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

Select Area Fisheries Enhancement (SAFE) Spring Chinook Salmon and Coho Salmon Programs

NMFS Consultation Number: WCRO-2025-00274

Action Agencies: Bonneville Power Administration (BPA)
National Marine Fisheries Service (NMFS)
U.S. Fish and Wildlife Service (USFWS)

Program Operators: Oregon Department of Fish and Wildlife (ODFW)
Washington Department of Fish and Wildlife (WDFW)
Clatsop County Fisheries (CCF)

Affected Species and Determinations:

ESA-Listed Species	**Status**	**Is Action Likely to Adversely Affect Species or Critical Habitat?**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
Lower Columbia River coho salmon (*Oncorhynchus kisutch*)	T	Yes	No	No
Lower Columbia River steelhead (*O. mykiss*)	T	Yes	No	No
Lower Columbia River Chinook salmon *(O. tshawytscha)*	T	Yes	No	No
Columbia River chum salmon (*O. keta*)	T	Yes	No	No
Upper Willamette Spring Chinook Salmon *(O. tshawytscha)*	T	Yes	No	No

Upper Willamette Winter Steelhead (*O. mykiss*)	T	No	No	No
Upper Columbia River spring-run Chinook salmon *(O. tshawytscha)*	E	No	No	No
Snake River spring/summer run Chinook salmon *(O. tshawytscha)*	T	Yes	No	No
Snake River fall-run Chinook salmon *(O. tshawytscha)*	T	No	No	No
Middle Columbia River steelhead (*O. mykiss*)	T	No	No	No
Upper Columbia River steelhead (*O. mykiss*)	T	No	No	No
Snake River Basin steelhead (*O. mykiss*)	T	No	No	No
Snake River sockeye salmon (*O. nerka*)	E	No	No	No
Eulachon (*Thaleichthys pacificus*)	T	No	No	No
Southern green sturgeon (*Acipenser medirostris*)	T	No	No	No
Southern Resident killer whale (*Orcinus orca*)	E	No	No	No

Fishery Management Plan That Describes Essential Fish Habitat (EFH) in the Project Area	**Does the Action Have an Adverse Effect on EFH?**	**Are EFH Conservation Recommendations Provided?**
Pacific Coast Salmon	No	No
Pacific Coast Groundfish	No	No
Coastal Pelagic Species	No	No

Consultation Conducted By: National Marine Fisheries Service, West Coast Region,
Sustainable Fisheries Division

Issued By:

Ryan J. Wulff
Assistant Regional Administrator for Sustainable Fisheries

Date: March 05, 2025

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1. Introduction

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

The underlying activities that drive the proposed action are the funding, operation and maintenance, and monitoring and evaluation of three hatchery programs for spring Chinook salmon and coho salmon in the Select Area Fisheries Enhancement (SAFE) project, which are produced (i.e., collected and reared) at various hatchery facilities in the Lower Columbia River and its tributaries, and acclimated and released from SAFE hatchery and net pen facilities (SAFE facilities) in the Lower Columbia River estuary. These three SAFE hatchery programs and SAFE facility operation and maintenance activities are collectively funded by the Bonneville Power Administration (BPA), National Marine Fisheries Service (NMFS), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), Clatsop County Fisheries (CCF), and U.S. Fish and Wildlife Service (USFWS). The hatchery facilities are primarily operated by ODFW, WDFW, and CCF. Each program is described in detail in a Hatchery and Genetic Management Plan (HGMP), which were submitted to the National Marine Fisheries Service (NMFS) for review. NMFS is evaluating these programs here under section 7 of the ESA.

The three SAFE programs that are the subject of this consultation are isolated harvest programs. The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg, Mahnken, and Iwamoto 2004). NMFS defines integrated hatchery programs as those that are reproductively connected or “integrated” with a natural population, promote natural selection over hatchery-influenced selection, contain genetic resources that represent the ecological and genetic diversity of a species, and are included in a salmon ESU or steelhead DPS. When a hatchery program actively maintains distinctions or promotes differentiation between hatchery fish and fish from a native population, then NMFS refers to the program as “isolated” (also referred to as segregated). Isolated programs promote domestication or selection in the hatchery over selection in the wild and may culture a stock of fish with phenotypes (e.g., different ocean migrations and spatial and temporal spawning distribution) different from the natural population.

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 ESA of 1973, as amended (16 U.S.C. 1531, et seq.), and implementing regulations at 50 CFR 402. The opinion documents consultation on the actions proposed by the action agencies and operators.

NMFS 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 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 (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through NMFS' Environmental Consultation Organizer (ECO). A complete record of this consultation is on file at the Sustainable Fisheries Division (SFD) of NMFS in Portland, Oregon.

1.2 CONSULTATION HISTORY

The first hatchery consultations in the Columbia Basin followed the first listings of Columbia Basin salmon under the Endangered Species Act (ESA). Snake River sockeye salmon were listed as an endangered species on November 20, 1991, Snake River spring/summer Chinook salmon and Snake River fall Chinook salmon were listed as threatened species on April 22, 1992, and the first hatchery consultation and opinion were completed on April 7, 1994 {NMFS, 1994 #697}. The 1994 opinion was superseded by "Endangered Species Act Section 7 Biological Opinion on 1995-1998 Hatchery Operations in the Columbia River Basin, Consultation Number 383" completed on April 5, 1995 (NMFS 1994). This opinion determined that hatchery actions jeopardize listed Snake River salmon and required implementation of reasonable and prudent alternatives (RPAs) to avoid jeopardy.

A new opinion was completed on March 29, 1999, after Upper Columbia River (UCR) steelhead were listed under the ESA (62 FR 43937, August 18, 1997) and following the expiration of the previous opinion on December 31, 1998 (NMFS 1999). That opinion concluded that Federal and non-Federal hatchery programs jeopardize Lower Columbia River (LCR) steelhead and Snake River steelhead protected under the ESA and described RPAs necessary to avoid jeopardy. Those measures and conditions included restricting the use of non-endemic steelhead for hatchery broodstock and limiting stray rates of non-endemic salmon and steelhead to less than 5% of the annual natural population in the receiving stream. Soon after, NMFS reinitiated consultation when LCR Chinook salmon, UCR spring Chinook salmon, Upper Willamette Chinook salmon, Upper Willamette steelhead, Columbia River chum salmon, and Middle Columbia steelhead were added to the list of endangered and threatened species (Smith 1999).

Between 1991 and the summer of 1999, the number of distinct groups of Columbia Basin salmon and steelhead listed under the ESA increased from 3 to 12, and this prompted NMFS to reassess its approach to hatchery consultations. In July 1999, NMFS announced that it intended to conduct five consultations and issue five opinions "instead of writing one biological opinion on all hatchery programs in the Columbia River Basin" (Smith 1999). Opinions would be issued for hatchery programs in the (1) Upper Willamette, (2) Middle Columbia River (MCR), (3) LCR, (4) Snake River, and (5) UCR, with the UCR NMFS' first priority (Smith 1999). Between August 2002 and October 2003, NMFS completed consultations under the ESA for approximately twenty hatchery programs in the UCR. For the MCR, NMFS completed a draft opinion, and distributed it to hatchery operators and to funding agencies for review on January 4, 2001, but completion of consultation was put on hold pending several important basin-wide review and planning processes.

The increase in ESA listings during the mid to late 1990s triggered a period of investigation, planning, and reporting across multiple jurisdictions and this served to complicate, at least from a resources and scheduling standpoint, hatchery consultations. A review of Federal funded hatchery programs ordered by Congress was underway at about the same time that the 2000

Federal Columbia River Power System (FCRPS) opinion was issued by NMFS (NMFS 2000). The Northwest Power and Conservation Council (Council) was asked to develop a set of coordinated policies to guide the future use of artificial propagation, and RPA 169 of the FCRPS opinion called for the completion of NMFS-approved hatchery operating plans (i.e., HGMPs) by the end of 2003. The RPA required the Action Agencies to facilitate this process, first by assisting in the development of HGMPs, and then by helping to implement identified hatchery reforms. Also at this time, a new *U.S. v. Oregon* Columbia River Fisheries Management Plan (CRFMP), which included goals for hatchery management, was under negotiation and new information and science on the status and recovery goals for salmon and steelhead was emerging from Technical Recovery Teams (TRTs). Work on HGMPs under the FCRPS opinion was undertaken in cooperation with the Council's Artificial Production Review and Evaluation process, with CRFMP negotiations, and with ESA recovery planning (Foster 2004; Jones Jr. 2002). HGMPs were submitted to NMFS under RPA 169; however, many were incomplete and, therefore, were not found to be sufficient for ESA consultation.

ESA consultations and an opinion were completed in 2007 for nine hatchery programs that produce a substantial proportion of the total number of salmon and steelhead released into the Columbia River annually. These programs are located in the LCR and MCR and are operated by the USFWS and by the Washington Department of Fish and Wildlife (WDFW). NMFS' opinion (NMFS 2007a) determined that operation of the programs would not jeopardize salmon and steelhead protected under the ESA.

On May 5, 2008, NMFS published a Supplemental Comprehensive Analysis (SCA) ((NMFS 2008e)) and an opinion and RPAs for the FCRPS to avoid jeopardizing ESA-listed salmon and steelhead in the Columbia Basin (NMFS 2008c). The SCA environmental baseline included "the past effects of hatchery operations in the Columbia River Basin. Where hatchery consultations have expired or where hatchery operations have yet to undergo ESA section 7 consultation, the effects of future operations cannot be included in the baseline. In some instances, effects are ongoing (e.g., returning adults from past hatchery practices) and included in this analysis despite the fact that future operations cannot be included in the baseline. The Proposed Action does not encompass hatchery operations per se, and therefore no incidental take coverage is offered through this biological opinion to hatcheries operating in the region. Instead, we expect the operators of each hatchery to address its obligations under the ESA in separate consultations, as required" (see NMFS 2008e, p. 5-40).

Because it was aware of the scope and complexity of ESA consultations facing the co-managers and hatchery operators, NMFS offered substantial advice and guidance to help with the consultations. In September 2008, NMFS announced its intent to conduct a series of ESA consultations and that "from a scientific perspective, it is advisable to review all hatchery programs (i.e., Federal and non-Federal) in the UCR affecting ESA-listed salmon and steelhead concurrently" (Walton 2008). In November 2008, NMFS expressed again the need for re-evaluation of UCR hatchery programs and provided a "framework for ensuring that these hatchery programs are in compliance with the Federal Endangered Species Act" (Jones Jr. 2008). NMFS also "promised to share key considerations in analyzing HGMPs" and provided those materials to interested parties in February 2009 (Jones Jr. 2009).

On April 28, 2010 (Walton 2010), NMFS issued a letter to "co-managers, hatchery operators, and hatchery funding agencies" that described how NMFS "has been working with co-managers throughout the Northwest on the development and submittal of fishery and hatchery plans in compliance with the Federal ESA." NMFS stated, "In order to facilitate the evaluation of hatchery and fishery plans, we want to clarify the process, including consistency with *U.S. v. Oregon*, habitat conservation plans and other agreements…." With respect to "Development of Hatchery and Harvest Plans for Submittal under the ESA," NMFS clarified: "The development of fishery and hatchery plans for review under the ESA should consider existing agreements and be based on best available science; any applicable multiparty agreements should be considered, and the submittal package should explicitly reference how such agreements were considered. In the Columbia River, for example, the *U.S. v. Oregon* agreement is the starting place for developing hatchery and harvest plans for ESA review…."

Beginning in 1991, listing of various Evolutionarily Significant Unit (ESUs) under the ESA complicated harvest management and severely limited execution of mixed-stock fisheries in the mainstem Columbia River. Regarding the SAFE Program, BPA, NMFS, ODFW, CCF, and WDFW have been focused on maximizing the commercial and recreational salmon fisheries potential of the Columbia River while minimizing impact on the recovering ESA-listed stocks. The SAFE project was originally conceived as part of the 1993 Strategy for Salmon, the Northwest Power Planning Council (NPPC, currently Northwest Power and Conservation Council, NPCC) recommended terminal-fishing sites be developed to allow harvest of known hatchery production while minimizing incidental harvest of weak stocks ("[f]und a study to evaluate potential terminal fishery sites and opportunities. This study should include: general requirements for developing those sites (*e.g.*, construction of acclimation/release facilities for hatchery smolts so that adult salmon would return to the area for harvest); the potential number of harvesters that might be accommodated; type of gear to be used; and other relevant information needed to determine the feasibility and magnitude of the program.") NMFS, in the Snake River Salmon Recovery Team and in the Proposed Recovery Plan for Snake River Salmon, also recommended terminal area fishing and selective fishing as the best harvest schemes for meaningful fishing opportunity where mixed-stock fisheries include weak, depressed, or endangered stocks. The SAFE Project was subsequently initiated and funded by BPA in 1993 to mitigate fisheries by providing the opportunity to harvest locally-produced salmon stocks in off-channel areas of the Columbia River.

In 1993, BPA completed an Environmental Assessment (EA) of Youngs Bay Salmon Rearing and Release Program under the National Environmental Policy Act (NEPA), and in 1994, prepared a categorical exclusion for research activities to identify and evaluate potential sites for expansion of the SAFE Project. In 1995, BPA completed an EA for expansion of the SAFE Project to include net pens in new sites, including Deep River, and issued a Finding of No Significant Impact (FONSI). On March 24, 1998, BPA and NMFS began informal ESA Section 7(a)(2) consultation. On July 23, 1998, BPA initiated formal Section 7 consultation with NMFS by submitting its Biological Assessment proposing to fund WDFW, ODFW, and CCF to investigate the feasibility of expanding the numbers of terminal fisheries sites in the Lower Columbia River in the study area downstream of river mile 49.

The first section 7 biological opinion was issued in 1998 while five species upriver of the SAFE project were proposed for listing: Upper Willamette steelhead, Mid-Columbia steelhead, Columbia River chum, Upper Willamette Spring Chinook, and Lower Columbia Fall Chinook. The re-initiation of formal consultation occurred in 1999 once those species were officially listed (64 CFR 14308). NMFS determined that the description of the SAFE project activities considered in the original 1998 opinion remained applicable. The opinion evaluated the effects of SAFE project operations for the first two phases: 2 years of initial research and investigation of potential sites, salmon stocks, and methodologies (including different net pen rearing regimes and harvest options), followed by roughly 8 years of expansion, and data monitoring. The final phase includes(d) the establishment of terminal fisheries operating at full capacity at all acceptable sites; however, this has been constrained by stock availability and funding limitations. BPA conducted a Supplemental Analysis to the 1995 EA/FONSI in 2010, for the increase of spring chinook and coho smolts released from the single, consolidated Deep River net pen site. In the time since its launch as a pilot study, the SAFE project, including these three SAFE programs, has evolved to include multiple funding and operating entities and complexities.

Non-treaty ocean, commercial, and recreational fishing of SAFE fish from SAFE areas (Buoy 10 to Bonneville Dam) was reported on in subsequent SAFE Reports (ODFW 2009, ODFW 2013, ODFW 2017c). Harvest of SAFE fish from select areas is covered over the years by the interim Management Agreement, the 2008-2017 *U.S. v. Oregon* Management Agreement, and the 2018-2027 *U.S. v. Oregon* Management Agreement (NMFS 2018b). Consultation with NOAA Fisheries regarding the 2008-2017 *U.S. v. Oregon* Management Agreement resulted in a biological opinion dated May 5, 2008 (NMFS 2008) with a finding of no significant impact (FONSI) for all activities described in the Management Agreement (including Select Area fisheries and test fishing research) (ODFW 2017c), and more recently resulted in an updated *U.S. v. Oregon* biological opinion (NMFS 2018a). Harvest-related production of SAFE fish is also a related activity partially covered in other opinions, including NMFS' biological opinion covering Mitchell Act funding ((NMFS 2024b) and the Upper Willamette River hatchery programs (NMFS 2019).

Between the years 2005-2017, co-managers submitted HGMPs for the Oregon Coho salmon and Oregon Chinook salmon, and the Washington Coho salmon SAFE Programs. Final HGMPs were submitted for formal review in 2017. The HGMPs were found to be sufficient for NMFS consideration in 2018.

On May 3, 2021, NMFS issued a new comprehensive biological opinion and reached a no jeopardy and no adverse modification conclusion after evaluating the funding, operation and maintenance, and monitoring and evaluation of three hatchery programs for spring Chinook salmon and coho salmon in the SAFE project, which are produced (i.e., collected and reared) at various hatchery facilities in the Lower Columbia River and its tributaries, and acclimated and released from SAFE hatchery and net pen facilities (SAFE facilities) in the Lower Columbia River estuary.

On June 6, 2024, NMFS informed the Bonneville Power Administration and U.S. Fish and Wildlife Service, by letter, that given NMFS' receipt of new information regarding the management of hatchery programs in the Lower Columbia River, the SAFE Opinion should be reinitiated. The 2021 SAFE Opinion (NMFS 2021) incorporated the pHOS limits for applicable natural populations from the 2017 Mitchell Act Opinion (NMFS 2017c). This was problematic because take associated with hatchery fish from the SAFE program and from other hatchery programs was not prescribed for the relevant incidental take statements for the ESA consultations.

In 2024, a new consultation (NMFS 2024b)was completed for the Mitchell Act-funded hatchery programs, with prescribed pHOS and PNI limits, as well as numerous additional measures addressing impacts to ESA-listed species, for these hatchery programs. As noted in the June 6, 2024, reinitiation letter from NMFS to the action agencies, the effects of the Mitchell Act programs occur in close proximity with the effects of the SAFE hatchery programs. This Opinion takes into consideration the 2024 Mitchell Act Opinion, while setting out separate limitations that apply solely to this action, as discussed in further detail below.

This opinion on the funding, operation and maintenance, and monitoring and evaluation of these three SAFE hatchery programs is based on latest HGMPs ((ODFW 2025b); (ODFW 2025a); WDFW 2018) and supplemental information (WDFW 2025, ODFW 2025) submitted to NMFS by the operators. This new biological opinion will supersede the 2021 SAFE Opinion.

1.3 PROPOSED ACTION

"Action," as applied under the ESA, means all activities, of any kind, authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). For EFH consultation, "Federal action" means any on-going or proposed action authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910). Because the actions of the Federal agencies are subsumed within the effects of the hatchery program, and any associated research, monitoring and evaluation, the details of each hatchery program are summarized in this section.

The proposed action is to fund the operators to: (1) acclimate and release juveniles from the SAFE spring Chinook salmon and coho salmon hatchery programs in the Lower Columbia River estuary at SAFE facilities, (2) monitor and evaluate these programs, and (3) operate and maintain the SAFE facilities. The federal funding provided by BPA, NMFS, and USFWS (Action Agencies) to the operators/co-managers for these activities helps support full implementation of these hatchery programs, as described, in brief, below and in (ODFW 2025b), (ODFW 2025a), and (WDFW 2025)(Table 1; Figure 1) in their entirety.

The USFWS provides funding through their Sport Fish Restoration Act (SFR Act, 16 U.S.C. §§ 777 to 777-k), to ODFW, to support the Salmon and Trout Enhancement Program (STEP) grant and other Office of Conservation Investment grants or activities. Thus, a portion of ODFW funded activities, as mentioned below, may be through annual grants administered by the USFWS. BPA provides funding under the Pacific Northwest Electric Power Planning and Conservation Act (Northwest Power Act). NMFS provides funding through the Pacific Salmon Treaty. Non-federal funding is also provided by ODFW, WDFW, and CCF. All of these combined funding sources are necessary in order for the operators to fully implement the three SAFE hatchery programs. Other funding may also support the production of SAFE hatchery fish since a variety of hatchery facilities are used throughout the Lower Columbia River and tributaries to implement the SAFE program, but this funding is ancillary to the funding specified above, and governed by ESA consultations as described below.

The operators' implementation of the SAFE programs in their entirety includes: (1) the use of hatchery facilities throughout the Lower Columbia River and its tributaries[1] for the collection and rearing of juvenile SAFE spring Chinook salmon and coho salmon, (2) transport of juveniles to SAFE facilities in the estuary, (3) acclimation and release of juveniles from SAFE facilities, (4) operation and maintenance of SAFE hatchery facilities and net pens, and (5) associated SAFE monitoring and evaluation activities. The details for the operators' production of SAFE hatchery fish is specified below and in Appendix A. Of these activities necessary for full implementation of the three SAFE programs, the operators' use of various hatchery facilities throughout the Lower Columbia River and tributaries to collect broodstock, take eggs, and rear juvenile salmon is necessary for the proposed action to occur, but not part of the proposed action covered in this opinion. ESA consultation has already been completed for the operation and funding of these hatchery facilities by NMFS (NMFS 2019 and 2024). The operation of these hatchery facilities is governed by those consultations; they are also used for the production of SAFE hatchery fish. The end result is the acclimation and release of hatchery fish from the SAFE facilities specified in Figure 1. The full details of the production of SAFE fish is further described below.

As previously noted, the SAFE programs operate in close proximity with other coho and Chinook programs in the Lower Columbia which were recently considered as part of the Mitchell Act Biological Opinion (NMFS 2024). Certain aspects of the SAFE programs, such as broodstock collection activities, are carried out in conjunction with the operation of Mitchell Act-funded programs, and the effects attributable to the SAFE programs overlap with that from other programs. While the conclusions of this Opinion pertain only to the SAFE programs, it will be necessary to discuss other programs where the actions or effects cannot be separated out.

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[1] Facilities used for SAFE production are described in WDFW and ODFW's respective HGMPs and supplemental information ((ODFW 2025b); (ODFW 2025a); ODFW 2025; WDFW 2018; WDFW 2025)

Table 1. Programs included in the Proposed Action.

Program	HGMP Date	Program Operator(s)	Funding Agencies	Program Type
SAFE Coho Salmon Program	October 19, 2017 May, 2021[2] February 2025	ODFW, CCF	BPA, NMFS, ODFW, CCF	Isolated harvest for fisheries supplementation
SAFE Spring Chinook Salmon Program	March 31, 2017 May 2021[2][1] February 2025	ODFW, CCF	BPA, NMFS, USFWS, ODFW, CCF	
SAFE Type-N Coho Salmon Program (terminating in 2025)	Deep River Type-N July 24, 2018[3]	WDFW	NMFS, WDFW	

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[2] ODFW and WDFW submitted HGMPs prior to the initial consultation of the SAFE program in 2021, and ODFW submitted a document with revised proposed management measures on January 17, 2025 (ODFW 2025).

[3] The last release of Deep River coho will occur in spring of 2025, and releases from this location will be discontinued. WDFW submitted a document revising the HGMPs on Jan 15, 2025(WDFW 2025).

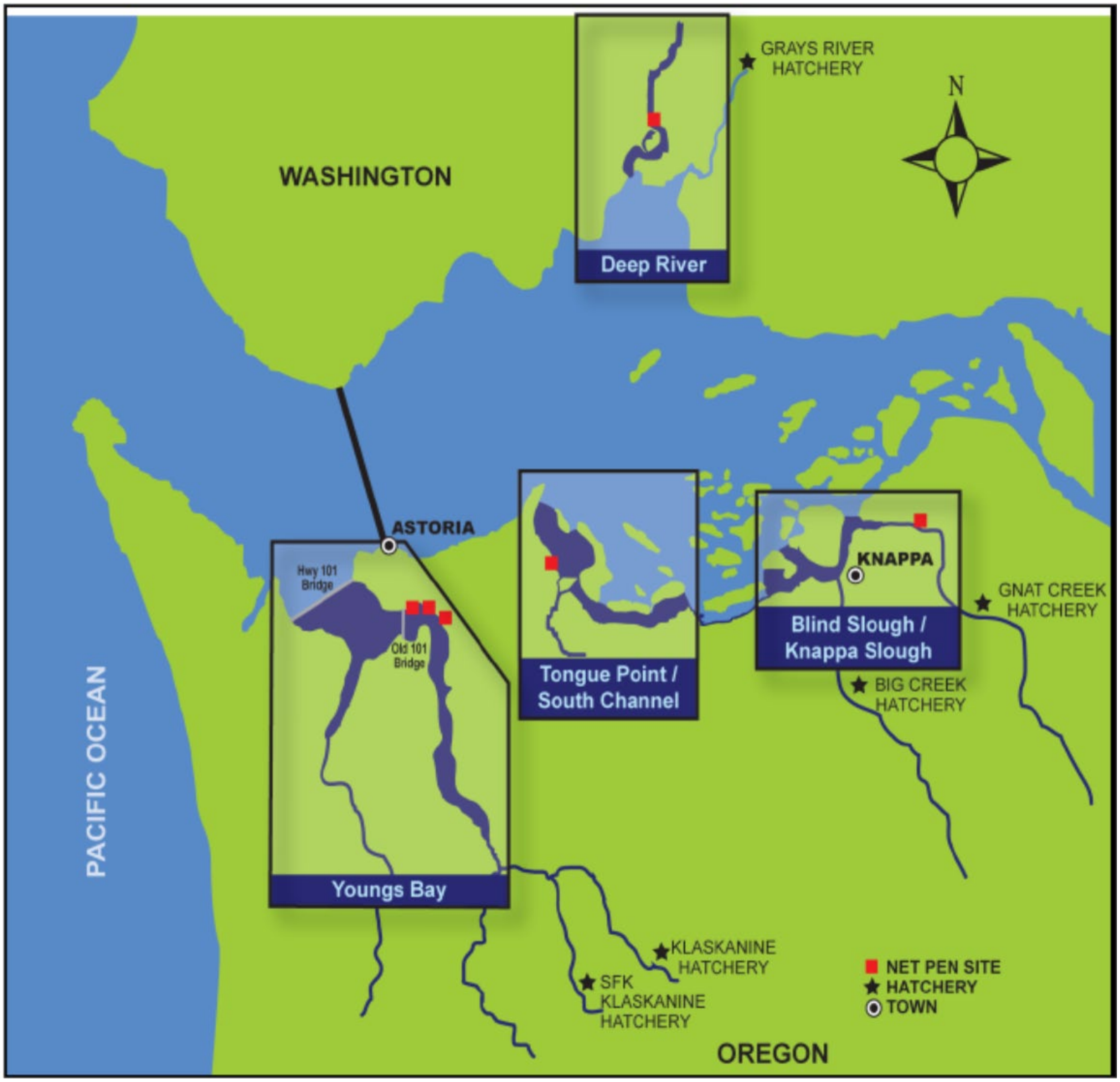

Figure 1. Locations where SAFE hatchery spring Chinook salmon and coho salmon are acclimated and released from net pens and other hatchery facilities in the Lower Columbia River estuary.

We considered, under the ESA, whether or not the proposed action would cause any other activities. This is not a simple or straightforward consideration for hatchery programs in the Columbia Basin, as such programs typically interact in various aspects of their operations, and most programs, including the SAFE programs considered here, are explicitly intended to provide fish for harvest. The primary purpose of the proposed action is to assist operators/co-managers with the full implementation of the SAFE programs (by funding acclimation and release at SAFE facilities, monitoring and evaluation, and SAFE facility O&M) such that SAFE hatchery salmon returning to the Lower Columbia River estuary are available for harvest. These commercial and recreational fisheries are an explicitly intended outcome of the production of SAFE hatchery fish. However, management of these fisheries is not entirely under the jurisdiction of the action agencies, and is subject to other management agreements among other co-managers responsible for fisheries management. Since ESA consultation has already been completed on the fisheries targeting SAFE returning salmon, these other opinions govern the allowable impacts (NMFS 2018a; NMFS 2018b) and are included in the Environmental Baseline section of the opinion below.

1.3.1 Proposed hatchery production and juvenile acclimation and release

To fully implement the SAFE programs, the operators and co-managers (CCF, ODFW, WDFW) propose to produce and release up to 3.795 million spring Chinook salmon smolts and up to 4.889 million coho salmon smolts annually[4] as described in the three HGMPs and updated documents ((ODFW 2025b); (ODFW 2025a); ODFW 2025; WDFW 2018; WDFW 2025)(where "production" includes collection and rearing and is an interrelated and interdependent action covered in other ESA consultations) for acclimation and release at the SAFE facilities that will continue to occur at the locations specified in those documents and shown in Figure 1. The operators' production proposal for the full implementation of the SAFE programs includes a 10% variability in actual smolt production releases due to variability in survival, growth, and other factors outside the control of the hatchery operators.

Broodstock to produce the hatchery smolt production specified above will all be hatchery-origin salmon collected at several ODFW- and WDFW-operated facilities (Table 2. Broodstock collection locations for the ODFW and WDFW SAFE programs.). The total return of hatchery salmon to these facilities is typically greater than the need and therefore allows for eggs to be taken from surplus returns for the SAFE program. As described above, the actual operation of these broodstock collection facilities, including interrelated and interdependent broodstock and egg collection and rearing actions, have already undergone ESA consultation for effects on ESA-listed salmon and steelhead and is currently governed by the Mitchell Act and Upper Willamette River Opinions (NMFS 2019 and 2024). This information is included here for clarity because it is an intended component of the action necessary for the full implementation of the SAFE program, and contextualizes the proposed action for acclimation and release activities covered by this opinion. For spring Chinook salmon production, broodstock is collected from the Clackamas, North Santiam River, and South Santiam River at hatchery facilities operated by ODFW. For coho salmon production, broodstock is collected from Big Creek, Beaver Creek, and Washington Cascade strata hatcheries (Cowlitz, Kalama, Lewis, and Washougal) by ODFW and WDFW (the Deep River program is being terminated after smolt release in 2025, and the final broodstock collection occurred in fall of 2023)). The Mitchell Act Opinion and other related consultations and corresponding incidental take statements cover certain operations of these facilities, thus are included as part of the environmental baseline below.

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[4] This includes WDFW's final coho release in 2025 and ODFW and CCF's spring Chinook and coho releases, as well as 10% for annual variability.

Table 2. Broodstock collection locations for the ODFW and WDFW SAFE programs.

Program	Stock	Collection Location
Spring Chinook Salmon (OR)	Clackamas River (ODFW Stock 19)	Clackamas Hatchery; North Fork Dam[1]
	North Fork Santiam River (ODFW Stock 21)	Minto Fish Collection Facility[2]
	South Fork Santiam River (ODFW Stock 24)	Foster Fish Collection Facility[2]
Coho Salmon (OR)	Big Creek (ODFW Stock 13)[3]	Big Creek Hatchery[1]
Coho Salmon (WA)	Elochoman. Backup: Cowlitz, Kalama, Lewis, Washougal River Type N[4]	Beaver Creek Hatchery. Backup: Cowlitz Hatchery, Kalama Falls Hatchery, Lewis River Hatchery, Washougal Hatchery

[1] The take associated with collecting brood at these facilities is governed by NMFS (2024).

[2] The take associated with collecting brood at these facilities are governed by NMFS (2019).

[3] Klaskanine and South Fork Klaskanine hatcheries functions include providing backup coho broodstock to Big Creek (Stock 13). Since these broodstock collection facilities will be used as a backup in the event of a brood stock collection shortage at Big Creek Hatchery, there is no definitive number of adults that will be collected for the program. To satisfy the proposed smolt production goal for the broodstock portion of the coho salmon program, about 3,000 pairs are needed.

[4] Broodstock collection for SAFE no longer occurs at Beaver Creek or Washington Cascade strata hatcheries because the program is terminating in 2025 and final broodstock collection has concluded.

For the production of spring Chinook salmon, as described above, NMFS and ODFW will coordinate through other hatchery production and harvest forums and consultations (NMFS 2024b) for Clackamas stock, *U.S. v. Oregon* harvest (NMFS 2018b), Willamette hatcheries (NMFS 2019b)) to appropriately adjust broodstock sources, annual production levels, and incorporation of harvest-related tools to avoid or decrease effects on ESA-listed fish from spring Chinook SAFE hatchery production. For the acclimation and release of spring Chinook salmon at SAFE facilities, as described in Section 1.3 above, NMFS proposes to continue providing Pacific Salmon Treaty funding, (currently supporting operator production and release of up to 1.5 million smolts), BPA proposes to continue providing Northwest Power Act funding (which currently supports operator production and release of up to 900,000 smolts), and USFWS proposes to continue providing Sport Fish Restoration Act funding. ODFW will continue to fund production and release of the remaining smolts, up to 1.9 million smolts. As described both above and below, the production activities in the Willamette River Basin (broodstock/egg collection and rearing activities) are covered by other consultations ((NMFS 2024b), NMFS 2019).

For the production of coho salmon, which as described above will no longer involve production by WDFW programs, NMFS, WDFW, and ODFW will coordinate through other hatchery production and harvest forums and consultations ((NMFS 2024b)and 2018b) to appropriately adjust broodstock sources, annual production levels, and incorporation of harvest-related tools to avoid or decrease effects on ESA-listed fish from coho SAFE hatchery production. For the acclimation and release of coho salmon at SAFE facilities, as described in Section 1.3 above, BPA proposes to continue providing Northwest Power Act funding. The specific production groups are further specified in Appendix A.

Fish health staff monitor the fish throughout their rearing cycle for signs of disease. Mortalities are checked daily and live grab samples are taken monthly. Fish are also tested prior to transfer to acclimation sites and before release. Spring Chinook salmon are also vaccinated at Gnat Creek Hatchery prior to arriving at net pens to help prevent vibriosis outbreaks. Coho salmon are vaccinated at approximately 100/lb for vibriosis and furunculosis once they are in the net pens. Sampling, testing, and treatment/control procedures are outlined in multiple documents (IHOT 1995) ; (PNFHPC 1989).

In the net pens, fish health is monitored daily and any mortalities are examined for signs of disease. If an outbreak occurs, pathology staff will take fish back to the lab for necropsy and gram stains, then recommend a treatment as needed, typically with medicated feed (TM-200). Usually, ODFW pathologists will receive samples to confirm the diagnosis. If significant losses occur in any of the net pens, mortalities are bagged, frozen, and put in the facility dumpster. No exchange of nets is made between different rearing sites, to minimize risk of disease transfer. All coho salmon are released volitionally. Spring Chinook salmon smolt are released from net pens once they show signs of wanting to leave (i.e., circling the pens) using methods which promote rapid emigration. Large high tides in late evening are preferred by CCF for releasing smolts as Ledgerwood et al. (1997) found that fish released near high tide emigrated out of Youngs Bay within one tidal cycle.

1.3.2 Proposed research, monitoring, and evaluation

Monitoring and evaluation (M&E) activities performed for these programs is funded by BPA through the SAFE project in Oregon and Washington (BPA Project #1993-06000). These activities will conclude for WDFW after the SAFE Type-N Coho Salmon Program is terminated in 2025. Additional monitoring elements necessary for evaluating the program effects are funded through the Coded Wire Tag (CWT) recovery project in Oregon (NOAA – Mitchell Act). The following goals of the SAFE programs to monitor and evaluate risks have been put in place:

- Up to 100% adipose fin clips, with between 2-16% CWT of coho salmon in Oregon and 45,000 coho salmon CWT in Washington.[5]
- Spawning ground surveys along with CWT analysis will be conducted in SAFE drainage streams to determine the extent of natural spawning of program fish.
- Local area streams will be monitored for natural and hatchery-origin coho escapement based on adipose fin clip identification and CWT will be collected for evaluation.
- Hatchery fish will be monitored through standard fish health production monitoring and reporting.
- Juvenile fish will be monitored monthly by a fish health expert and disposal of affected fish or eggs will be disposed of following Integrated Hatchery Operations Team (IHOT) policy.
- Available wild fish data will be obtained from juvenile and adult surveys by ODFW and WDFW[6] and other affiliates.

