/WDFW	
	Deschutes Coho	WDFW	
Dungeness	Dungeness River Hatchery Spring Chinook	WDFW	NMFS (2016h); NMFS (2019i); NMFS (2022n)
	Dungeness River Hatchery Coho	WDFW	
	Dungeness River Hatchery Fall Pink	WDFW	
	Dungeness River Summer chum Supplementation	WDFW	NC
East Kitsap	Grovers Creek Hatchery Fall Chinook	ST	NC (Bureau of Indian Affairs is the action agency)
	Grovers Creek Chum	ST	
	Agate Pass Net-Pen Coho	ST	
Elwha	Lower Elwha Hatchery Native Steelhead	LEKT	NMFS (2012a); NMFS (2014c)
	Lower Elwha Hatchery Elwha Coho	LEKT	
	Elwha Channel Hatchery Chinook	WDFW	
	Lower Elwha Hatchery Elwha Chum	LEKT	
	Lower Elwha Hatchery Pink	LEKT	
Green/ Duwamish	Soos Creek Hatchery Fall Chinook	WDFW	NMFS (2019h)
	Keta Creek Coho (w/Elliott Bay Net-pens)	MIT/ST	
	Soos Creek Hatchery Coho	WDFW	
	Keta Creek Hatchery Chum	MIT	
	Marine Technology Center Coho	WDFW	
	Fish Restoration Facility (FRF) Coho	MIT	
	FRF Fall Chinook	MIT	
	FRF Steelhead	MIT	
	Green River Native Late Winter Steelhead	WDFW	
	Soos Creek Hatchery Summer Steelhead	WDFW	
Hood Canal	Hoodsport Fall Chinook	WDFW	NMFS (2016f); NMFS (2022i)
	Hoodsport Fall Chum	WDFW	
	Hoodsport Pink	WDFW	
	Enetai Hatchery Fall Chum	SkIT	
	Quilcene NF Hatchery Coho	USFWS	
	Quilcene Bay Net-Pens Coho	SkIT/USFWS	
	Port Gamble Bay Net-Pens Coho	PGST/USFWS	
	Port Gamble Hatchery Fall Chum	PGST	
	Hamma Hamma Chinook Salmon	WDFW	
	Hood Canal Steelhead Supplementation	WDFW	

Watershed/ Bundle	Program	Program operator[a]	ESA consultation status[b]
Lake Washington Basin	Issaquah Hatchery Fall Chinook	WDFW	NMFS (2021g)
	Issaquah Hatchery Coho	WDFW	
	Cedar River Hatchery Sockeye	WDFW	
	UW Coho	MIT	
	UW Chinook	MIT	
Nisqually River	Nisqually FH Clear Creek/Kalama Creek Fall Chinook	NIT	NC
	Kalama Creek Coho	NIT	
Nooksack/ Georgia Strait	Skookum Creek Hatchery SF Nooksack Chinook Salmon	LN	NC
	Kendall Creek North/Middle Fork Nooksack Native Spring Chinook Salmon Restoration Hatchery	WDFW	
	Lummi Bay Hatchery Chinook Salmon	LN	
	Samish Fall Chinook Salmon Hatchery	WDFW	
	Whatcom Creek Hatchery Fall Chinook Salmon	WDFW/BTC	
	Glenwood Springs Hatchery Fall Chinook Salmon	LLTK	
	Skookum Creek Hatchery Coho Salmon	LN	
	Kendall Creek Hatchery Coho Salmon	WDFW	
	Lummi Bay Hatchery Coho Salmon	LN	
	Kendall Creek Hatchery Nooksack Fall Chum Salmon	WDFW	
	Lummi Bay Hatchery Chum Salmon	LN	
	Whatcom Creek Hatchery Chum Salmon	WDFW/BTC	
Puyallup/ White	Clarks Creek Fall Chinook	PTI	NC
	Voights Creek Fall Chinook	WDFW	
	Voights Creek Coho	WDFW	
	Diru Creek Fall Chum	PTI	
	White River Spring Chinook	MIT/PTI	
	White River Winter Steelhead	MIT	
	Minter/Hupp White River Spring Chinook	WDFW	
	Puyallup Acclimation Sites and Lake Kapowsin Net-Pens, Fall Coho Voights Creek Stock	PTI	
Skagit River	Upper Skagit Hatchery Chum	USIT	NMFS (2022f)
	Skagit River Chum	WDFW	
	Chum Remote Site Incubator	SSIT	
	Skagit River Spring Chinook	WDFW	NC
	Skagit River Fall Chinook	WDFW	
	Skagit River Summer Chinook	SRSC/WDFW	
	Skagit River Coho	WDFW	
	Baker River Sockeye	WDFW/PSE	
	Baker River Coho	WDFW/PSE	
Skokomish River	McKernan Hatchery Chum	WDFW	NC
	George Adams Fall Chinook	WDFW	
	George Adams Coho	WDFW	
	NF Skokomish Hatchery Coho	SkIT/WDFW/TP	
	NF Skokomish Hatchery Steelhead	SkIT/WDFW/TP	
	NF Skokomish Hatchery Spring Chinook	SkIT/WDFW/TP	
	Cushman (Sportsman's Park) Sockeye	SkIT/WDFW/TP	
Snohomish River basin	Tulalip Hatchery Chinook Sub-yearling	TT	
	Wallace River Hatchery Summer Chinook	WDFW	

Watershed/ Bundle	Program	Program operator[a]	ESA consultation status[b]
	Wallace River Hatchery Coho	WDFW	NMFS (2017c); NMFS (2021e); NMFS (2022k)
	Tulalip Hatchery Coho	TT	
	Tulalip Hatchery Fall Chum	TT	
	Everett Bay Net-Pen Coho	WDFW	
	Wallace River Hatchery Integrated Chum Salmon Rescue Program	WDFW	
Steelhead, Early Winter	Kendall Creek Winter Steelhead	WDFW	NMFS (2016i)
	Dungeness River Early Winter Steelhead	WDFW	
	Whitehorse Ponds Winter Steelhead	WDFW	
	Snohomish/Skykomish Winter Steelhead	WDFW	NMFS (2016k)
	Snohomish/Tokul Creek Winter Steelhead	WDFW	
Steelhead, Summer	South Fork Skykomish Summer Steelhead	WDFW	NMFS (2021h)
Stillaguamish River	Stillaguamish Fall Chinook Natural Stock Restoration	STI	NMFS (2019g)
	Stillaguamish Summer Chinook Natural Stock Restoration	WDFW/STI	
	Stillaguamish Late Coho	STI	
	Stillaguamish Fall Chum	STI	

[a] BTC = Bellingham Technical College; LEKT = Lower Elwha Klallam Tribe; LN = Lummi Nation; MIT = Muckleshoot Indian Tribe; NIT = Nisqually Indian Tribe; PGST = Port Gamble S'Klallam Tribe; PSE = Puget Sound Energy; PTI = Puyallup Tribe of Indians; SkIT = Skokomish Indian Tribe; SqIT = Squaxin Island Tribe; SRSC = Skagit River System Cooperative; SSIT = Sauk-Suiattle Indian Tribe; ST = Suquamish Tribe; STI = Stillaguamish Tribe of Indians; TP = Tacoma Power; TT = Tulalip Tribes; USFWS = United States Fish and Wildlife Service; USIT = Upper Skagit Indian Tribe; WDFW = Washington Department of Fish and Wildlife.
[b] Completed Biological Opinion(s) are shown with citations. NC = ESA consultation has not been completed.

Columbia River Basin hatchery programs that have been addressed in previously completed ESA section 7 consultations.

Biological Opinion	Programs Authorized in Opinion	Citation
USFWS Artificial Propagation Programs in the Lower Columbia and Middle Columbia River	Little White Salmon/Willard National Fish Hatchery Complex Coho	NMFS (2007a), NMFS (2016r)
	Little White Salmon/Willard National Fish Hatchery Complex spring Chinook	
	Little White Salmon/Willard National Fish Hatchery Complex URB fall Chinook	
	Carson National Fish Hatchery spring Chinook	
	Spring Creek National Fish Hatchery fall Chinook (tule)	
	Eagle Creek National Fish Hatchery coho	
	Eagle Creek National Fish Hatchery winter steelhead	
	Warm Springs National Fish Hatchery Warm Springs River spring Chinook	
Consultation on Remand for Operation of the Federal Columbia River Hydropower System	Yakima River kelt reconditioning program	NMFS (2008k); NMFS (2014g)
	Upper Columbia River kelt reconditioning program	
Letter: Request for Concurrence with the Yakima Nation Fisheries' assessment of potential impacts	Lake Cle Elum/ Yakima Basin Lakes	Turner (2009)
Umatilla River Spring Chinook Salmon, Fall Chinook Salmon, and Coho Salmon Hatchery Programs	Umatilla spring Chinook	NMFS (2011f; 2016j)
	Umatilla fall Chinook	
	Umatilla coho	
Snake River Fall Chinook Salmon Hatchery Programs, ESA Section 10(a)(1)(A) permits, numbers 16607 and 16615	Lyons Ferry Hatchery Snake River fall Chinook	NMFS (2012b)
	Fall Chinook salmon Acclimation program	
	Idaho Power Company fall Chinook	
	Nez Perce Tribal Hatchery Snake River fall Chinook	
Entiat National Fish Hatchery Summer Chinook Salmon Hatchery Program	Entiat summer Chinook	NMFS (2013f)

Biological Opinion	Programs Authorized in Opinion	Citation
Snake River Sockeye Salmon Hatchery Program	Snake River sockeye	NMFS (2013e)
Yakima River Spring Chinook Salmon, Summer/Fall Chinook Salmon, and Coho Salmon Hatchery Programs	Upper Yakima River spring Chinook/Cle Elum Supplementation and Research Facility (CESRF)	NMFS (2013a)
	Yakima River summer and fall run Chinook production program	
	Yakima River coho Reintroduction program	
Sandy River Spring Chinook Salmon, Coho Salmon, Winter Steelhead, and Summer Steelhead Programs	Sandy River spring Chinook	NMFS (2014e)
	Sandy River coho	
	Sandy River winter steelhead	
	Sandy River summer steelhead	
Issuance of Section 10(a)(1)(A) Permit 18928 for the Chief Joseph Hatchery Okanogan Spring Chinook Salmon Program	Chief Joseph Hatchery Okanogan spring Chinook	NMFS (2014a)
Reinitiation of the Issuance of Three Section 10(a)(1)(A) Permits for the Upper Columbia River Chiwawa River, Nason Creek, and White River Spring Chinook Salmon Hatchery Programs	Chiwawa spring Chinook	NMFS (2015b)
	Nason Creek spring Chinook	
Six Lower Snake River Spring/Summer Chinook Salmon Hatchery Programs	Catherine Creek spring/summer Chinook	NMFS (2016l)
	Upper Grande Ronde spring/summer Chinook	
	Imnaha River spring/summer Chinook	
	Lookingglass Creek spring Chinook	
	Lostine spring/summer Chinook	
	Tucannon River Endemic spring Chinook	
Issuance of a Section 10(a)(1)(A) Permit 18583 for the Upper Columbia Wenatchee River Summer Steelhead Hatchery Program	Wenatchee summer steelhead	NMFS (2016c)
Issuance of Four Section 10(a)(1)(A) Permits for	Methow Hatchery spring Chinook	NMFS (2016a)
	Winthrop National Fish Hatchery spring Chinook	

Biological Opinion	Programs Authorized in Opinion	Citation
Spring Chinook Salmon Hatchery Programs in the Methow Subbasin		
Mitchell Act	Bonneville coho	NMFS (2017j)
	Bonneville fall Chinook (tule)	
	Big Creek Chinook (tule)	
	Big Creek coho	
	Big Creek chum	
	Big Creek winter steelhead	
	Gnat Creek winter steelhead	
	Klaskanine winter steelhead	
	Klaskanine coho	
	Klaskanine fall Chinook (tule)	
	Clackamas summer steelhead	
	Clackamas winter steelhead	
	Clackamas spring Chinook	
	Grays River coho	
	N. F. Toutle fall Chinook (tule)	
	N. F. Toutle coho	
	Kalama fall Chinook (tule)	
	Kalama coho (type N)	
	Kalama summer steelhead	
	Kalama winter steelhead	
	Washougal fall Chinook (tule)	
Mitchell Act (cont.)	Washougal coho	
	Walla Walla spring Chinook	
	Ringold Springs steelhead	
	Ringold Springs coho[1]	
	Clearwater River coho restoration project	
	Lostine River coho restoration project;	
	Deep River coho (MA/SAFE)	
	Deep River fall Chinook	
	Klickitat coho	
	Klickitat URB fall Chinook	
	Klickitat spring Chinook	
	Klickitat (Skamania) summer steelhead	

Biological Opinion	Programs Authorized in Opinion	Citation
Mitchell Act (cont.)	Beaver Creek summer steelhead	
	Beaver Creek winter steelhead	
	Beaver Creek (Elochoman) coho[1]	
	South Toutle summer steelhead	
	Coweeman winter steelhead	
	Cathlamet Channel Net-pen spring Chinook	
	Klineline winter steelhead (Salmon Cr.)	
	Washougal summer steelhead (Skamania Hatchery)	
	Washougal winter steelhead (Skamania Hatchery)	
	Rock Creek winter steelhead	
	Kalama spring Chinook	
	Umatilla River coho	
	Sandy River spring Chinook	
	Sandy River winter steelhead	
	Sandy River summer steelhead	
	Sandy River coho	
	Carson National Fish Hatchery spring Chinook	
	Little White Salmon National Fish Hatchery spring Chinook	
	Willard National Fish Hatchery fall Chinook	
	Eagle Creek National Fish Hatchery winter steelhead	
	Eagle Creek National Fish Hatchery coho	
Issuance of a Tribal 4(d) Rule Determination for a Tribal Resource Management Plan (TRMP) submitted by the Confederated Tribes of the Colville Reservation (CTCR), and Funding and Carrying out Activities Pursuant to that TRMP	CTCR summer/fall Chinook	NMFS (2017a)
	CTCR spring Chinook	
	CTCR steelhead	
Mid-Columbia Coho Salmon Restoration Program: Operation and Construction	Mid-Columbia Coho Restoration Program	NMFS (2017l)
Four Lower Snake River Steelhead Hatchery Programs	Grande Ronde Basin summer steelhead	NMFS (2017k)
	Little Sheep Creek summer steelhead	
	Lyons Ferry summer steelhead	

Biological Opinion	Programs Authorized in Opinion	Citation
	Tucannon River summer steelhead	
Leavenworth National Fish Hatchery Spring Chinook Salmon Program (Reinitiation 2016)	Leavenworth National Fish Hatchery Spring Chinook	NMFS (2017p)
Little White Salmon National Fish Hatchery Upriver Bright Fall Chinook Salmon Program	Little White Salmon National Fish Hatchery URB fall Chinook (Corps)	NMFS (2017b)
Two Steelhead Hatchery Programs in the Methow River	Wells Complex summer steelhead	NMFS (2017h)
	Winthrop National Fish Hatchery	
Five Snake River Basin Spring/Summer Chinook Salmon Hatchery Programs	Rapid River spring Chinook	NMFS (2017g)
	Hells Canyon spring Chinook	
	South Fork Salmon River (SFSR) summer Chinook	
	Johnson Creek Artificial Propagation and Enhancement Project summer Chinook	
	South Fork Chinook Eggbox Project summer Chinook	
Five Clearwater River Basin Spring/Summer Chinook Salmon and Coho Salmon Hatchery Programs	Kooskia spring Chinook	NMFS (2017f)
	Clearwater Fish Hatchery spring/summer Chinook	
	Nez Perce Tribal Hatchery spring/summer Chinook	
	Dworshak spring Chinook	
	Clearwater River coho (at Dworshak and Kooskia)	
Nine Snake River Steelhead Hatchery Programs and one Kelt Reconditioning Program in Idaho	Steelhead Streamside Incubator (SSI) Project	NMFS (2017e)
	Dworshak National Fish Hatchery B-Run Steelhead	
	East Fork Salmon Natural A-run Steelhead	
	Hells Canyon Snake River A-run Summer Steelhead	
	Little Salmon River A-run Summer Steelhead	
	Pahsimeroi A-run Summer Steelhead	
	South Fork Clearwater (Clearwater Hatchery) B-Run Steelhead	
	Upper Salmon River A-Run Steelhead	
	Salmon River B-Run	
	Snake River Kelt Reconditioning	
	Chelan Falls summer/fall Chinook	

Biological Opinion	Programs Authorized in Opinion	Citation
Four Summer/Fall Chinook Salmon and Two Fall Chinook Salmon Hatchery Programs in the Upper Columbia River Basin	Wenatchee summer/fall Chinook	NMFS (2017r); NMFS et al. (2017)
	Methow summer/fall Chinook	
	Wells summer/fall Chinook	
	Priest Rapids fall Chinook	
	Ringold Springs fall Chinook	
Four Salmon River Basin Spring/Summer Chinook Salmon Hatchery Programs in the Upper Salmon River Basin	Yankee Fork spring Chinook	NMFS (2017t)
	Panther Creek summer Chinook	
	Panther Creek summer Chinook egg box	
	Upper Salmon River spring Chinook	
	Pahsimeroi summer Chinook	
Hood River Spring Chinook Salmon and Winter Steelhead Programs	Hood River spring Chinook	NMFS (2017d)
	Hood River winter steelhead	
Middle Columbia River Summer Steelhead and Spring Chinook Programs	Touchet endemic summer steelhead	NMFS (2017d)
	Umatilla summer steelhead	
	Round Butte spring Chinook	
	Walla Walla spring Chinook	
Willamette River basin programs	Spring Chinook Reintroduction/Outplant Program	NMFS (2000a), NMFS (2008i), and NMFS (2019l)
	North Santiam Spring Chinook Hatchery Program	
	South Santiam Spring Chinook Hatchery Program	
	McKenzie Spring Chinook Program	
	Middle Fork Willamette Spring Chinook Hatchery Program	
	Upper Willamette Summer Steelhead Hatchery Program	
	Rainbow Trout Mitigation Program	

[1]Proposed future program.

Appendix C

1. APPENDIX: Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations (Revised May 2023)[75]

NMFS applies available scientific information, identifies the types of circumstances and conditions that are unique to individual hatchery programs, then refines the range in effects for a specific hatchery program. Our analysis of a Proposed Action addresses six factors:

(1) The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock

(2) Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities

(3) Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the migration corridor, estuary, and ocean

(4) Research, monitoring, and evaluation (RM&E) that exist because of the hatchery program

(5) Operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program

(6) Fisheries that would not exist but for the hatchery program, including terminal fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds

Because the purpose of biological opinions is to evaluate whether proposed actions pose unacceptable risk (jeopardy) to listed species, much of the language in this appendix addresses risk. However, we also consider that hatcheries can be valuable tools for conservation or recovery, for example when used to prevent extinction or conserve genetic diversity in a small population, or to produce fish for reintroduction.

The following sections describe each factor in detail, including as appropriate, the scientific basis for and our analytical approach to assessment of effects. The material presented in this Appendix is only scientific support for our approach; social, cultural, and economic considerations are not included. The scientific literature on effects of salmonid hatcheries is large and growing rapidly. This appendix is thus not intended to be a comprehensive literature review, but rather a

[75] This version of the appendix supersedes all earlier dated versions and the NMFS (2012d) standalone document of the same name.

periodically updated overview of key relevant literature we use to guide our approach to effects analysis. Because this appendix can be updated only periodically, it may sometimes omit very recent findings, but should always reflect the scientific basis for our analyses. Relevant new information not cited in the appendix will be cited in the other sections of the opinion that detail our analyses of effects.

In choosing the literature we cite in this Appendix, our overriding concern is our mandate to use “best available science”. Generally, “best available science” means recent peer-reviewed journal articles and books. However, as appropriate we cite older peer-reviewed literature that is still relevant, as well as “gray” literature. Although peer-review is typically considered the “gold standard” for scientific information, occasionally there are well-known and popular papers in the peer-reviewed literature we do not cite because we question the methodology, results, or conclusions. In citing sources, we also consider availability, and try to avoid sources that are difficult to access. For this reason, we generally avoid citing master’s theses and doctoral dissertations, unless they provide unique information.

1.1 Factor 1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock

A primary consideration in analyzing and assessing effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the biological benefits and risks of using ESA-listed fish (natural or hatchery-origin) for hatchery broodstock. It considers the maximum number of fish proposed for collection and the proportion of the donor population collected for hatchery broodstock. “Mining” a natural population to supply hatchery broodstock can reduce population abundance and spatial structure

1.2 Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural and hatchery fish at adult collection facilities.

There are three aspects to the analysis of this factor: genetic effects, ecological effects, and encounters at adult collection facilities. We present genetic effects first. For the sake of simplicity, we discuss genetic effects on all life stages under factor 2.

1.2.1. Genetic effects

1.2.1.1. Overview

Based on currently available scientific information, we generally view the genetic effects of hatchery programs as detrimental to the ability of a salmon population’s ability to sustain itself in the wild. We believe that artificial breeding and rearing is likely to result in some degree of change of genetic diversity and fitness reduction in hatchery-origin. Hatchery-origin fish can thus pose a risk to diversity and to salmon population rebuilding and recovery when they interbreed with natural-origin fish. However, conservation hatchery programs may prevent extinction or accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford et al. 2011).

We recognize that there is considerable debate regarding aspects of genetic risk. The extent and duration of genetic change and fitness loss and the short- and long-term implications and consequences for different species (i.e., for species with multiple life-history types and species subjected to different hatchery practices and protocols) remain unclear and should be the subject of further scientific investigation. As a result, we believe that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that harmonize conservation with the implementation of treaty Indian fishing rights and other applicable laws and policies (NMFS 2011d). We expect the scientific uncertainty surrounding genetic risks to be reduced considerably in the next decade due to the rapidly increasing power of genomic analysis (Waples et al. 2020).

Four general processes determine the genetic composition of populations of any plant or animal species (e.g., Falconer et al. 1996):

- Selection- changes in genetic composition over time due to some genotypes being more successful at survival or reproduction (i.e., more fit) than others
- Migration- individuals, and thus their genes, moving from one population to another
- Genetic drift- random loss of genetic material due to finite population size
- Mutation- generation of new genetic diversity through changes in DNA

Mutations are changes in DNA sequences that are generally so rare[76] that they can be ignored for relatively short-term evaluation of genetic change, but the other three processes are considerations in evaluating the effects of hatchery programs on the productivity and genetic diversity of natural salmon and steelhead populations. Although there is considerable biological interdependence among them, we consider three major areas of genetic effects of hatchery programs in our analyses (Figure 84):

- Within-population genetic diversity
- Among-population genetic diversity/outbreeding
- Hatchery-influenced selection

[76] For example, the probability of a random base substitution in a DNA molecule in coho salmon is .000000008 (Rougemont et al. 2020).

The first two areas are well-known major concerns of conservation biology (e.g., Frankham et al. 2010; Allendorf et al. 2013), but our emphasis on hatchery-influenced selection— what conservation geneticists would likely call “adaptation to captivity” (Allendorf et al. 2013, pp. 408-409)— reflects the fairly unique position of salmon and steelhead among ESA-listed species. In the case of ESA-listed Pacific salmon and steelhead, artificial propagation in hatcheries has been used as a routine management tool for many decades, and in some cases the size and scope of hatchery programs has been a factor in listing decisions.

In the sections below we discuss these three major areas of risk, but preface this with an explanation of some key terms relevant to genetic risk. Although these terms may also be listed in a glossary in the biological opinion to which this appendix accompanies, we felt that it was important to include them here, as this appendix may at times be used as a stand-alone document.