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[5] Adipose fin clip and CWT rates are considered goals and can vary depending on fish pathology/mortality and clipping and tagging quality which can alter the resulting clip and tag proportions. Each group of fish, distinguished by its stock, release timing and release location, has approximately 25,000 fish tagged with CWTs. The tag rate depends on the size of the release group.

[6] Monitoring specific to SAFE will be discontinued by WDFW after the final release of coho from Deep River.

1.3.3 Proposed operation, maintenance, and construction of hatchery facilities

Several routine maintenance activities occur in or near water that could impact fish in the area including: sediment/gravel removal/relocation from intake and/or outfall structures, pond cleaning, pump maintenance, debris removal from intake and outfall structures, and maintenance and stabilization of existing bank protection. All in-water maintenance activities considered "routine" for the purposes of this action will occur within existing structures or the footprint of areas that have already been impacted. When maintenance activities occur within water, they will comply with the following guidance:

- In-water work will:
    - Be done during the allowable freshwater work times established for each location, or comply with an approved variance of the allowable freshwater work times with the appropriate state agencies
    - Follow a pollution and erosion control plan that addresses equipment and material storage sites, fueling operations, staging areas, cement mortars and bonding agents, hazardous materials, spill containment and notification, and debris management
    - Cease if fish are observed in distress at any time as a result of the activities
    - Include notification of NMFS staff

- Equipment will:
    - Be inspected daily, and be free of leaks before leaving the vehicle staging area
    - Work above ordinary high water or in the dry whenever possible
    - Be sized correctly for the work to be performed and have approved oils / lubricants when working below the ordinary high water mark
    - Be staged and fueled in appropriate areas 150 feet from any water body
    - Be cleaned and free of vegetation before they are brought to the site and prior to removal from the project area net pens

Both the ODFW spring Chinook salmon and the coho salmon programs use net pens for some of the over-winter or two-week acclimation. These net pens are located in Youngs Bay, Tongue Point, and Blind Slough (Figure 1). Net pens at each rearing/acclimation/release site consist of two to four individual 6.1 m^2 inside dimension frames of high-density polyethylene pipe (33 cm) filled with Styrofoam. A wooden walkway of 2" x 12" lumber is bolted to the plastic frame for access. A 3.1 m deep net hung within each frame confines the fish during rearing and acclimation. Mesh sizes of 3.2-19.0 mm (0.125-0.750") are utilized and adjusted depending on fish size. Vertical plastic standpipes are submerged around the perimeter of each pen to maintain the shape of the net. Actual rearing area of each net is approximately 91 m^3 (3,200 ft^3). There are currently 76 pens at Youngs Bay, 37 at Tongue Point, and 15 at Blind Slough. Fish are grown and released from these pens under varying management and grow-out regimes including 2-week acclimation, over-winter, and full-term net-pen rearing (ODFW 2017b); (ODFW 2017a). The WDFW Coho salmon program uses Deep River net pens for acclimation starting in November through smoltification in March/April. The 40 net pens in Deep River each have a volume of 147 m^3 and mesh sizes used are appropriate to retain the fish until smolt stage is reached without premature escape. Predator measures of cover nettings and electrical grid fences are used to minimize predation impact (WDFW 2018). Releases from this location will end after the spring 2025.

No major catastrophic disasters related to net-pen rearing or related operational activities have occurred in the past, though several minor incidents, such as floating debris, have torn holes in nets allowing early escapement for a small number of fish. Net pens are checked for holes during regular washing schedules to prevent accidental releases, and net pen complexes are sufficiently constructed to avoid accidents due to adverse weather.

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 provide 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 non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

NMFS has determined the proposed action is not likely to adversely affect many ESA-listed species or their critical habitat. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations section (Section 2.12, below). These include the following species: Upper Willamette winter steelhead, Middle Columbia steelhead, Upper Columbia spring Chinook salmon and steelhead, Snake River fall Chinook and sockeye salmon and steelhead, eulachon, Southern green sturgeon, and Southern Resident killer whales.

2.1 ANALYTICAL APPROACH

This biological 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 reasonably 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 biological opinion relies on the 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 designation(s) of critical habitat for UWR Chinook Salmon ESU, LCR Chinook Salmon ESU, LCR Coho Salmon ESU, LCR Steelhead DPS, UWR Steelhead DPS, Columbia River Chum Salmon ESU, Snake River Spring/Summer-run Chinook Salmon ESU, Snake River Fall-run Chinook Salmon ESU, UCR Spring-run Chinook Salmon ESU, Snake River sockeye Salmon ESU, MCR Steelhead DPS, UCR Steelhead DPS, and Snake River Basin Steelhead DPS uses 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 biological 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). 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, 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 2.7**.**

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**.**8.

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 2.8), we conclude whether species are jeopardized or critical habitat is adversely modified (Section 2.9).

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.

2.2.1 Status of Listed Species

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).

Listed Salmonids

In describing the range-wide status of listed salmon and steelhead species, we rely on viability assessments, status reviews, and criteria in 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 2).

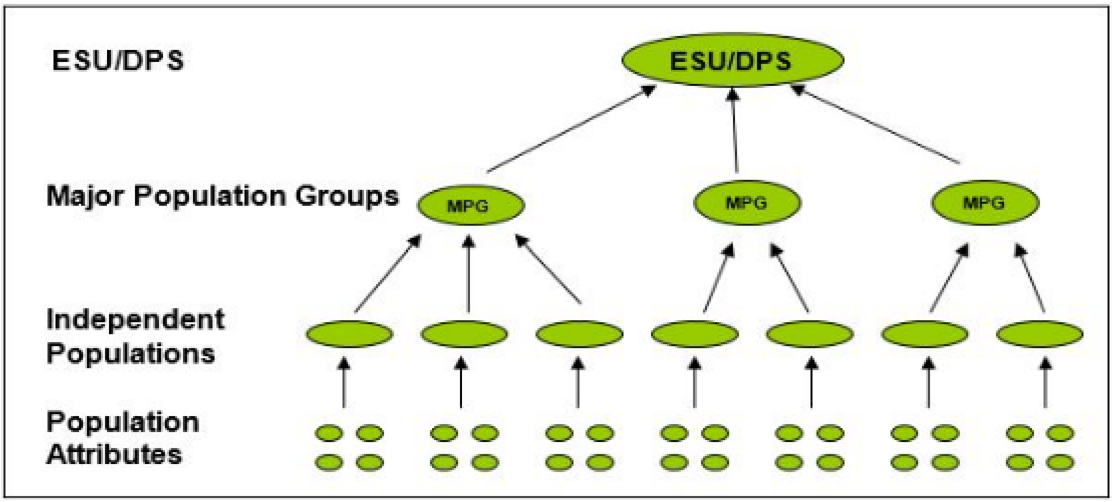

Figure 2. Hierarchical approach to ESU viability criteria.

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.

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 3). The LAA species analyzed in this consultation occur in five recovery domains and NLAA species occur in additional recovery domains as detailed in the NLAA section.

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.[7]

Although the TRTs dealing with anadromous fish species operated from the common set of biological principles 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.

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[7] 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.

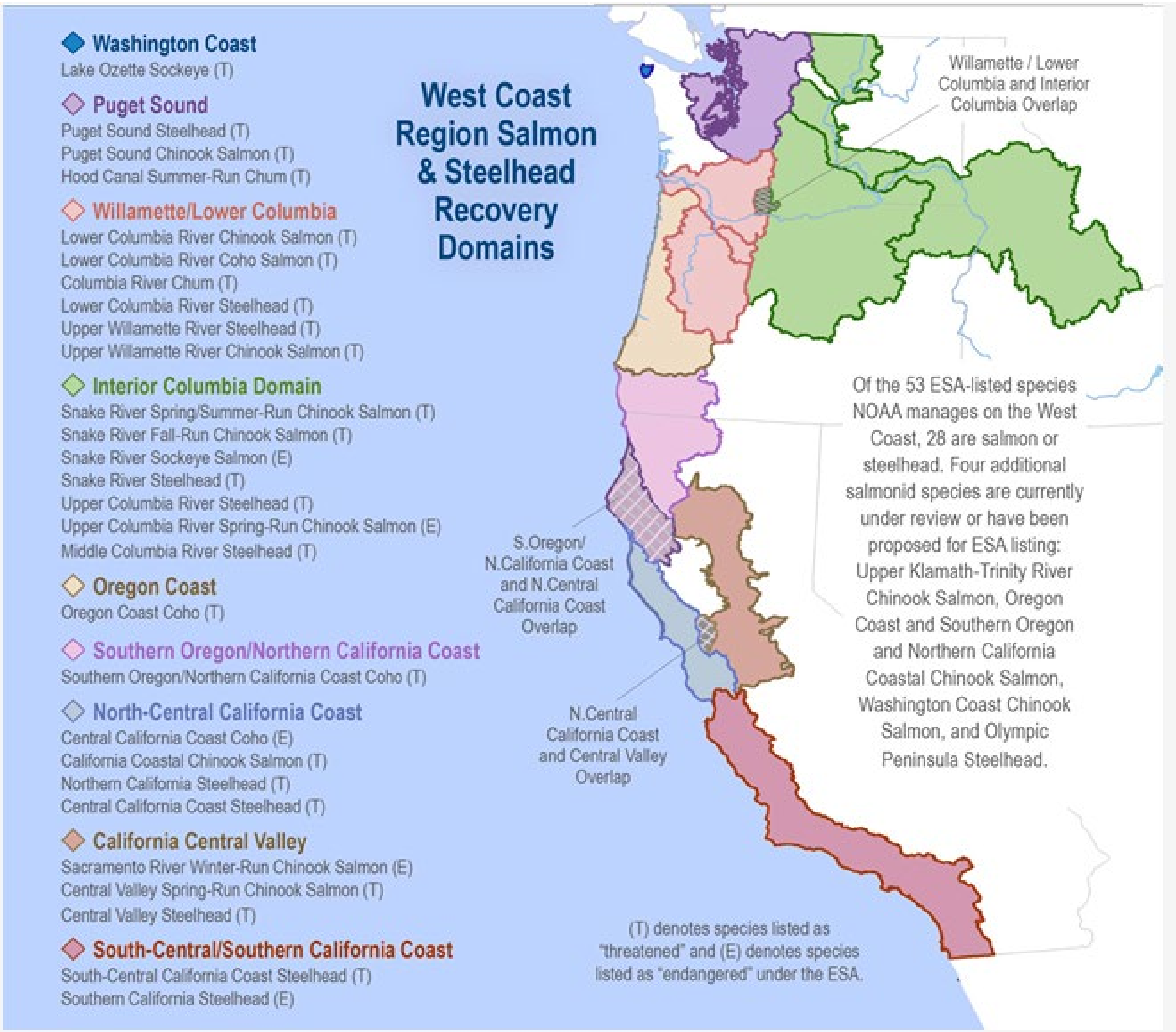

Figure 3. Map showing the range of NMFS' West Coast Region and the encompassed recovery domains for salmon and steelhead listed under the ESA. The ESUs and DPSs of ESA-listed salmon and steelhead addressed in this Opinion (either in the LAA or NLAA sections) are a subset of those listed on the left side of the figure. T indicates ESUs and DPSs that are listed as Threatened and E indicates an Endangered listing.

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, McElhany, and Ruckelshaus 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.

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 3. The TRTs identified 93 demographically independent populations of Pacific Chinook salmon (Table 3). 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 3. Chinook salmon ESA-listed salmon populations considered in this Opinion.

Recovery Domain	ESU	MPGs[a]	Populations
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
Totals	**8 ESUs**	**29**	**128**

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 2022i). Hatchery programs can affect naturally produced populations of salmon and steelhead in a variety of ways, including competition (for spawning sites and food) and predation effects, disease effects, genetic effects (e.g., outbreeding depression, hatchery-influenced selection), broodstock collection effects (e.g., to population diversity), and facility effects (e.g., water withdrawals, effluent discharge) (NMFS 2018b). 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 (NMFS 2005a).

Willamette/Lower Columbia Recovery Domain

Lower Columbia River Chinook Salmon ESU

On March 24, 1999, NMFS listed the LCR 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 LCR Chinook salmon was designated on September 2, 2005 (70 FR 52706). In 2022, NMFS completed its most recent 5-year review for LCR Chinook salmon (NMFS 2022b).

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 LCR Chinook Salmon ESU was released October 21, 2022 (NMFS 2022b), and this section summarizes the current findings, as updated by that review.

The LCR 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 UWR 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 (Table 4). These are distributed through three ecological zones[8]. A combination of life-history types, based on run timing and ecological zones, result in six MPGs. The run timing distributions across the 32 historical populations are: nine spring populations, 21 early-fall populations, and two late-fall populations (Table 6, Figure 4).

Within the geographic range of the Lower Columbia River Chinook Salmon ESU, 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 4), while the remaining programs are excluded (70 FR 37159; (NMFS 2022b)). For a detailed description of how NMFS evaluates and determines whether to include hatchery fish in an ESU or DPS, see NMFS (Bjorkstedt et al. 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 6). 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 2013b).

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 each year. 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 (Adicks 2013).

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) (Adicks 2013). 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.

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[8] 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).

Currently, the abundance of all fall Chinook salmon greatly exceeds that of the spring component (Ford 2022).

Table 4. Lower Columbia River Chinook Salmon ESU description and MPGs (Ford 2022); (NMFS 2022b). The designations "(C)" and "(G)" identify Core[a] and Genetic Legacy populations, respectively.

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 non-endemic 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 2022b). 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).

Table 5. Lower Columbia River Chinook salmon populations and recommended status under the recovery scenario (NMFS 2013b).

MPG	Population (State)	Contribution[b]	Recovery Scenario[a]	
			Target Persistence Probability	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]	Hd	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 (Adicks 2013).

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 (Adicks 2013).

[d] Oregon analysis indicates a low probability of meeting the delisting objectives for these populations.

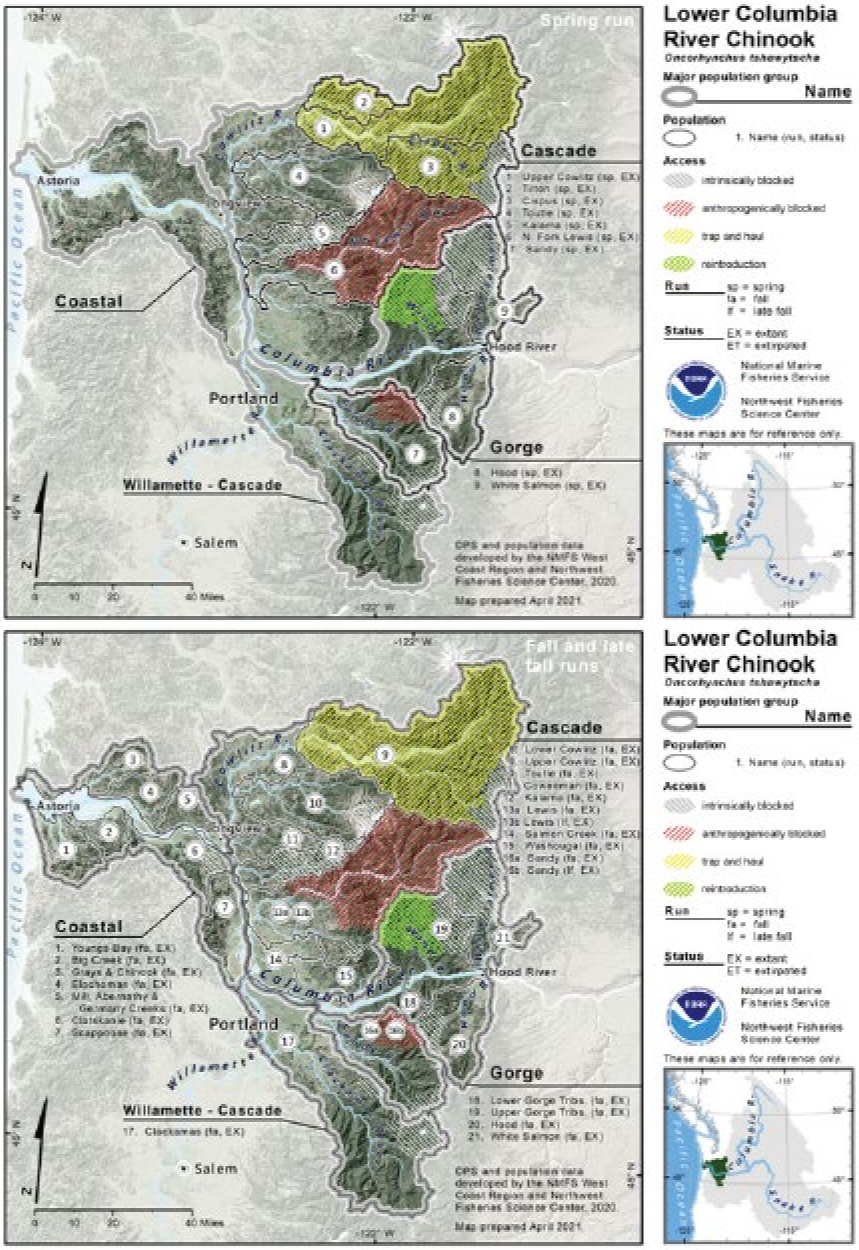


Figure 4. Maps of the Lower Columbia River Chinook Salmon ESU's spawning and rearing areas for Chinook salmon Demographically Independent Populations (DIPs or 'populations'), illustrating populations and MPGs. Several watersheds contain, or historically contained, both fall and spring runs. The upper figure illustrates spring-run populations and the lower figure illustrates fall-run populations (Ford 2022).

Table 6. 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

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 5. Additionally, Table 5 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 5 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 5 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 (2013b) 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 5) 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 7 captures the geometric mean of natural spawner counts available, indicating that in more recent years more populations are being monitored.

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 7) set in the recovery plan (refer above to Table 5). 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 5). Decreases in hatchery contribution were also noted for several populations. Relative to baseline VSP levels identified in the recovery plan (Adicks 2013), there has been an overall improvement in the status of a number of spring and fall-run populations (Table 7), 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 7. Current 5-year geometric mean of raw natural-origin spawner abundances compared to the recovery scenario presented in the recovery plan (Adicks 2013) 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
	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

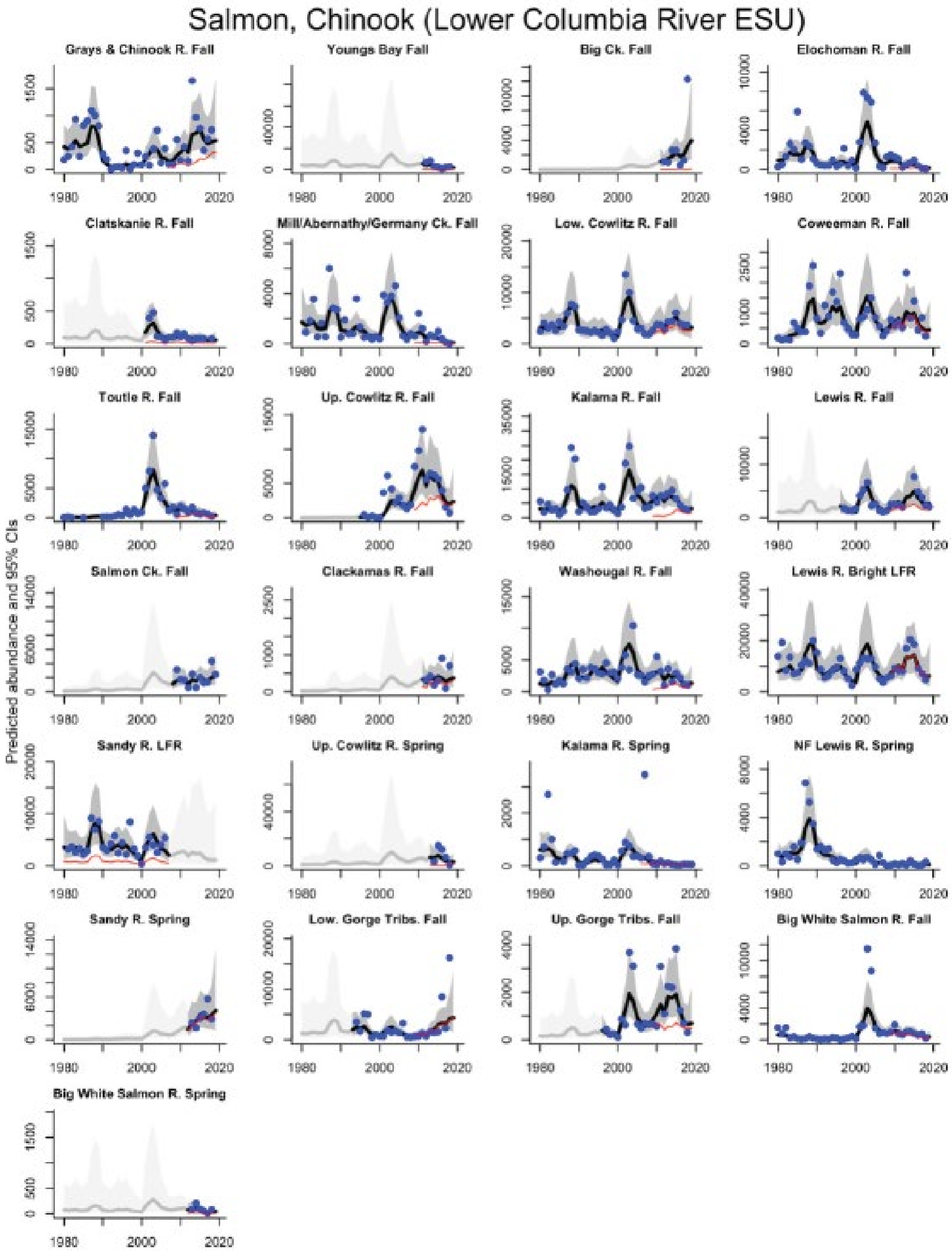


Figure 5. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other 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).

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 6). 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.

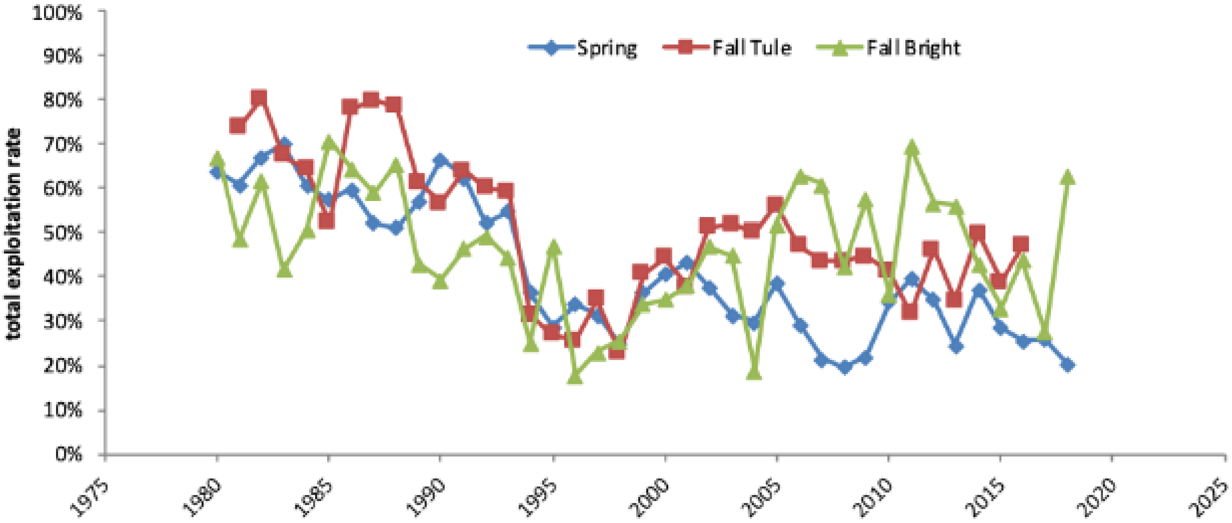


Figure 6. Total ERs on the three components of the Lower Columbia River Chinook salmon ESU (Ford 2022) (see Section 2.4, Environmental Baseline for geographic distribution of the ERs).

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.

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 2017f). 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 mid-2020s at the earliest.

Hatchery contributions remain high for a number of populations (Table 8), 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, UWR 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 2022b). Although several measures have been implemented to reduce risk, the pHOS remains high in the Coastal and Gorge MPGs (NMFS 2022b). 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 2017c). In the 2022 status review (NMFS 2022b), we concluded 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 2016a).

Table 8. 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
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 (Ford 2022).

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 2013b).

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 (Adicks 2013) 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 (Adicks 2013) includes details on large scale issues including:

- Ecological interactions,
- Changing environmental conditions, 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 (Adicks 2013) 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 into our analysis here, and the recovery plan is included in the record for this determination.

In our recent five-year status review (NMFS 2022b), 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 associated 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 2022b). Additionally, the risk to the species persistence from changing environmental conditions is an increasing concern (NMFS 2022b).

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 2022b).

Upper Willamette River Chinook Salmon ESU

On March 24, 1999, NMFS listed the UWR 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 UWR Chinook salmon (NMFS 2024a). 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 7). 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 9).

The UWR Chinook Salmon ESU only has one MPG (Table 9), containing the seven populations listed in Table 9. A recovery plan was finalized for this species on August 5, 2011 (ODFW and NMFS 2011). The broad sense recovery goal for the ESU is to achieve for all UWR 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 UWR 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 UWR 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 UWR basin (ODFW and NMFS 2011).

Table 9. Upper Willamette River Chinook Salmon ESU description and MPG (Jones 2015); (NWFSC 2015); (Ford 2022); (NMFS 2024a).

ESU Description	
Threatened	Listed under ESA in 1999; updated in 2014.
1 MPG	7 historical populations

ESU Description	
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 generalized life history traits of UWR Chinook salmon are summarized in Table 10. Typically, adult UWR 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).

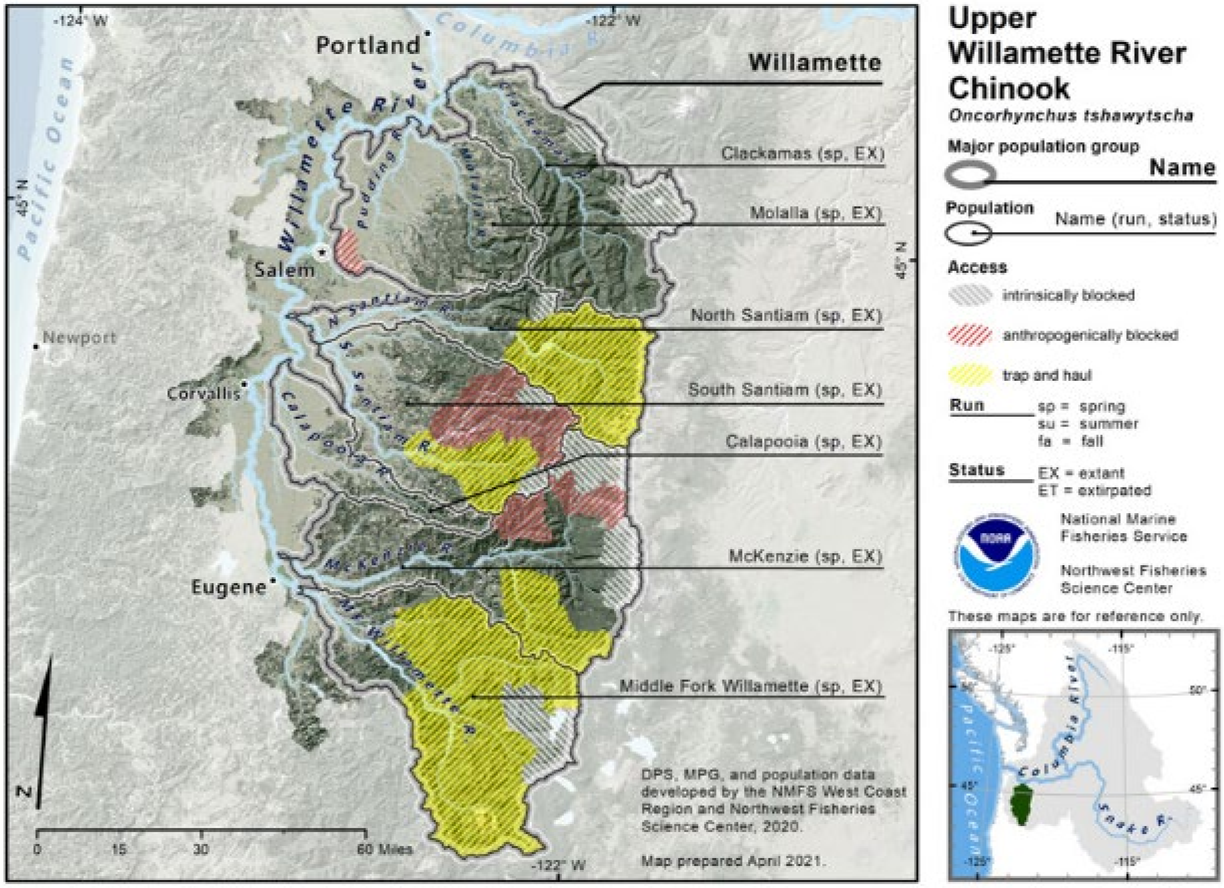


Figure 7. Map of the seven populations within the Upper Willamette River Chinook salmon ESU. Areas that are accessible (green), accessible only via trap-and-haul programs (yellow), or blocked (cross-hatched), are indicated accordingly (Ford 2022).

Table 10. 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 and NMFS 2011).

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 and Lindsey 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 UWR fish populations. Little information exists on the life-history characteristics of the historical UWR 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 UWR Chinook salmon still contain a unique set of genetic resources compared to other Chinook salmon stocks in the WLC Domain (ODFW and NMFS 2011).

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 8) 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.

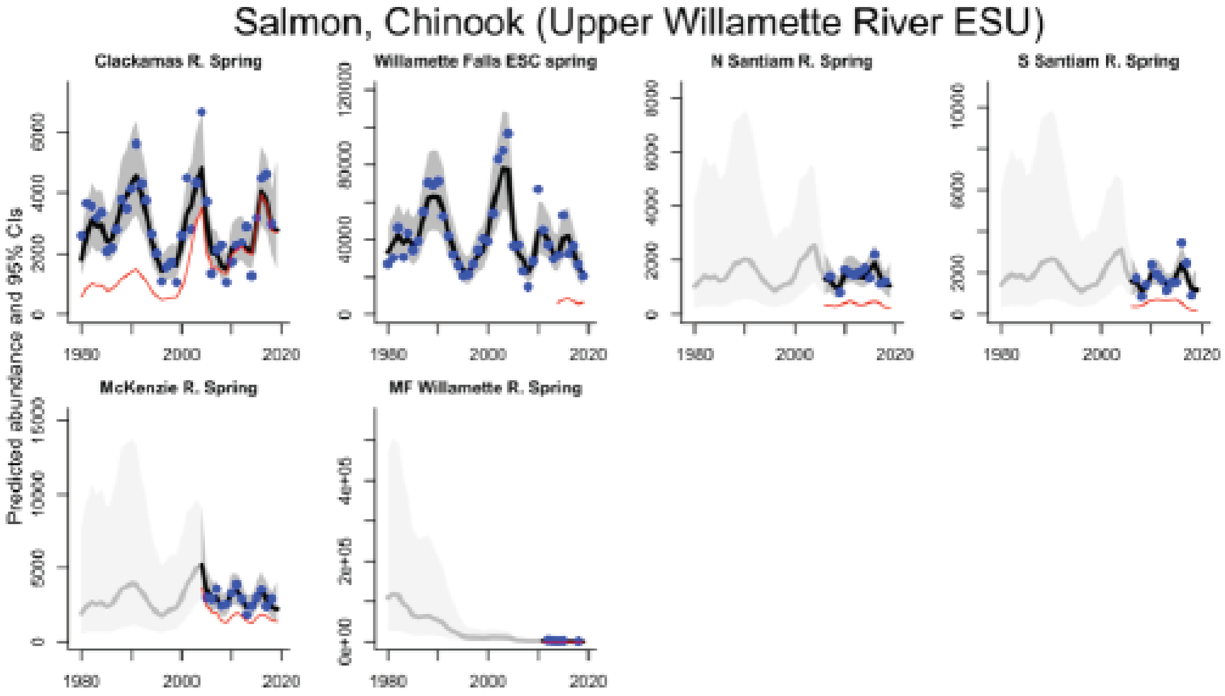


Figure 8. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other 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).

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 8), 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 UWR Chinook salmon populations. Table 11 includes the most up-to-date available data for natural-origin Chinook salmon spawner estimates from UWR subbasins relative to their recovery scenario expectation in the recovery plan.

Table 11. Current 5-year geometric mean of raw natural-origin spawner abundances compared to the recovery scenario presented in the recovery plan (ODFW and NMFS 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

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 9). 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 and WDFW 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 UWR spring Chinook salmon according to the provisions of the FMEP is not likely to jeopardize the continued existence of the ESU (NMFS 2001a).

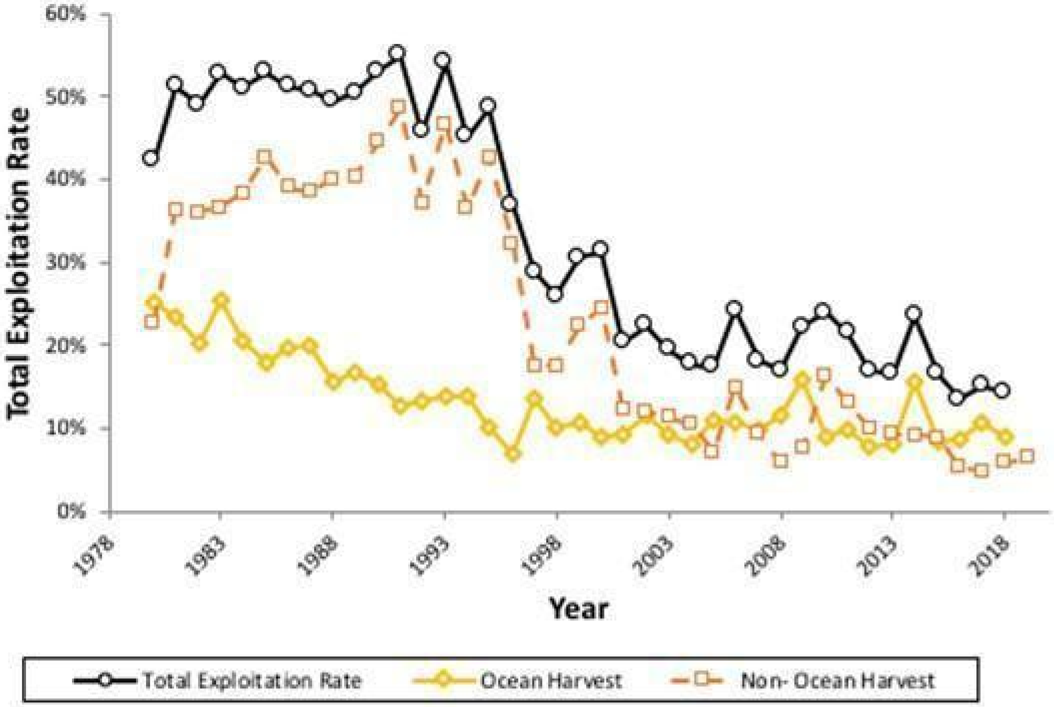


Figure 9. Ocean harvest, terminal harvest, and escapement rates for spring-run Upper Willamette River Chinook salmon, based on coded-wire tag (CWT) recoveries (Ford 2022). Ocean harvest rates for hatchery and unmarked naturally produced fish are assumed to be comparable; terminal fisheries have been 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).

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).

Hatcheries

For UWR Chinook salmon, diversity and productivity concerns include potential 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 UWR basin evaluating a number of changes to minimize the potential influence of hatchery-origin fish on natural-origin Chinook salmon and steelhead (NMFS 2019d). Through the provisions of NMFS (2019b) and individual HGMPs, hatcheries in the UWR have reduced releases of spring-run Chinook salmon in the McKenzie and North Santiam Rivers (Figure 10 and Table 12), while shifting production to other basins (Ford 2022)Ford, 2022 #2432}. In addition, NMFS (2019b) calls for further action in the McKenzie River to further reduce the number of hatchery fish spawning naturally.

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).

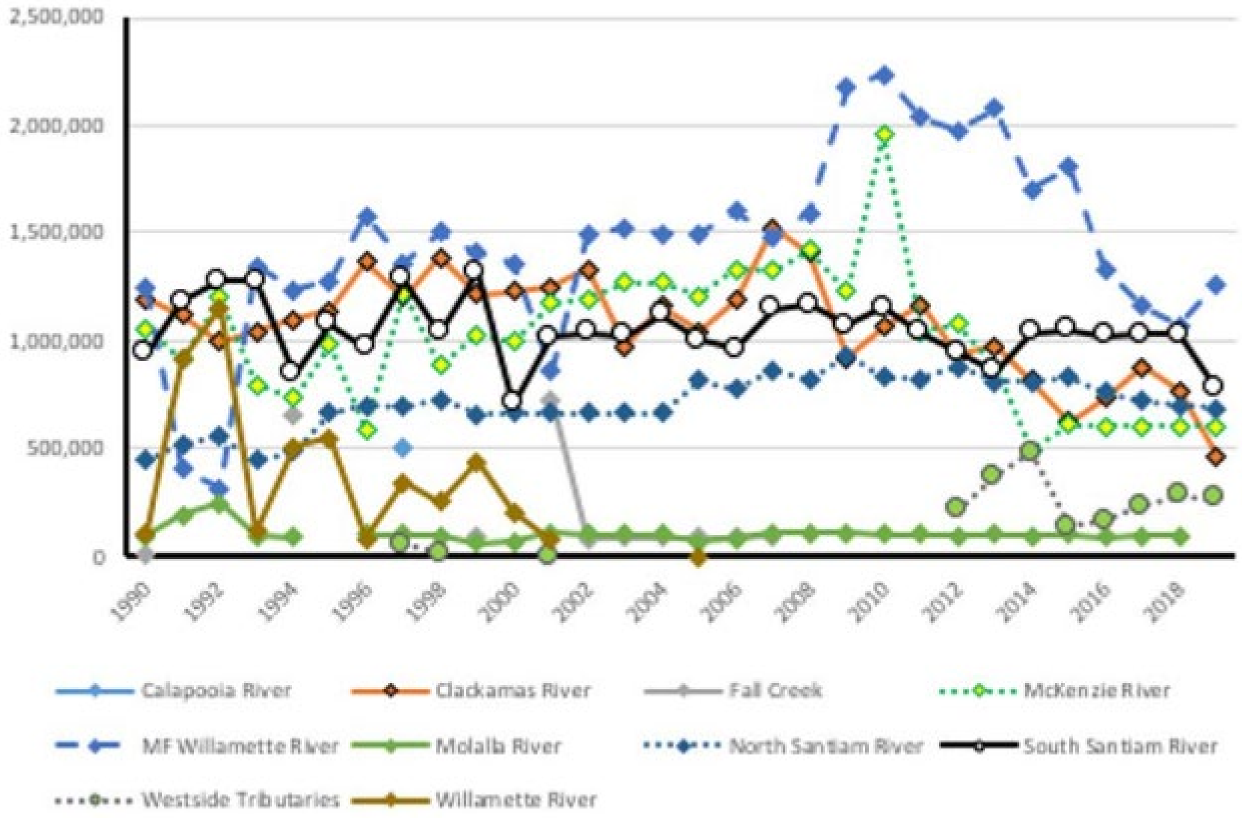


Figure 10. Hatchery releases of juvenile spring-run Chinook salmon into basins of the Upper Willamette River Chinook salmon ESU, 1990–2019. Data for 2019 may be incomplete. Releases of juveniles weighing <2.5 g were not included. Releases into the Row and Coast Fork Rivers were combined under Westside Tributaries (Ford 2022). Data from the Regional Mark Information System (https://www.rmpc.org, June 2020).

Table 12. 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 (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 (Ford 2022) due to many years of available data at that particular location

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 UWR Chinook salmon ESU since the 2015 viability review (Ford 2022). The magnitude of this change is not sufficient to suggest a change in risk category, however, so the UWR Chinook salmon ESU remains at "moderate" risk of extinction (Ford 2022).

Limiting Factors

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the UWR Chinook Salmon ESU. Understanding the limiting factors and threats that affect the UWR 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 UWR tributaries. These actions eventually will provide benefit to the UWR 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 UWR is in private ownership, making successful efforts to protect and restore habitat on private lands key to recovery in the UWR, particularly in the face of continuing development. There are also substantial portions of federal land in the UWR, 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 UWR 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 UWR Chinook salmon (ODFW and NMFS 2011) provides a detailed discussion of limiting factors and threats, and describes strategies for addressing each of them (Chapter 5 in ODFW et al. (ODFW and NMFS 2011)). Rather than repeating the extensive discussion from the recovery plan, this discussion in Chapter 5 is incorporated here by reference.

Additionally, the NWFSC outlines in Ford (Ford 2022) additional limiting factors for the UWR 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 UWR 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 12). 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 UWR salmon persistence has not changed significantly since our previous status review for the UWR Chinook Salmon ESU, and they remain listed as threatened (Ford 2022).

Interior Columbia Recovery Domain

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 2022e).

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 13 lists the natural and hatchery populations included in the ESU.

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 11 shows a map of the ESU area. The recovery plan (NMFS 2017d) provides three scenarios that represent a range of potential strategies that can be pursued simultaneously that address the entire life cycle of the species that would achieve delisting criteria (Table 14).

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 2022e).

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 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 2022e). 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 2022e).

Table 13. Snake River Fall-Run Chinook Salmon ESU description and MPGs (Ford 2022).

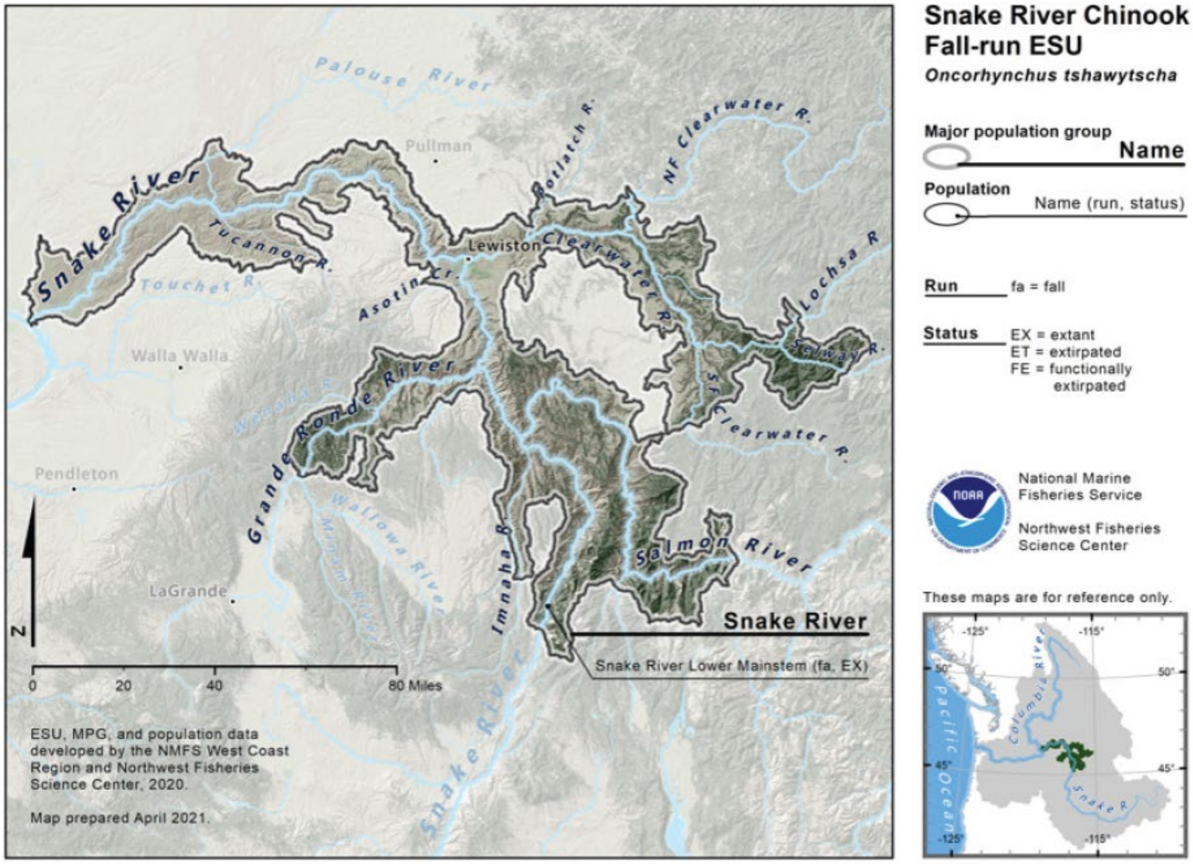
ESU Description	
Threatened	Listed under ESA in 1992; updated in 2022
1 MPG	2 historical populations (1 extirpated)
MPG	***Population***
Snake River	Lower Mainstem Fall-Run
Artificial production	
Hatchery programs included in ESU (4)	Lyons Ferry National Fish Hatchery (LFH) fall, Acclimation Ponds Program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

Table 14. Potential ESA Viability Scenarios for Snake River Fall-Run Chinook salmon (NMFS 2017d**).**

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	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	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.

Viability Scenarios and Viability Criteria	Abundance and Productivity Metrics	Spatial Structure and Diversity Metrics
for the currently extirpated Middle Snake River population.	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	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 Production Emphasis Areas [NPEAs])	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 depending on the proportion of natural production coming from NPEAs and the level of hatchery influence remaining in the NPEAs.	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
		c. Numbers of fish showing the historically dominant subyearling life-history pattern are stable or increasing.
	b. Population-level productivity metrics for Scenario B would apply: most recent 20-year geometric mean intrinsic productivity > 1.7	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.



ESU, MPG, and population data developed by the NMFS West Coast Region and Northwest Fisheries Science Center, 2020.

Map prepared April 2021.

Figure 11. Map of the Snake River Fall-Run Chinook Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

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.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.

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)[9] 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.

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[9] PBT is where 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.

Abundance and Productivity

In 2013, adult spawner abundance reached over 20,000 fish (Figure 12). 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 12). 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 15), 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 (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)[10] during climate challenges in the ocean and rivers. Escapements have been increasing since 2020 and have continued through 2022 (WDFW and ODFW 2022).

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.

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[10] The ICTRT (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. (Bevan et al. 1994) as the minimum abundance threshold for the extant Lower Snake River Fall-Run Chinook salmon population.

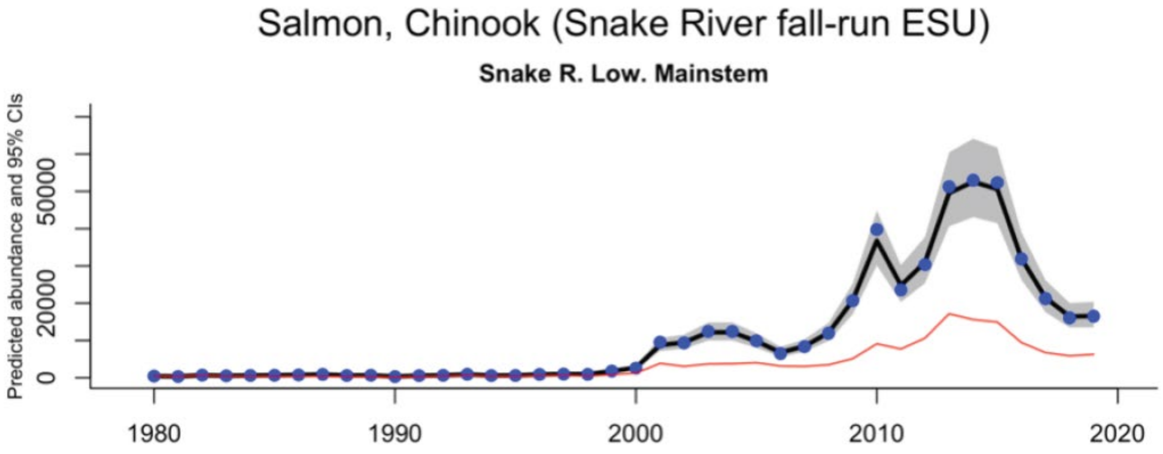

Figure 12. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance (Ford 2022). Points show the annual raw spawning abundance estimates.

Table 15. 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

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 13) 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 1996b). 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).

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 14).

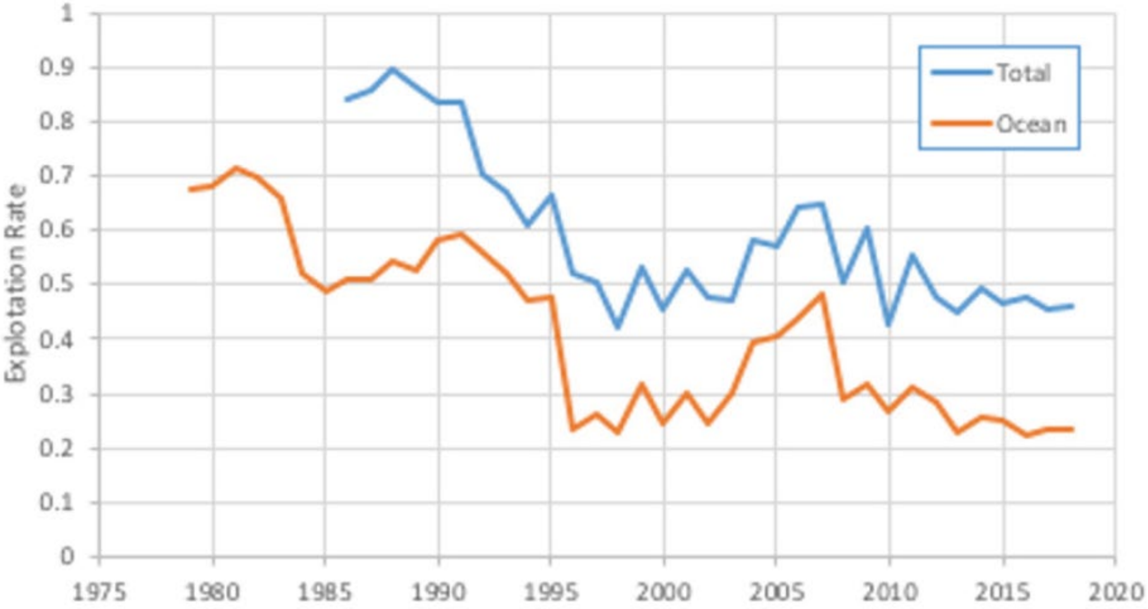

Figure 13. Total ER for Snake River Fall-Run Chinook salmon. Data for marine ERs from the Chinook Technical Committee (CTC) model (Calibration 1503) and for in-river harvest rates from the Columbia River Technical Advisory Committee (Ford 2022).

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 Lyons Ferry Hatchery (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 14).

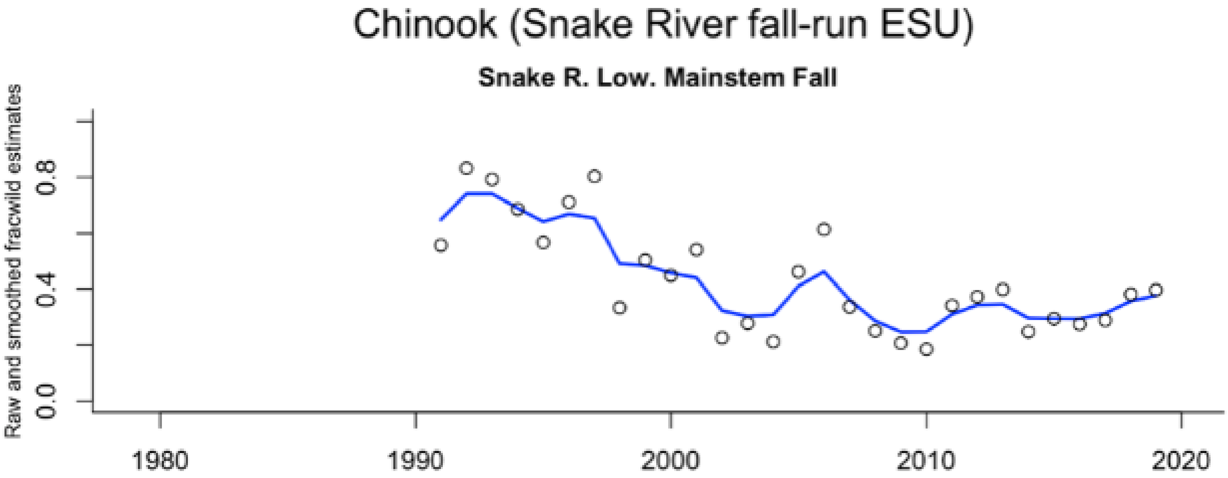

Figure 14. Smoothed trend in the estimated fraction of the natural spawning population consisting of fish of natural origin. Points show the annual raw estimates (Ford 2022)**.**

The NMFS Snake River Fall-run Chinook Recovery Plan (NMFS 2017d) 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 14). 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 14 above (while meeting total specific pHOS criteria; see Table 14 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).

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 16. 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).

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.

Table 16. 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.

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 2017d).

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 2017d).
The recovery plan (NMFS 2017d) 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 2017d) 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.

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 2022g).

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 2022g). However, inside the geographic range of the ESU, there are a total of 18 hatchery spring/summer-run Chinook salmon programs currently operational (NMFS 2022g). Table 17 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 15 shows a map of the current ESU and the MPGs within the ESU.

Table 17. Snake River spring/summer-run Chinook Salmon ESU description and MPGs (NMFS 2022g).

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 National Fish Hatchery (NFH) spring, Kooskia spring, Clearwater Hatchery spring, Nez Perce Tribal Hatchery spring

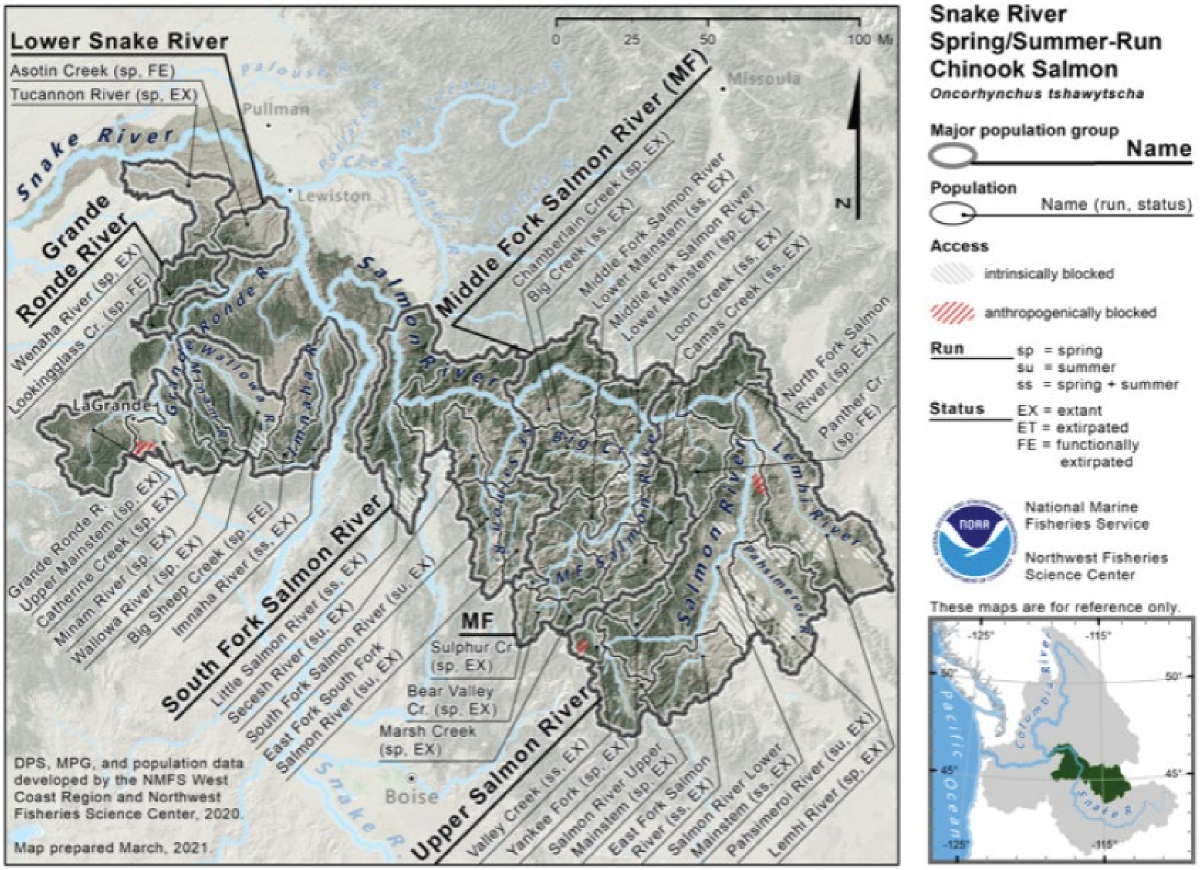

Figure 15. The Snake River spring/summer-run Chinook salmon ESU’s spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

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 UWR 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 and Waples 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 (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. Changing environmental conditions are also recognized as a possible factor in Snake River salmon declines (Tolimieri and Levin 2004); (Scheuerell and Williams 2005); (NMFS 2012b).

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 2017e). 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 (MCR 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 2017e). 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 (NMFS 2015c). 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.

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 2016c) to an overall rating of maintained due to an increase in abundance/productivity (Table 18). 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 16). 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 18 and Figure 16 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[11] (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.

Harvest

Harvest impacts on the spring component of this ESU are essentially the same as those on the UCR Chinook Salmon 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 is nearly identical to that of the UCR 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 2018b). 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 2018b).

Table 18. 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

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[11] 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).

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).

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**	
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.	1,000	163 (SD 114)	1.47 (0.34, 20/20)	High	Very Low	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**	
Lower Mainstem								
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
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

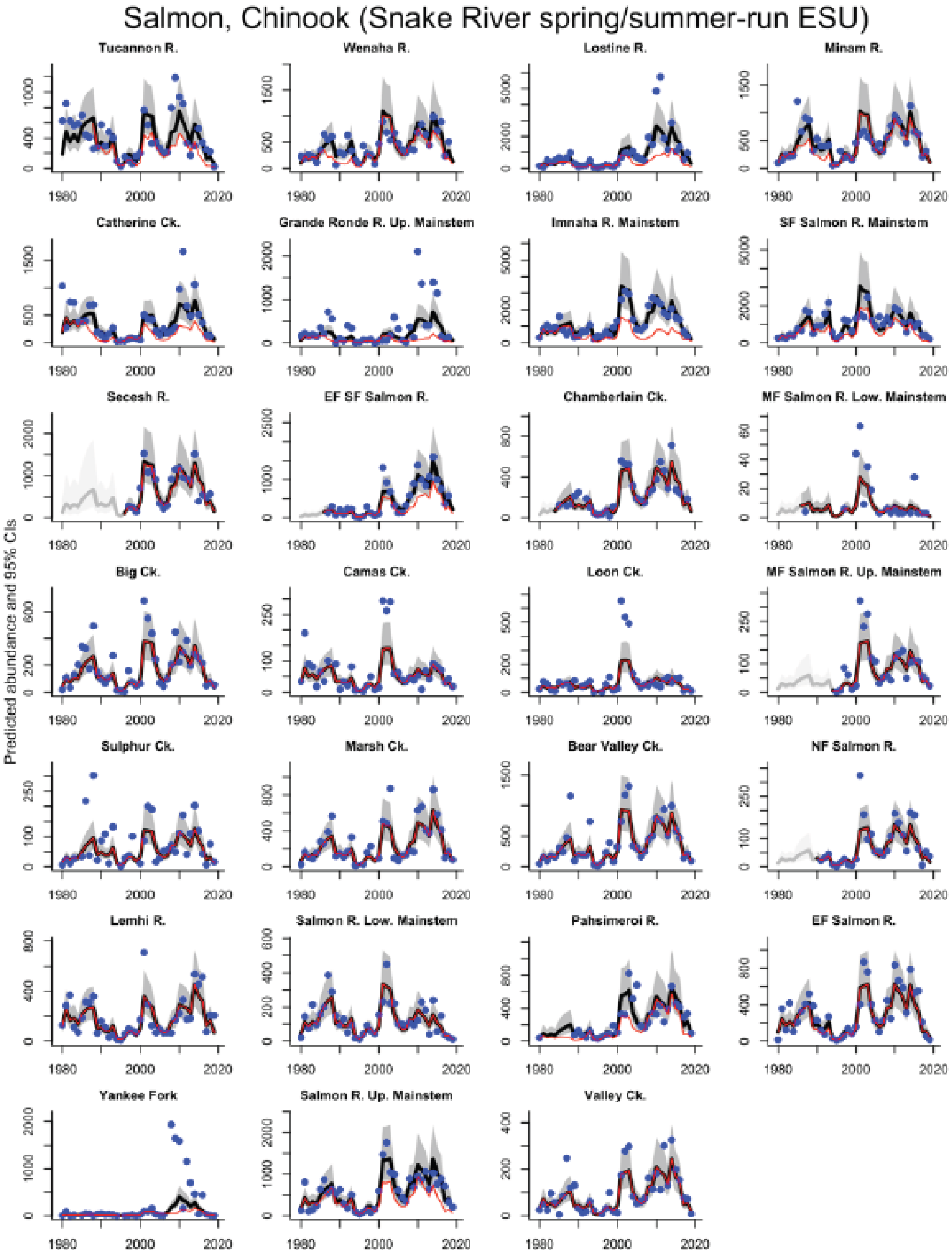

Figure 16. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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.

Contributions of Snake River spring/summer Chinook salmon are considered negligible in fisheries managed by the PFMC (PFMC 2016); (PFMC 2020), 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 2018c). Actual incidental take has remained the same since the 2016 5-year review and averaged 11.0% for the years 2014–2019 (NMFS 2022g). Estimated harvest rates for Snake River spring/summer Chinook salmon over the last four decades are shown in Figure 17.

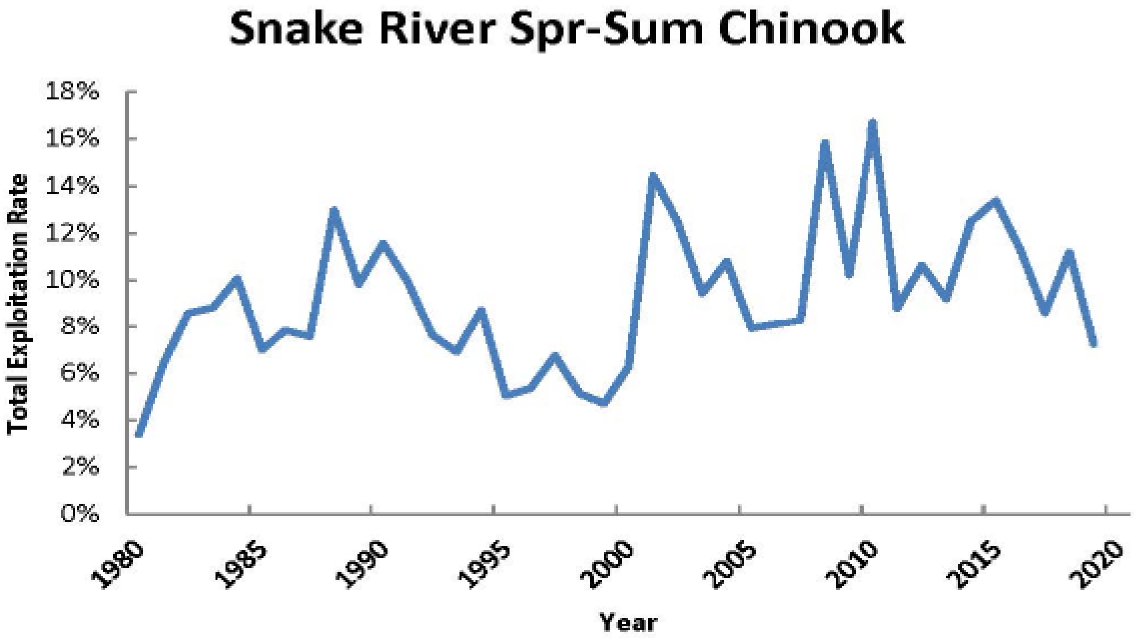

Figure 17. Total exploitation rates for Snake River spring/summer Chinook salmon in the mainstem Columbia River fisheries (NMFS 2022g). Data from the Columbia River Technical Advisory Team, recreated from NMFS (NMFS 2022g).

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.

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 2022g). The proportion of hatchery-origin spawners within populations varies considerably across MPGs (Table 19). 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 19. 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	2014–19	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

Population[a]	MPG	1995–99	2000–04	2005–09	2014–19	2015–19
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
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 (Ford 2022)

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).

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 2017e).

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 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 (NMFS 2022g) recommended that the Snake River spring/summer Chinook Salmon ESU maintain its classification as a threatened species.

Upper Columbia River Spring-run Chinook Salmon ESU

On March 24, 1999, NMFS listed the UCR 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 UCR Spring-run Chinook salmon was designated on September 2, 2005 (70 FR 2732). In 2022, NMFS completed its most recent 5-year review for UCR Spring-run Chinook salmon (NMFS 2022h).

Inside the geographic range of this ESU, eight natural populations within three MPGs have historically comprised the UCR 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 (NMFS 2022h)). Table 20 lists the hatchery and natural populations included (or excluded) in the ESU.

Table 20. Upper Columbia River Spring-run Chinook Salmon ESU description and MPG (updated data from NMFS (NMFS 2022h)).

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 18 shows the map of specific basins within the current ESU.

ESA-listed UCR 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. 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.

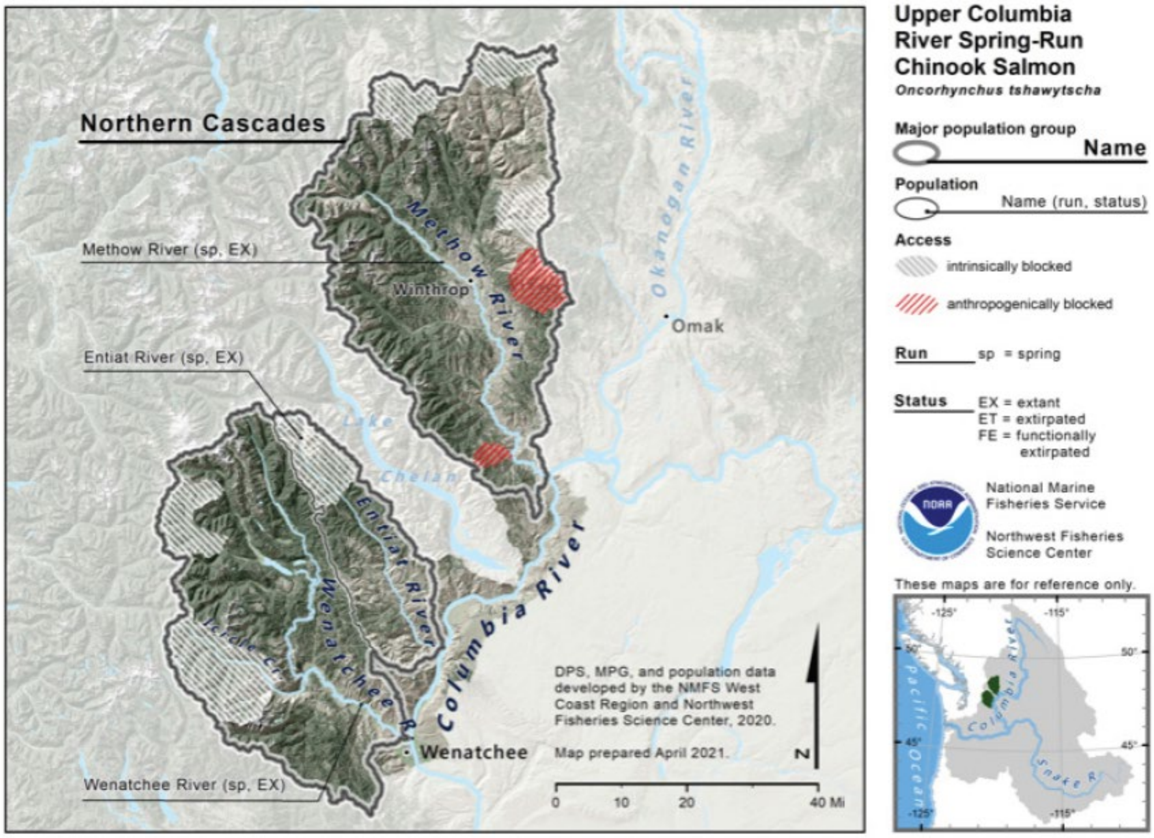

Figure 18. Map of the Upper Columbia River Spring-run Chinook Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

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 UCR Spring-run Chinook Salmon ESU, is at high risk and remains at endangered status (Ford 2022); (NMFS 2022h). 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 21) (UCSRB 2007).

Table 21. 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 (NMFS 2022h), data adapted from Table 5 in Ford (Ford 2022)).

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

Abundance and Productivity

All three populations in the UCR Spring-run Chinook Salmon ESU remain at high overall risk (Table 21). Natural origin abundance has decreased over the levels reported in the prior review (NMFS 2016d) for all populations in this ESU, in many cases sharply (**Figure 19**). 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 2022h). 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 2022h). 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 and Jordan 2020). Based on the information available for the 2022 review (Ford 2022), the risk category for the UCR 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 21).