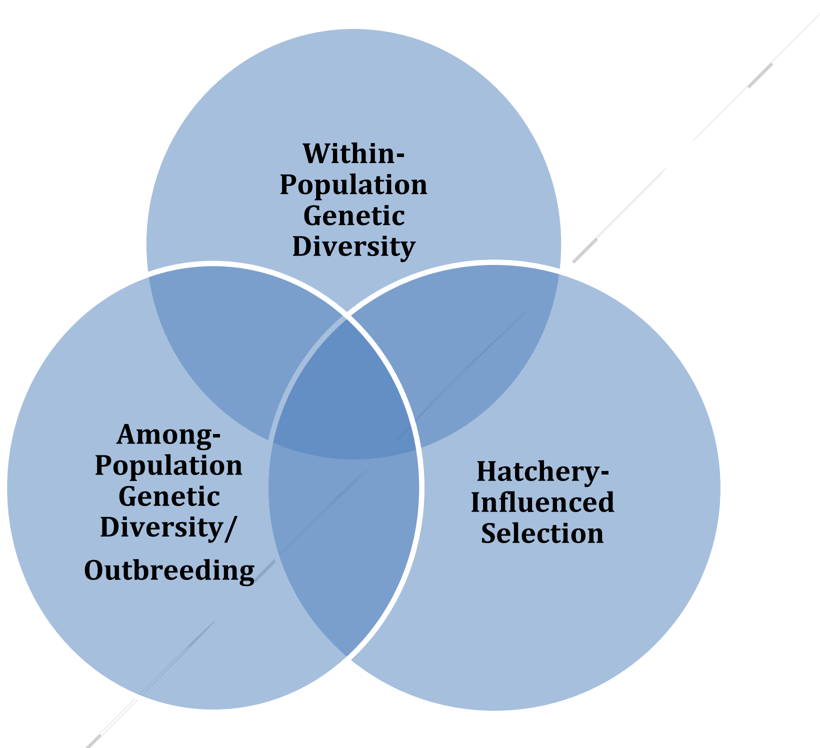

Figure 84. Major categories of hatchery program genetic effects analyzed by NMFS

1.2.1.1.1. Key Terms

The terms “wild fish” and “hatchery fish” are commonly used by the public, management biologists, and regulatory biologists, but their meaning can vary depending on context. For genetic risk assessment, more precise terminology is needed. Much of this terminology, and further derivatives of it, is commonly attributed to the Hatchery Scientific Review Group (HSRG), but were developed in 2004 technical discussions between the HSRG and scientists from the Washington Department of Fish and Wildlife (WDFW) and the Northwest Indian Fisheries Commission (HSRG 2009a).

- **Hatchery-origin (HO)**- refers to fish that have been reared and released by a hatchery program, regardless of the origin (i.e., from a hatchery or from spawning in nature) of their parents. A series of acronyms has been developed for subclasses of HO fish:
    - **Hatchery-origin recruits (HOR) –** HO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature, used for hatchery broodstock, or surplused.
    - **Hatchery-origin spawners (HOS)**- hatchery-origin fish spawning in nature. A very important derivative term, used both in genetic and ecological risk, is pHOS, the proportion of fish on the spawning grounds of a population consisting of HO fish. pHOS is the expected maximum genetic contribution of HO spawners to the naturally spawning population.
    - **Hatchery-origin broodstock (HOB)**- hatchery-origin fish that are spawned in the hatchery (i.e., are used as broodstock). This term is rarely used.
- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms parallel to those for HO fish has been developed for subclasses of NO fish:
    - **Natural-origin recruits (NOR) –** NO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature or used for hatchery broodstock.
    - **Natural-origin spawners (NOS)**- natural-origin fish spawning in nature.
    - **Natural-origin broodstock (NOB)**- natural-origin fish that are spawned in the hatchery (i.e., are used as broodstock). An important derivative term is pNOB, the proportion of a hatchery program's broodstock consisting of NO fish.

Hatchery programs are designated as either as "integrated" or "segregated". In the past these terms have been described in various ways, based on purpose (e.g., conservation or harvest) or intent with respect to the genetic relationship between the hatchery fish and the natural population they interact with. For purposes of genetic risk, we use simple functional definitions based on use of natural-origin broodstock:

- **Integrated hatchery programs**- programs that intentionally incorporate natural-origin fish into the broodstock at some level (i.e., pNOB > 0)
- **Segregated hatchery programs**- programs that do not intentionally incorporate natural-origin fish into the broodstock (i.e., pNOB = 0)

1.2.1.2. Within-population diversity effects

Within-population genetic diversity is a general term for the quantity, variety, and combinations of genetic material in a population (Busack et al. 1995). Within-population diversity is gained through mutations or gene flow from other populations (described below under outbreeding effects) and is lost primarily due to genetic drift. In hatchery programs diversity may also be lost through biased or nonrepresentational sampling incurred during hatchery operations, particularly broodstock collection and spawning protocols.

1.2.1.2.1. Genetic drift

Genetic drift is random loss of diversity due to population size. The rate of drift is determined not by the census population size (N_c), but rather by the effective population size (N_e). The effective size of a population is the size of a genetically "ideal" population (i.e., equal numbers of males and females, each with equal opportunity to contribute to the next generation) that will display as much genetic drift as the population being examined (e.g., Falconer et al. 1996; Allendorf et al. 2013)[77].

This definition can be baffling, so an example is useful. A commonly used effective-size equation is $Ne = 4 * N_m * N_f / (N_m + N_f)$, where N_m and N_f are the number of male and female parents, respectively. Suppose a steelhead hatchery operation spawns 5 males with 29 females. According to the equation, although 34 fish were spawned, the skewed sex ratio made this equivalent to spawning 17 fish (half male and half female) in terms of conserving genetic diversity because half of the genetic material in the offspring came from only 5 fish.

Various guidelines have been proposed for what levels of N_e should be for conservation of genetic diversity. A long-standing guideline is the 50/500 rule (Franklin 1980; Lande et al. 1987): 50 for a few generations is sufficient to avoid inbreeding depression, and 500 is adequate to conserve diversity over the longer term. One recent review (Jamieson et al. 2012) concluded the rule still provided valuable guidance; another (Frankham et al. 2014) concluded that larger values are more appropriate, basically suggesting a 100/1000 rule. See Frankham et al. (2010) for a more thorough discussion of these guidelines.

Although Ne can be estimated from genetic or demographic data, often-insufficient information is available to do this, so for conservation purposes it is useful to estimate effective size from census size. As illustrated by the example above, N_e can be considerably smaller than N_c. This is typically the case. Frankham et al. (2014) suggested a N_e/N_c range of ~0.1-0.2 based on a large review of the literature on effective size. For Pacific salmon populations over a generation, Waples (2004) arrived at a similar range of 0.05-0.3.

In salmon and steelhead management, effective size concerns are typically dealt with using the term effective number of breeders (N_b) in a single spawning season, with per-generation N_e equal

[77] There are technically two subcategories of N_e: inbreeding effective size and variance effective size. The distinction between them is usually not a concern in our application of the concept.

to the generation time (average age of spawners) times the average N_b (Waples 2004). We will use N_b rather than N_e where appropriate in the following discussion.

Hatchery programs, simply by virtue of being able to create more progeny than natural spawners are able to, can increase N_b in a fish population. In very small populations, this increase can be a benefit, making selection more effective and reducing other small-population risks (e.g., Lacy 1987; Whitlock 2000; Willi et al. 2006). Conservation hatchery programs can thus serve to protect genetic diversity; several programs, such as the Snake River sockeye salmon program, are important genetic reserves. However, hatchery programs can also directly depress N_b by three principal pathways:

- Removal of fish from the naturally spawning population for use as hatchery broodstock. If a substantial portion of the population is taken into a hatchery, the hatchery becomes responsible for that portion of the effective size, and if the operation fails, the effective size of the population will be reduced (Waples et al. 1994).
- Mating strategy used in the hatchery. N_b is reduced considerably below the census number of broodstock by using a skewed sex ratio, spawning males multiple times (Busack 2007), and by pooling gametes. Pooling milt is especially problematic because when milt of several males is mixed and applied to eggs, a large portion of the eggs may be fertilized by a single male (Gharrett et al. 1985; Withler 1988). This problem can be avoided by more structured mating schemes such as 1-to-1 mating. Factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_b (Fiumera et al. 2004; Busack et al. 2007) over what would be achievable with less structured designs. Considerable benefit in N_b increase over what is achievable by 1-to-1 mating can be achieved through a factorial design as simple as a 2 x 2 (Busack et al. 2007).
- Ryman-Laikre effect. On a per-capita basis, a hatchery broodstock fish can often contribute many more progeny to a naturally spawning population than a naturally spawning fish can contribute This difference in reproductive contribution causes the composite N_b to be reduced, which is called a Ryman-Laikre (R-L) effect (Ryman et al. 1991; Ryman et al. 1995). The key factors determining the magnitude of the effect are the numbers of hatchery and natural spawners, and the proportion of natural spawners consisting of hatchery returnees.

The initial papers on the R-L effect required knowledge of N_b in the two spawning components of the population. Waples et al. (2016) have developed R-L equations suitable for a wide variety of situations in terms of knowledge base. A serious limitation of any R-L calculation however, is that it is a snapshot in time. What happens in subsequent generations depends on gene flow between the hatchery broodstock and the natural spawners. If a substantial portion of the broodstock are NO fish, the long-term effective size depression can be considerably less than would be expected from the calculated per-generation N_b.

Duchesne et al. (2002), Tufto et al. (2003), and Wang et al. (2001) have developed analytical approaches to deal with the effective-size consequences of multiple generations of interbreeding between HO and NO fish. One interesting result of these models is that effective size reductions caused by a hatchery program can easily be countered by low levels of gene flow from other populations. Tufto (2017) recently provided us with R code (R Core Team 2019) updates to the Tufto et al. (2003) method that yield identical answers to the Duchesne et al. (2002) method, and we use an R (R Core Team 2019) program incorporating them to analyze the effects of hatchery programs on effective size.

Inbreeding depression, another N_e-related phenomenon, is a reduction in fitness and survival caused by the mating of closely related individuals (e.g., siblings, half-siblings, cousins). Related individuals are genetically similar and produce offspring characterized by low genetic variation, low heterozygosity, lower survival, and increased expression of recessive deleterious mutations (Frankham et al. 2010; Allendorf et al. 2013; Rollinson et al. 2014; Hedrick et al. 2016). Lowered fitness due to inbreeding depression exacerbates genetic risk relating to small population size and low genetic variation which further shifts a small population toward extinction (Nonaka et al. 2019). The protective hatchery environment masks the effects of inbreeding which becomes apparent when fish are released into the natural environment and experience decreased survival (Thrower et al. 2009). Inbreeding concerns in salmonids related to hatcheries have been reviewed by Wang et al. (2002) and Naish et al. (2007).

N_e affects the level of inbreeding in a population, as the likelihood of matings between close relatives is increased in populations with low numbers of spawners. Populations exhibiting high levels of inbreeding are generally found to have low N_e (Dowell Beer et al. 2019). Small populations are at increased risk of both inbreeding depression and genetic drift (e.g., Willi et al. 2006). Genetic drift is the stochastic loss of genetic variation, which is most often observed in populations with low numbers of breeders. Inbreeding exacerbates the loss of genetic variation by increasing genetic drift when related individuals with similar allelic diversity interbreed (Willoughby et al. 2015).

Hatchery populations should be managed to avoid inbreeding depression. If hatcheries produce inbred fish which return to spawn in natural spawning areas the low genetic variation and increased deleterious mutations can lower the fitness, productivity, and survival of the natural population (Christie et al. 2014). A captive population, which has been managed so genetic variation is maximized and inbreeding is minimized, may be used for a genetic rescue of a natural population characterized by low genetic variation and low Ne.

1.2.1.2.2. Biased/nonrepresentational sampling

Even if effective size is large, the genetic diversity of a population can be negatively affected by hatchery operations. Although many operations aspire to randomly use fish for spawning with respect to size, age, and other characteristics, this is difficult to do. For example, male Chinook salmon that mature precociously in freshwater are rarely if ever used as broodstock because they are not captured at hatchery weirs. Pressure to meet egg take goals is likely responsible for advancing run/spawn timing in at least some coho and Chinook salmon hatcheries (Quinn et al. 2002; Ford et al. 2006b). Ironically, random mating, a common spawning guideline for conservation of genetic diversity has been hypothesized to be effectively selecting for younger, smaller fish (Hankin et al. 2009).

The sampling examples mentioned thus far are more or less unintentional actions. There are also established hatchery practices with possible diversity consequences that are clearly intentional. A classic example is use of jacks in spawning, where carefully considered guidelines range from random usage to near exclusion of jacks (e.g., Seidel 1983; IDFG et al. 2020). Another is the deliberate artificial selection in the hatchery of summer and winter steelhead to smolt at one year of age, which has resulted in early spawning stocks of both ecotypes (Crawford 1979).

Another source of biased sampling is non-inclusion of precocious males in broodstock. Precociousness, or early male maturation, is an alternative reproductive tactic employed by Atlantic salmon (Baglinière et al. 1985; Myers et al. 1986), Chinook salmon (Bernier et al. 1993; Larsen et al. 2004), coho salmon (Iwamoto et al. 1984; Silverstein et al. 1992), steelhead (Schmidt et al. 1979; McMillan et al. 2012) , sockeye salmon (Ricker 1959), as well as several salmonid species in Asia and Europe (Dellefors et al. 1988; Kato 1991; Munakata et al. 2001; Morita et al. 2009).

Unlike anadromous males and females that migrate to the ocean to grow for a year or more before returning to their natal stream, precocious males generally stay in headwater reaches or migrate shorter distances downstream (Larsen et al. 2010) before spawning. They are orders of magnitude smaller than anadromous adults and use a ‘sneaker’ strategy to spawn with full size anadromous females (Fleming 1996). Precocious males are typically not subject to collection as broodstock, because of either size or location. Thus, to the extent this life history is genetically determined, hatchery programs culturing species that display precociousness unintentionally select against it.

The examples above illustrate the overlap between diversity effects and selection. Selection, natural or artificial, affects diversity, so could be regarded as a subcategory of within-population diversity. Analytically, here we consider specific effects of sampling or selection on genetic diversity. Broodstock collection or spawning guidelines that include specifications about non-random use of fish with respect to age or size, spawn timing, etc. (e.g., Crawford 1979) are of special interest. We consider general non-specific effects of unintentional selection due to the hatchery that are not related to individual traits in Section 1.2.1.4.

1.2.1.3. Among-population diversity/ Outbreeding effects

Outbreeding effects result from gene flow from other populations into the population of interest. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1997; Keefer et al. 2012; Westley et al. 2013). Natural straying serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources.

Hatchery fish may exhibit reduced homing fidelity relative to NO fish (Grant 1997; Quinn 1997; Jonsson et al. 2003; Goodman 2005), resulting in unnatural levels of gene flow into recipient populations from strays, either in terms of sources or rates. Based on thousands of coded-wire tag (CWT) recoveries, Westley et al. (2013) concluded that species propagated in hatcheries vary in terms of straying tendency: Chinook salmon > coho salmon > steelhead. Also, within Chinook salmon, “ocean-type” fish stray more than “stream-type” fish. However, even if hatchery fish home at the same level of fidelity as NO fish, their higher abundance relative to NO fish can cause unnaturally high gene flow into recipient populations.

Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997). Based on fundamental population genetic principles, a 1995 scientific workgroup convened by NMFS concluded that aggregate gene flow from non-native HO fish from all programs combined should be kept below 5 percent (Grant 1997), and this is the recommendation NMFS uses as a reference in hatchery consultations. It is important to note that this 5% criterion was developed independently and for a different purpose than the HSRG’s 5% pHOS criterion that is presented in Section 1.2.1.4.

Gene flow from other populations can increase genetic diversity (e.g., Ayllon et al. 2006), which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population’s level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland et al. 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICBTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstock.

In addition, unusual high rates of straying into other populations within or beyond the population’s MPG, salmon ESU, or a steelhead DPS, can have a homogenizing effect, decreasing intra-population genetic variability (e.g., Vasemagi et al. 2005), and increasing risk to population diversity, one of the four attributes measured to determine population viability (McElhany et al. 2000). The practice of backfilling — using eggs collected at one hatchery to compensate for egg shortages at another—has historically a key source of intentional large-scale “straying”. Although it now is generally considered an unwise practice, it still is common.

There is a growing appreciation of the extent to which among-population diversity contributes to a “portfolio” effect (Schindler et al. 2010), and lack of among-population genetic diversity is considered a contributing factor to the depressed status of California Chinook salmon populations (Carlson et al. 2011; Satterthwaite et al. 2015). Eldridge et al. (2009) found that among-population genetic diversity had decreased in Puget Sound coho salmon populations during several decades of intensive hatchery culture.

As discussed in Section 1.2.1.4, pHOS[78] is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze outbreeding effects.

Adult salmon may wander on their return migration, entering and then leaving tributary streams before spawning (Pastor 2004). These “dip-in” fish may be detected and counted as strays, but may eventually spawn in other areas, resulting in an overestimate of the number of strays that potentially interbreed with the natural population (Keefer et al. 2008). On the other hand, “dip-ins” can also be captured by hatchery traps and become part of the broodstock.

Strays may not contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (e.g., Saisa et al. 2003; Blankenship et al. 2007). The causes of poor reproductive success of strays are likely similar to those responsible for reduced productivity of HO fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Reisenbichler et al. 1977; Leider et al. 1990; Williamson et al. 2010).

1.2.1.4. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[79]), the third major area of genetic effects of hatchery programs that NMFS analyses, occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with HO fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program.

Hatchery-influenced selection can range from relaxation of selection that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to

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[78] It is important to reiterate that as NMFS analyzes them, outbreeding effects are a risk only when the HO fish are from a *different* population than the NO fish.

[79] We prefer the term “hatchery-influenced selection” or “adaptation to captivity” (Fisch et al. 2015) to “domestication” because in discussions of genetic risk in salmon “domestication” is often taken as equivalence to species that have been under human management for thousands of years; e.g., perhaps 30,000 yrs for dogs (Larson et al. 2014), and show evidence of large-scale genetic change (e.g., Freedman et al. 2016). By this standard, the only domesticated fish species is the carp (*Cyprinus carpio*) (Larson et al. 2014). “Adaptation to captivity”, a term commonly used in conservation biology (e.g., Frankham 2008), and becoming more common in the fish literature (Christie et al. 2011; Allendorf et al. 2013; Fisch et al. 2015) is more precise for species that have been subjected to semi-captive rearing for a few decades. We feel “hatchery-influenced selection” is even more precise, and less subject to confusion.

intentional selection for desired characteristics (Waples 1999), but in this section, for the most part, we consider hatchery-influenced selection effects that are general and unintentional. Concerns about these effects, often noted as performance differences between HO and NO fish have been recorded in the scientific literature for more than 60 years (Vincent 1960, and references therein).

Genetic change and fitness reduction in natural salmon and steelhead due to hatchery-influenced selection depends on:

- The difference in selection pressures presented by the hatchery and natural environments. Hatchery environments differ from natural environments in many ways (e.g., Thorpe 2004) Some obvious ones are food, density, flows, environmental complexity, and protection from predation.
- How long the fish are reared in the hatchery environment. This varies by species, program type, and by program objective. Steelhead, coho and "stream-type" Chinook salmon are usually released as yearlings, while "ocean-type" Chinook, pink, and chum salmon are usually released at younger ages.
- The rate of gene flow between HO and NO fish, which is usually expressed as pHOS for segregated programs and PNI for integrated programs.

All three factors should be considered in evaluating risks of hatchery programs. However, because gene flow is generally more readily managed than the selection strength of the hatchery environment, current efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between NO and HO fish[80]. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

1.2.1.4.1. Relative Reproductive Success Research

Although hundreds of papers in the scientific literature document behavioral, morphological and physiological differences between NO and HO fish, the most frequently cited research has focused on RRS of HO fish compared to NO fish determined through pedigree analysis. The influence of this type of research derives from the fact that it addresses fitness, the ability of the fish to produce progeny that will then return to sustain the population. The RRS study method is simple: genotyped NO and HO fish are released upstream to spawn, and their progeny (juveniles,

[80] Gene flow between NO and HO fish is often interpreted as meaning actual matings between NO and HO fish. In some contexts, it can mean that. However, in this document, unless otherwise specified, gene flow means contributing to the same progeny population. For example, HO spawners in the wild will either spawn with other HO fish or with NO fish. NO spawners in the wild will either spawn with other NO fish or with HO fish. But all these matings, to the extent they are successful, will generate the next generation of NO fish. In other words, all will contribute to the NO gene pool.

adults, or both) are sampled genetically and matched with the genotyped parents. In some cases, multiple-generation pedigrees are possible.

RRS studies can be easy to misinterpret (Christie et al. 2014) for at least three reasons:

- RRS studies often have little experimental power because of limited sample sizes and enormous variation among individual fish in reproductive success (most fish leave no offspring and a few leave many). This can lead to lack of statistical significance for HO:NO comparisons even if a true difference does exist. Kalinowski et al. (2005) provide a method for developing confidence intervals around RRS estimates that can shed light on statistical power.
- An observed difference in RRS may not be genetic. For example, Williamson et al. (2010) found that much of the observed difference in reproductive success between HO and NO fish was due to spawning location; the HO fish tended to spawn closer to the hatchery. Genetic differences in reproductive success require a multiple generation design, and only a handful of these studies are available.
- The history of the natural population in terms of hatchery ancestry can bias RRS results. Only a small difference in reproductive success of HO and NO fish might be expected if the population had been subjected to many generations of high pHOS (Willoughby et al. 2017).

For several years, the bulk of the empirical evidence of fitness depression due to hatchery-influenced selection came from studies of species that are reared in the hatchery environment for an extended period— one to two years—before release (Berejikian et al. 2004). Researchers and managers wondered if these results were applicable to species and life-history types with shorter hatchery residence, as it seemed reasonable that the selective effect of the hatchery environment would be less on species with shorter hatchery residence times (e.g., RIST 2009). Especially lacking was RRS information on "ocean-type" Chinook. Recent RRS work on Alaskan pink salmon, the species with the shortest hatchery residence time has found very large differences in reproductive success between HO and NO fish (Lescak et al. 2019; Shedd et al. 2022). The RRS was 0.42 for females and 0.28 for males (Lescak et al. 2019). This research suggests the "less residence time, less effect" paradigm should be revisited.

Collectively, some RRS results are now available for all eastern Pacific salmon species except sockeye salmon. Note that this is not an exhaustive list of references:

- Coho salmon (Theriault et al. 2011; Neff et al. 2015)
- Chum salmon (Berejikian et al. 2009)
- "Ocean-type" Chinook salmon (Anderson et al. 2012; Sard et al. 2015; Evans et al. 2019)
- "Stream-type" Chinook salmon (Ford et al. 2009; Williamson et al. 2010; Ford et al. 2012; Hess et al. 2012; Ford et al. 2015; Janowitz-Koch et al. 2018)

- Steelhead (Araki et al. 2007; Araki et al. 2009; Berntson et al. 2011; Christie et al. 2011)
- Pink salmon (Lescak et al. 2019; Shedd et al. 2022)

Although the size of the effect may vary, and there may be year-to-year variation and lack of statistical significance, the general pattern is clear: HO fish have lower reproductive success than NO fish.

As mentioned above, few studies have been designed to detect unambiguously a genetic component in RRS. Two such studies have been conducted with steelhead and both detected a statistically significant genetic component in steelhead (Araki et al. 2007; Christie et al. 2011; Ford et al. 2016a), but the two conducted with "stream-type" Chinook salmon (Ford et al. 2012; Janowitz-Koch et al. 2018) have not detected a statistically significant genetic component.

Detecting a genetic component of fitness loss in one species and not another suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between Chinook salmon and steelhead.[81] The possibility that steelhead may be more affected by hatchery-influenced selection than Chinook salmon by no means suggest that effects on Chinook are trivial, however. A small decrement in fitness per generation can lead to large fitness loss.

1.2.1.4.2. Hatchery Scientific Review Group (HSRG) Guidelines

Key concepts concerning the relationship of gene flow to hatchery-influenced selection were developed and promulgated throughout the Pacific Northwest by the Hatchery Scientific Review Group (HSRG), a congressionally funded group of federal, state, tribal, academic, and unaffiliated scientists that existed from 2000 to 2020. Because HSRG concepts have been so influential regionally, we devote the next few paragraphs to them.

The HSRG developed gene-flow guidelines based on mathematical models developed by Ford (2002) and by Lynch et al. (2001). Guidelines for segregated programs are based on pHOS, but guidelines for integrated programs also include PNI, which is a function of pHOS and pNOB. PNI is, in theory, a reflection of the relative strength of selection in the hatchery and natural environments; a PNI value greater than 0.5 indicates dominance of natural selective forces.

The HSRG guidelines (HSRG 2009b) vary according to type of program and conservation importance of the population. The HSRG used conservation importance classifications that were developed by the Willamette/Lower Columbia Technical Recovery Team (McElhany et al. 2003).[82] (Table 88). In considering the guidelines, we equate "primary" with a recovery goal of

[81] This would not be surprising. Although steelhead are thought of as being quite similar to the "other" species of salmon, genetic evidence suggests the two groups diverged well over 10 million years ago (Crête-Lafrenière et al. 2012).