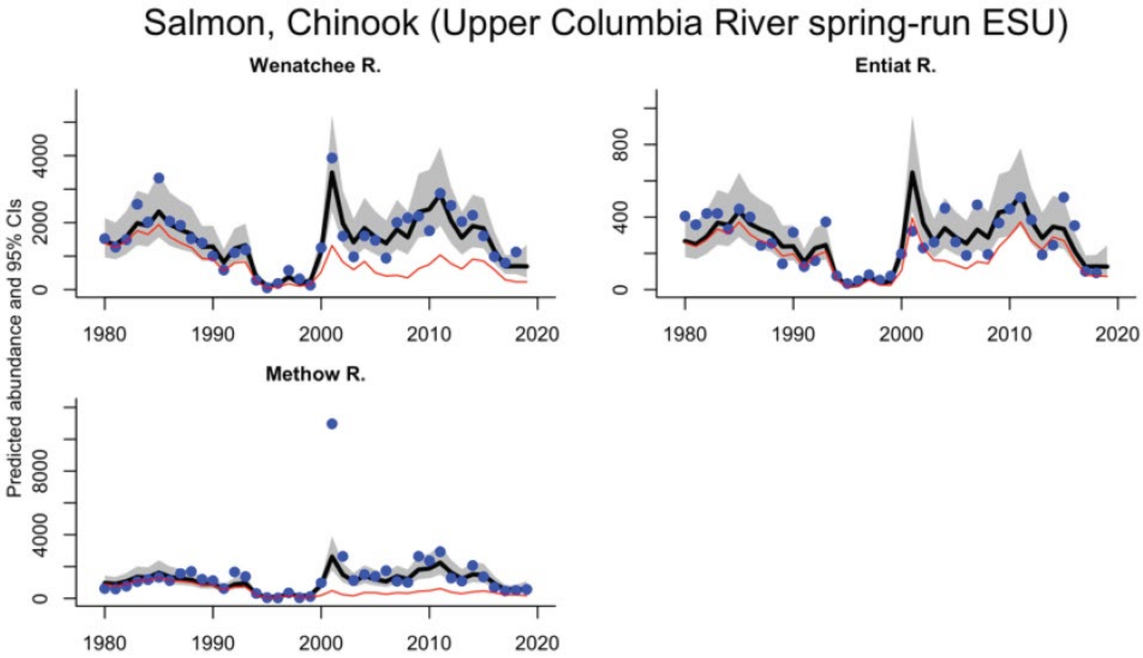

Figure 19. Smoothed trend in estimated total (thick black line, with 95% confidence internal in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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).

Harvest

Spring Chinook salmon from the UCR basin migrate offshore in marine waters and where impacts in ocean salmon fisheries are too low to be quantified. Contributions of UCR 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 UCR spring-run Chinook salmon returning to the Columbia River mouth (NMFS 2018a). Actual incidental take has remained the same since the 2016 5-year review and averaged 11% for the years 2014–2019 (NMFS 2022h). Exploitation rates have remained relatively low for non-treaty harvest, generally below the target rate of 2% (Figure 20).

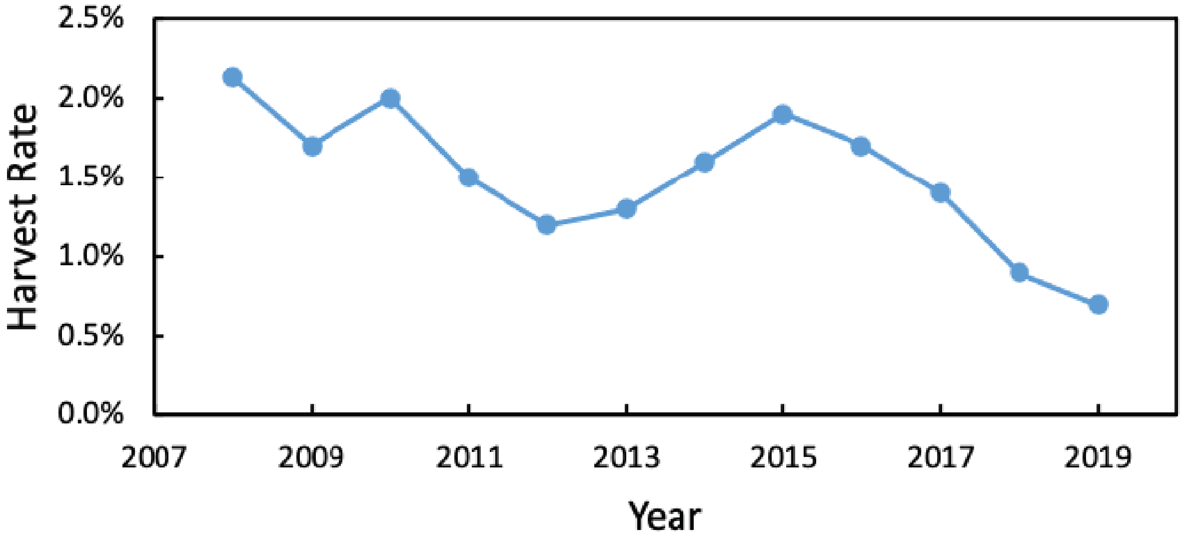

Figure 20. Non-treaty harvest rate for Upper Columbia River spring-run Chinook salmon. Data from the Columbia River Technical Advisory Committee (Figure reproduced from Ford (Ford 2022)).

Spatial Structure and Diversity

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

<u>Hatcheries</u>

Hatchery managers have continued to implement and monitor changes in their management actions since the 2016 5-year review for the hatchery programs within this ESU (Table 20). Although several measures have been implemented to reduce risk, the pHOS remains high in the Wenatchee and Methow Basins (Table 22). However, a better measure of hatchery genetic risk is the 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 2022h). We conclude that hatchery effects continue to present risks to the persistence of the UCR Spring-run Chinook Salmon ESU, but they are likely less of a risk compared to the 2016 5-year review (NMFS 2016d) 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 2022h).

The hatchery programs that affect the UCR 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 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 2022h).

Table 22. 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

Summary

Current estimates of natural-origin spawner abundance decreased substantially relative to the levels observed in the prior review (Faulkner et al. 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.

Limiting Factors

Understanding the limiting factors and threats that affect the UCR 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 UCR Basin were first affected by intensive commercial fisheries in the LCR. 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 UCR Basin (UCSRB 2007).

There are many factors that affect the abundance, productivity, spatial structure, and diversity of the UCR 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 (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 UCR Spring-run Chinook Salmon ESU remains unchanged from the prior review (NMFS 2016d). 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 2022h).

Status of the Coho Salmon ESUs

Only one ESU of coho salmon was evaluated in this Opinion, the LCR Coho Salmon ESU. The recovery domain and population information for this ESU is detailed below in Table 23.

Table 23. Coho salmon ESA-listed salmon populations considered in this Opinion.

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

Although run time variation is considered inherent to overall coho salmon life-history, LCR 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 LCR 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 2013b). 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 24) (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 inside 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 2013b). 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.

Table 24. 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 populations	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

Willamette/Lower Columbia Recovery Domain

Lower Columbia River Coho Salmon ESU

On June 28, 2005, NMFS listed the LCR 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 LCR coho salmon (NMFS 2022e).

Inside the geographic range of the ESU, 23 hatchery coho salmon hatchery programs are currently operational (Table 25). Table 25 lists the 21 hatchery programs currently included in the ESU and the two excluded programs (NMFS 2022e). LCR coho salmon are primarily limited to the tributaries downstream of Bonneville Dam (Figure 31).

Twenty-four historical populations within three MPGs comprise the LCR Coho Salmon ESU with generally low baseline persistence probabilities (Ford 2022); (NMFS 2022e). 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 21). Coho salmon in the Willamette River spawning above Willamette Falls are not considered part of the LCR Coho Salmon ESU (70 FR 37160).

In contrast to Chinook salmon and steelhead, LCR 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. (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 LCR coho salmon. NMFS' recovery plan took this into consideration by identifying each LCR coho salmon population's proposed life-history component(s).

Table 25. Lower Columbia River Coho Salmon ESU description and MPGs (Ford 2022); (NMFS 2022e)[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

ESU Description	
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 (NMFS 2022h) 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.

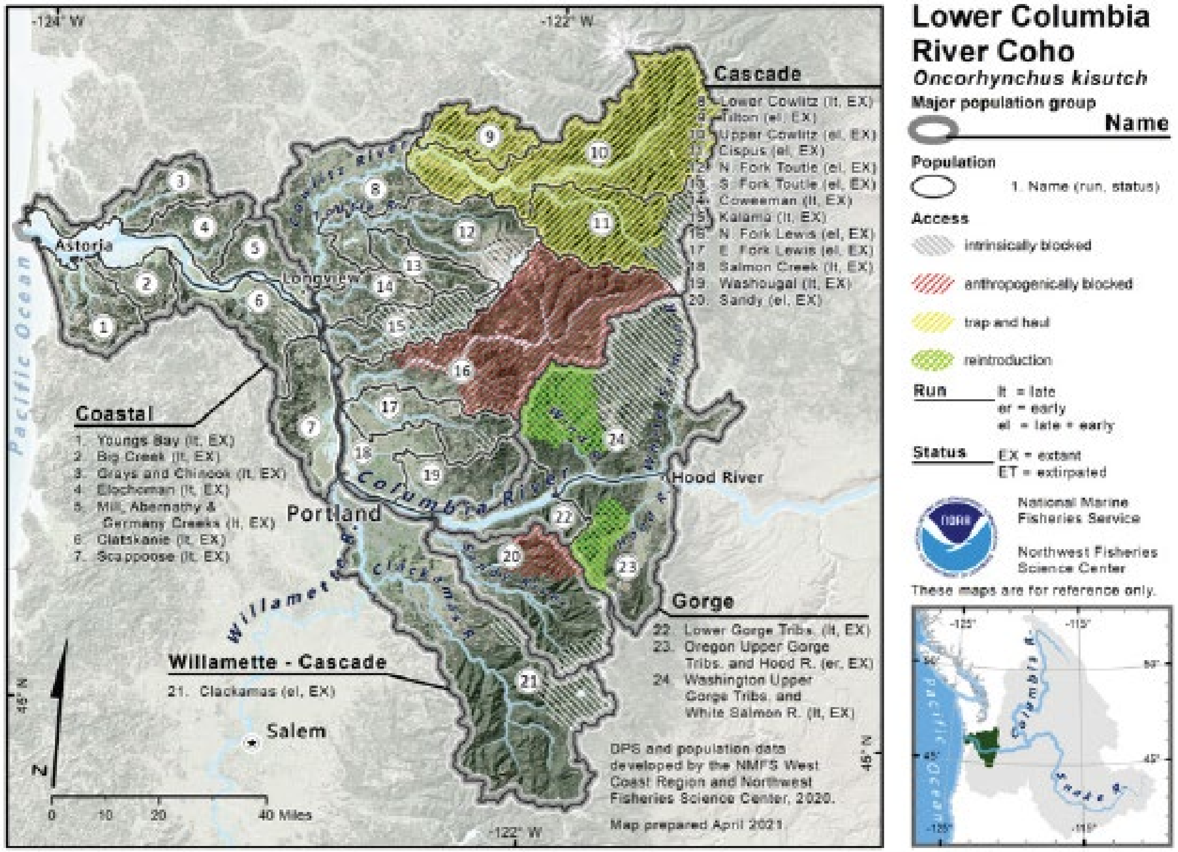

Figure 21. Map of the Lower Columbia River Coho Salmon ESU's spawning and rearing areas, illustrating demographically independent populations and MPGs. Areas that are accessible (green), accessible only via trap-and-haul programs (yellow), or blocked (cross-hatched) are indicated accordingly (Ford 2022).

In 2017 NMFS adopted the 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 2017c). 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 LCR 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 2017c).

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 LCR 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 26. 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%).

Abundance and Productivity

NMFS conducted viability status reviews of the LCR Coho Salmon ESU in 1996 (NMFS 1996a), in 2001 (NMFS 2001b), in 2005 (Good, Waples, and Adams 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 22). 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).

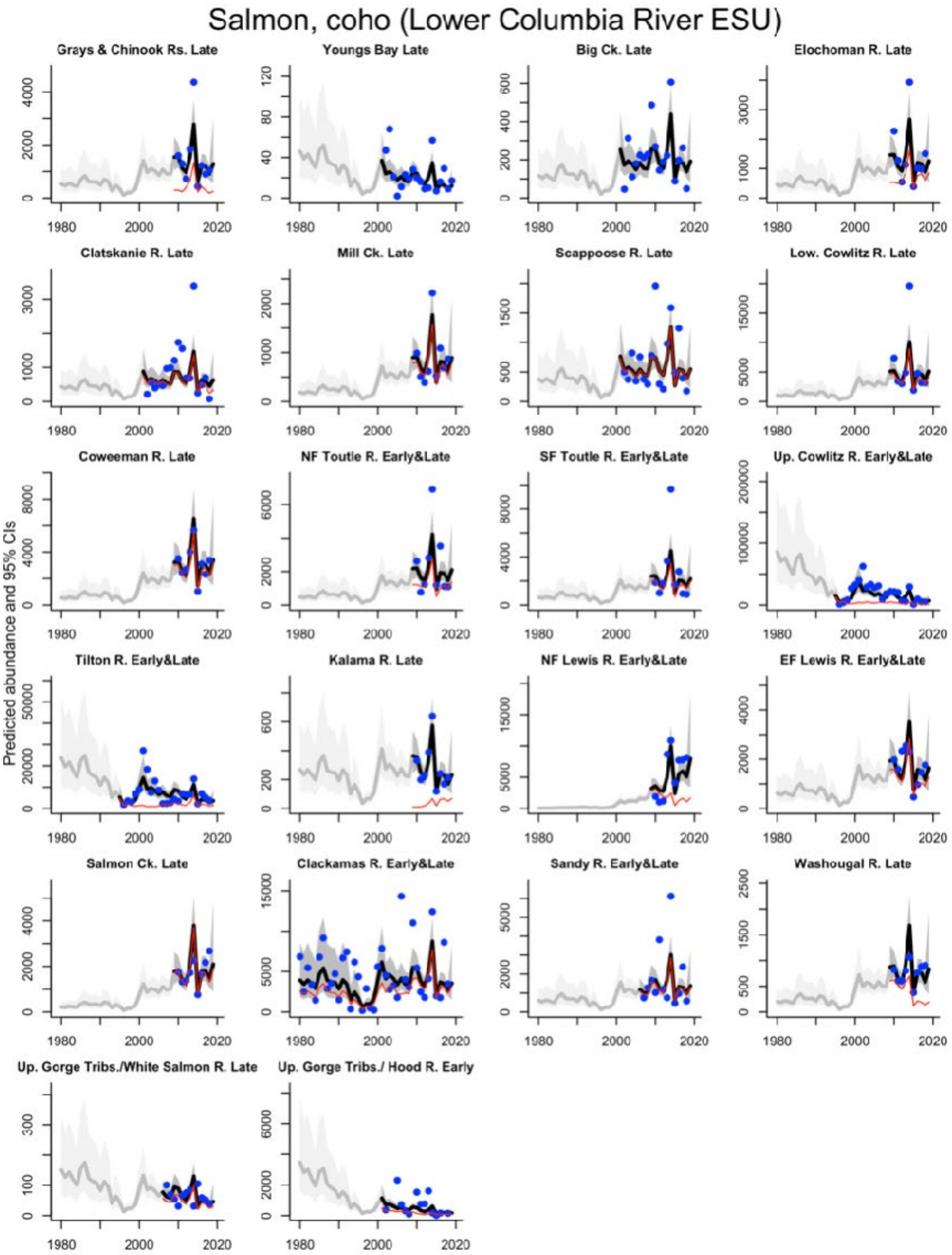

Figure 22. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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 26. 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

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 23). 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 2019); (Ford 2022).

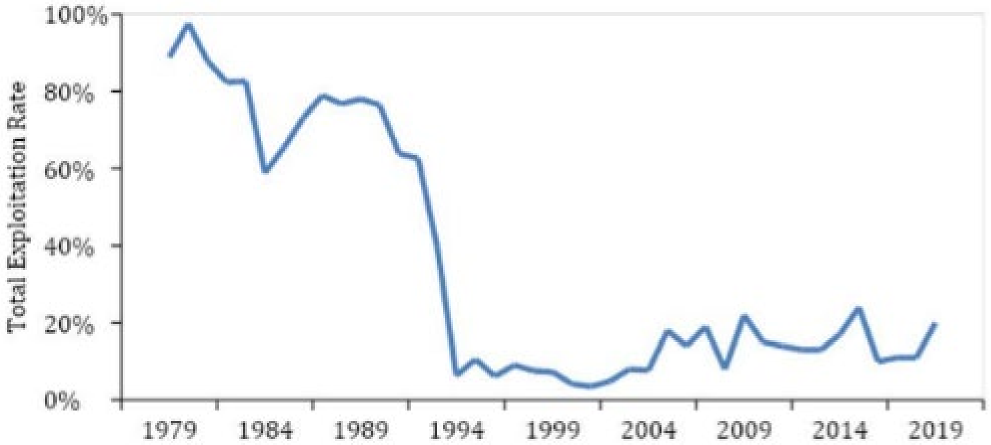

Figure 23. Total exploitation rate on natural Lower Columbia River coho salmon. Data (2005–19) from ODFW et al. (ODFW and WDFW 2020). Figure reproduced from Ford (Ford 2022).

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 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 and Hardiman 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, Kock, and Rondorf 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).

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 27). 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 from the low level of returns (shown in Table 26) 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 27). 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 27), 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 27). 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 27).

Table 27. 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 (Ford 2022).

Summary

Overall abundance trends for the LCR Coho Salmon ESU are generally negative (Ford 2022). Natural spawner and total abundances have decreased in almost all populations (Figure 22), and Coastal and Gorge MPG populations are all at low levels, with significant numbers of hatchery-origin coho salmon on the spawning grounds (Table 27). 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 22). 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 2022e). For individual populations, the risk of extinction spans the full range, from “low” to “very high” (Ford 2022). Overall, the LCR Coho Salmon ESU remains at “moderate” risk (Ford 2022), and viability is largely unchanged from the prior status review (NWFSC 2015).

Limiting Factors

Understanding the limiting factors and threats that affect the LCR 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 LCR 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 LCR Coho Salmon ESU available from various sources (NMFS 2013b).

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

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

- Predation.

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

- Ecological interactions,
- Changing environmental conditions, 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 LCR 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 2013b). 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 2013b). NMFS (NMFS 2011a) and Lower Columbia Fish Recovery Board (LCFRB)(LCFRB 2010b) 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 (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 2013b).

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 2017c) expects Federal funding guideline requirements to reduce limiting factors relative to hatchery effects over the course of the next decade.

Status of the Chum Salmon ESU

One chum salmon ESU was evaluated in this Opinion, the Columbia River Chum Salmon ESU. The recovery domain and population information for this ESU is detailed below in Table 28.

Table 28. Chum salmon ESA-listed salmon population considered in this Opinion.

Recovery Domain	ESU	MPGs	Populations
Willamette/Lower Columbia	Columbia River chum salmon	3	17
Total	1 ESU	3	17

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, Williams, and Lichatowich 1991). Chum salmon fry emerge from March through May (LCFRB 2010b), 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 2010b). Their small size at emigration is thought to make chum salmon more susceptible to predation mortality during this life stage (LCFRB 2010b).

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 2013c); (NMFS 2013b). 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 2013c); (NMFS 2013b). 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 2010b).

Juvenile chum salmon rear in the Columbia River estuary from February through June before beginning long-distance ocean migrations (LCFRB 2010b). 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). All chum salmon die after spawning once.

Willamette/Lower Columbia Recovery Domain

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 2022e).

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 29. This ESU is comprised of three MPGs and has 17 natural populations (Table 29). 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 24). Inside the geographic range of the ESU, three hatchery chum salmon programs are currently operational. Table 29 lists these hatchery programs, which are all included in the ESU (NMFS 2022e).

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 29).

Table 29. 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 2013b); (NMFS 2022e).

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.

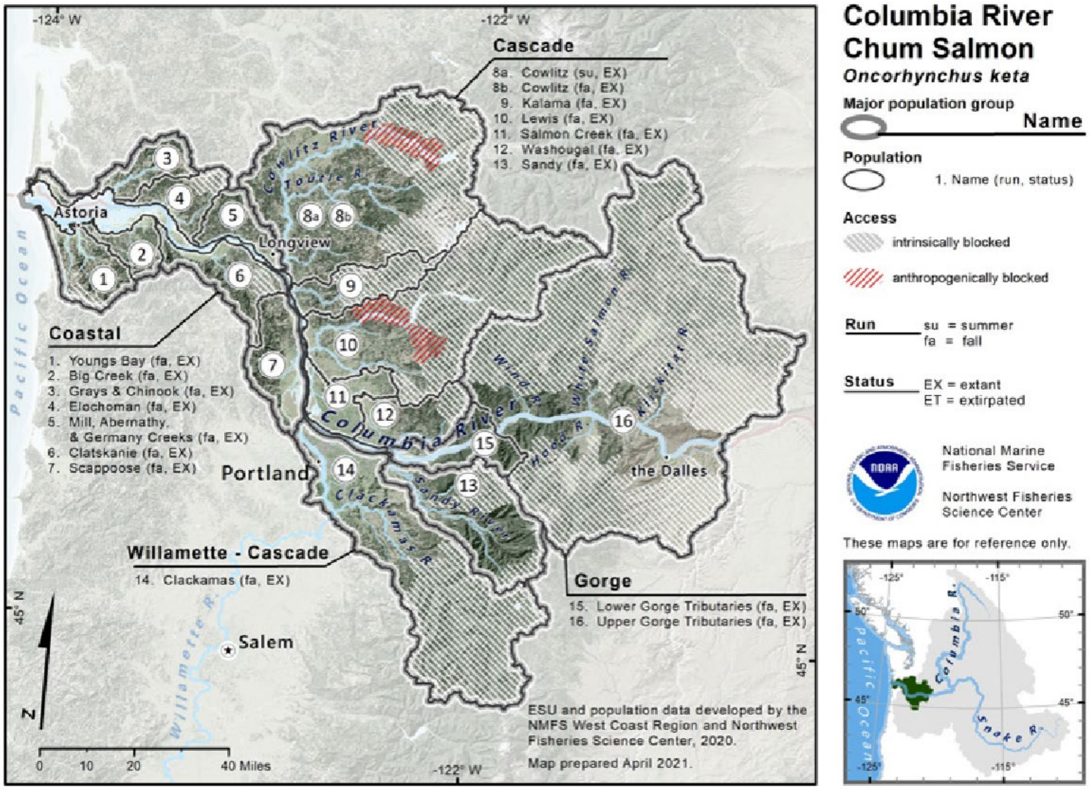

Figure 24. Map of the Columbia River chum salmon ESU's spawning and rearing areas, illustrating all 17 demographically independent populations and the three MPGs. Note that Population 8, Cowlitz River, contains two demographically independent populations, a fall and a summer run (Ford 2022).

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 30, 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 30. 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

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 2013b). 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 2013b); (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 25). 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 30 and Table 31). 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).

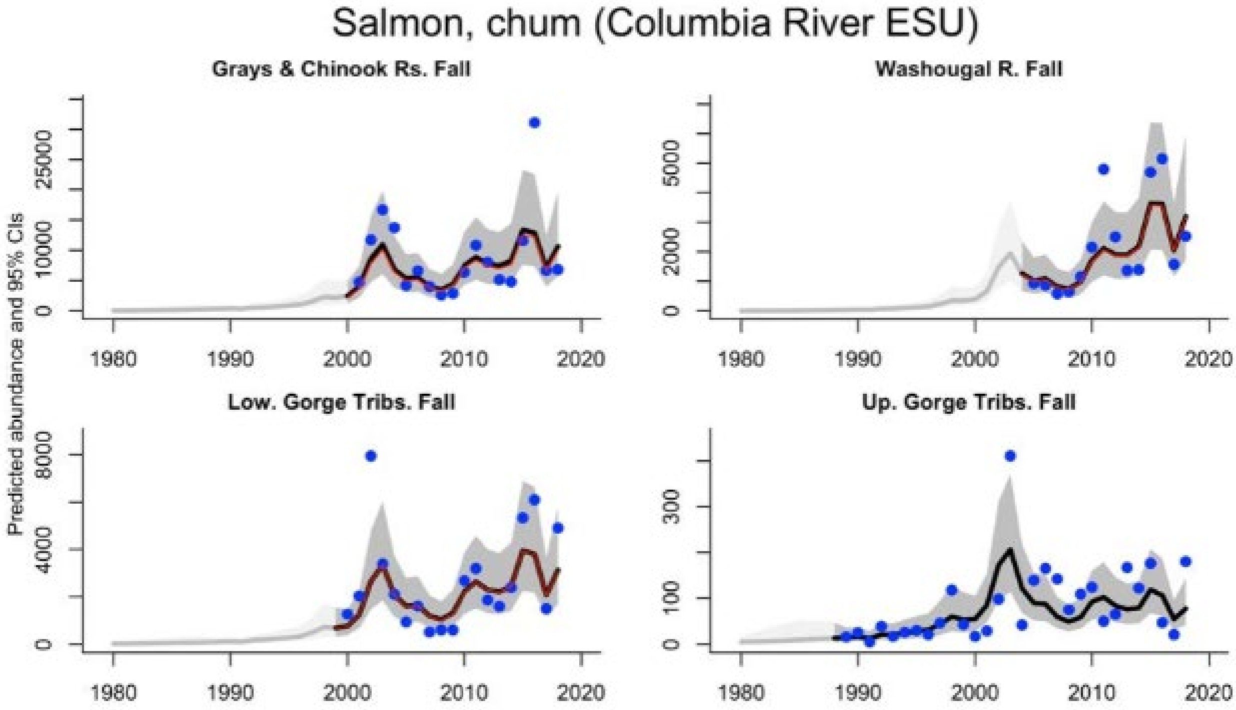

Figure 25. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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 changing environmental conditions. 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 LCR 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 LCR chum salmon ESU therefore remains at "moderate" risk of extinction, and the viability is largely unchanged from the prior review.

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 2018b). Data on the incidental harvest of chum salmon in LCR 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 and WDFW 2020). Overall, the exploitation rate has been estimated at below 1% for the last five years (Ford 2022).

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).

Hatcheries

Hatchery managers have continued to implement and monitor changes in chum hatchery management since the 2016 5-year review (NMFS 2022e). 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 26), the vast majority of spawning fish are of natural-origin (>90%; Table 31) (Allendorf et al. 2022). Existing hatchery programs for chum salmon are important for the conservation and recovery of this ESU (NMFS 2017c). The most recent status review concluded that risk to this ESU from hatchery programs is low (NMFS 2022e).

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 2013b). 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 (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 2022e)[12].

Table 31. 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 (Ford 2022)

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[12] The NWFSC viability assessment identified risk category as "moderate" (Ford 2022).

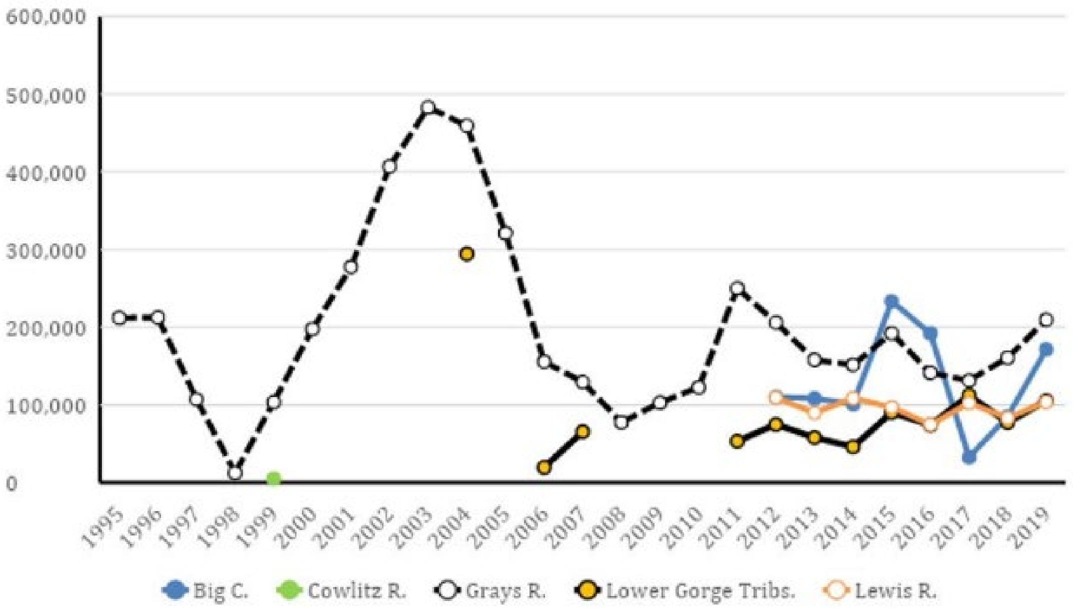

Figure 26. Releases of juvenile chum salmon into the Lower Columbia River. All releases were from sources originating from within the ESU. Data from the Regional Mark Information System (https://www.rmpc.org, April 2020). Figure reproduced from Ford (Ford 2022).

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 2013b). 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 (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 2022e)[13].

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

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

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 2013b). 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 changing environmental conditions.

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 2013b) describes limiting factors on a regional scale and how they apply to the four listed species from the LCR considered in the plan, including the Columbia River Chum Salmon ESU (NMFS 2013b). Chapter 4 (NMFS 2013b) includes details on large scale issues including the following:

- Ecological interactions,
- Changing environmental conditions, 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 2013b) 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.

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 27). 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 2015b).

Interior Columbia Recovery Domain

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 2022f). 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 32).

Table 32. Snake River Sockeye Salmon ESU description and MPG (Ford 2022); (NMFS 2022f).

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

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 2015b) (Figure 27). 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 2015b). 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, Cooney, and ICTRT 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).

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.

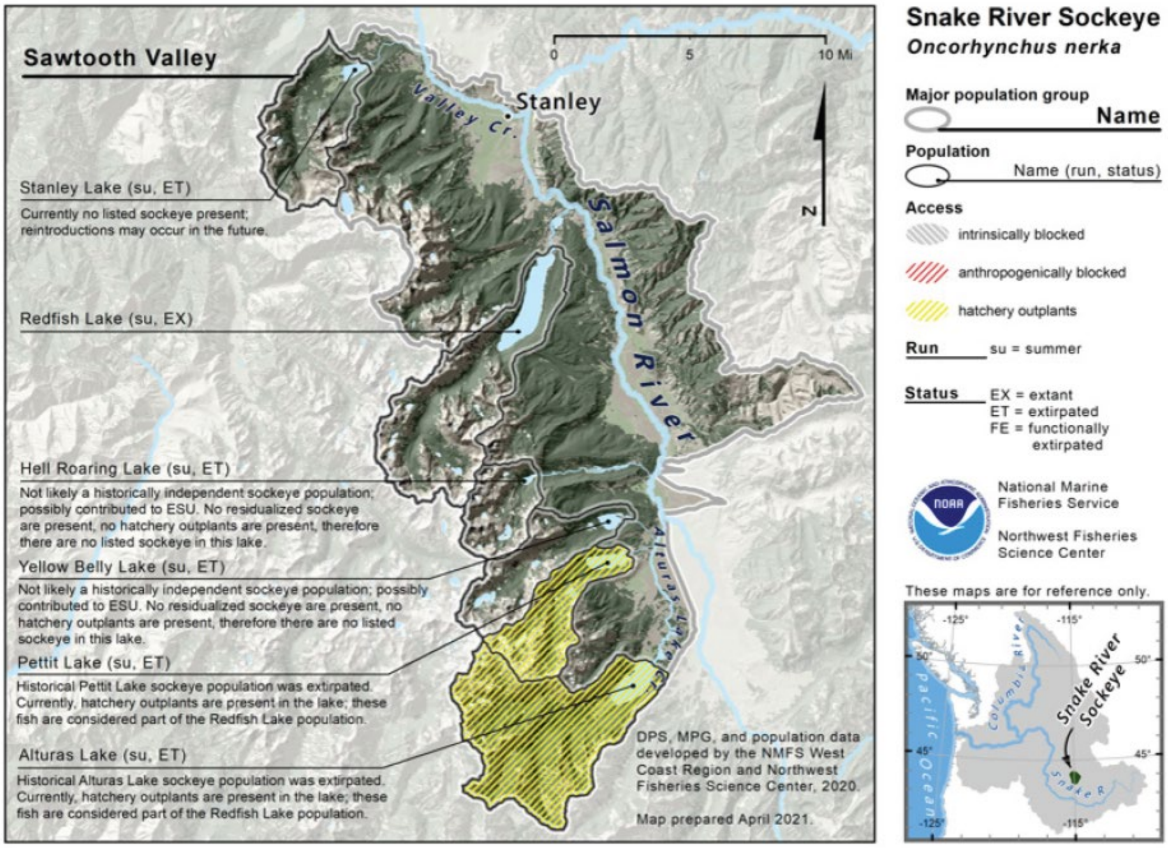

Figure 27. Map of the Snake River Sockeye Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

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).

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.) (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 28) 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, Plaster, and Powell 2021)[14].

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

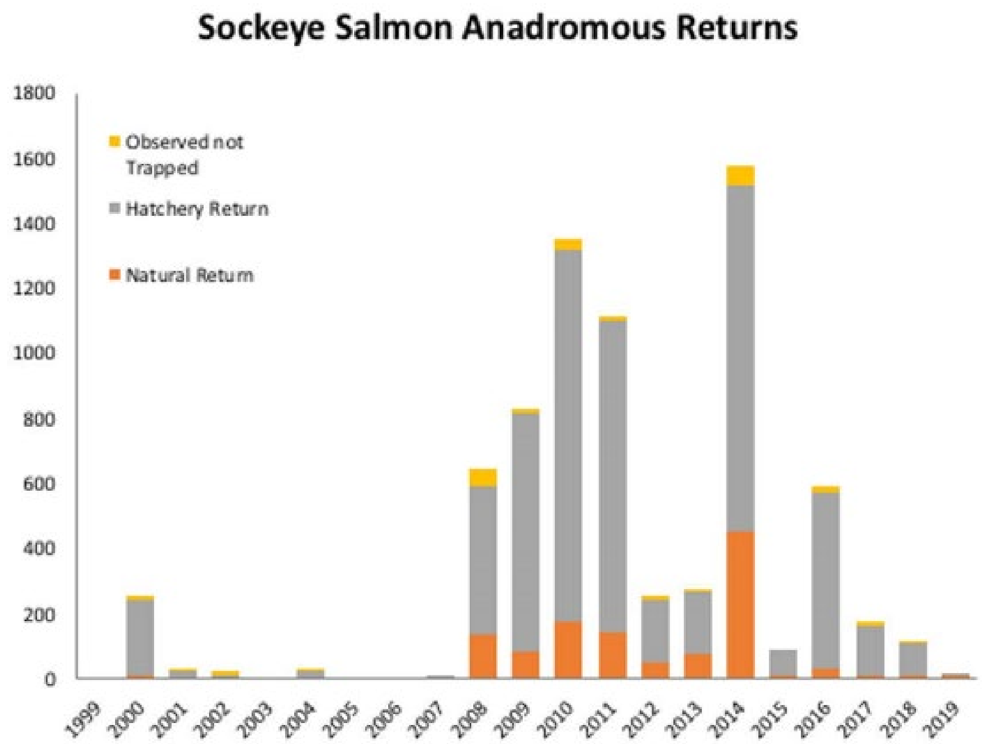


Figure 28. Snake River sockeye salmon anadromous returns, 1999–2019 (figure from Johnson et al. (Johnson, Plaster, et al. 2020).