[82] Development of conservation importance classifications varied among technical recovery teams (TRTs); for more

"viable" or "highly viable", and "contributing" with a recovery goal of "maintain". We disregard the guidelines for "stabilizing", because we feel they are inadequate for conservation guidance.

Table 88. HSRG gene flow guidelines (HSRG 2009b).

	Program classification	
Population conservation importance	Integrated	Segregated
Primary	PNI ≥ 0.67 and pHOS ≤ 0.30	pHOS ≤ 0.05
Contributing	PNI ≥ 0.50 and pHOS ≤ 0.30	pHOS ≤ 0.10
Stabilizing	Existing conditions	Existing conditions

Although they are controversial, the HSRG gene flow guidelines have achieved a considerable level of regional acceptance. They were adopted as policy by the Washington Fish and Wildlife Commission (WDFW 2009), and were recently reviewed and endorsed by a WDFW scientific panel, who noted that the "…HSRG is the primary, perhaps only entity providing guidance for operating hatcheries in a scientifically defensible manner…" (Anderson et al. 2020). In addition, HSRG principles have been adopted by the Canadian Department of Fisheries and Oceans, with very similar gene-flow guidelines for some situations (Withler et al. 2018)[83].

The gene flow guidelines developed by the HSRG have been implemented in areas of the Pacific Northwest for at most 15 years, so there has been insufficient time to judge their effect. They have also not been applied consistently, which complicates evaluation. However, the benefits of high pNOB (in the following cases, 100 percent) has been credited with limiting genetic change and fitness loss in supplemented Chinook populations in the Yakima (Washington) (Waters et al. 2015) and Salmon (Idaho) (Hess et al. 2012; Janowitz-Koch et al. 2018) basins.

Little work toward developing guidelines beyond the HSRG work has taken place. The only notable effort along these lines has been the work of Baskett et al. (2013), who developed a model very similar to that of Ford (2002), but added the ability to impose density-dependent survival and selection at different life stages. Their qualitative results were similar to Ford's, but

information, documents produced by the individual TRT's should be consulted.

[83] Withler et al. (2018) noted a non-genetic biological significance to a pHOS level of 30%. Assuming mating is random with respect to origin (HO or NO) in a spawning aggregation of HO and NO fish, NOxNO matings will comprise the majority of matings only if pHOS is less than 30%.

the model would require some revision to be used to develop guidelines comparable to the HSRG's.

NMFS has not adopted the HSRG gene flow guidelines per se. However, at present the HSRG guidelines are the only scientifically based quantitative gene flow guidelines available for reducing the risk of hatchery-influenced selection. NMFS has considerable experience with the HSRG guidelines. They are based on a model (Ford 2002) developed by a NMFS geneticist, they have been evaluated by a NMFS-lead scientific team (RIST 2009), and NMFS scientists have extended the Ford model for more flexible application of the guidelines to complex situations (Busack 2015) (Section 1.2.1.4.3).

At minimum, we consider the HSRG guidelines a useful screening tool. For a particular program, based on specifics of the program, broodstock composition, and environment, we may consider a pHOS or PNI level to be a lower risk than the HSRG would but, generally, if a program meets HSRG guidelines, we will typically consider the risk levels to be acceptable. However, our approach to application of HSRG concepts varies somewhat from what is found in HSRG documents or in typical application of HSRG concepts. Key aspects of our approach warrant discussion here.

1.2.1.4.2.1. PNI and segregated hatchery programs

The PNI concept has created considerable confusion. Because it is usually estimated by a simple equation that is applicable to integrated programs, and applied in HSRG guidelines only to integrated programs, PNI is typically considered to be a concept that is relevant only to integrated programs. This in turn has caused a false distinction between segregated and integrated programs in terms of perceptions of risk. The simple equation for PNI is:

$$PNI \approx pNOB / (pNOB + pHOS).$$

In a segregated program, pNOB equals zero, so by this equation PNI would also be zero. You could easily infer that PNI is zero in segregated programs, but this would be incorrect. The error comes from applying the equation to segregated programs. In integrated programs, PNI can be estimated accurately by the simple equation, and the simplicity of the equation makes it very easy to use. In segregated programs, however, a more complicated equation must be used to estimate PNI. A PNI equation applicable to both integrated and segregated programs was developed over a decade ago by the HSRG (HSRG 2009a, equation 9), but has been nearly completed ignored by parties dealing with the gene flow guidelines:

$$PNI \approx \frac{h^2 + (1.0 - h^2 + \omega^2) * pNOB}{h^2 + (1.0 - h^2 + \omega^2) * (pNOB + pHOS)},$$

where h^2 is heritability and ω^2 is the strength of selection in standard deviation units, squared. Ford (2002) used a range of values for the latter two variables. Substituting those values that created the strongest selection scenarios in his simulations (h^2 of 0.5 and ω^2 of 10), which is appropriate for risk assessment, results in:

$$PNI \approx \frac{0.5 + 10.5 * pNOB}{0.5 + 10.5 * (pNOB + pHOS)}$$

HSRG (2004b) offered additional guidance regarding isolated programs, stating that risk increases dramatically as the level of divergence increases, especially if the hatchery stock has been selected directly or indirectly for characteristics that differ from the natural population. More recently, the HSRG concluded that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs (HSRG 2014). This can be easily demonstrated using the equation presented in the previous paragraph: a pHOS of 0.05, the standard for a primary population affected by a segregated program, yields a PNI of 0.49, whereas a pHOS of 0.024 yields a PNI of 0.66, virtually the same as the standard for a primary population affected by an integrated program.

1.2.1.4.2.2. The effective pHOS concept

The HSRG recognized that HO fish spawning naturally may on average produce fewer adult progeny than NO spawners, as described above. To account for this difference, the HSRG (2014) defined *effective* pHOS as:

$$pHOS_{eff} = (RRS * HOS_{census}) / (NOS + RRS * HOS_{census}),$$

where RRS is the reproductive success of HO fish relative to that of NO fish. They then recommend using this value in place of $pHOS_{census}$ in PNI calculations.

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

In some cases, adjusting pHOS downward may be appropriate, particularly if there is strong evidence of a non-genetic component to RRS. Wenatchee spring Chinook salmon (Williamson et al. 2010) is an example case with potentially justified adjustment by RRS, where the spatial distribution of NO and HO spawners differs, and the HO fish tend to spawn in poorer habitat.

However, even in a situation like the Wenatchee spring Chinook salmon, it is unclear how much of an adjustment would be appropriate.

By the same logic, it might also be appropriate to adjust pNOB in some circumstances. For example, if hatchery juveniles produced from NO broodstock tend to mature early and residualize (due to non-genetic effects of rearing), as has been documented in some spring Chinook salmon and steelhead programs, the “effective” pNOB might be much lower than the census pNOB.

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

1.2.1.4.2.3. Gene flow guidelines in phases of recovery

In 2012 the HSRG expanded on the original gene flow guidelines/standards by introducing the concept of recovery phases for natural populations (HSRG 2012), and then refined the concept in later documents (HSRG 2014; 2015; 2017). They defined and described four phases:

1. Preservation
2. Re-colonization
3. Local adaptation
4. Fully restored

The HSRG provided guidance on development of quantitative “triggers” for determining when a population had moved (up or down) from one phase to another. As explained in HSRG (2015), in the preservation and re-colonization phase, no PNI levels were specified for integrated programs (Table 89). The emphasis in these phases was to “Retain genetic diversity and identity of the existing population”. In the local adaptation phase, when PNI standards were to be applied, the emphasis shifted to “Increase fitness, reproductive success and life history diversity through local adaptation (e.g., by reducing hatchery influence by maximizing *PNI*)”. The HSRG provided additional guidance in HSRG (2017), which encouraged managers to use pNOB to “…the extent possible…” during the preservation and recolonization phases.

Table 89. HSRG gene flow guidelines/standards for conservation and harvest programs, based on recovery phase of impacted population (Table 2 from HSRG 2015).

Natural Population		Hatchery Broodstock Management	
Designation	Status	Segregated	Integrated
Primary	Fully Restored	pHOS<5%	PNI>0.67
	Local Adaptation	pHOS<5%	PNI>0.67
	Re-colonization	pHOS<5%	Not Specified
	Preservation	pHOS<5%	Not Specified
Contributing	Fully Restored	pHOS<10%	PNI>0.50
	Local Adaptation	pHOS<10%	PNI>0.50
	Re-colonization	pHOS<10%	Not Specified
	Preservation	pHOS<10%	Not Specified
Stabilizing	Fully Restored	Current Condition	Current Condition
	Local Adaptation	Current Condition	Current Condition
	Re-colonization	Current Condition	Current Condition
	Preservation	Current Condition	Current Condition

We have two concerns regarding the phases of recovery approach. First, although the phase structure is intuitively appealing, no scientific evidence was presented the HSRG for existence of the phases. Second, while we agree that conservation of populations at perilously low abundance may require prioritization of demographic over genetic concerns, we are concerned that high pHOS/low PNI regimes imposed on small recovering populations may prevent them from advancing to higher recovery phases[84]. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020). In response, the HSRG in issued revised guidance for the preservation and recolonization phases (HSRG 2020):

1. *Preservation – No specific pHOS or PNI recommendations, but hatchery managers are encouraged to use as many NOR brood as possible. In some cases (e.g., very low Recrutis per spawner (R/S) values at low spawner abundances or low intrinsic productivity), it may be preferable to use all available NORs in the hatchery brood and allow only extra hatchery-origin recruits (HORs) to spawn naturally.*
2. *Recolonization – No specific pHOS or PNI recommendations, but managers are encouraged to continue to use some NOR in broodstock (perhaps 10%-30% of NORs), while allowing the majority of NORs to spawn naturally.*

[84] According to Andy Appleby, past HSRG co-chair, the HSRG never intended this guidance to be interpreted as total disregard for pHOS/PNI standards in the preservation and recovery phases (Appleby 2020).

1.2.1.4.3. Extension of PNI modeling to more than two population components

The Ford (2002) model considered a single population affected by a single hatchery program—basically two population units connected by gene flow—but the recursion equations underlying the model are easily expanded to more than two populations (Busack 2015). This has resulted in tremendous flexibility in applying the PNI concept to hatchery consultations.

A good example is a system of genetically linked hatchery programs, an integrated program in which in which returnees from a (typically smaller) integrated hatchery program are used as broodstock for a larger segregated program, and both programs contribute to pHOS (Figure 85). It seems logical that this would result in less impact to the natural population than if the segregated program used only its own returnees as broodstock, but because the two-population implementation of the Ford model did not apply, there was no way to calculate PNI for this system.

Extending Ford's recursion equations (equations 5 and 6) to three populations allowed us to calculate PNI for a system of this type. We successfully applied this approach to link two spring Chinook salmon hatchery programs: Winthrop NFH (segregated) and Methow FH (integrated). By using some level of Methow returnees as broodstock for the Winthrop program, PNI for the natural population could be increased significantly[85](Busack 2015). We have since used the multi-population PNI model in numerous hatchery program consultations in Puget Sound and the Columbia basin, and have extended to it to include as many as ten hatchery programs and natural production areas.

[85] Such programs can lower the effective size of the system, but the model of Tufto (Section 1.2.1.4) can easily be applied to estimate this impact.

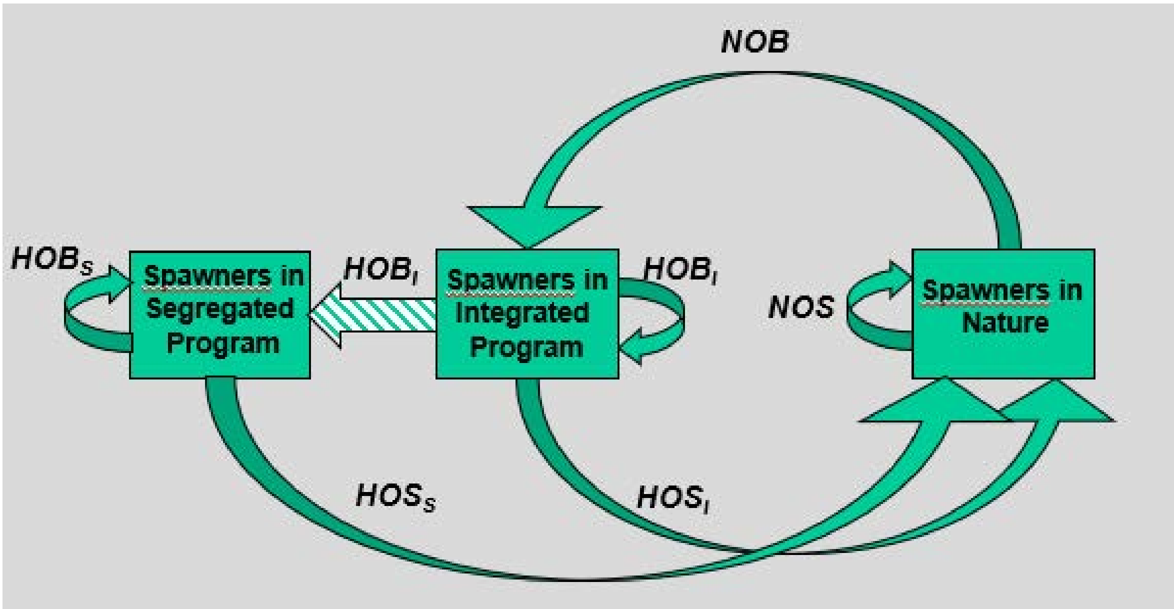


Figure 85. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOS$_I$) and a segregated program (HOS$_S$). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOB$_I$) as broodstock, but the segregated uses returnees from the integrated program (HOB$_I$ above striped arrow) as all or part of its broodstock, genetically linking the two programs. The system illustrated here is functionally equivalent to the HSRG's *(HSRG 2014)*"stepping stone" concept.

1.2.1.4.4. California HSRG

Another scientific team was assembled to review hatchery programs in California and this group developed guidelines that differed somewhat from those developed by the "Northwest" HSRG (California HSRG 2012). The California team:

Felt that truly isolated programs in which no HO returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept of segregated programs. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5 percent.

Rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as "the amount of spawning by NO fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between HO and NO fish, and societal values, such as angling opportunity."

Recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50 percent in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5 percent, even approaching 100 percent at times.

Recommended for conservation programs that pNOB approach 100 percent, but pNOB levels should not be so high they pose demographic risk to the natural population by taking too large a proportion of the population for broodstock.

1.2.2. Ecological effects

Ecological effects for this factor (i.e., hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds) refer to effects from competition for spawning sites and redd superimposition, contributions to marine-derived nutrients, and the removal of fine sediments from spawning gravels. Ecological effects on the spawning grounds may be positive or negative.

To the extent that hatcheries contribute added fish to the ecosystem, there can be positive effects. For example, when anadromous salmonids return to spawn, hatchery-origin and natural-origin alike, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production (Kline et al. 1990; Piorkowski 1995; Larkin et al. 1996; Gresh et al. 2000; Murota 2003; Quamme et al. 2003; Wipfli et al. 2003). As a result, the growth and survival of juvenile salmonids may increase (Hager et al. 1976; Bilton et al. 1982; Holtby 1988; Ward et al. 1988; Hartman et al. 1990; Johnston et al. 1990; Larkin et al. 1996; Quinn et al. 1996; Bradford et al. 2000; Bell 2001; Brakensiek 2002).

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

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences, such as increased competition, and potential for redd superimposition. Although males compete for access to females, female spawners compete for spawning sites. Essington et al. (2000) found that aggression of both sexes increases with spawner density, and is most intense with conspecifics. However, females tended to act aggressively towards heterospecifics as well. In particular, when there is spatial overlap between natural-and hatchery-origin spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of ESA-listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (e.g., Fukushima et al. 1998).

1.2.3. Adult Collection Facilities

The analysis also considers the effects from encounters with natural-origin fish that are incidental to broodstock collection. Here, NMFS analyzes effects from sorting, holding, and handling natural-origin fish in the course of broodstock collection. Some programs collect their broodstock from fish voluntarily entering the hatchery, typically into a ladder and holding pond, while others sort through the run at large, usually at a weir, ladder, or sampling facility. The more a hatchery program accesses the run at large for hatchery broodstock – that is, the more fish that are handled or delayed during migration – the greater the negative effect on natural- and hatchery-origin fish that are intended to spawn naturally and on ESA-listed species. The information NMFS uses for this analysis includes a description of the facilities, practices, and protocols for collecting broodstock, the environmental conditions under which broodstock collection is conducted, and the encounter rate for ESA-listed fish.

NMFS also analyzes the effects of structures, either temporary or permanent, that are used to collect hatchery broodstock, and remove hatchery fish from the river or stream and prevent them from spawning naturally, on juvenile and adult fish from encounters with these structures. NMFS determines through the analysis, for example, whether the spatial structure, productivity, or abundance of a natural population is affected when fish encounter a structure used for broodstock collection, usually a weir or ladder.

1.3. Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the migratory corridor, estuary, and ocean (Revised June 1, 2020)

NMFS also analyzes the potential for competition, predation, and disease when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas.

1.3.1. Competition

Competition and a corresponding reduction in productivity and survival may result from direct or indirect interactions. Direct interactions occur when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish, and indirect interactions occur when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (Rensel et al. 1984). Natural-origin fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, take up residency before natural-origin fry emerge from redds, and residualize.

Hatchery fish might alter natural-origin salmon behavioral patterns and habitat use, making natural-origin fish more susceptible to predators (Hillman et al. 1989; Steward et al. 1990). Hatchery-origin fish may also alter natural-origin salmonid migratory responses or movement patterns, leading to a decrease in foraging success by the natural-origin fish (Hillman et al. 1989; Steward et al. 1990). Actual impacts on natural-origin fish thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward et al. 1990).

Several studies suggest that salmonid species and migratory forms that spend longer periods of time in stream habitats (e.g., coho salmon and steelhead) are more aggressive than those that outmigrate at an earlier stage (Hutchison et al. 1997). The three least aggressive species generally outmigrate to marine (chum salmon) or lake (kokanee and sockeye salmon) habitats as post-emergent fry. The remaining (i.e., more aggressive) species all spend one year or more in stream habitats before outmigrating. Similarly, Hoar (1951) did not observe aggression or territoriality in fry of early migrants (chum and pink salmon), in contrast to fry of a later migrating species (coho salmon) which displayed high levels of both behaviors. Hoar (1954) rarely observed aggression in sockeye salmon fry, and observed considerably less aggression in sockeye than coho salmon smolts. Taylor (1990) found that Chinook salmon populations that outmigrate as fry are less aggressive than those that outmigrate as parr, which in turn are less aggressive than those that outmigrate as yearlings.

Although *intraspecific* interactions are expected to be more frequent/intense than *interspecific* interactions (e.g., Hartman 1965; Tatara et al. 2012), this apparent relationship between aggression and stream residence appears to apply to *interspecific* interactions as well. For example, juvenile coho salmon are known to be highly aggressive toward other species (e.g., Stein et al. 1972; Taylor 1991). Taylor (1991) found that coho salmon were much more aggressive toward size-matched *ocean*-type Chinook salmon (early outmigrants), but only moderately more aggressive toward size-matched *stream*-type Chinook salmon (later outmigrants). Similarly, the findings of Hasegawa et al. (2014) indicate that masu salmon (*O. masou*) , which spend 1 to 2 years in streams before outmigrating, dominate and outcompete the early-migrating chum salmon.

A few exceptions to this general stream residence-aggression pattern have been observed (e.g., Lahti et al. 2001; Young 2003; Hasegawa et al. 2004; Young 2004), but all the species and migratory forms evaluated in these studies spend one year or more in stream habitat before outmigrating. Other than the Taylor (1991) and Hasegawa et al. (2014) papers noted above, we are not aware of any other studies that have looked specifically at interspecific interactions between early-outmigrating species (e.g., sockeye, chum, and pink salmon) and those that rear longer in streams.

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

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a time near the release point. These non-migratory smolts (residuals) may compete for food and space with natural-origin juvenile salmonids of similar age (Bachman 1984; Tatara et al. 2012). Although this behavior has been studied and observed most frequently in hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well (Parkinson et al. 2017). Adverse impacts of residual hatchery Chinook and coho salmon on natural-origin salmonids can occur, especially given that the number of smolts per release is generally higher than for steelhead; however, residualism in these species has not been as widely investigated as it has in steelhead. Therefore, for all species, monitoring of natural stream areas near hatchery release points may be necessary to determine the potential effects of hatchery smolt residualism on natural-origin juvenile salmonids.

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

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile natural-origin fish in freshwater (Steward et al. 1990; California HSRG 2012)
- Rearing hatchery fish to a size sufficient to ensure that smoltification occurs
- Releasing hatchery smolts in lower river areas, below rearing areas used by natural-origin juveniles
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with natural-origin juveniles is likely

Critical information for analyzing competition risk is quality and quantity of spawning and rearing habitat in the action area,[86] including the distribution of spawning and rearing habitat by quality, and best estimates for spawning and rearing habitat capacity. Additional important information includes the abundance, distribution, and timing for naturally spawning hatchery fish and natural-origin fish; the timing of emergence; the distribution and estimated abundance for progeny from both hatchery and natural-origin natural spawners; the abundance, size,

[86] "Action area," in ESA section 7 analysis documents, means all areas to be affected directly or indirectly by the action in which the effects of the action can be meaningfully detected and evaluated.

distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

1.3.2. Predation

Predation is another potential ecological effect of hatchery releases. Predation, either direct (consumption by hatchery fish) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Here we consider predation by hatchery-origin fish, by the progeny of naturally spawning hatchery fish, and by birds and other non-piscine predators attracted to the area by an abundance of hatchery fish.

Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish released at a later stage that are more likely to migrate quickly to the ocean, can still prey on fry and fingerlings that are encountered during the downstream migration. Some of these hatchery fish do not emigrate and instead take up residence in the stream where they can prey on stream-rearing juveniles over a more prolonged period, as discussed above. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat.

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

Some reports suggest that hatchery fish can prey on fish that are as large as 1/2 their length (Hargreaves et al. 1986; Pearsons et al. 1999; HSRG 2004b and references therein), but other studies have concluded that salmonid predators prey on fish up to 1/3 their length (Horner 1978; Hillman et al. 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996; Daly et al. 2009). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

Size is an important determinant of how piscivorous hatchery-origin fish are. Keeley et al. (2001) reviewed 93 reports detailing the relationship between size and piscivory in 17 species of stream-dwelling salmonids. *O. mykiss* and Pacific salmon were well represented in the reviewed reports. Although there is some variation between species, stream-dwelling salmonids become piscivorous at about 100 mm FL, and then piscivory rate increases with increasing size. For example:

- For 140 mm fish, 15% would be expected to have fish in their diet but would not be primarily piscivorous; 2% would be expected to be primarily piscivorous (> 60% fish in diet).
- For 200 mm fish, those figures go to 32% (fish in diet) and 11% (primarily piscivorous).

The implication for hatchery-origin fish is pretty clear: larger hatchery-origin fish present a greater predation risk because more of them eat fish, and more of them eat primarily fish.

There are two key measures that hatchery programs can implement to reduce or avoid the threat of predation:

- Ensuring that a high proportion of the hatchery fish are fully smolted. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery- and natural-origin fish present within and downstream of release areas.
- Releasing hatchery smolts in lower river areas near river mouths and below upstream areas used for stream-rearing young-of-the-year naturally produced salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.

The two measures just mentioned will reduce minimize residualism as well as predation. The following measures can also help minimize residualism:

- Allowing smolts to exit the hatchery facility volitionally rather than forcing them out
- Ensuring that hatchery rearing regimes and growth rates produce fish that meet the minimum size needed for smolting, but are not so large as to induce desmoltification or early maturation
- Removing potential residuals based on size or appearance before release. This is likely impractical in most cases

1.3.3. Disease

The release of hatchery fish, as well as hatchery effluent, into juvenile rearing areas can lead to pathogen transmission; and contact with chemicals, or altering environmental conditions (e.g., dissolved oxygen) can result in disease outbreaks. Fish diseases can be subdivided into two main categories:

- Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites.
- Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by environmental factors (e.g., low dissolved oxygen), but can also have genetic causes.