<u>Harvest</u>

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 UCR (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 UCR stocks (Figure 29).

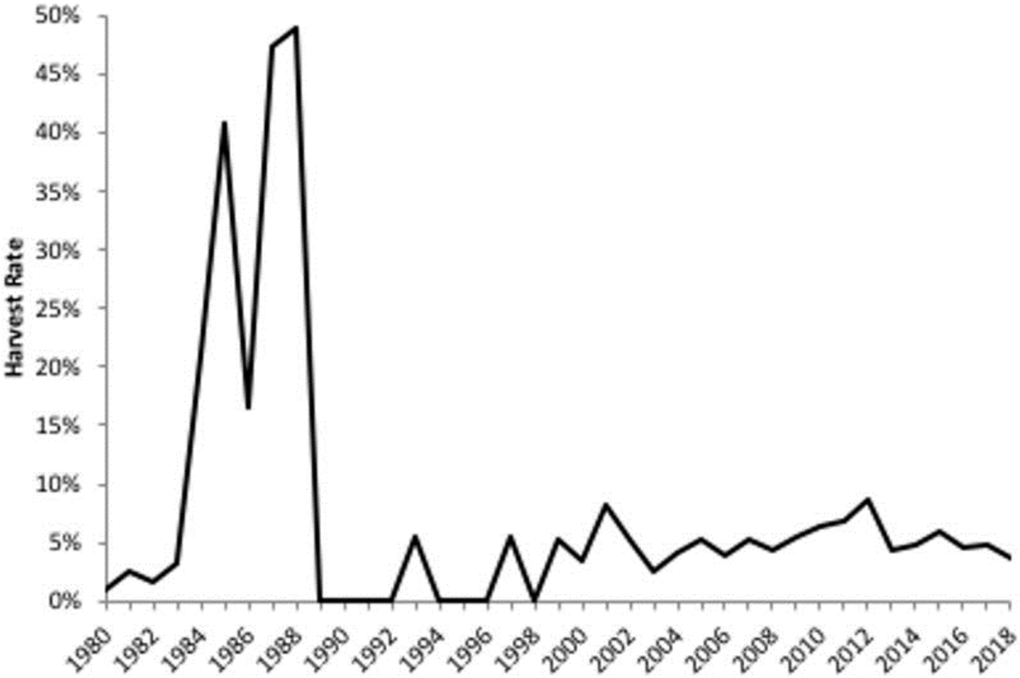


Figure 29. Exploitation rates on Snake River sockeye salmon. Figure reproduced from Ford (Ford 2022).

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 2015b). 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 2015b). Historical accounts indicate that Alturas Lake Creek supported an early timed riverine, and may have also contained lake shoal spawners (NMFS 2015b).

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 2015b). 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 2015b). 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.

<u>Hatcheries</u>

Currently, there are two ESA-listed sockeye salmon hatchery programs in the Snake River basin (Table 32). The hatchery programs' priorities are genetic conservation and building sufficient returns to support sustained outplanting (NMFS 2013a);(NMFS 2015b). 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, Plaster, et al. 2020). 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 2022f). 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, Kozfkay, et al. 2020).

In 2020, there were only 26 adult hatchery returns (NMFS 2022f) 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, Plaster, et al. 2020). 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, Plaster, et al. 2020). 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).

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).

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 UCR 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 2015b). 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 2015b); (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 2015b).

The recovery plan (NMFS 2015b) 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
- Changing environmental conditions

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 2015b).

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).

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 2013b).

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 LCR, emergence timing differs slightly between winter and summer life-history types and among subbasins (NMFS 2013b). 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 (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 LCR, 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 2013b).

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 and ODFW 2011).

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 and Taft 1954); (Narver 1969); (Ward and Slaney 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 LCR steelhead, MCR steelhead, UCR steelhead, UWR steelhead, and Snake River Basin steelhead. Within these steelhead DPSs 72 demographically independent populations were identified (Table 33). 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 33. Steelhead ESA-listed salmon populations considered in this Opinion.

Recovery Domain	DPS	MPGs	Populations
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**	**18**	**72**

Willamette/Lower Columbia Recovery Domain

Lower Columbia River Steelhead DPS

On March 19, 1998, NMFS listed the LCR 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 LCR steelhead was designated on September 2, 2005 (70 FR 52833). The most recent 5-year review for LCR steelhead was released in 2022 (NMFS 2022e). 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 2022e).

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 34). The LCR Steelhead DPS is composed of 23 historical populations, split by summer or winter life history, resulting in four MPGs (Table 34). There are six summer populations and seventeen winter populations (Table 34).

Lower Columbia River steelhead exhibit a complex life history (Figure 30, Table 35). Lower Columbia River basin populations include summer and winter steelhead (Ford 2022); (NMFS 2022e). The two life-history types differ in degree of sexual maturity at freshwater entry, spawning time, and frequency of repeat spawning (NMFS 2013b). 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, Chilcote, and Loch 1986); (Busby et al. 1996); (Hulett, Wagemann, and Leider 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 LCR subbasins and also return to other Columbia River tributaries as far upriver as Oregon's Fifteenmile Creek.

Table 34. Lower Columbia River Steelhead DPS description and MPGs (Ford 2022); (NMFS 2022e). The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively (NMFS 2013b).

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

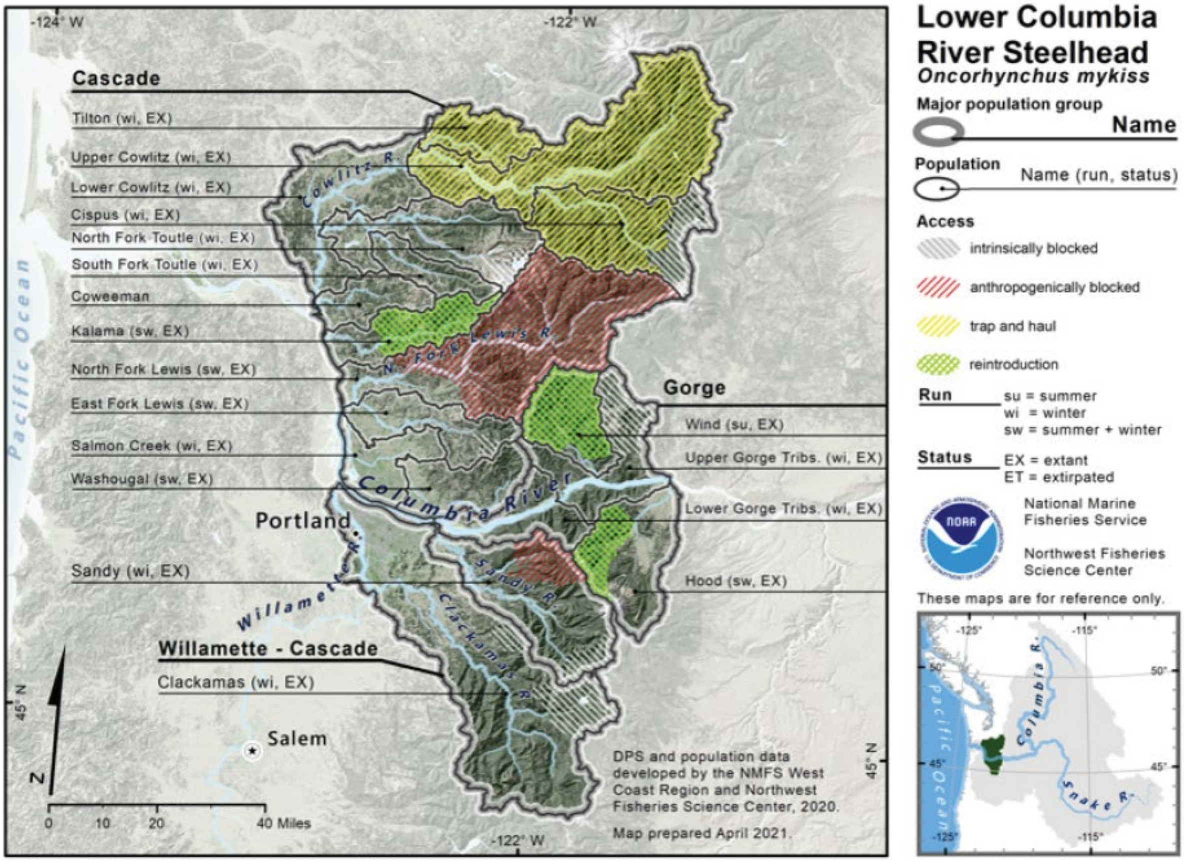


Figure 30. Map of 23 winter and summer-run steelhead demographically independent populations in the Lower Columbia River steelhead DPS. The DPS is separated into two MPGs: Cascade and Gorge. Areas that are accessible (green), accessible only via trap-and-haul programs (yellow), or blocked (cross-hatched), are indicated accordingly (Ford 2022).

Table 35. Life history and population characteristics of LCR steelhead.

Characteristic	Life-History Features	
	Summer	**Winter**
Number of extant populations	10	23
Life history type	Stream	Stream
River entry timing	May-November	November-April
Spawn timing	late February-May	late April-June
Spawning habitat type	Upper watersheds, streams	Rivers and tributaries
Emergence timing	March-July	March-July
Duration in freshwater	1-3 years (mostly 2)	1-3 years (mostly 2)
Rearing habitat	River and tributary main channels	River and tributary main channels

Estuarine use	Briefly in the spring, peak abundance in May	Briefly in the spring, peak abundance in May
Ocean migration	North to Canada and Alaska, and into the N Pacific	North to Canada and Alaska, and into the N Pacific
Age at return	3-5, occasionally 6 years	3-5, occasionally 6 years
Recent natural spawners	1,500	3,500
Recent hatchery adults	2,000	9,000

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 LCR 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%).

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 31, Table 36). Although the five-year geometric abundance means are near recovery plan goals for many populations (Table 36), 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 36); 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 31).

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 2022e). 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 2022e). 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 LCR steelhead fisheries with 2018 harvest rates for winter-run steelhead in mainstem fisheries at 0.3% (NMFS 2018b), 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).

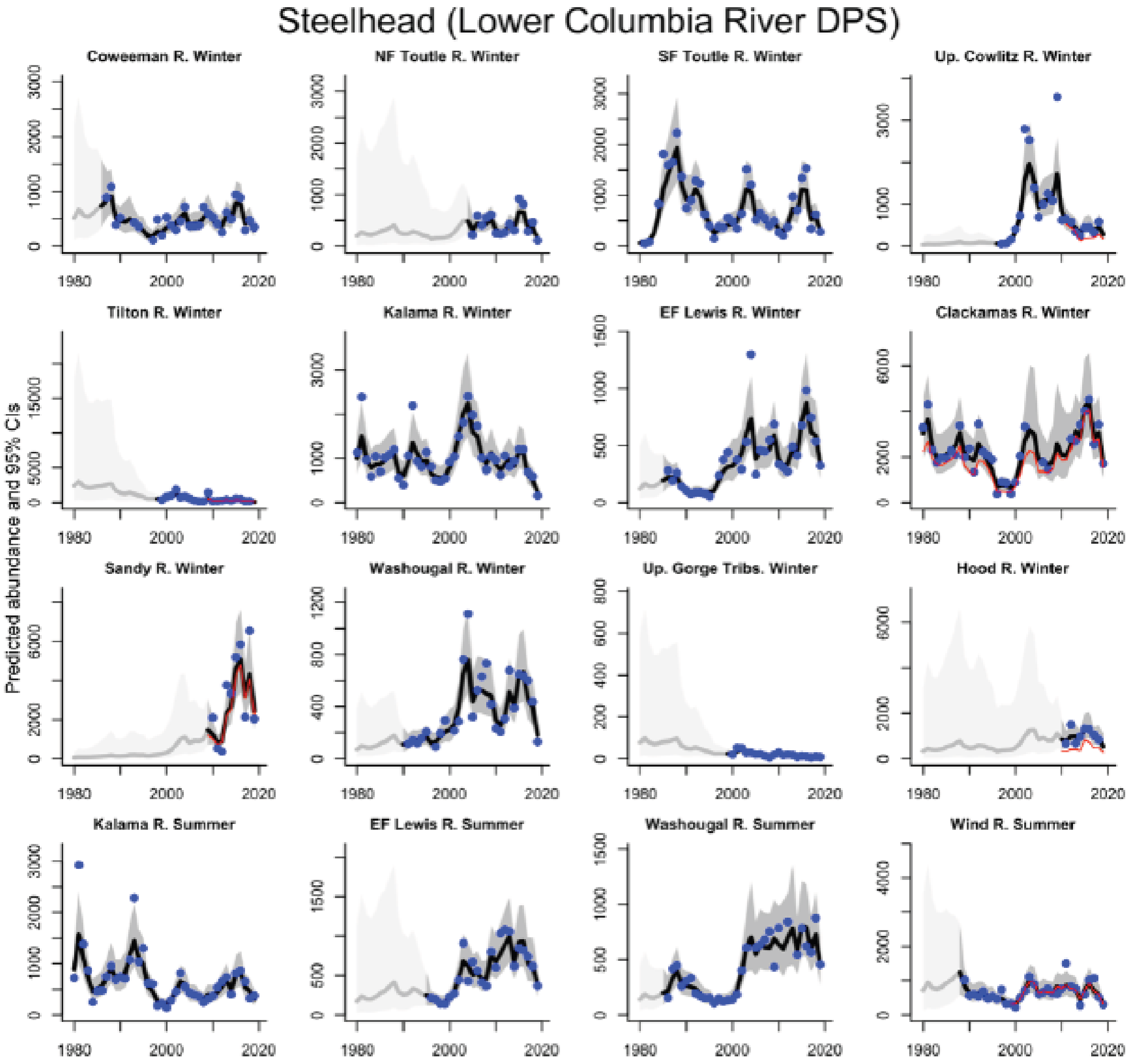


Figure 31. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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 36. 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

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).

Hatcheries

Total steelhead hatchery releases in the LCR 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 37), 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 LCR steelhead hatchery management since the 2016 5-year review (NMFS 2022e). 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 37. 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

Population[a]	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
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).

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 LCR steelhead DPS is therefore considered to be at “moderate” risk (Ford 2022), and the viability is largely unchanged from the prior review (NWFSC 2015).

Limiting Factors

Understanding the limiting factors and threats that affect the LCR 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 LCR 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 LCR Steelhead DPS available from various sources (NMFS 2013b).

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 LCR considered in the plan. Chapter 9 of the plan discusses the limiting factors that pertain specifically to LCR 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,
- Changing environmental conditions, 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 LCR 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 2017c) 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 LCR 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 2013b), but this will be alleviated by switching to hatchery broodstocks whose genetic origins are from those in the LCR (NMFS 2017c).

2.2.2.1.1 Upper Willamette River Steelhead DPS

On March 25, 1999, NMFS listed the UWR 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 UWR Steelhead was completed in 2024 (NMFS 2024a). The NWFSC finalized its updated biological viability assessment for Northwest Pacific salmon and steelhead listed under the ESA in January 2022 (Ford 2022).

The UWR 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 UWR 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 38)(Ford 2022); (NMFS 2024a). 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 (NMFS 2005c), 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 (NMFS 2005c).

Table 38. 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 2024a).

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 UWR 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 and NMFS 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 and NMFS 2011).

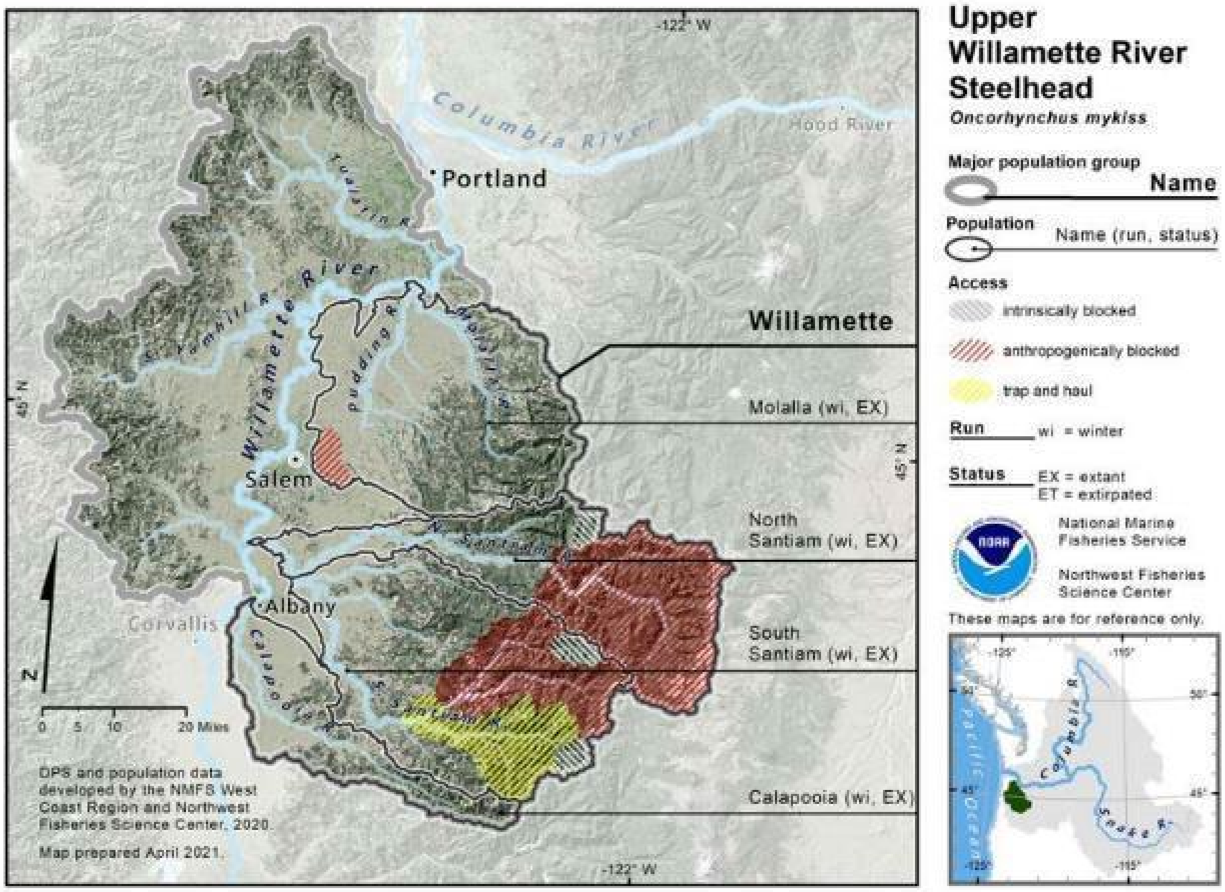


Figure 32. Map of the four demographically independent populations in the Upper Willamette River steelhead DPS (Ford 2022).

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 UWR 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).

2.2.2.1.1.2 Abundance and Productivity

Abundance and life history data for steelhead in the UWR 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, Sharpe, and Friesen 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. 2018); (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 33, Table 39). 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 40), 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).

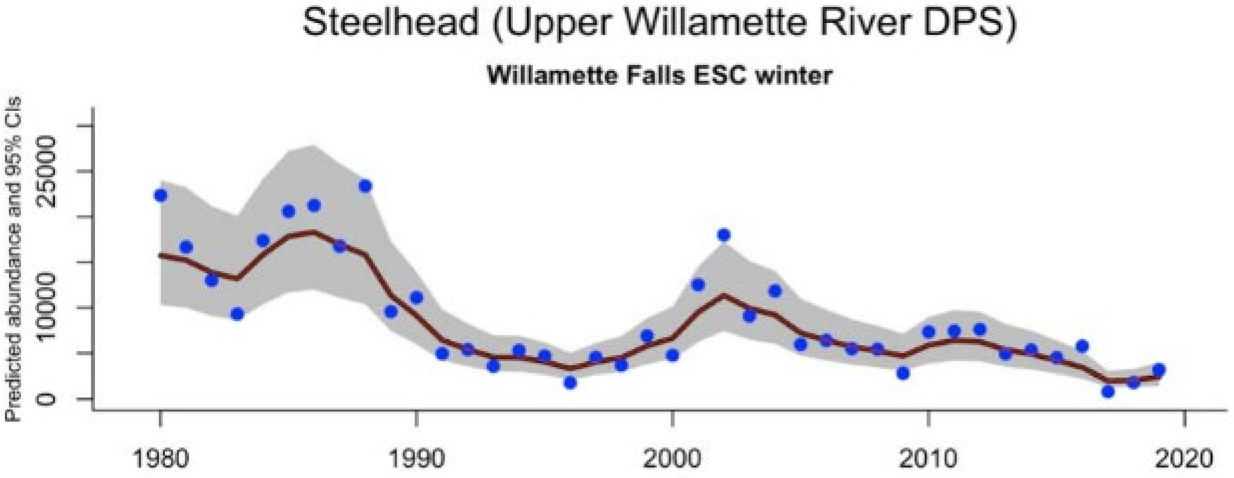


Figure 33. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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. 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)	—	—	—

2.2.2.1.1.2.2.1 Harvest

There is no consumptive fishery for winter steelhead in the UWR (Ford 2022). Winter-run steelhead in the Columbia River fishery are intercepted at a low rate, 0.2% (ODFW and WDFW 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 UWR steelhead (Ford 2022).

2.2.2.1.1.2.2.1 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).

2.2.2.1.1.2.2.2 Hatcheries

Winter-run steelhead hatchery programs were terminated in the late 1990s (Ford 2022). Currently, the only steelhead programs in the UWR release Skamania Hatchery-origin summer-run steelhead. Annual total releases for the entire UWR DPS (including the McKenzie and Middle Fork Willamette Rivers) have decreased slightly, to 500,000 (2015–19; Figure 34). Still, the legacy of previous hatchery-origin releases persists in the UWR.

A recent genetic study by Johnson et al. (Johnson et al. 2021) 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 (LCR, 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 UWR, 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 40).

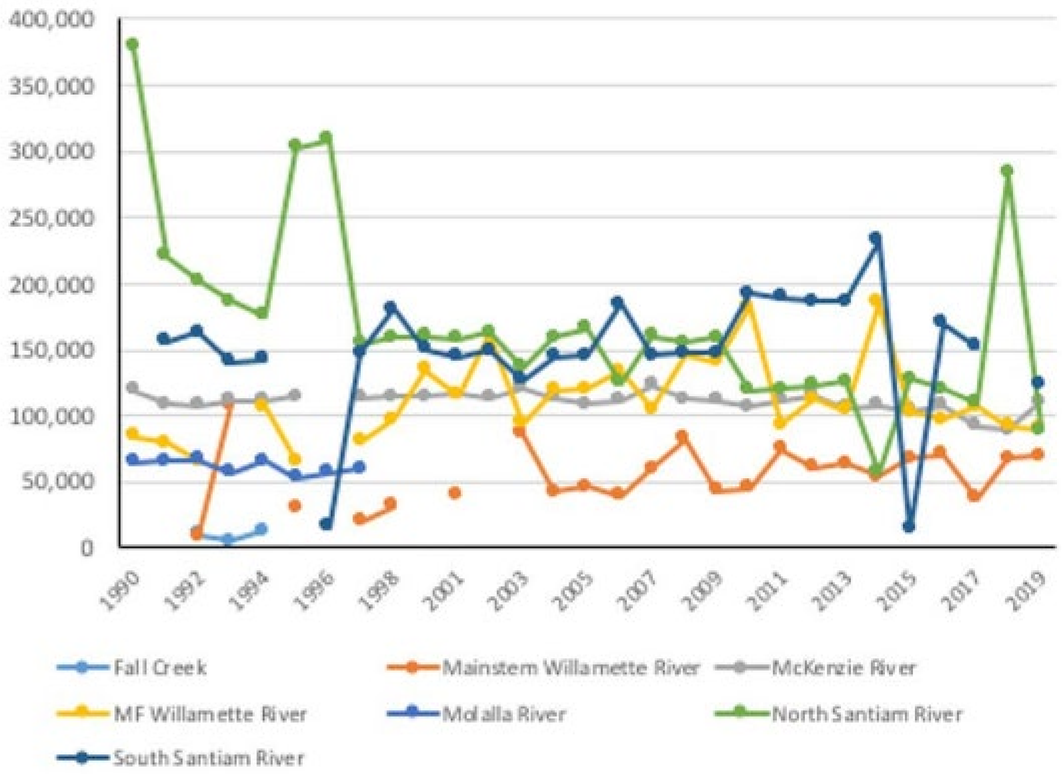


Figure 34. Annual releases of hatchery-origin (Skamania stock) summer-run steelhead into Willamette River tributaries, by sub-basin. Releases of fish <2.5 g are not included. All releases are considered to be out-of-DPS in origin. Data from the Regional Mark Information System (https://www.rmpc.org, April 2020)(Figure reproduced from Ford (Ford 2022)).

Table 40. Current 5-year geometric mean of raw natural-origin abundances and recovery scenario targets presented in the recovery plan (ODFW and NMFS 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

2.2.2.1.1.2.2.3 Summary

Overall, the UWR steelhead DPS continued to decline in abundance (Table 39, Figure 33). 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. 2018); (Johnson et al. 2021). 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 2008c), 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 UWR Steelhead DPS is therefore at "moderate-to-high" risk, with a declining viability trend (Ford 2022).

2.2.2.1.1.3 Limiting Factors

Understanding the limiting factors and threats that affect the UWR 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 UWR 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 and NMFS 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 UWR Steelhead DPS (ODFW and NMFS 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 is potentially a concern. Genetic analysis suggests that there is some level of introgression among native late-winter steelhead and summer steelhead (Friesen and Ward 1999), although reports from ODFW seem to indicate that the gene flow rate has recently been reduced to acceptable levels due to changes in the hatchery operations (ODFW 2024) . 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).

Interior Columbia Recovery Domain

Middle Columbia River Steelhead DPS

On March 25, 1999, NMFS listed the MCR 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 MCR steelhead was designated on September 2, 2005 (70 FR 52808). The most recent 5-year review for MCR steelhead was released in 2022 (NMFS 2022c).

The MCR 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 UCR tributaries (upstream of Priest Rapids Dam) and the Snake River. Four MPGs, composed of 19 historical populations (2 extirpated), comprise the MCR Steelhead DPS (Figure 35). 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 41). As explained by NMFS (NMFS 2005c), 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 (NMFS 2005c).

Table 41. Middle Columbia River Steelhead DPS description and MPGs (Ford 2022); (NMFS 2022c). 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

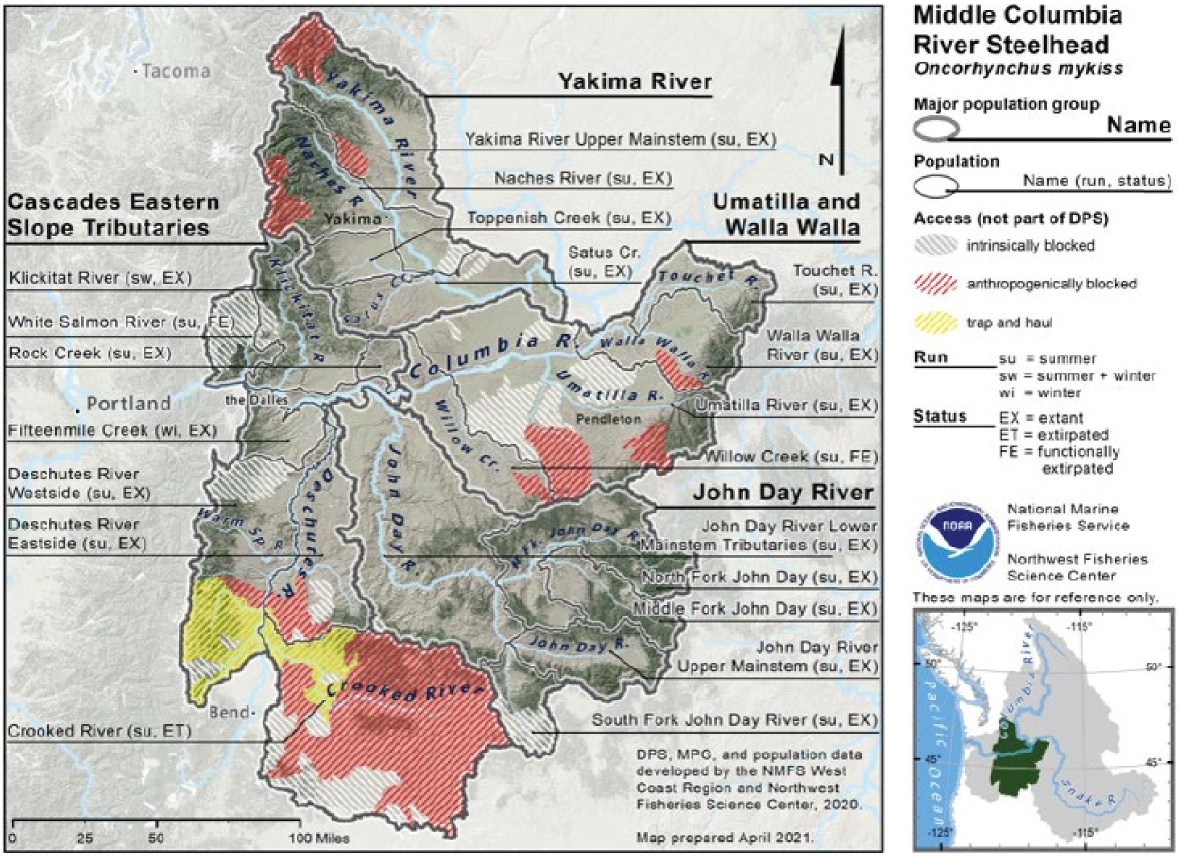


Figure 35. Map of the Middle Columbia River steelhead DPS's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

Steelhead exhibit more complex life history traits than other Pacific salmonid species as discussed in previous steelhead specific DPS sections above. While MCR 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 and ODFW 2011).

The MCR Steelhead DPS includes the only populations of inland winter steelhead in the Columbia River (those populations in the LCR Steelhead DPS and UWR 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); (Murtagh 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 and ODFW 2011).

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 MCR 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, Waples, and Adams 2005). In the MCR 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 and Reeves 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).

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 36). 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 36). 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 36).

Five-year geometric mean natural-origin and total abundance (Figure 36) 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 36).

Total spawning escapements have decreased in the most recent brood cycle for all three populations in the Umatilla/Walla Walla MPG as well (Figure 36). The 15-year trend in natural-origin abundance was positive for the Umatilla River population and slightly negative for Touchet River (Figure 36), though the trends are shallow (Ford 2022). Population productivity was cyclical, with most populations following a similar pattern of growth and decline (Ford 2022).

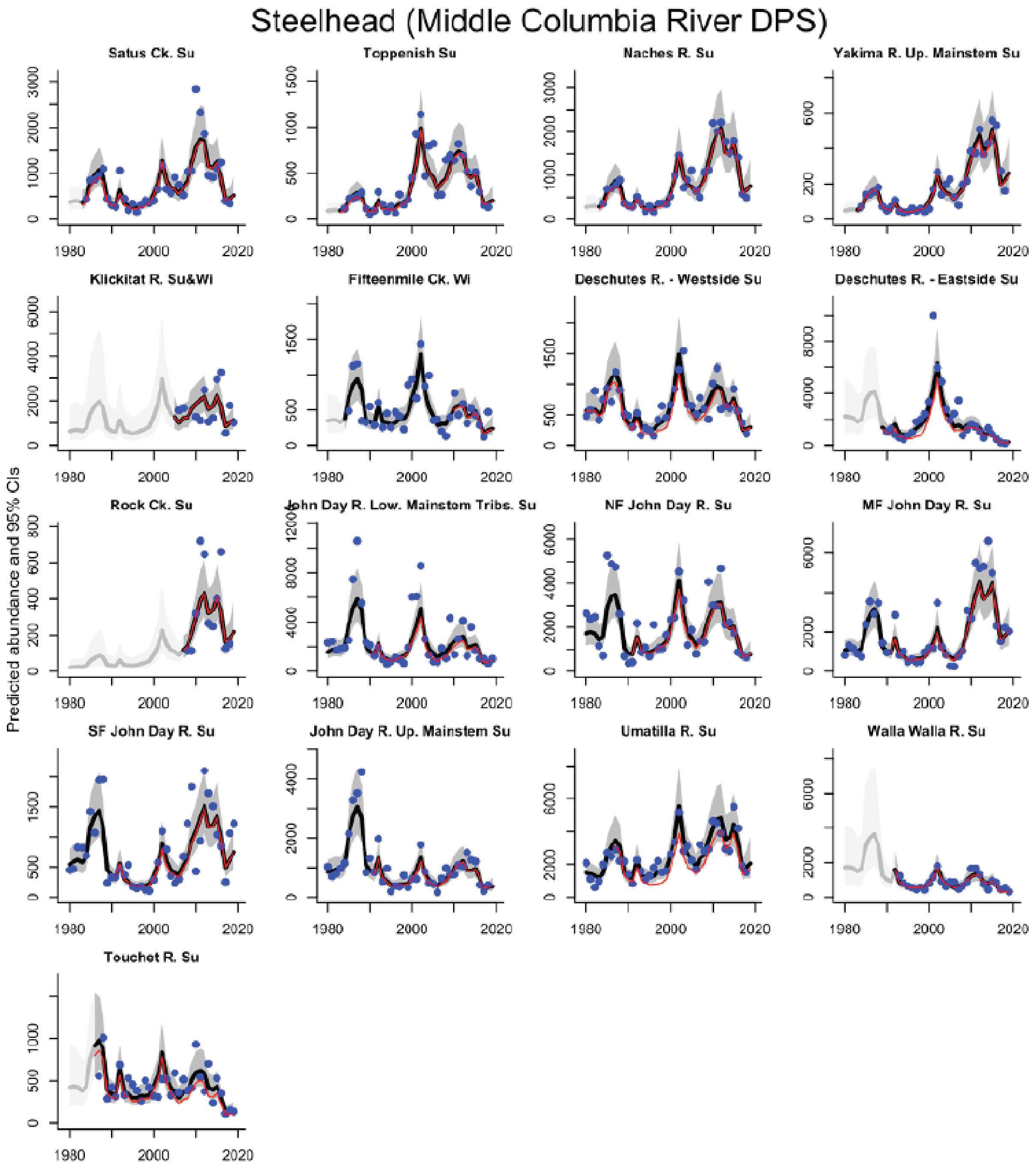


Figure 36. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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 42. 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

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**
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
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

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 2023b). The majority of harvest related impacts on MCR steelhead occurs in the mainstem Columbia River. Fisheries that impact MCR 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 2016b) and limits on incidental harvest rates for MCR steelhead have remained the same (NMFS 2018b). Pursuant to the Agreement, non-treaty fisheries (Figure 37) are managed subject to limits on the winter and summer components of the MCR steelhead DPS of 2% and 4%, respectively (NMFS 2018b). Over the past six years (run year 2014 through 2019), harvest rates of MCR 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 2022c). There are no specific limits for impacts in treaty fisheries for MCR steelhead, but harvest rates have remained the same since the 2016 5-year review (NMFS 2016b) and have not changed under the 2018 Management Agreement (NMFS 2018b).