Pathogens can be categorized as exotic or endemic. For our purposes, exotic pathogens are those that have little to no history of occurrence within the boundaries of the state where the hatchery program is located. For example, *Oncorhynchus masou* virus (OMV) would be considered an exotic pathogen if identified anywhere in Washington state because it is not known to occur there. Endemic pathogens are native to a state, but may not be present in all watersheds.

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

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

The last two terms above require some explanation. A continual pathogen reservoir is created when a standing crop of susceptible hosts keeps the pathogen from burning itself out. For example, stocking certain susceptible strains of trout can ensure that the pathogen is always present. Pathogen amplification occurs when densities of pathogens that are already present increase beyond baseline levels due to hatchery activities. A good example is sea lice in British Columbia (e.g., Krkošek 2010). The pathogen is endemic to the area and is normally present in wild populations, but salmon net pens potentially allow for a whole lot more pathogen to be produced and added to the natural environment.

Continual pathogen reservoir and pathogen amplification can exist at the same time. For example, stocked rainbow trout can amplify a naturally occurring pathogen if they become infected, and if stocking occurs every year, the stocked animals also can act as a continual pathogen reservoir.

Pathogen transmission between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Steward et al. 1990; Naish et al. 2007). This lack of reporting is because both hatchery and natural-origin salmon and trout are susceptible to the same pathogens (Noakes et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum*, the cause of Bacterial Kidney Disease).

Several state, federal, and tribal fish health policies, in some cases combined with state law, limit the disease risks associated with hatchery programs (IHOT 1995; ODFW 2003; USFWS 2004; NWIFC and WDFW 2006). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic pathogens. For example, the policy for Washington (NWIFC and WDFW 2006) divides the state into 14 Fish Health Management Zones[87] (FHMZs), and specifies requirements for transfers within and across FHMZs. Washington state law lists pathogens for which monitoring and reporting is required (regulated pathogens), and the Washington Department of Fish and Wildlife typically requires monitoring and reporting for additional pathogens. Reportable pathogen occurrence at a Washington hatchery is communicated to the state veterinarian, but also to fish health personnel at a variety of levels: local, tribal, state, and federal.

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

In addition to the state, federal, and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery through the treatment of incoming water (e.g., by using ozone), or by leaving the hatchery through hatchery effluent (Naish et al. 2007). Although preventing the exposure of fish to any pathogens before their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment compared to hatcheries likely reduces the risk of fish encountering pathogens at infectious levels (Naish et al. 2007).

[87] Puget Sound consists of five FHMZs, the Columbia basin only 1.

Treating the hatchery effluent reduces pathogen amplification, but does not reduce disease outbreaks within the hatchery caused by pathogens present in the incoming water supply. Another challenge with treating hatchery effluent is the lack of reliable, standardized guidelines for testing or a consistent practice of controlling pathogens in effluent (LaPatra 2003). However, hatchery facilities located near marine waters likely limit freshwater pathogen amplification downstream of the hatchery without human intervention because the pathogens are killed before transmission to fish when the effluent mixes with saltwater.

Noninfectious diseases are typically caused by environmental factors (e.g., low dissolved oxygen). Hatchery facilities routinely use a variety of chemicals for treatment and sanitation purposes. Chlorine levels in the hatchery effluent, specifically, are monitored with a National Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires regular monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent to ensure compliance with environmental standards and to prevent fish mortality.

In contrast to infectious diseases, which typically are manifest by a limited number of life stages and over a protracted time period, non-infectious diseases caused by environmental factors typically affect all life stages of fish indiscriminately and over a relatively short time period. Because of the vast literature available on rearing of salmon and trout in aquaculture, one group of non-infectious diseases that are expected to occur rarely in current hatchery operations are those caused by nutritional deficiencies

1.3.4. Ecological Modeling

While competition, predation, and disease are important effects to consider, they are events which can rarely, if ever, be observed and directly measured. However, these behaviors have been established to the point where NMFS can model these potential effects to the species based on known factors that lead to competition or predation occurring. In our Biological Opinions, we use the Predation, Competition, and Delayed Mortality (PCD) Risk model version 4.1.0 based on Pearsons et al. (2012). PCD Risk is an individual-based model that simulates the potential number of ESA-listed natural-origin juveniles lost to competition, predation, and delayed mortality (from disease, starvation, etc.) due to the release of hatchery-origin juveniles in the freshwater environment.

The PCD Risk model has undergone considerable modification since 2012 to increase supportability, reliability, transparency, and ease of use. Notably, the current version no longer operates as a compiled FORTRAN program in a Windows environment. The current version of the PCD Risk model (Version 4.1.0) is an R package (R Core Team 2019). A macro-enabled Excel workbook is included as an interface to the model that is used as a template for creating model scenarios, running the model, and reporting results. Users with knowledge of the R programming language have flexibility to develop and run more complex scenarios than can be created by the Excel template. The current model version no longer has a probabilistic mode for defining input parameter values. We also further refined the model by allowing for multiple hatchery release groups of the same species to be included in a single run.

There have also been a few recent modifications to the logic and parameterization of the model. The first was the elimination of competition equivalents and replacement of the disease function with a delayed mortality parameter. The rationale behind this change was to make the model more realistic; competition rarely directly results in death in the model because it takes many competitive interactions to suffer enough weight loss to kill a fish. Weight loss is how adverse competitive interactions are captured in the model. However, fish that lose competitive interactions and suffer some degree of weight loss are likely more vulnerable to mortality from other factors such as disease or predation by other fauna such as birds or bull trout. Now, at the end of each run, the competitive impacts for each fish are assessed, and the fish has a probability of delayed mortality based on the competitive impacts. This function will be subject to refinement based on research. For now, the probability of delayed mortality is equal to the proportion of a fish's weight loss. For example, if a fish has lost 10% of its body weight due to competition and a 50% weight loss kills a fish, then it has a 20% probability of delayed death, (0.2 = 0.1/0.5).

Another change in logic was to the habitat segregation parameter to make it size-independent or size-dependent based on hatchery species. Some species, such as coho salmon, are more aggressive competitors than other species, such as chum and sockeye salmon. To represent this difference in behavior more accurately in the model, for less aggressive species such as chum and sockeye salmon, hatchery fish segregation is random, whereas for more aggressive species, segregation occurs based on size, with the largest fish eliminated from the model preferentially.

1.3.5. Acclimation

One factor that can affect hatchery fish distribution and the potential to spatially overlap with natural-origin spawners, and thus the potential for genetic and ecological impacts, is the acclimation (the process of allowing fish to adjust to the environment in which they will be released) of hatchery juveniles before release. Acclimation of hatchery juveniles before release increases the probability that hatchery adults will home back to the release location, reducing their potential to stray into natural spawning areas.

Acclimating fish for a time also allows them to recover from the stress caused by the transportation of the fish to the release location and by handling. Dittman et al. (2008) provide an extensive literature review and introduction to homing of Pacific salmon. They note that, as early as the 19th century, marking studies had shown that salmonids would home to the stream, or even the specific reach, where they originated. The ability to home to their home or "natal" stream is thought to be due to odors to which the juvenile salmonids were exposed while living in the stream (olfactory imprinting) and migrating from it years earlier (Dittman et al. 2008; Keefer et al. 2014). Fisheries managers use this innate ability of salmon and steelhead to home to specific streams by using acclimation ponds to support the reintroduction of species into newly accessible habitat or into areas where they have been extirpated (Quinn 1997; Dunnigan 1999; YKFP 2008).

Dittman et al. (2008) reference numerous experiments that indicated that a critical period for olfactory imprinting is during the parr-smolt transformation, which is the period when the salmonids go through changes in physiology, morphology, and behavior in preparation for transitioning from fresh water to the ocean (Hoar 1976; Beckman et al. 2000). Salmon species with more complex life histories (e.g., sockeye salmon) may imprint at multiple times from emergence to early migration (Dittman et al. 2010). Imprinting to a particular location, be it the hatchery, or an acclimation pond, through the acclimation and release of hatchery salmon and steelhead is employed by fisheries managers with the goal that the hatchery fish released from these locations will return to that particular site and not stray into other areas (Fulton et al. 1981; Quinn 1997; Hard et al. 1999; Bentzen et al. 2001; Kostow 2009; Westley et al. 2013). However, this strategy may result in varying levels of success in regards to the proportion of the returning fish that stray outside of their natal stream. (e.g., (Kenaston et al. 2001; Clarke et al. 2011).

Increasing the likelihood that hatchery salmon and steelhead home to a particular location is one measure that can be taken to reduce the proportion of hatchery fish in the naturally spawning population. When the hatchery fish home to a particular location, those fish can be removed (e.g., through fisheries, use of a weir) or they can be isolated from primary spawning areas. Factors that can affect the success of acclimation as a tool to improve homing include:

- Timing acclimation so that a majority of the hatchery juveniles are going through the parr-smolt transformation during acclimation
- A water source distinct enough to attract returning adults
- Whether hatchery fish can access the stream reach where they were released
- Whether the water quantity and quality are such that returning hatchery fish will hold in that area before removal and/or their harvest in fisheries.

1.4. Factor 4. Research, monitoring, and evaluation that exists because of the hatchery program

NMFS analyzes proposed research, monitoring, and evaluation (RM&E) activities associated with proposed hatchery programs for their effects on listed species and designated critical habitat. Such activities include, but are not limited to, the following:

- Observation during surveying (in-water or from the bank)
- Collecting and handling (purposeful or inadvertent)

- Sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping, and observing the fish (in-water or from the bank)

Some RM&E actions may capture fish, induce injury, cause behavioral changes, and affect redds. Any negative effects from RM&E are weighed against the value of new information, particularly information that tests key assumptions and that reduces uncertainty. NMFS also considers the overall effectiveness of the RM&E program. There are five factors that we consider when assessing the beneficial and negative effects of hatchery RM&E:

- Status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat
- Critical uncertainties concerning effects on the species
- Performance monitoring to determine the effectiveness of the hatchery program at achieving its goals and objectives
- Identifying and quantifying collateral effects
- Tracking compliance of the hatchery program with the terms and conditions for implementing the program.

After assessing the proposed hatchery RM&E, and before making any recommendations to the action agency(s), NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost. The following subsections describe effects to listed fish species associated with typical RM&E activities and risk mitigation measures.

1.4.1. Observing

For some activities, listed fish and redds of listed fish are observed in-water (e.g., by snorkel surveys, wading surveys, or observation from the banks). Direct observation is the least disruptive method for determining a species' presence/absence and estimating its relative numbers. Effects of direct observation are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting fish behavior and causing minimal to no disturbance to redds. Fish frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors, and are typically not expected to significantly disrupt normal behavioral patterns or create the likelihood of injury.

Redds may be observed or encountered during some RM&E activities. Trained and knowledgeable surveyors are typically aware of risk reduction measures, such as not walking on redds, avoiding disturbance to nearby sediments and gravel, affording disturbed fish time and space to reach cover, and minimizing time present.

1.4.2. Capturing/handling

Any physical handling or psychological disturbance is known to be stressful to fish (Sharpe et al. 1998). Primary contributing factors to stress and death from handling are excessive doses of anesthetic, differences in water temperatures (between the river and holding vessel), dissolved oxygen conditions, the amount of time fish are held out of the water, and physical trauma. Stress increases rapidly if the water temperature exceeds 18ºC or dissolved oxygen is below saturation. Fish transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding in traps if the traps are not emptied regularly. Decreased survival can result from high stress levels, and may also increase the potential for vulnerability to subsequent challenges (Sharpe et al. 1998).

NMFS has developed general guidelines to reduce impacts when collecting listed adult and juvenile salmonids (NMFS 2000c; 2008b) that have been incorporated as terms and conditions into section 7 opinions and section 10 permits for research and enhancement. Additional monitoring principles for supplementation programs have been developed by Galbreath et al. (2008).

1.4.3. Fin clipping and tagging

Many studies have examined the effects of fin clips on fish growth, survival, and behavior. Although the results of these studies vary somewhat, it appears that generally fin clips do not alter fish growth (Brynildson et al. 1967; Gjerde et al. 1988). Mortality among fin-clipped fish is variable, but can be as high as 80 percent (Nicola et al. 1973). In some cases, though, no significant difference in mortality was found between clipped and un-clipped fish (Gjerde et al. 1988; Vincent-Lang 1993). The mortality rate typically depends on which fin is clipped. Recovery rates are generally higher for adipose- and pelvic-fin-clipped fish than for those that have clipped pectoral, dorsal, or anal fins (Nicola et al. 1973), probably because the adipose and pelvic fins are not as important as other fins for movement or balance (McNeil et al. 1979). However, some work has shown that fish without an adipose fin may have a more difficult time swimming through turbulent water (Reimchen et al. 2003; Buckland-Nicks et al. 2011).

In addition to fin clipping, two commonly available tags are available to differentially mark fish: passive integrated transponder (PIT) tags, and coded-wire tags (CWTs). PIT tags consist of small radio transponders that transmit an ID number when interrogated by a reader device.[88] CWTs

[88] The same technology, more commonly called RFID (radio frequency identification), is widely used in inventory control and to tag pets.

are small pieces of wire that are detected magnetically and may contain codes[89] that can be read visually once the tag is excised from the fish.

PIT tags are inserted into the body cavity of the fish just in front of the pelvic girdle. The tagging procedure requires that the fish be captured and extensively handled. Thus, tagging needs to take place where there is cold water of high quality, a carefully controlled environment for administering anesthesia, sanitary conditions, quality control checking, and a recovery tank.

Most studies have concluded that PIT tags generally have very little effect on growth, mortality, or behavior. Early studies of PIT tags showed no long-term effect on growth or survival (Prentice et al. 1984; Prentice et al. 1987; Rondorf et al. 1994). In a study between the tailraces of Lower Granite and McNary Dams (225 km), Hockersmith et al. (2000) concluded that the performance of yearling Chinook salmon was not adversely affected by orally or surgically implanted sham radio tags or PIT tags. However, (Knudsen et al. 2009) found that, over several brood years, PIT tag induced smolt-adult mortality in Yakima River spring Chinook salmon averaged 10.3 percent and was at times as high as 33.3 percent.

CWTs are made of magnetized, stainless-steel wire and are injected into the nasal cartilage of a salmon and thus cause little direct tissue damage (Bergman et al. 1968; Bordner et al. 1990). The conditions under which CWTs should be inserted are similar to those required for PIT tags. A major advantage to using CWTs is that they have a negligible effect on the biological condition or response of tagged salmon (Vander Haegen et al. 2005); however, if the tag is placed too deeply in the snout of a fish, it may kill the fish, reduce its growth, or damage olfactory tissue (Fletcher et al. 1987; Peltz et al. 1990). This latter effect can create problems for species like salmon because they use olfactory clues to guide their spawning migrations (Morrison et al. 1987).

Mortality from tagging is both acute (occurring during or soon after tagging) and delayed (occurring long after the fish have been released into the environment). Acute mortality is caused by trauma induced during capture, tagging, and release—it can be reduced by handling fish as gently as possible. Delayed mortality occurs if the tag or the tagging procedure harms the animal. Tags may cause wounds that do not heal properly, may make swimming more difficult, or may make tagged animals more vulnerable to predation (Howe et al. 1982; Matthews et al. 1990; Moring 1990). Tagging may also reduce fish growth by increasing the energetic costs of swimming and maintaining balance.

1.4.4. Masking

Hatchery actions also must be assessed for risk caused by masking effects, defined as when hatchery fish included in the Proposed Action are not distinguishable from other fish. Masking undermines and confuses RM&E, and status and trends monitoring. Both adult and juvenile

[89] Tags without codes are called blank wire tags (BWTs).

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

1.5. Factor 5. Construction, operation, and maintenance, of facilities that exist because of the hatchery program

The construction/installation, operation, and maintenance of hatchery facilities can alter fish behavior and can injure or kill eggs, juveniles, and adults. These actions can also degrade habitat function and reduce or block access to spawning and rearing habitats altogether. Here, NMFS analyzes changes to: riparian habitat, channel morphology, habitat complexity, in-stream substrates, and water quantity and quality attributable to operation, maintenance, and construction activities. NMFS also confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

1.6. Factor 6. Fisheries that exist because of the hatchery program

There are two aspects of fisheries that are potentially relevant to NMFS' analysis:

- Fisheries that would not exist but for the program that is the subject of the Proposed Action, and listed species are inadvertently and incidentally taken in those fisheries.
- Fisheries that are used as a tool to prevent the hatchery fish associated with the HGMP, including hatchery fish included in an ESA-listed salmon ESU or steelhead DPS, from spawning naturally.

"Many hatchery programs are capable of producing more fish than are immediately useful in the conservation and recovery of an ESU and can play an important role in fulfilling trust and treaty obligations with regard to harvest of some Pacific salmon and steelhead populations. For ESUs listed as threatened, NMFS will, where appropriate, exercise its authority under section 4(d) of the ESA to allow the harvest of listed hatchery fish that are surplus to the conservation and recovery needs of the ESU, in accordance with approved harvest plans" (NMFS 2005d). In any event, fisheries must be carefully evaluated and monitored based on the take, including catch and release effects, of ESA-listed species.

Appendix D

Mathematical relationship between a hatchery production increase and corresponding pHOS increase

This appendix describes the relationship between a hypothetical hatchery production increase and its effect on pHOS within an affected natural population. This relationship can be shown mathematically using the standard pHOS equation, in which NOS represents the abundance of natural-origin spawners, which we assume to be constant for this illustration. Using the standard pHOS equation with HOS_B representing abundance of hatchery-origin spawners before increasing production, pre-production increase pHOS ($pHOS_B$) is written as:

$$pHOS_B = \frac{HOS_B}{HOS_B + NOS} \quad (1)$$

After increasing hatchery spawners by I% from hatchery production increase, HOS_R represents the resultant abundance of hatchery-origin spawners. The resultant pHOS ($pHOS_R$) is written as:

$$pHOS_R = \frac{HOS_R}{HOS_R + NOS} \quad (2)$$

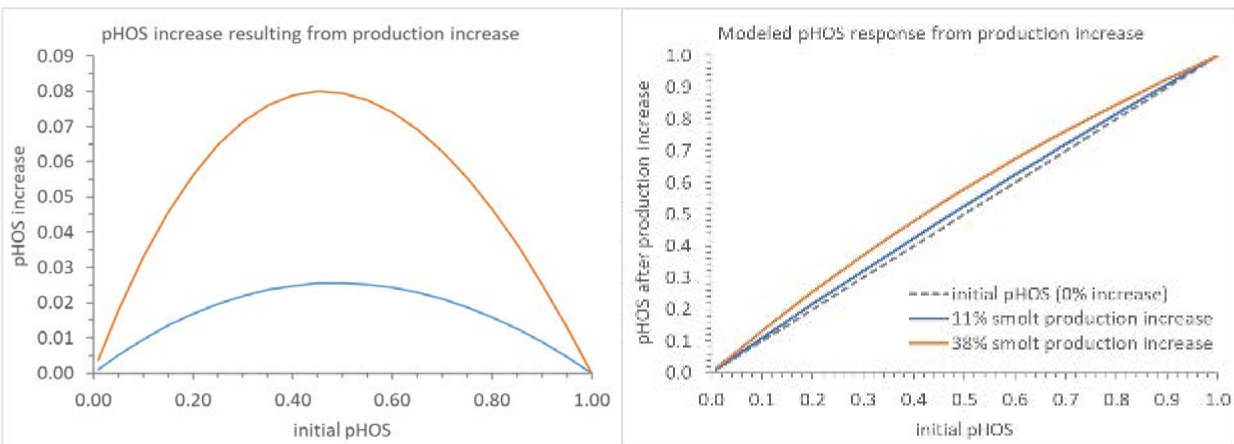
$pHOS_R$ can be calculated from $pHOS_B$ and I by first rearranging Equation 1 to solve for NOS:

$$NOS = \frac{HOS_B - (HOS_B \cdot pHOS_B)}{pHOS_B} \quad (3)$$

Next, in Equation 2, NOS can be substituted with the right side of Equation 3, and HOS_R can be substituted with ($HOS_B \cdot I$), where I is the percent increase in abundance of hatchery-origin spawners in the form of a proportion (e.g., 0.38 for a 38% increase). The resulting equation can be simplified to give:

$$pHOS_R = \frac{(I \ \cdot pHOS_B) + pHOS_B}{(I \cdot pHOS_B) + 1} \tag{4}$$

Equation 4 can be used to plot the relationship between initial pHOS ($pHOS_B$) and resulting pHOS ($pHOS_R$) following different levels of hatchery production increase (I), given the assumptions described above, as shown below:



Modeled pHOS increase (left panel) and resultant pHOS (right panel) for smolt production increases of 38% and 11% at a generalized population scale, assuming the abundance of hatchery-origin spawners increases by the same magnitude as the smolt production increase.

Appendix E

Estimating Hatchery-Wild Composition of Puget Sound and Columbia River Chinook Salmon

To provide a rough estimate the hatchery/wild composition of Puget Sound and Columbia River Chinook during the retrospective time frame used to evaluate the prey program (2009–2018), we can examine the mark-rate (adipose fin-clipped vs. adipose intact) of mature fish returning to their natal rivers from post-season Chinook FRAM model runs. These are years in which mass-marking (adipose fin clipping of all hatchery fish) was in place for most Chinook hatchery production in Puget Sound and the Columbia River, thus the mark-rate of overall returns can provide a rough estimate of the hatchery/wild composition. Here we used Chinook FRAM post-season validation runs based on base period calibration Round 7.1.1, and summarized the returns to the river for all Chinook FRAM model stocks[90] originating from Puget Sound of the Columbia River. Note that these estimates are for fish returning to the river, not for proportion of hatchery fish on the spawning grounds. Many hatchery-origin fish, particularly those from segregated (or isolated) programs, that return to natal rivers do not spawn in the wild because they are removed via weirs, other traps (e.g., off-channel hatchery collection ponds), or in-river fisheries.

There are some exceptions to the assumption that the mark rate of returning Chinook represents a suitable surrogate for the hatchery/wild composition, however, as not all hatchery production is entirely mass marked. For some stocks, including White River spring Chinook, Nooksack River spring Chinook, and Dungeness and Elwha Chinook, large portions or even all of the hatchery production was unclipped in the years being assessed. For other stocks, there are double index tag programs, which require releasing a number of unclipped coded-wire tagged hatchery fish commensurate with the number of clipped coded-wire tagged fish. As a result of this, not all unclipped returns can be considered to be hatchery fish. Conversely, there are also some stocks where wild fish get clipped and coded-wire tagged, including Lewis River Wild and Hanford Upriver Brights in the Columbia River, although the magnitude of these clipped wild fish being released is much less than the magnitude of unclipped hatchery fish being released.
One other consideration to note, if there is a desire to use these estimated mark-rates of returning fish as a surrogate for the mark rate or hatchery/wild composition of ocean abundances for these stocks, is that some stocks (particularly those from Puget Sound) are exposed to mark-selective fisheries in marine waters, where retention of adipose clipped Chinook is permitted, but unclipped Chinook must be released. This results in clipped fish being removed from the system at a higher rate than unclipped fish, so the mark-rate of Chinook in the ocean prior to exposure to these fisheries would be even higher. For all these reasons, it would be best to treat the mark-rate as a lower bound of an estimate of the hatchery proportion.

[90] https://framverse.github.io/fram_doc/calcs_appendices.html#Appendix_2_Chinook_FRAM_stocks

Table 1: Annual returns of unmarked and marked Chinook, in addition to the proportion marked for Columbia River and Puget Sound Chinook FRAM stocks.

	COLUMBIA RIVER			PUGET SOUND		
RETURN YEAR	UNMARKED	MARKED	% MARKED	UNMARKED	MARKED	% MARKED
2009	293,044	268,448	48%	41,448	122,531	75%
2010	408,631	561,661	58%	35,046	154,053	81%
2011	387,128	462,160	54%	32,582	164,621	83%
2012	303,143	420,193	58%	46,819	191,654	80%
2013	751,888	666,284	47%	43,427	174,670	80%
2014	693,572	649,907	48%	33,131	88,299	73%
2015	902,927	757,571	46%	41,766	115,661	73%
2016	496,745	361,734	42%	52,939	180,209	77%
2017	332,850	336,076	50%	61,945	246,981	80%
2018	198,355	223,685	53%	54,242	182,126	77%
2019	261,687	204,178	44%	45,068	149,468	77%
2020	372,892	372,531	50%	39,285	101,867	72%