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 MCR 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).

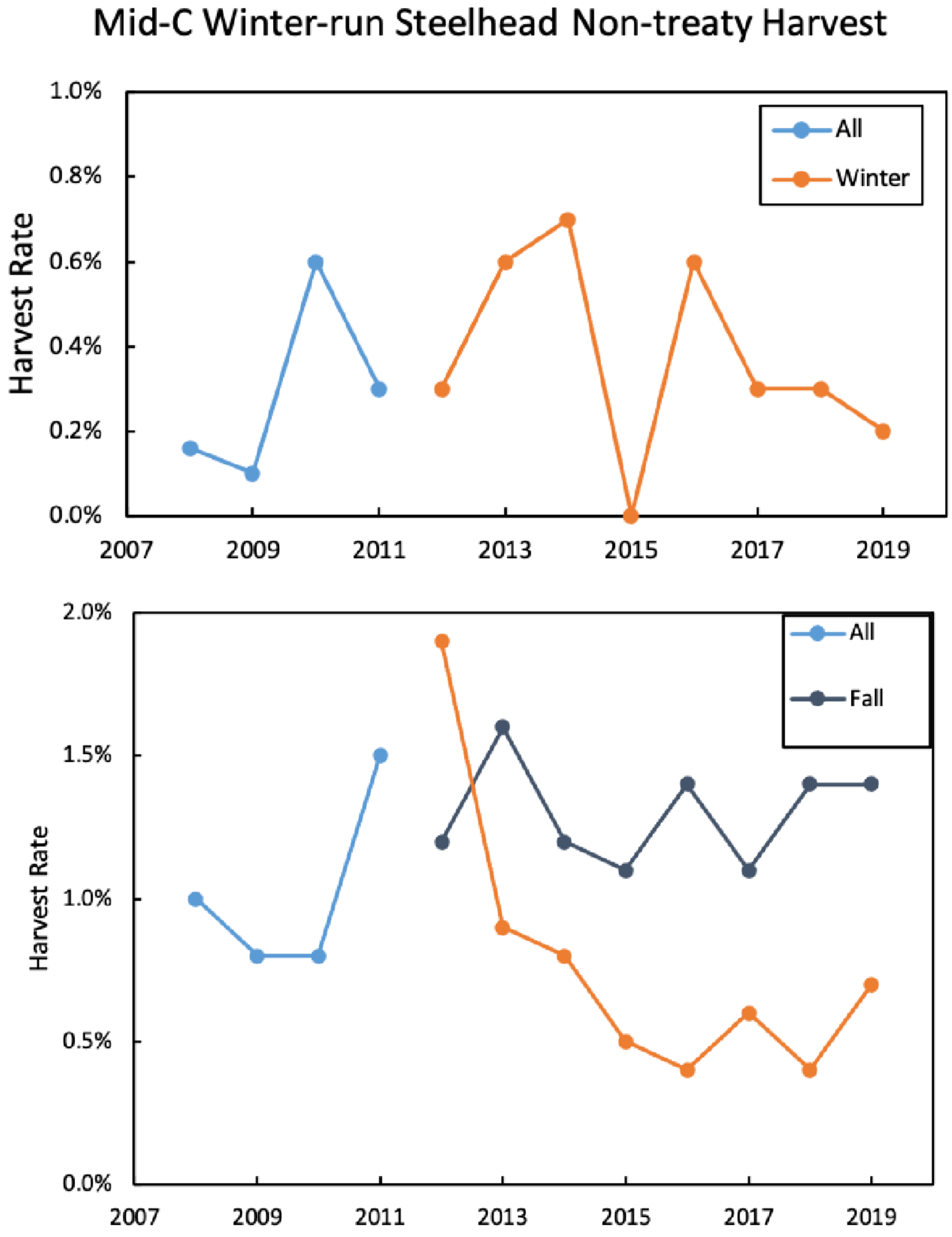

Mid-C Winter-run Steelhead Non-treaty Harvest

Figure 37. 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 (Ford 2022)).

Hatcheries

The proportions of hatchery-origin returns in natural spawning areas varies between the MPGs within the MCR Steelhead DPS (Table 43), 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 2007); (NMFS 2008d); (NMFS 2017c); (NMFS 2018b); (NMFS 2019a).

Out-of-DPS hatchery strays may pose a risk to some Oregon MCR steelhead populations, particularly the Eastside and Westside Deschutes and John Day populations (NMFS 2022c). NMFS's 2016 5-year review (NMFS 2016b) 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 2016b).

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 2022c). 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 2022c).

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 2022c). 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 2019c), and the Round Butte Hatchery summer steelhead program (Deschutes River) is proposing to incorporate natural-origin adults into the broodstock (NMFS 2022c).

Table 43. 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

Summary

The MCR Steelhead DPS does not currently meet the viability criteria described in the MCR Steelhead Recovery Plan (NMFS 2009); (NMFS 2022c). In addition, several of the factors cited by the 2005 Biological Review Team (Good, Waples, and Adams 2005) remain as concerns or key uncertainties. While recent (5-year) returns are declining across all populations (Figure 36), 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 42). 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 43). Overall, the MCR Steelhead DPS remains at “moderate” risk of extinction (Ford 2022), with viability unchanged from the prior review (NWFSC 2015).

Limiting Factors

Understanding the limiting factors and threats that affect the MCR 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 MCR 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 MCR 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 MCR Steelhead DPS populations (Ford 2022).

The recovery plan (NMFS 2009) 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 and ODFW 2011).
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 MCR Steelhead DPS (NMFS 2009). 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 2009). 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
- Changing environmental conditions

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

Overall, the MCR Steelhead DPS is not currently meeting the viability criteria (adopted from the ICTRT) in the Mid-Columbia Steelhead Recovery Plan (NMFS 2009). In addition, several factors cited by the 2005 Biological Review Team remain as concerns or key uncertainties

(Good, Waples, and Adams 2005). The population level viability ratings remained largely unchanged from the prior review (NWFSC 2015) for each MPG within the DPS (Ford 2022).

Upper Columbia River Steelhead DPS

On August 18, 1997, NMFS listed the UCR Steelhead DPS as an endangered species (62 FR 43937). The UCR 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 UCR Steelhead DPS was designated on September 2, 2005 (70 FR 52630). The most recent five-year review for UCR Steelhead was released in 2022 (NMFS 2022h).

The UCR 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 44, Figure 38) (Ford 2022); (NMFS 2022h).

As with other Steelhead DPSs, NMFS has defined the UCR Steelhead DPS to include only the anadromous members of this species (70 FR 67130). The UCR Steelhead DPS is composed of one extant MPG with four extant populations (Table 44 and Figure 38).

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

Table 44. Upper Columbia River Steelhead DPS description and MPGs (Ford 2022); (NMFS 2022h).

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

DPS Description	
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)

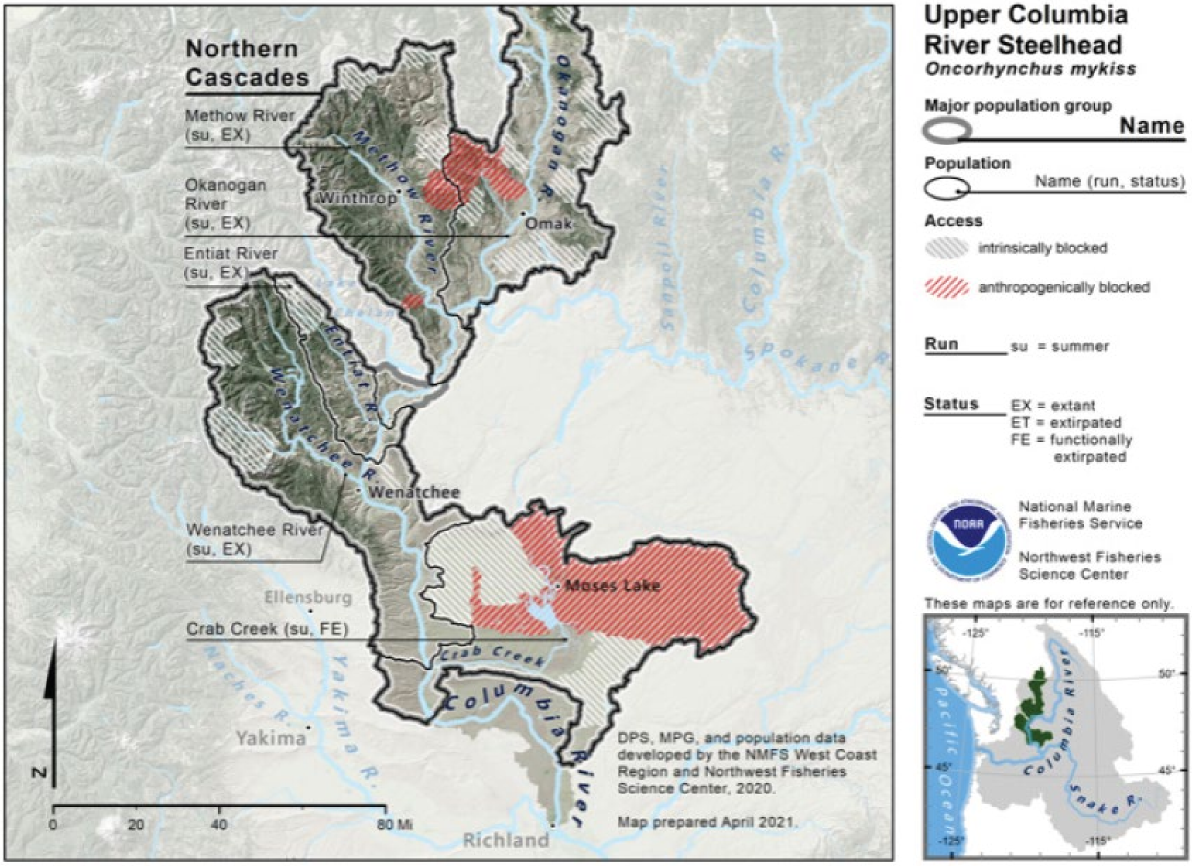


Figure 38. Map of the Upper Columbia River Steelhead DPS's spawning and rearing areas, illustrating natural populations and MPGs (Ford 2022).

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 UCR 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).

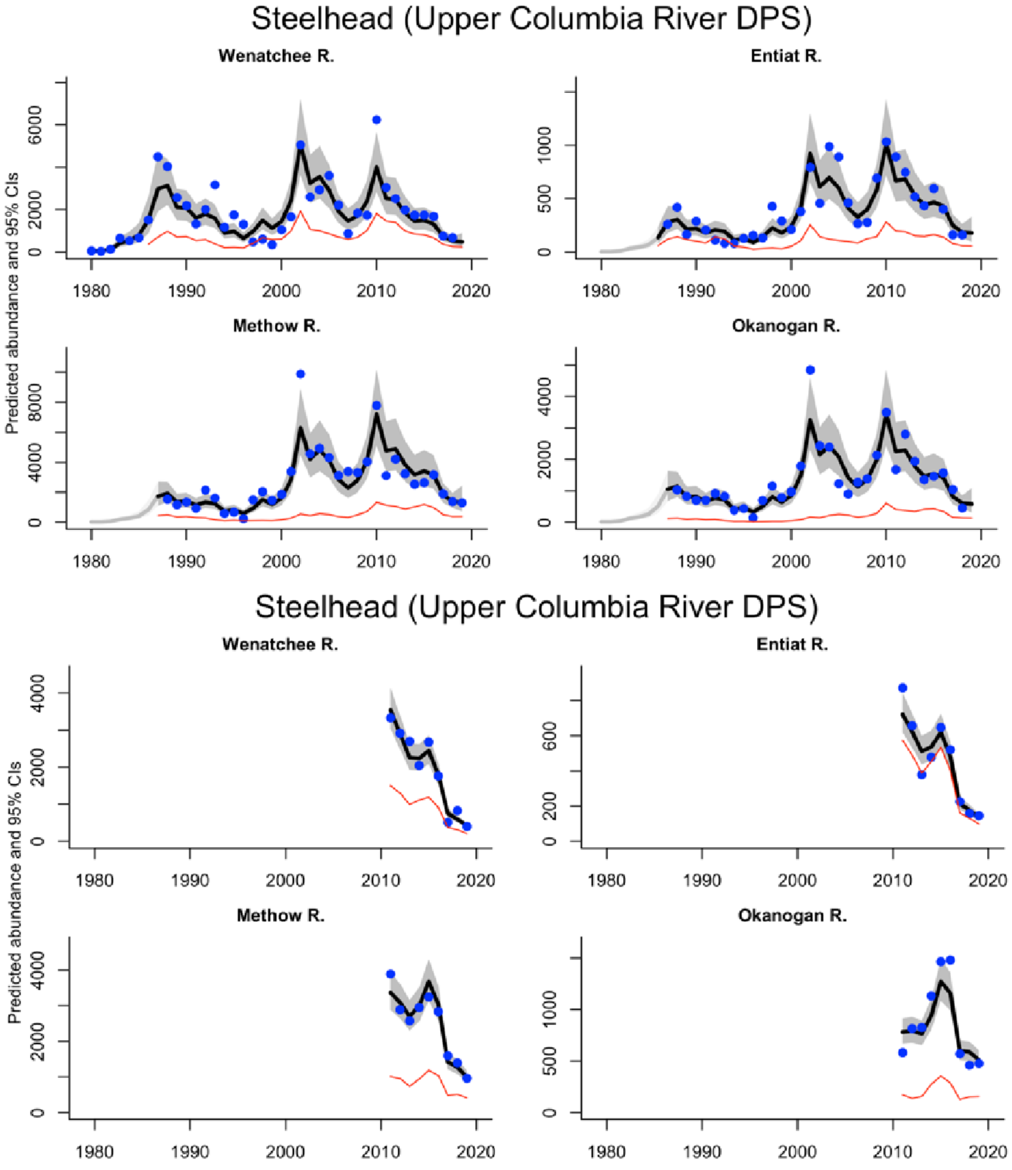


Figure 39. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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).

Abundance and Productivity

All four populations in the UCR Steelhead DPS remain at high overall risk (NMFS 2022h). Natural origin abundance has decreased over the levels reported in the prior review for all populations in this DPS, in many cases sharply (Figure 39). 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 39). 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.

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 45). The overall diversity ratings remain unchanged at high risk (Table 45). 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 2022h). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

Table 45. 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 (NMFS 2022h), adapted using data from Ford (Ford 2022)).

		Risk Rating for Spatial Structure/Diversity			
Risk Rating for Abundance/ Productivity		Very Low	Low	Moderate	High
	Very Low (<1%)	Highly Viable	Highly Viable	Viable	Maintained
	Low (1–5%)	Viable	Viable	Viable	Maintained
	Moderate (6–25%)	Maintained	Maintained	Maintained	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 UCR 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 45).

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 2022h). The majority of harvest on UCR steelhead occurs in the mainstem Columbia River (NMFS 2022h). 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 2018b). Overall, impacts on UCR 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 UCR steelhead but harvest rates have remained the same since the 2016 5-year review and have not changed under the 2018 Management Agreement (NMFS 2018b).

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 UCR tributaries (Ford 2022). In recent years, UCR exploitation rates have been stable at around 1.5% (Figure 40). As of 2012, rates are estimated over two management intervals per year, Fall and Winter/Spring/Summer (Figure 40).

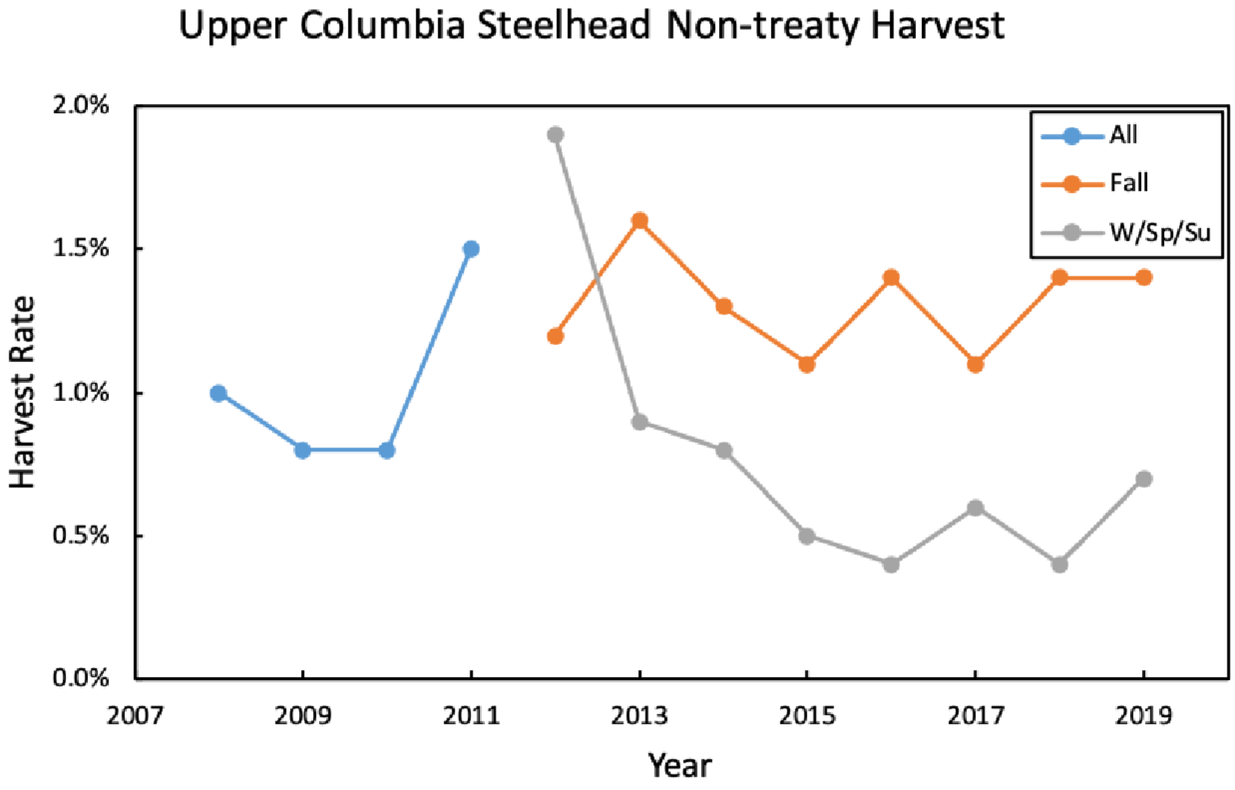


Figure 40. Harvest rates for non-treaty Upper Columbia River steelhead. As of 2012, reporting is generated across two management periods, Fall (orange line) and Winter/Spring/Summer (gray line). Prior to 2012, harvest rate reporting was across all of the calendar year (Figure from Ford (Ford 2022)).

Spatial Structure and Diversity

With the exception of the Okanogan population, the UCR 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 UCR 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 UCR steelhead DPS tributaries, and should allow for future analyses of current genetic structure and any impacts of changing hatchery release practices.

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 2022h).

The proportions of hatchery-origin returns in natural spawning areas remain high across the DPS, especially in the Methow and Okanogan river populations (Table 46), 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 2022h). 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 46. Five-year mean of fraction natural-origin spawners (sum of all estimates divided by the number of estimates) (table from Ford (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

Summary

The most recent estimates (five-year geometric mean) of total and natural-origin spawner abundance have declined since the NWFSC (NWFSC 2015) viability assessment, largely erasing gains observed over the past two decades for all four populations (Figure 39, Table 46). Recent declines are persistent and large enough to result in small, but negative 15-year trends in abundance for all four populations (Figure 39). The abundance and productivity viability rating for the Wenatchee River exceeds the minimum threshold for 5% extinction risk (Ford 2022). The overall UCR 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).

Limiting Factors

Understanding the limiting factors and threats that affect the UCR 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 UCR steelhead at rates that approached or exceeded optimal maximum sustainable yield, probably 69% for steelhead, as estimated in Chapman (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 LCR, 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 continue to affect the abundance, productivity, spatial structure, and diversity of the UCR 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 UCR 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, 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 46). 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).

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 2022c).

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 41) (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 47) (NMFS 2022c). 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 (NMFS 2005c).

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 47. Snake River Basin Steelhead DPS description and MPGs (Ford 2022); (NMFS 2022c).

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

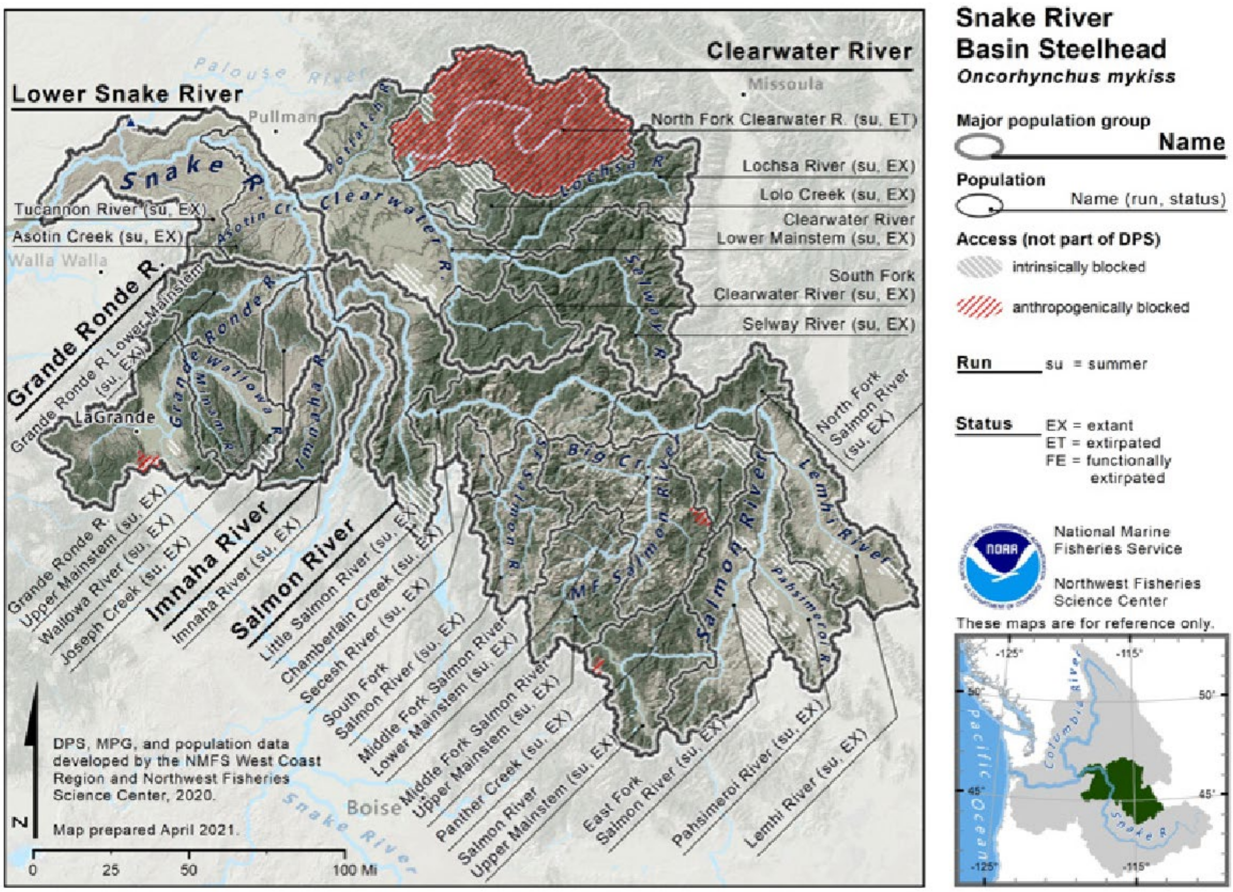


Figure 41. Snake River Basin steelhead DPS spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

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).

Abundance, Productivity, Spatial Structure, and Diversity

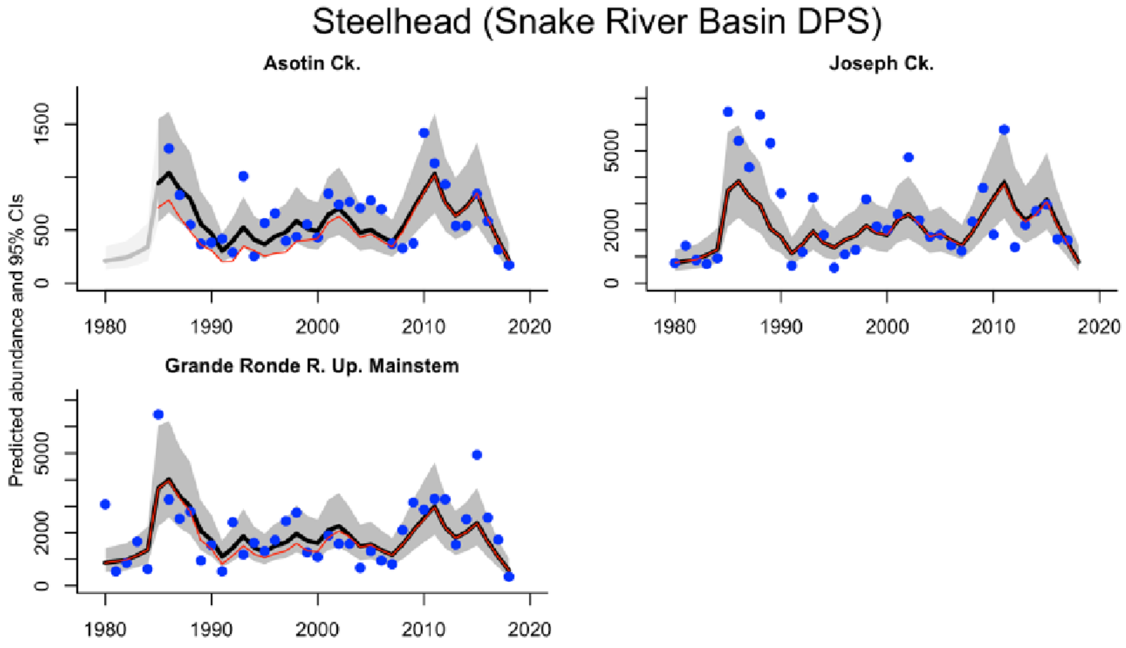
Status of the species is determined based on the abundance, productivity, spatial structure, and diversity of its constituent natural populations. Best available information indicates that the species, in this case the Snake River Basin Steelhead DPS, ranges from moderate to high risk and remains at 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).

Abundance and Productivity

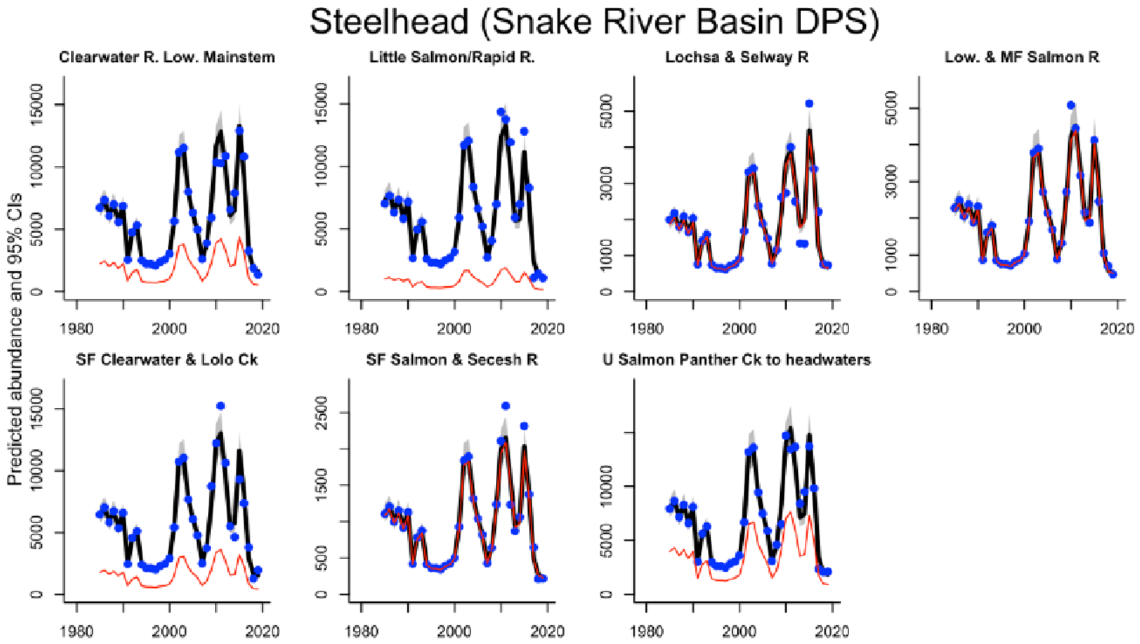
Based on the updated viability information available for this review, none of the five MPGs meet the viability criteria set forth in the 2017 recovery plan, and the viability of many individual populations remains uncertain (Ford 2022); (NMFS 2022c). Of particular note, the updated, population-level abundance estimates have made very clear the recent (last 5 years) sharp declines (Figure 42) that are extremely worrisome, were they to continue (Ford 2022); (NMFS 2022c). The most recent 5-year metric indicates that each population has decreased by about 50% (Figure 42). The viability metrics used in these analyses (standardized Pacific Northwest-wide and ICTRT) are intentionally based on long-time periods (10 to 20-year geometric means) to buffer against the rapid swings in abundance that salmon and steelhead populations are known to exhibit (Ford 2022).

Based on 20-year geometric means, productivity for all populations remains above replacement (Ford 2022); (NMFS 2022c). 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 2022c).

a)



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
0
5000
10000
15000
1000
3000
5000
500
1500
2500
1980
2000
2020

c)

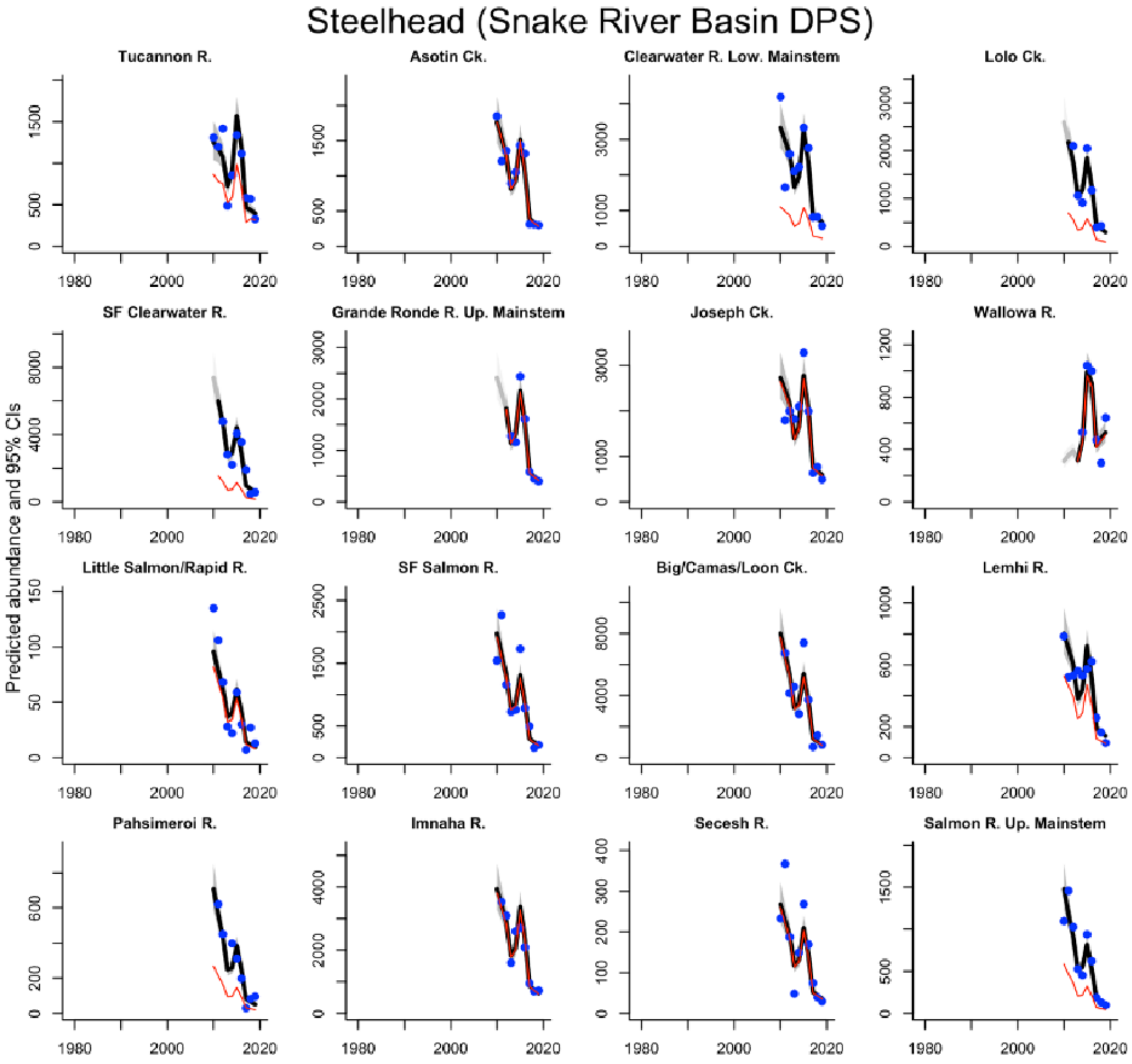


Figure 42. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with 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.

Harvest

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

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 2023a). The majority of harvest-related impacts on Snake River Basin steelhead occurs in the mainstem Columbia River (NMFS 2022c). Overall, impacts on Snake River Basin steelhead have declined since the 2016 5-year review (NMFS 2016c). Impacts in treaty fisheries have declined from 13.8% in 2016 5-year review period (NMFS 2016c) to an average of 8.7% during years 2014–2019 (NMFS 2022c). 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 2022c). Harvest rates have decreased since the 2016 5-year review (NMFS 2016c). Impacts in treaty and non-treaty fisheries are limited by the 2018–2027 *U.S. v. Oregon* Management Agreement (NMFS 2018b). Therefore, harvest continues to pose a moderate risk to Snake River Basin steelhead (NMFS 2022c).

Spatial Structure and Diversity

Spatial structure risk ratings for all of the Snake River Basin steelhead populations were low or very low risk (Table 48) given the evidence of broad distribution of natural production within populations (NMFS 2022d). The exception was Panther Creek, which was given a high-risk rating for spatial structure (Table 48) based on the lack of spawning in the upper sections (NMFS 2022d). 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 2022d). Diversity risk ratings were low to moderate and nearly unchanged from the previous 5-year review period (Table 48).

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 47), plus one kelt reconditioning program (NMFS 2022d). 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 47).

Table 48. 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

	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**
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).

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 49) 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 2022d). 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 2022d).

Summary

Population abundance declines since the 2016 5-year review (NMFS 2016c) are sharp and are expected to negatively affect productivity in the coming years corresponding with these declines (NMFS 2022d). These declines in abundance, according to short-term metrics, are of greater concern if they continue through the next 5-year review period (NMFS 2022d). 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 2022d). 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 2022d).

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 (Baker 2017). 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 2017e), 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).

Table 49. 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

Population	MPG	1995–99	2000–04	2005–09	2010–14	2015–19
Lemhi River (SU)	Salmon River	—	—	—	0.66	0.66
Pahsimeroi River	Salmon River	—	—	—	0.38	0.38
Secesh River	Salmon River	—	—	—	0.97	0.97
Upper Salmon River	Salmon River	—	—	—	0.40	0.40

Status of Eulachon (Southern DPS)

On March 18, 2010, NMFS listed the southern DPS of Pacific eulachon (*Thaleichthys pacificus*) as a threatened species (NMFS 2017b). 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 43). 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.

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 (Kitada, Hayash, and Kishino 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 (Kitada, Hayash, and Kishino 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 (Kitada, Hayash, and Kishino 2000).

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 44 and Figure 45, 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.

Table 50 provides a summary of listing and recovery plan information, status and major threats for the eulachon. Table 51 provides a summary of eulachon migration, spawning, egg emergence, and larval drift for the Columbia River subpopulation, and Table 52 provides a summary of documented river-entry and spawn-timing for eulachon.

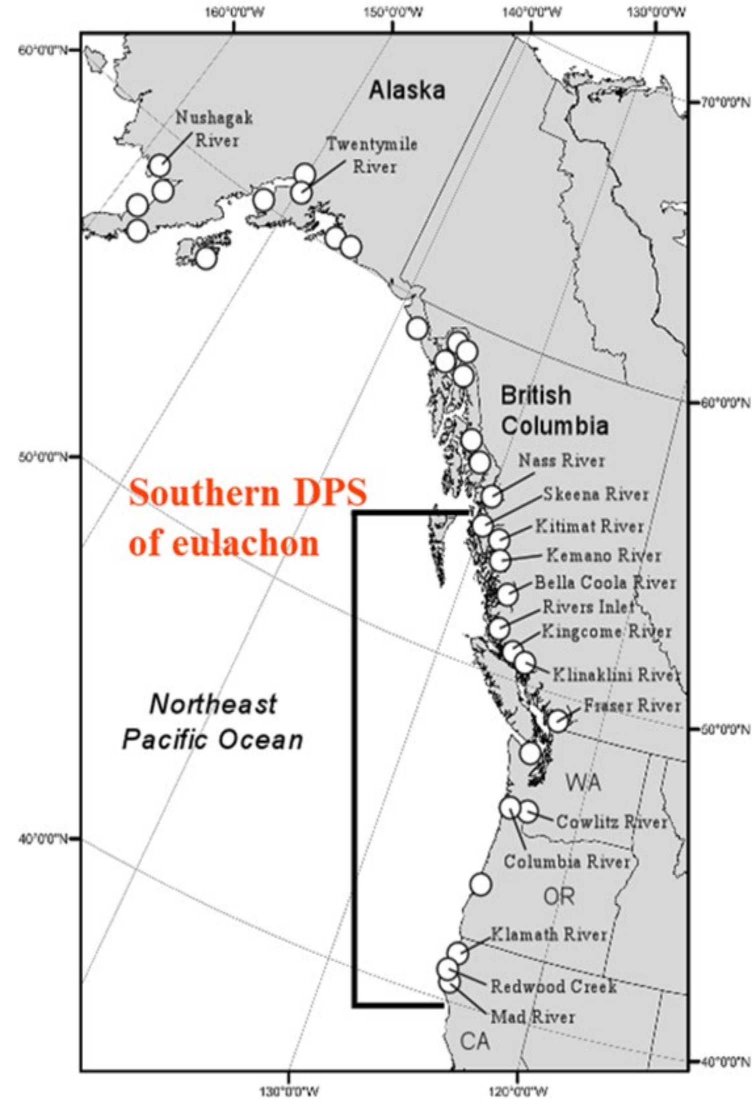


Figure 43. Distribution of the southern district population segment of eulachon.

Table 50. 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 (NMFS 2017b)	NMFS (NMFS 2022a)	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 2022j), none of the eulachon mean sustainable stock biomass (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 recovery 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 through 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

Table 51. 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[1]	0–146	Columbia	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░									░	░	░	▓
Adult Migration[2]	0–146	Columbia	▓	▓	░	░	░	░	░															░	░	▓
Adult Migration[2]		Grays	░	▓	▓	░																				
Adult Migration[2]		Cowlitz	▓	▓	▓	▓	░	░																		░
Adult Migration[2]		Kalama		░	░	▓	▓	░																		
Adult Migration[2]		Lewis	░	░	░	▓	▓	░	░																	
Adult Migration[2]		Sandy		░	░	░	▓	▓	░	░																
Spawning[2]	30–146	Columbia	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░									░	░	░	░
Spawning[2]	30–146	Columbia	▓	▓	░	░	░	░	░															░	░	▓
Spawning[2]		Grays	░	▓	▓	░																				
Spawning[3]	30–73	Columbia	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░									░	░	░	░
Spawning[2]		Cowlitz	▓	▓	▓	▓	░	░																		░
Spawning[2]		Kalama	▓	░	░	▓	▓	░																		
Spawning[2]		Lewis	░	░	░	▓	▓	░	░																	
Spawning[2]		Sandy		░	░	░	▓	▓	▓	░																
Eggs/Larval emergence-drift[1,2]	Plume–146	Columbia	░	░	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░							░	░	░	░
Eggs/Larval emergence-drift[2]	Plume–146	Columbia	▓	▓	▓	░	░	░	░	░	░	░	░											░	░	░
Eggs/Larval emergence-drift[2]	Plume–23	Grays	░	░	▓	▓	░	░	░	░																
Eggs/Larval emergence-drift[3]	Plume–146	Columbia	░	░	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░							░	░	░	░
Eggs/Larval emergence-drift[2]	Plume–68	Cowlitz	░	▓	▓	▓	▓	░	░	░	░	░														░
Eggs/Larval	Plume–73	Kalama		░	░	░	▓	▓	░	░	░															

emergence-drift[2]				░	░	░	▓	▓	░	░	░															
Eggs/Larval emergence-drift[2]	Plume–85	Lewis	░	░	░	░	▓	▓	░	░	░	░	░	░												
Eggs/Larval emergence-drift[2]	Plume–121	Sandy		░	░	░	░	▓	▓	░	░	░	░	░	░											

[1] (LCFRB 2004b)

[2] Table A-9 in (Drake et al. 2010)

3. (Romano, Howell, and Rien 2002)

Table 52. 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	
Oregon																		
Tenmile Creek	5					░	░	░	░	■	■	■	░	░	░	░		
Columbia Basin																		
Columbia River	8	░	░	░	░	■	■	■	■	■	■	░	░	░	░			
Cowlitz River	8		░	░	■	■	■	■	■	■	■							
Sandy River	5				░			░	░	■	■	■	░					
Washington																		
Elwha River	1												■	■	■			
British Columbia																		
Fraser River	3,9										░	■	■	■	░			
Kemano River	6										■	■						
Bella Coola River	10										■	■						
Kitimat River	2,7										■	░	░	░	░	░		
Skeena River	11									■	■							
Nass River	4										■	■						░

a; 1- (Shaffer et al. 2007) ; 2- (Pedersen, Orr, and Hay 1995) ; 3- (Ricker, Manzer, and Neave 1954) ; (Hart and McHugh 1944); 4- (Langer, Shepherd, and Vroom 1977) ; 5- (WDFW and ODFW 2001) as cited in (Moody 2008); 6- Lewis et al. (2002) as cited in Moody (2008); 7- Kelson (1996) as cited in (Moody 2008) ; 8- (WDFW and ODFW 2001) ;9- (Hart 1943) 10- (Moody 2008); 11- (Lewis 1997) .

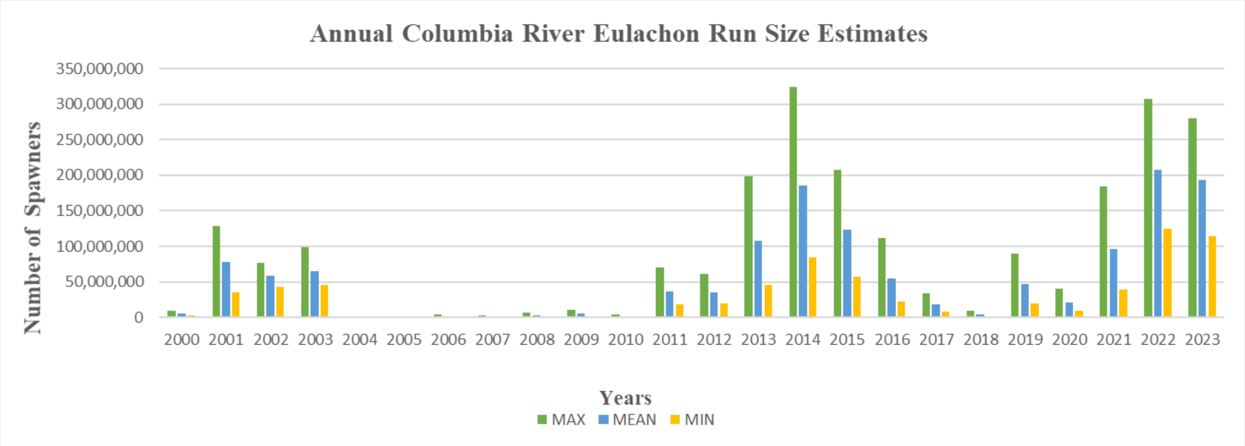


Figure 44. Columbia River subpopulation run size estimations for the years 2000 through 2023.

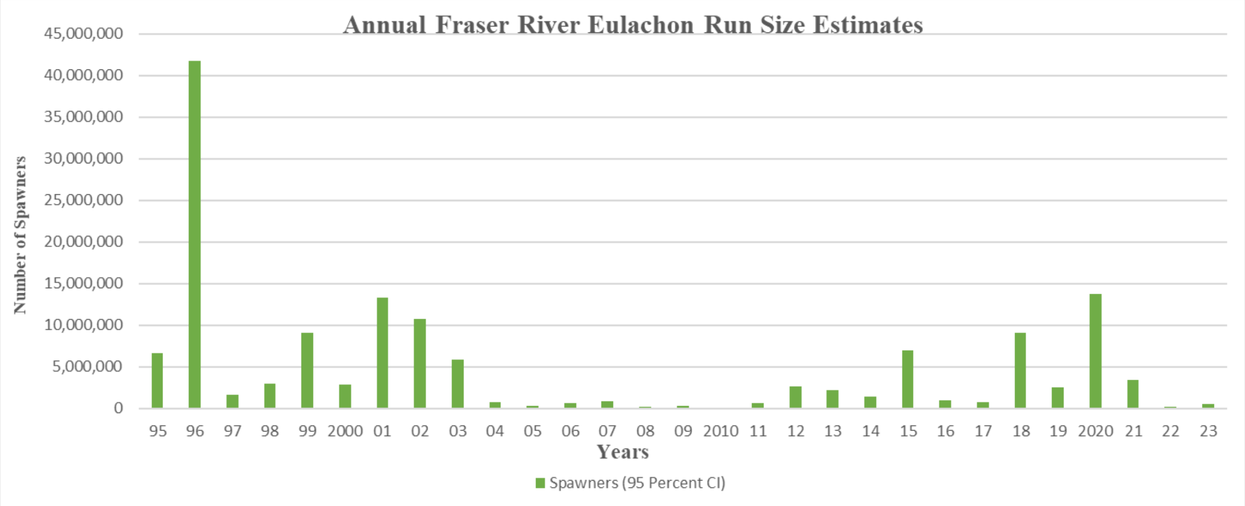


Figure 45. Fraser River subpopulation run size estimations for the years 1995 through 2023.

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. 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[15] within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5). To determine the conservation value of each watershed to species viability, NMFS's 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 2005a). 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 1 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 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

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[15] 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 2005a).

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 2005b).

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 5. Specific major factors affecting PBFs and habitat related limiting factors within the Action Area are described for each species. 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 2008b).

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’s 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 2016e).

Willamette/Lower Columbia Recovery Domain

NMFS has designated critical habitat in the Willamette/Lower Columbia recovery domain for the UWR Chinook Salmon ESU, LCR Chinook Salmon ESU, LCR Coho Salmon ESU, LCR Steelhead DPS, UWR Steelhead DPS, and the Columbia River Chum Salmon ESU.

Critical habitat for UWR 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 2005b). 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 LCR 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 2005b). The LCR 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 LCR 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 2015a). The LCR rearing/migration corridor downstream of the spawning range is considered to have a high conservation value.

Critical habitat for LCR 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 2005b). The LCR 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 UWR 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 2005b). 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 ESU 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 2005b). The LCR 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 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 2016e).

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 2016e).

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 2016e).

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, UCR Spring-run Chinook Salmon ESU, Snake River Sockeye Salmon ESU, MCR Steelhead DPS, UCR Steelhead DPS, and Snake River Basin Steelhead DPS (Table 5).

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 UCR 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 2005b). 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 MCR 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 2005b). The LCR 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 UCR 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 2005b). 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 2005b). 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 HUC5 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 2016e).

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 2016e).

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 River and UCR 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 2016e).

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 2016e). They can negatively impact critical habitat and the organisms associated with these areas.

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 0. 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 2008e).

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 2008e).

In addition, model studies indicate that, together, hydrosystem operations and reduced river flows caused by changing environmental conditions 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's 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 2008e).

NMFS (NMFS 2005b) 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 2008d).

Changing environmental conditions- Effects on Salmon and Steelhead

This section starts with a general discussion regarding vulnerability of salmonids to changing environmental conditions and temperature increase, then proceeds with discussions specific to freshwater, estuarine, and oceanic habitats. It concludes with a discussion on uncertainty in climate predictions.

General Vulnerability of Salmonids to Changing Environmental Conditions

Changing environmental conditions are 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). Changing environmental conditions are 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.

Changing environmental conditions have 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, Tohver, and Hamlet 2010); (Wade et al. 2013); (Tohver, Hamlet, and Lee 2014); (Mauger et al. 2015); (Crozier et al. 2019); (Crozier et al. 2021); (Crozier and Siegel 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. Changing environmental conditions are 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 changing environmental conditions.

Crozier et al. (Crozier et al. 2019) performed a detailed climate 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 changing environmental conditions (Figure 46). The rest were determined to have either moderate or very high vulnerability.

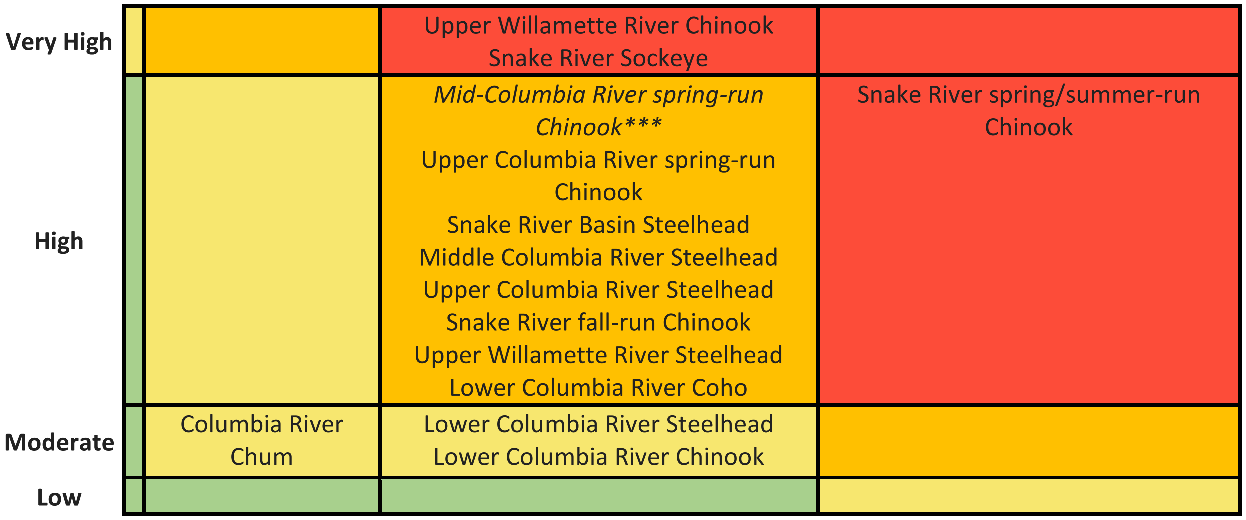
Habitat preservation and restoration actions can help mitigate the adverse impacts of changing environmental conditions on salmonids (e.g., (Battin et al. 2007); (ISAB 2007); (Beechie et al. 2013); (Crozier 2019). For example, restoring connections to historical floodplains, off-channel freshwater habitats, 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 environmental conditions 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 and Anderson 2013); (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. (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 (NMFS 2022e). 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 and Weitkamp 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. 2008).

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, Zabel, and Hamlet 2008); (Martins et al.

2011). Temperature is also an important behavioral cue for migration (Sykes, Johnson, and Shrimpton 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).

Figure 46. Vulnerability of salmon ESUs and steelhead DPSs to changing environmental conditions, including those considered in this Opinion, as determined by Crozier et al. (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. (Crozier et al. 2019).



Very High	🟨	🟧	🟥 Upper Willamette River Chinook Snake River Sockeye	🟥
High	🟩	🟨	🟧 *Mid-Columbia River spring-run Chinook**** Upper Columbia River spring-run Chinook Snake River Basin Steelhead Middle Columbia River Steelhead Upper Columbia River Steelhead Snake River fall-run Chinook Upper Willamette River Steelhead Lower Columbia River Coho	🟥 Snake River spring/summer-run Chinook
Moderate	🟩	🟨 Columbia River Chum	🟨 Lower Columbia River Steelhead Lower Columbia River Chinook	🟧
Low	🟩	🟩	🟩	🟨

As 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, Tohver, and Hamlet 2009).

Changing environmental conditions in Freshwater

As described previously, changing environmental conditions are 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. 2008); (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 and Zabel 2006). Certain salmon populations inhabiting regions that are already near or exceeding thermal maxima will be most affected by further increases in temperature and perhaps the rate of the increases while the effects of altered flow are less clear and likely to be basin-specific (Crozier et al. 2008); (Wade 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 (Bond 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 changing environmental conditions 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 and Blanchard 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).

Changing environmental conditions in Estuaries

In estuarine environments, the two big concerns associated with changing environmental conditions are rates of sea level rise and temperature warming (Wainwright and Weitkamp 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 and Weitkamp 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 and Weitkamp 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.

Changing environmental conditions 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 and

Nye 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 and Mantua 2016), and past strong El Niño events (Pearcy 2002); (Fisher, Peterson, and Rykaczewski 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, Peterson, and Kosro 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 and Mantua 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 and Blanchard 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 1992); (Weitkamp and Neely 2002); (Morris et al. 2007). The response of these ecosystems to changing environmental conditions 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[16] provides annual summaries of these ocean indicators and additional indicators based on large-scale physical, regional-scale physical, and local-scale biological data

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[16] https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

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. Changing environmental conditions play 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); (Black 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 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 and McKinnell 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. (Haigh et al. 2015) and Mathis et al. (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[17]. The NWFSC's most recent 2022 summary of ocean ecosystem indicators[18] reported 2022 was a mix of good and bad ocean

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[17] https://www.ncei.noaa.gov/access/monitoring/pdo/

[18] https://www.fisheries.noaa.gov/west-coast/science-data/2022-summary-ocean-ecosystem-indicators

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 remainder of fall was punctuated by strong positive anomalies. The existing regional climate cycles will interact with global changing environmental conditions in unknown and unpredictable ways.

Uncertainty in Climate Predictions

There is considerable uncertainty in the predicted effects of changing environmental conditions on the globe as a whole, and on Pacific Northwest in particular and there is also the question of indirect effects of changing environmental conditions and whether human "climate refugees" will move into the range of salmon and steelhead, increasing stresses on their respective habitats (Dalton, Mote, and [Eds.] 2013); (Poesch et al. 2016).

Many of the effects of changing environmental conditions (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. 2008); (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 changing environmental conditions 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. 2008); (Waples, Beechie, and Pess 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); (Beaudreau and Whitney 2016).

Changing environmental conditions are 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

The "Action Area" means all areas to be affected directly or indirectly by the Proposed Action, in which the effects of the action can be meaningfully detected, measured, and evaluated (50 CFR 402.02). The Action Area resulting from this analysis includes the Columbia River estuary[19] and plume[20].

Available knowledge and techniques are insufficient to discern the role and contribution of the Proposed Action to density dependent interactions affecting salmon and steelhead growth and survival in the Pacific Ocean. From the scientific literature, the general conclusion is that the influence of density dependent interactions on growth and survival is likely immeasurably small. While there is evidence that hatchery production can impact salmon survival at sea, the degree of impact or level of influence is not yet understood or predictable. Given these same limitations, we conclude here that the appropriate action area does not extend out into the ocean, beyond the plume of the Columbia River. NMFS will monitor emerging science and information and will reinitiate Section 7 consultation in the event that new information reveals effects of the action to ESA-listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

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

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[19] The estuary is broadly defined to include the entire continuum where tidal forces and river flows interact, regardless of the extent of saltwater intrusion. This geographic scope encompasses areas from Bonneville Dam (River Mile [RM] 146; River Kilometer [RKm] 235) to the mouth of the Columbia River. The scope includes the lower portion of the Willamette River (from Willamette Falls, at RM 26.6 [RKm 42.6], to the Willamette River's confluence with the Columbia River), along with the tidally influenced portions of other tributaries below Bonneville Dam. This region experiences ocean tides, extending up the Columbia River to Bonneville Dam and up the Willamette River to Willamette Falls (south of Portland at Oregon City, Oregon) from the mouth of the Columbia River.

[20] The plume is generally defined by a reduced-salinity contour of approximately 31 parts per thousand near the ocean surface. The plume varies seasonally with discharge, prevailing near-shore winds, and ocean currents. For purposes of this opinion, the plume is considered to be off the immediate coast of both Oregon and Washington and to extend outward to the continental shelf. This definition is consistent with the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead NMFS (2017a)

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 consequences to listed species or designated critical habitat from ongoing agency activities or existing 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 Habitat and Hydropower

A discussion of the baseline condition of habitat and hydropower throughout the Columbia River Basin occurs in our Biological Opinion on the Mitchell Act Hatchery programs (NMFS 2024b). Here we summarize some of the key impacts on salmon and steelhead habitat, primarily in the lower Columbia River and estuary because some of the effects from the Proposed Action are in this subarea.

Anywhere hydropower exists, some general effects exist, though those effects vary depending on the hydropower system. In the Action Area, some of these general effects from hydropower systems on biotic and abiotic factors include, but are not limited to:

- Juvenile and adult passage survival at the five run-of-river dams on the mainstem Columbia River (safe passage in the migration corridor);
- Water quantity (i.e., flow) and seasonal timing (water quantity and velocity and safe passage in the migration corridor; cover/shelter, food/prey, riparian vegetation, and space associated with the connectivity of the estuarine floodplain);
- Temperature in the reaches below the large mainstem storage projects (water quality and safe passage in the migration corridor)
- Sediment transport and turbidity (water quality and safe passage in the migration corridor)
- Total dissolved gas (water quality and safe passage in the migration corridor)
- Food webs, including both predators and prey (food/prey and safe passage in the migration corridor)

Furthermore, the mainstem dams and the associated reservoirs present fish-passage hazards, 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 (NMFS 2024b). Mainstem dams and reservoirs can also affect water quality by influencing temperature due to storage, diversions, and irrigation return flows, reducing turbidity, increasing total dissolved gas, and contributing toxic contaminants. All of these impacts affect the migration of adults and juveniles in the mainstem Columbia River.

Specifically, for LCR salmonid populations above Bonneville Dam, hydropower effects include impacts from upstream and downstream passage at Bonneville Dam and loss of important spawning and rearing habitat in the lower reaches of the tributaries used by the Upper Gorge populations that was inundated by Bonneville pool. Although not in the action area, salmon and steelhead have faced competition and predation above the dams, which may impact fitness of these fish as they pass within the Action Area.

The Biological Opinion on the Mitchell Act Hatchery programs (NMFS 2024b) provides a substantial discussion on the impacts on salmon and steelhead habitat within the Lower Columbia River ESUs/DPS. These impacts on tributary habitat resulting from the widespread development and other land use activities have disrupted watershed processes, reduced water quality, and diminished habitat quantity, quality, and complexity in most of the LCR subbasins. Past and/or current land use or water management activities have adversely affected stream and side channel structure, riparian conditions, floodplain function, sediment conditions, and water quality and quantity, as well as the watershed processes that create and maintain properly functioning conditions for salmon and steelhead (NMFS 2014); (LCFRB 2010a); (LCFRB 2010a); (ODFW and WDFW 2010). Oregon's recovery plan for the LCR ESA-listed species contains a detailed description of the factors affecting habitat quantity and quality in the Columbia River Basin (ODFW and WDFW 2010). ODFW and WDFW (2010) also identified increased fine sediments in the spawning grounds from forest and rural roads, and from glacially influenced water transfers between basins. Also identified as limiting factors affecting the physical habitat quality include past activities, such as stream cleaning, straightening and channelization, diking, wetland filling, and lack of larger wood recruitment, which resulted in the loss of habitat diversity for all three listed species in the basin.

2.4.2 **Columbia River Estuary and Plume**

The estuary and plume of the Columbia River do not have unambiguous, agreed-upon boundaries. For purposes of this document, we define estuary and plume as they are described in current recovery planning documents.(e.g.`, (NMFS 2011a)). The Columbia River estuary is the tidally influenced portion of the river and tributary reaches upstream from the Columbia mouth, which extends upstream146 miles to Bonneville Dam and up the Willamette River to Willamette Falls. During low flows, reversal of river flow has been measured as far upstream as Oak Point at RM 53 (RKm 84.8). The intrusion of saltwater is generally limited to Harrington Point at RM 23 (RKm 36.8), but saltwater intrusion can extend past Pillar Rock at RM 28 (RKm 44.8).

The Columbia River plume is generally defined by a reduced-salinity contour near the ocean surface of approximately 31 parts per thousand (Fresh et al. 2005). The plume's location varies seasonally with discharge, winds, and currents. In summer, it extends far to the south and offshore along the Oregon coast. During the winter, it shifts northward and inshore along the Washington coast. Strong density gradients between ocean and plume waters create stable habitat features where organic matter and organisms are concentrated (Fresh et al. 2005). The plume can extend beyond Cape Mendocino, California, and influences salinity in marine waters as far away as San Francisco. Here we limit discussion of the plume to be off the immediate coasts of both Oregon and Washington and to extend outward to the continental shelf (30-50 km).

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 4 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. The estuary and plume served as a physical and biological engine for salmon. Juveniles from hundreds of populations of steelhead, chum, Chinook, and coho salmon entered the estuary and plume every month of the year, with their timing honed over evolutionary history to make use of habitats rich with food. This genetic variation in behavior was an important trait that allowed salmon and steelhead to occupy many habitat niches in time and space.

Today the estuary and plume are much different. Notably, jetties at the mouth of the river restrict the marine flow of nutrients into the estuary. Dikes and levees lining the Washington and Oregon shores prevent access to areas that once were wetlands. New islands have been formed by dredged materials, and pile dike fields reach across the river, redirecting flows. Less visible but arguably equally important are changes in the size, timing, and magnitude of flows that, 200 years ago, regularly allowed the river to top its banks and provide salmon and steelhead with important access to habitats and food sources. Flow factors, along with ocean tides, are key determinants of habitat opportunity and capacity in the estuary and plume.

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 (LCREP 1999). 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.

The estuary and plume provide salmonids with a food-rich environment where they can undergo the physiological changes needed to make the transition from freshwater to saltwater habitats, and vice versa. Every anadromous salmonid that spawns in the Columbia River basin undergoes such a transformation twice in its lifetime—the first time during its first year of life (or soon after) when migrating out to sea, and the second time 1 to 3 years later, as an adult returning to spawn. The transition zone where juvenile salmonids undergo this transformation is thought to extend from the estuary itself to the near-shore ocean and plume habitats and into rich upwelling areas near the continental shelf (Casillas 1999).

The estuary and plume also serve as rich feeding grounds where juveniles have the opportunity for significant growth as they make the important transition from freshwater to seawater. Studies have shown that juvenile salmon released within the estuary and plume returned as larger adults and in greater numbers than juveniles released outside the transition zone (Emmett and Schiewe 1997 as cited in Casillas 1999). Thus, although juvenile salmonids face risks from a variety of threats in the estuary and plume, these environments are critically important. In the salmon life cycle, successful estuarine and plume residency by juveniles is critical for fast growth and the transition to a saltwater environment.

Below we discuss in more detail the current state of the estuary and plume, but it is essential to understand beforehand that utilization of the estuary and plume, and thus the impacts because of changes to these areas vary considerably according to major life history types of the salmonids experiencing them. Anadromous salmonids fall into two major life history classes, according to freshwater rearing strategy: ocean-type and stream-type. Ocean-type salmonids migrate to sea early in their first year of life, after spending only a short period in freshwater (Fresh et al. 2005). Ocean types may rear in the estuary for weeks or months, making extensive use of shallow, vegetated habitats such as marshes and swamps, where significant changes in flow and habitat have occurred (Fresh et al. 2005). Conversely, stream-type salmonids migrate to sea after rearing for more extended periods in freshwater, usually at least one year (Fresh et al. 2005). In terms of ESA-listed fish, coho, steelhead, sockeye, and upper Columbia spring Chinook, and spring/summer Chinook in the Snake Basin, are stream-type fish. Fall Chinook and chum are ocean-type fish. Lower Columbia and Willamette spring Chinook are technically ocean-type fish but naturally represent a mixture of the two types. Within these major types, historically there was a considerable diversity of estuary use, especially in ocean-type Chinook, with fish utilizing the estuary at various fry, fingerling, subyearling, and yearling stages (Fresh et al. 2005), but many previously common patterns are now considered rare.

Both ocean- and stream-type salmonids experience significant mortality in the estuary. However, as just mentioned, because the two types typically spend different amounts of time in the estuary and plume environments and use different habitats, they are subject to somewhat different combinations of threats and opportunities. For ocean-type juveniles, mortality is believed to be related most closely to lack of habitat, changes in food availability, and the presence of contaminants, including persistent, bioaccumulative contaminants present in sediments in the shallow-water habitats where ocean-type juveniles rear in the estuary. Stream types are affected by these same factors, although presumably to a lesser degree because of their shorter residency times in the estuary. However, stream types are particularly vulnerable to bird predation in the estuary because they tend to use the deeper, less turbid channel areas located near habitat preferred by piscivorous birds (Fresh et al. 2005). Table 53 compares the relative importance of major limiting factors to the two life-history types. The factors are explained in the next sections.

Table 53. Relative importance to ocean- and stream-type salmonids of limiting factors in the Columbia estuary, for factors rated as significant or higher in one of the two life-history types. Adapted from Table 3-1 of NMFS (2011a).

Factor	Ocean-type	Stream-type
Flow-related habitat changes	Major	Moderate
Sediment-related habitat changes	Significant	Moderate
Flow-related changes to access to off-channel habitat	Major	Moderate
Bankful elevation changes	Major	Minor
Flow-related plume changes	Moderate	Major
Water temperature	Major	Moderate
Reduced macrodetrital inputs	Major	Moderate
Avian and pinniped predation	Minor	Major
Toxicants	Significant	Minor-Moderate

Estuary and plume limiting factors are a vast topic, about which much has been written, and the interplay of factors can be quite complicated. Here we follow NMFS (2011a) in considering three major categories, the effects of which can be interrelated: changes in physical habitat, changes in food web that have largely been driven by physical habitat changes; and toxicants.

Habitat-Related Limiting Factors

Mean flow into the estuary has been reduced 16% from historical levels, but the pattern of flow has changed considerably. Spring freshets, important for downstream migration, have been reduced 44% and occur earlier in the year, and flow is higher than it was historically at other times of the year. This decreased flow, coupled with overall changing environmental conditions, has increased mean water temperatures at Bonneville Dam 4° C since 1938, and temperature levels of 20°C, considered the upper tolerance level for salmon (NRC 2004) occur earlier in the year and more frequently than they did historically. Variation in flow has been reduced, particularly the frequency of bank overflows, which historically was a key element in sustaining the food web.

Development and decreased flow have decreased the size of the estuary about 20%. Much of the decrease is due to reduction in channel complexity and increase in diking. By some estimates, over 70% of the historical tidal marsh habitat is now inaccessible. Levee construction has reduced the frequency of overbank flows because more water is now needed to cause overbank flow, now 24,000 cubic feet per second (cfs) compared to 18,000 cfs historically (Kukulka and Jay 2003). The reduction in overbank events reduces the availability of food and refugia for ocean-type juveniles rearing in the estuary. Less dominant stream-type juveniles are affected the same way.

The combination of decreased flow and upstream impoundments have reduced sediment inputs 60%, which has reduced the ability of the estuary to build habitat, and also had food web consequences in the estuary and plume. The plume supports ocean productivity by increasing primary plant production during the spring freshet period, distributing juvenile salmonids in the coastal environment, concentrating food sources and providing refugia from predators in the more turbid, low-salinity plume waters (Fresh et al. 2005). Changes in the volume and timing of Columbia River flow have altered both the size and structure of the plume during the spring and summer months (NPCC 2000). Reductions in spring freshets and associated sediment transport processes may now be suboptimal for juvenile salmonids (Casillas 1999). Changes in flow to the plume include surface area, volume, extent and intensity of frontal features, and the extent and distance offshore (Fresh et al. 2005).

Food-Web Limiting Factors

The estuarine food web historically was based on macrodetrital inputs that originated from emergent, forested, and other wetland rearing areas in the estuary (NPCC 2004). Today, detrital sources from emergent wetlands in the estuary are approximately 84 % less than they were historically (Bottom et al. 2005). The reduction of macrodetritus in the estuary reduces the food sources for juvenile salmonids. As a result, juveniles may have reduced growth, lipid content, and fitness prior to ocean migration or may need to reside longer in the estuary. Macrodetrital plant production has declined because of revetment construction, disposal of dredged material in areas where plant materials or insects could drop into the water, simplification of habitat through the removal of large wood, and reductions in flow.

Historically, much of the detrital inputs occurred during overbank events, which provided additional shallow-water habitat for juvenile salmonids and resulted in significant detrital inputs to the estuary.

The current food web is based on decaying phytoplankton delivered from upstream reservoirs and nutrient inputs from urban, industrial, and agricultural development. The amount of this microdetritus has increased dramatically (Bottom et al. 2005). The switch in the estuarine food web from a macrodetritus-based source to a microdetritus-based source has altered the productivity of the estuary (Bottom et al. 2005). The substitution of detrital sources in the estuary also has contributed to changes in the spatial distribution of the food web (Bottom et al. 2005). Historically the macrodetritus based food web was distributed evenly throughout the estuary, including in the many shallow-water habitats favored by ocean-type salmonids. But the contemporary microdetrital food web is concentrated within the estuarine turbidity maximum in the middle region of the estuary (Bottom et al. 2005). This location is less accessible to ocean-type fish that use peripheral habitats and more accessible to species such as American shad that feed in deep-water areas. Pelagic fish such as shad may also benefit from the fact that the estuarine turbidity maximum traps particles and delays their transport to the ocean up to 4 weeks, compared to normal transport of around 2 days (NPCC 2004).

Another aspect of the food web change is predation and competition. Predation and competition for habitat and prey resources limit the success of juvenile salmonids entering the estuary and plume. Competition among salmonids and between salmonids and other fish may be occurring in the estuary (LCFRB 2004a), with the estuary possibly becoming overgrazed when large numbers of ocean-type salmonids enter the area. Food availability may be reduced as a result of the temporal and spatial overlap of juveniles from different locations (Bisbal and McConnaha 1998). Ecosystem-scale changes in the estuary have altered the relationships between salmonids and other fish, birds, and mammal species, both native and exotic. Some native species' abundance levels have decreased from historical levels, while others have increased to levels far exceeding those in recorded history, with associated changes in predation of salmon and steelhead juveniles. Changes in physical habitat have increased opportunities for piscivorous birds such as terns and cormorants, to which stream-type smolts are especially vulnerable. Predation by northern pikeminnows has likely increased as well due to lower turbidity; both stream- and ocean-type juveniles are affected. Predation by pinnipeds has also increased over historical levels.

The introduction of exotic species has altered the ecosystem through competition, predation, disease, parasitism, and alterations in the food web. At least 37 fish species, 27 invertebrate species, and 18 plant species have been introduced into the estuary (NPCC 2004; Sytsma et al. 2004). Introduced species affect ocean-type ESUs more than they do stream-type ESUs because of the ocean types' longer juvenile estuary residency times and use of shallow-water habitats. Two of these introduced species have had especially profound consequences. American shad adult returns now exceed 4 million annually (NPCC 2004). Shad do not eat salmonids, but they exert tremendous pressure on the estuary food web given the sheer weight of their biomass. Some evidence suggests that planktivorous American shad have an impact on the abundance and size of *Daphnia* in Columbia River mainstem reservoirs (Haskell et al. 1996 in ISAB 2008), thereby reducing this important food source for subyearling fall Chinook.

2.4.3 **Harvest**

The impacts of SAFE fisheries on ESA-listed salmon and steelhead are managed under the auspices of the *U.S. v. Oregon* 2018-2027 management agreement and NMFS (2018a) section 7 Biological Opinion[21]. The SAFE fisheries for spring Chinook salmon are managed under the winter/spring management period. Fishery impacts in the SAFE areas are included in the total allowable fishery impacts for non-treaty fisheries per the agreement. The impacts allowed each year is dependent upon the abundance of spring Chinook stocks based upon a sliding scale where higher impacts are allowed when abundance is high and lower impacts when abundance is lower (NMFS 2018b). A similar fall management period exists for SAFE coho salmon fisheries affecting ESA-listed salmon and steelhead in these areas. Impacts from SAFE fall fisheries are included in the allowable impacts for non-treaty fisheries during this period per the agreement and NMFS (2018a). Therefore, any fishing-related effects of the proposed action are currently authorized by NMFS (2018a).

Two of the primary goals of the SAFE project were to develop fisheries that provided greater protection for depressed and listed stocks and to maximize harvest of returning SAFE produced adults while minimizing catch of non-SAFE stocks. The Oregon SAFE Spring Chinook program is managed to provide hatchery spring Chinook salmon to supplement harvest in ocean, Columbia River, and Select Area commercial and recreational fisheries. Coded-wire tag recoveries from 2010-2019 broods indicate harvest rates of SAFE spring Chinook from Oregon sites range from 80% for Tongue Point releases to over 88% for Blind Slough releases and 93% for Youngs Bay releases. Since program fish liberations primarily originate from net pens, escapement of SAFE spring Chinook is considered natal if the tags are recovered in Oregon Select Area basins (i.e., Tributaries draining into Youngs Bay, Blind Slough and Tongue Point) and non-natal (stray) if recovered anywhere else. The overall stray rate for all release areas combined is 0.8%; this includes recoveries in tributaries to the Columbia River, including the Willamette River. The stray rate to the Upper Willamette River (above Willamette Falls) is 0.1% ((ODFW 2025b)).

The Oregon SAFE Coho program is managed to provide Coho production to supplement harvest in ocean, Columbia River, and Select Area commercial fisheries and ocean, Columbia River and Select Area recreational fisheries. Incidental take of listed stocks in Select Area fisheries is included in biological assessments and opinions adopted for Columbia River fisheries (*U.S. v. Oregon* 2008; *U.S. v. Oregon* 2018; NMFS 2018a). Impact rates on ESA-listed fish in SAFE fisheries has been negligible as most (greater than 94%) of the fish are of SAFE origin (ODFW 2021b).

The Washington SAFE Deep River net pen program is designed to put marked hatchery coho salmon in ocean, Buoy 10, and terminal fisheries where they can be harvested with minimal impact on ESA-listed natural-origin fish. These coho salmon are not meant to contribute to any

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[21] This Opinion encompasses the impacts of all harvest in the action area, and the impacts of all harvest, including SAFE fisheries, is included in the environmental baseline.

natural populations or recovery of the ESU (WDFW 2018). Releases from the Deep River Net Pens will conclude in 2025.

2.4.4 **Hatcheries**

A more comprehensive discussion of hatchery programs in the Columbia Basin can be found in the current Biological Opinions governing hatchery management in the Lower Columbia River (e.g., NMFS 2017a; NMFS 2019(NMFS 2024b)). The Mitchell Act funded programs have all gone through ESA Section 7 consultations and thus are included as part of the baseline both for past effects and for effects into the future. The Mitchell Act opinion (NMFS 2024b) observed that, because most programs are ongoing, the past effects of each are reflected in the most recent status of the species ((Ford 2022)) and were summarized in Section 2.2.1 of this opinion. Similarly in the Upper Willamette River, broodstock collection and juvenile rearing have also gone through ESA section 7 consultation (NMFS 2019) and thus these actions are included as part of the environmental baseline.

In the past, hatcheries have been used to compensate for factors that limit anadromous salmonid viability (e.g., harvest, human development) by maintaining fishable returns of adult salmon and steelhead. Hatchery programs started being used in the 1980s and 1990s as a tool to conserve the genetic resources of depressed natural populations and to reduce short-term extinction risk (e.g., Snake River sockeye salmon). Hatchery programs have also been used to help improve viability and expand spatial distribution by supplementing natural population abundance. The changes in hatchery practices are ongoing and will continue to pose risks associated with hatchery practices generally, but reformed practices are expected to reduce the impacts of hatchery fish on natural-origin populations and are included in the environmental baseline (NMFS 2024b).

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. 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 402.17). In our analysis, which describes the effects of the proposed action, we considered 50 CFR 402.17(a) and (b).

This section describes the methodology NMFS follows to analyze hatchery effects. The methodology is based on the best available scientific information.

“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, including abundance, productivity, diversity, and spatial structure. The effects of a hatchery program on the status of an ESU or steelhead DPS "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 also analyzes and takes into account the effects of hatchery facilities, for example, operation of fish collection facilities and water use, on each VSP attribute and on designated critical habitat.

NMFS' analysis of the proposed action is in terms of effects expected on ESA-listed species and designated critical habitat, based upon the best scientific information. The effects are assessed at a site-specific level, population scale, as well as at the ESU and DPS level, in order for NMFS to make a jeopardy determination based on a comprehensive assessment of effects.

In general, the effects range from beneficial to negative for hatchery programs depending upon the specific goals and objectives of the program. In the case of SAFE programs in this consultation, the goal of all of the programs is for fishery harvest and there are no other conservation or supplementation objectives. Since there are no purposeful beneficial goals of these SAFE programs with respect to natural-origin salmon and steelhead in the Lower Columbia region, NMFS is evaluating the effects of the action and use of "best management practices" to minimize hatchery-related risks to the local, natural populations. When hatchery programs use fish originating from a different population, MPG, or from a different ESU or DPS, NMFS is particularly interested in how effective the program will be at isolating hatchery fish and avoiding co- occurrence and effects that potentially put the natural population at a disadvantage.

NMFS analyzes six categories of effects to determine the risks and benefits of the hatchery program. Essentially every biological and ecological effect of a hatchery program is evaluated within one or more of the following categories. These six categories are:

(1) broodstock origin and collection,

(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds,

(3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, mainstem rivers, estuary, and ocean,

(4) research, monitoring, and evaluation (RM&E) supporting hatchery program implementation,

(5) operation, maintenance, and construction of hatchery facilities (i.e., facility effects), and

(6) fisheries that would not exist but for the availability of hatchery fish to catch.

These six categories of effects are collectively analyzed by NMFS in previous opinions (NMFS 2018a; NMFS 2019, NMFS 2024) and below for the proposed action.

2.5.1 Broodstock Collection

All of the hatchery broodstock used to produce juvenile salmon for release at SAFE net pens is entirely fish of hatchery-origin. No natural-origin salmon are collected and used to produce SAFE hatchery fish. Natural-origin salmon may return to hatchery facilities where broodstock are collected and spawned, but none of these fish are purposefully used for SAFE broodstock. The HGMPs describe previous years' collections and the management protocols for collecting broodstock for the spring Chinook salmon and coho salmon programs releasing hatchery fish at the SAFE net pens.

For each of the hatchery facilities used to collect broodstock for the production of salmon for the proposed action, existing ESA Biological Opinions govern operations at these facilities. When these fish are collected, it is one set of actions collecting broodstock for various programs, including the SAFE programs. Nonetheless, we consider the full range of effects of the collection activities below, notwithstanding any existing coverage or prior analysis.

SAFE program fish consist of those non-listed, hatchery-origin fish already collected, and surplus to, several hatchery programs in the basin. Specifically, for the spring Chinook salmon releases, the Clackamas stock is collected from the Clackamas Hatchery on the Clackamas River, and the North and South Santiam broodstocks are collected from the Minto Fish Facility and Foster Fish Facility, respectively. The NMFS (2019) Biological Opinion assessed the effects of broodstock collection on ESA-listed salmon and steelhead in those populations, and we concluded that the effects of broodstock collection on natural-origin fish populations in the Upper Willamette River are low.

Adult salmon are collected at the Fish Collection Facilities as the base of the federal dams. Most salmon are trapped and hauled above the dams for reintroduction purposes. Other salmon are used for broodstock to continue the hatchery program, and are handled and spawned at the hatchery, as described in those opinions. Adult broodstock collected for the SAFE production is a small component of this overall broodstock collection effort, and does not add any additional effects on natural-origin spring Chinook salmon. Therefore, the effects associated with the proposed action on natural-origin Chinook populations included in the Upper Willamette Chinook salmon ESU will continue to be low.

For coho salmon, a similar situation occurs. Broodstock collection for the SAFE coho program occurs at Big Creek Hatchery[22], and consists of non-listed hatchery origin coho already collected for, and surplus to, other programs. No natural-origin coho salmon are used for SAFE broodstock. NMFS (2024) evaluated the effects of broodstock collection on ESA-listed salmon and steelhead in the Lower Columbia region.

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[22] As stated above, coho broodstock collection for the Deep River program terminating in 2025 has already occurred.

For both Chinook and coho broodstock collection, the collection activities can potentially harm ESA-listed fish through handling and incidental mortality. As described in the Mitchell Act and Willamette opinions(NMFS 2024b, 2019b)), the levels of handling and mortality are low and do not pose unacceptable risk levels to natural-origin populations, particularly where those fish are being outplanted above dams for conservation purposes. Because the SAFE programs do not add to or affect the amount of handling or mortality involved with the existing programs, the effects to the species remain low, as described in the related biological opinions discussed in Environmental Baseline.

For the coho salmon program in Oregon, Klaskanine hatchery facilities may be used as a backup facility to collect coho salmon if insufficient returns occur at Big Creek hatchery. However, the Mitchell Act opinion (NMFS 2024b) fully evaluated operation of this hatchery and collection of fall Chinook salmon broodstock, which would overlap the collection of coho salmon (if needed). Thus, there are no additional effects from what was assessed in the Mitchell Act opinion (NMFS 2024b) in the event coho salmon broodstock need to be collected at Klaskanine hatchery facilities.

2.5.2 Hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds

NMFS analyzes the effects of hatchery returns and the progeny of naturally-spawning hatchery fish on spawning grounds. There are two aspects to this analysis: genetic effects and demographic effects. Generally speaking, genetic effects can impact ESA-listed salmon through several pathways. First, when hatchery-origin salmon stray onto natural spawning grounds, they can potentially interbreed with natural-origin salmon, impact their fitness and lower the productivity of naturally-spawning populations (reviewed by Christie et al. 2014; Koch and Narum 2021). In some cases, the relatively low fitness of hatchery-origin fish that spawn in the wild can be inherited and expressed by their naturally-produced offspring (Araki et al., 2009; but see Dayan et al. 2024). Second, when exogenous stocks are propagated and released by hatchery programs, inadvertent interbreeding with local, natural populations can impact local genetic diversity. Lastly, unintentional selection and genetic drift can drastically reduce the effective population size and genetic diversity of hatchery populations (Ryman and Laikre 1991)), such that interbreeding with natural-origin populations can reduce overall genetic diversity. Accordingly, NMFS generally views genetic effects from salmon hatchery programs as a risk to the diversity and productivity of ESA-listed salmon species.

NMFS also recognizes that there may be benefits to having hatchery fish spawn naturally in certain circumstances, and that domestication risks may be irrelevant when demographic or short-term extinction risks significantly threaten population abundance, diversity and productivity. Conservation hatchery programs may accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also serve as genetic reservoirs, conserving genetic diversity and locally-adapted traits that might otherwise be lost through the demographic collapse of a naturally-spawning population (Ford 2011). Furthermore, NMFS recognizes there is often considerable uncertainty regarding genetic risk. The underlying causes for fitness loss in hatchery-origin fish remains unclear (Koch and Narum 2021), and may involve domestication selection, heritable epigenetic effects from the hatchery environment, gamete incompatibility that occurs during artificial breeding, a combination of these, or possibly other mechanisms. Current research aims to address these and other uncertainties associated with genetic risks of hatchery-origin fish.

Overall, NMFS believes that hatchery intervention can be a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit genetic interactions between hatchery- and natural-origin fish, and implement hatchery practices that balance conservation goals with the implementation of fisheries and applicable laws and policies.

In the case of the Proposed Action, hatchery fish are released with the sole purpose of providing salmon for harvest. There are no conservation objectives associated with SAFE programs and, therefore, there are no demographic benefits intended for the listed ESUs. Thus, the following analysis is focused on the potential genetic effects from salmon produced by SAFE hatchery programs on natural-origin salmon populations in Lower Columbia River (LCR) tributaries.

Straying of SAFE Program Spring Chinook Salmon

Beginning in 1989 (ODFW) and 1999 (WDFW), spring Chinook salmon have been propagated and released by SAFE program operators. As adults, spring Chinook salmon return from the ocean to freshwater in the spring and early summer. They then “hold” in freshwater for several months, until they spawn in late September and early October. Given this aspect of their life history, spring Chinook salmon produced and released by SAFE programs are available to harvest in commercial fisheries for several months, as they typically home to and hold near SAFE release sites in the Lower Columbia River. Harvest rates on SAFE spring Chinook salmon are very high and, therefore, relatively few of these hatchery-origin salmon survive until late September, when they might otherwise stray into LCR tributaries and interact with natural-origin fish. The incidence of straying by SAFE program spring Chinook into nearby fall Chinook salmon populations is very low, and genetic interactions are likely limited by differences in peak spawn timing. Importantly, no primary or contributing populations of spring Chinook salmon occur in the Coast Stratum of the Lower Columbia River Chinook Salmon ESU, where SAFE programs operate.

Results from a recent query of the Regional Mark Information System (RMIS; 01/22/2025) indicated that, of all coded-wire tagged spring Chinook salmon released from ODFW’s SAFE facilities in years 2017-2021 and subsequently recovered (n = 2,915 recoveries), only 42 were recovered from natural spawning grounds (equating to an annual mean of 14 HOR adult strays, as estimated through expansions of recovered tags). The vast majority of tagged recoveries were collected by in-river commercial fisheries (n = 1,904) or adult collection facilities operated by hatchery programs (n = 716). The greatest number of spring Chinook salmon strays from ODFW’s SAFE program were reported from Big Creek (n = 7) and the Plympton Creek tributary of the Clatskanie River (n = 10). No more than five strays from ODFW’s SAFE spring Chinook salmon program were reported from any other river during this 5-year period. Neither Big Creek nor the Clatskanie River represent historical habitat for spring Chinook salmon, and are not critical for the conservation and recovery of Lower Columbia River spring Chinook salmon (NMFS 2013). With regard to Clatskanie River fall Chinook salmon, previous analyses have suggested that the natural-origin population has been functionally extirpated (NMFS 2017). Actions to recover the LCR fall Chinook salmon ESU have focused pHOS reductions on other "index" populations (NMFS 2017, 2024), and Chinook salmon recovery efforts in the Clatskanie River focus on rebuilding abundance through hatchery supplementation (NMFS 2024). Therefore, we expect some future straying in "non-index" populations (e.g., 10 fish in Clatskanie River), but the level of effect is minimal and is not a factor for recovery of LCR Chinook populations.

Results from a similar RMIS query (01/23/2025) indicated that most SAFE spring Chinook salmon released from WDFW's Deep River netpens are either harvested or collected by hatchery facilities. Of the tagged juveniles released in years 2017-2021 and subsequently recovered as adults (n = 171), most were reported from fisheries (n = 96) or hatchery facilities (n = 53), and 12% were recovered from natural spawning grounds (n = 21). All but one of the tagged fish recovered from spawning grounds were found in the Grays or Elochoman rivers, where spring Chinook salmon do not naturally occur. Implementation of the Proposed Action will immediately discontinue releases of spring Chinook salmon from WDFW's Deep River netpens, so that there will be no straying adults attributable to the Deep River netpens once the last adults from this program return in 2028, thereby eliminating the ongoing genetic risk from WDFW's SAFE program to Elochoman and Grays River Chinook salmon. Until then, there will likely be some continued straying into the Grays and Elochoman rivers, though WDFW measures to remove returning hatchery adults will control the level of impact until it is eliminated.

Overall, our analysis of tag recoveries from spring Chinook salmon released by ODFW and WDFW SAFE programs indicates that these programs contribute very little to pHOS in LCR Chinook salmon populations (Table 54a).

Table 54a. Maximum pHOS limits by ESA-listed natural population of LCR Chinook salmon as established by NMFS (2024). Limits are evaluated against a four-year running average of estimated pHOS. Mean pHOS (2020-2023) for each population is provided, and mean pHOS estimates from SAFE Programs appear in the far-right column.

Population	pHOS limit	Mean pHOS (2020-2023)	Mean pHOS from SAFE Program (2020-2023)
Grays/Chinook Rivers	50%	79%	3%
Elochoman/Skamokawa Rivers	50%	53%	1%
Mill/Abernathy/Germany Cr.	50%	75%	0%
Coweeman River	10%	8%	0%
Lower Cowlitz River	30%	9%	0%
Toutle River	30%	30%	0%
North Fork Lewis River	10%	47%	0%
Washougal River	30%	19%	0%
Kalama River	10%	33%	0%

NMFS' queries and analysis of RMIS data further revealed that, where spring Chinook salmon from ODFW and WDFW SAFE programs have been recovered from the spawning grounds of extant populations of LCR spring Chinook salmon, such as in the Kalama, Lewis, and Sandy rivers, they have contributed an average pHOS of <1% during the period 2018-2022. Notably, no SAFE spring Chinook salmon were detected in the Upper Cowlitz, Cispus, Tilton, Toutle, or Hood river spring Chinook salmon populations during this period.

Coho Salmon

Adult LCR coho salmon return from the ocean in the late fall and early winter, typically spawning within weeks of their return to freshwater. Harvest rates on SAFE Program coho salmon are regularly high, but a small proportion of SAFE coho salmon escape fisheries or collection by hatcheries, and instead stray to natural spawning grounds. Results from a recent RMIS query (02/20/2025) indicated that, of all coded-wire tagged coho salmon released from SAFE facilities in years 2018-2022 and subsequently recovered (n = 9,637 recoveries), most were either harvested by fisheries (n = 6,319) or collected by hatchery facilities (n = 3,074). Only 94 were recovered from natural spawning grounds. Of fish recovered from spawning grounds, most were reported from Big Creek (n = 27) or the Grays River (n = 34). All but one of the tagged coho salmon recovered from the Grays River had been released from WDFW's Deep River netpens.

The conservation and recovery plan for Lower Columbia River coho salmon identifies the Big Creek subbasin as an area prioritized for SAFE hatchery production, and not critical to the conservation and recovery of LCR coho salmon (NMFS 2013). However, NMFS (2024) has established pHOS limits in other LCR coho salmon populations to meet conservation and recovery goals. Recent pHOS has exceeded these limits in several populations (Table 54), and various pHOS reduction measures have been identified and will be implemented in accordance with NMFS (2024).

As to contributions to pHOS in these streams from the SAFE programs, coded-wire tag data indicate that coho salmon released by SAFE programs contribute little to observed pHOS in core populations of LCR coho salmon, with the exception of fish released from WDFW's Deep River netpens, which sometimes stray into the Grays River. The Proposed Action includes discontinuation of coho salmon releases from the Deep River netpens in 2025, which will further contribute to a pHOS reduction in the Grays River that is expected to fall below 10% overall, including SAFE fish. Coho salmon released from other SAFE release sites are very rarely encountered in other primary or contributing populations of LCR coho salmon (Table 54b). For this reason, the effect of the proposed action as a result of hatchery adults straying into natural-origin coho populations is very low.

Table 54b. Maximum pHOS limits by ESA-listed natural population of LCR coho salmon as established by NMFS (2024). Limits are evaluated against a three-year running average of estimated pHOS. Mean pHOS (2021-2023) for each population is provided, and mean pHOS from SAFE Programs appears in the right column.

Population	pHOS limit	Mean pHOS (2021-2023)	Mean pHOS from SAFE Program (2021-2023)
Grays/Chinook Rivers	10%	42%	<1%

Elochoman/Skamokawa Rivers	30%	25%	<1%
Clatskanie River	10%	23%	<1%
Scappoose River	10%	2%	0%
Lower Cowlitz River	30%	15%	0%
Coweeman River	10%	13%	0%
South Fork Toutle	10%	14%	0%
North Fork Toutle	30%	16%	0%
East Fork Lewis	10%	11%	0%
Washougal River	30%	27%	0%
Clackamas River	10%	3%	0%

2.5.3 Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas (tributaries, mainstem, estuary, and ocean).

The ecological effects of the hatchery programs on juvenile salmon and steelhead in the Lower Columbia River are assessed below. The ecological interactions evaluation in this biological opinion is somewhat different than NMFS has applied in previous analyses such The Mitchell Act and Upper Willamette River hatcheries opinions (NMFS 2024b, 2019b) due to the proposed action. This proposed action occurs entirely in the estuary and plume, consistent with the action area as described in Section 2.3, where ecological interactions are entirely different than in freshwater areas with daily tidal changes, species composition, abundance of hatchery fish, river temperatures, and other aspects. The behaviors of juvenile salmon in estuarine habitats are greatly different than in freshwater rivers and streams.

The ecological interactions between hatchery-origin and natural-origin salmonids in the action area of the Lower Columbia River is an important effect to fully evaluate, yet specific quantitative analyses to do so do not exist. NMFS uses PCDRisk to inform ecological interactions in freshwater habitat areas, but the model is not applicable to marine habitats where the behavior of salmonids is entirely different.

Adult, immature, and large juvenile Chinook and coho salmon in marine waters feed heavily on fish, particularly forage fish, and are large enough to prey on younger juvenile salmonids (Beamish 2018a); (Riddell et al. 2018). However, there is substantial available information showing that predation on juvenile salmonids by Chinook and coho salmon in marine waters is rare. Many diet studies of adult, immature, and large juvenile Chinook and coho salmon in marine waters only identify specific taxa that made up more than about 1–5% of the diet (i.e., “common” prey taxa), and do not mention specific taxa that were consumed at lower levels (e.g., (Silliman 1941); (Beacham 1986); (Daly, Brodeur, and Weitkamp 2009); (Daly et al. 2012); (Brodeur, Buchanan, and Emmett 2014); (Thayer, Field, and Sydeman 2014); (Hertz et al. 2015); (Osgood et al. 2016); (Daly, Brodeur, and Auth 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 or coho salmon stomach contents (Prakash 1962); (Brodeur, Lorz, and Pearcy 1987); (Brodeur 1990a); (Landingham, Sturdevant, and Brodeur 1998); (Hunt, Mulligan, and Komori 1999); (Kaeriyama et al. 2004); (Wainwright et al. 2008); (Chamberlin 2021); (Weitkamp et al. 2022). Where juvenile salmonids have been consumed by Chinook or coho salmon (Reid 1961); (Fresh, Cardwell, and Koons 1981); (Wing 1985); (Duffy et al. 2010); (Sturdevant, Orsi, and Fergusson 2012); (Daly et al. 2019); (Beauchamp et al. 2020), 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, near the mouth of the Columbia River, and in inside areas of southeast Alaska during early summer after large pulses of small juvenile fish have entered these areas). Outside of these areas, predation by Chinook or coho salmon on salmonids in marine waters is exceedingly rare.

In an effort to better understand juvenile salmonid interactions, NMFS has identified the spatial and temporal overlap of juvenile hatchery fish and natural-origin salmon and steelhead (as described in the following sections). NMFS is unaware of any additional assessments of ecological interactions specifically for releases of hatchery fish from net pens in the Lower Columbia River estuary. This analysis relies on the best available scientific information to assess the risks posed by the presence of juvenile hatchery fish in the action area. In addition, much work has been conducted on the ecological interactions between hatchery fish and juvenile salmon in other areas. Many of the results of these studies have been included here in the assessment, as appropriate for juvenile salmon and steelhead ecological interactions.

There are three primary types of effects considered here: competition between hatchery and natural salmon and steelhead, predation by hatchery fish on juvenile salmon and steelhead, and transfer of disease pathogens from hatchery fish to juvenile salmon and steelhead. Each effect is a function of both spatial and temporal overlap; the effect can only take place when hatchery and natural-origin salmon and steelhead encounter each other or are rearing together.

The proposed action specifies the species released from the SAFE facilities, the timing of those releases, and the size of smolts released. All of these factors are analyzed here with respect to the spatial and temporal overlap with natural-origin salmonids to determine the extent of ecological interactions. The specific details of the SAFE releases is further described in Appendix A.

In order to evaluate the effects of competition, predation, and disease on juvenile salmon and steelhead, this opinion considers the following spatial and temporal factors:

- Establish the area of potential overlap between releases of hatchery fish and co-occurring juvenile natural-origin salmon and steelhead in the same area.
- Establish when hatchery fish from each program are released, and thus available to interact with juvenile natural-origin salmon and steelhead.

Given PCDrisk is not used here for modeling ecological interactions in the estuary, the effects below are not quantitative but describe the potential risks on a qualitative basis.

Spatial Overlap

As stated above, the main ecological effects are competition, predation, and disease, which can only occur when natural and hatchery-origin fish co-occur. The spatial overlap between hatchery spring Chinook salmon and coho salmon released as part of the proposed action, and natural-origin salmon and steelhead is confined to the Lower Columbia River estuary (Figure 1). The releases of hatchery fish occur from the net pens in Blind Slough, Tongue Point, Deep River (ending in 2025), and Youngs Bay, all near the mouth of the Columbia River near Astoria, Oregon. All fish are released as smolts that have been acclimated for some time to saltwater while in the net pens. The physiological state of these fish is to readily emigrate towards the ocean within a short period of time.

While there is currently no data suggesting this occurs with the SAFE programs, it is possible a proportion of hatchery-origin smolts 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 in other locations, 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. However, the issue of residualism for these species has not been as widely investigated compared to steelhead. Therefore, for all species, monitoring in the vicinity of net pen 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, including residualism, by taking the following steps:

- 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 and Bjornn 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.

The entire action area is the lowermost 23 miles of the Lower Columbia River before entering the ocean out past the tips of the jetties. The potential spatial overlap would only occur in this area. All habitats upriver of the net pens would not be affected by the proposed action because hatchery fish from the net pens do not occur there.

For the reasons described above, hatchery-released fish will readily emigrate towards the ocean within a short period of time. While there is a possibility these fish will residualize, it is unlikely that there will be a discernible ecological effect on natural-origin ESA listed species in the 23 mile area of potential spatial overlap.

Temporal Overlap

In addition to the geographic extent of hatchery fish released within the Lower Columbia River estuary (i.e., space), another aspect of the interaction between hatchery fish and natural-origin juvenile salmon and steelhead (and the potential for ecological effects of competition, predation, and disease) is the period of time affected by the presence of hatchery fish. For the proposed action, hatchery spring Chinook salmon are released at specified times when their physiological state is smolting in March and April (see Appendix A for further details). Hatchery coho salmon are also released as smolts in March, April, and May. Hatchery fish are released in batches all at once when they are ready to emigrate to the ocean. Releases do not occur each day throughout these two-month windows. Further information on emigration timing is below.

The target release size for all hatchery fish in the proposed action is the smolt life stage for both spring Chinook salmon and coho salmon. Depending upon the species, average fork length ranges from 5.5 to seven inches (145-178 mm) for spring Chinook salmon and five to seven inches (120-170 mm) for coho salmon. Given that hatchery fish are released as smolts and in the estuary, the potential interaction period is expected to be short (less than one week) because the hatchery fish are actively emigrating to the ocean. The physiological condition of the hatchery smolts triggers their desire to emigrate. There is some occurrence of residualism, as discussed above.

Roegner et al. (2016) provides detailed information on the presence of juvenile salmonids in the Lower Columbia River estuary throughout the year which informs the temporal overlap of the proposed action with natural-origin salmonids that may also be present in the action area. They found all species and life stages may potentially be found in the estuary during the period of March through May, when hatchery fish are released from the net pens. The use of estuary habitat by salmonids differs among life stages, with smolts primarily using the deeper waters of the estuary and younger life stages using shallower, nearshore habitats.

Large high tides in late evening are preferred by CCF for releasing smolts as Ledgerwood et al. (1997) found that fish released near high tide emigrated out of Youngs Bay within one tidal cycle.

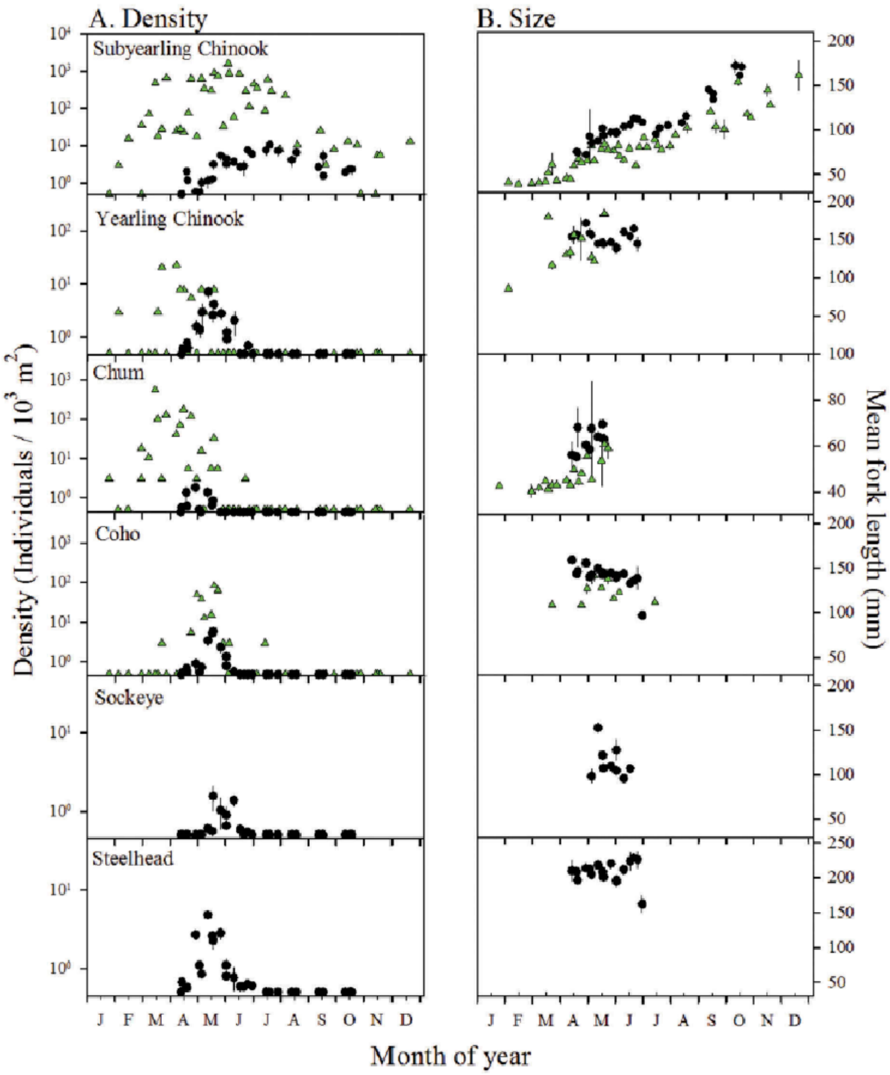

Figure 47. Time series of density and length of salmonids in the Lower Columbia River estuary. Circles represent fish found in channel habitat and triangles represent fish found in shoreline habitats. Figure taken from Roegner et al. (2016).

Predation

Predation among salmonids is most likely to occur when different life stages co-occur in the same habitats. Older aged life stages of salmon and steelhead are known to predate upon younger aged fish that are smaller, especially larger hatchery steelhead co-occurring in microhabitats with younger, smaller salmonids (Naman and Sharpe 2012)(Naman and Sharpe 2012). As discussed above, this risk is limited to incidences of spatial and temporal overlap.

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. Hatchery fish are released at a later stage to reduce predation from hatchery fish on natural-origin egg, fry and fingerling, and 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. Studies (Berejikian et al. 2000); (Melnychuk et al. 2014) also 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. Predator buffering (also termed predator swamping) may yield beneficial effects to affected natural populations. However, this mechanism is not yet well studied or understood.

In the Lower Columbia River estuary, predation by hatchery fish released from the SAFE programs can occur, especially for younger aged chum salmon and fall Chinook salmon fry that may be present in the estuary. LCR and UWR steelhead DPSs and upriver salmon ESUs are unlikely to co-occur, and if any encounters with SAFE program-released fish did occur, for other reasons such as size they are unlikely to be preyed upon by SAFE program juveniles. This predation risk is likely to be low because spring Chinook salmon and coho salmon are found primarily in the deeper water habitats where smaller salmonids are not able to reside (Roegner et al. 2016). Younger and smaller salmon primarily occur in the shallow, nearshore habitats where hatchery coho salmon and spring Chinook salmon are not common. In addition, the exposure time of hatchery fish released from the net pens is likely to be less than one week, which minimizes the overall potential for predation to occur from the proposed action. Other similar sized smolts are not at risk to predation from hatchery fish.

Thus, although the risk cannot be precisely quantified, we can infer from the available information discussed above that this risk is not likely to be a significant overall concern for populations in the action area. The studies showing that predation is rare even when the circumstances raise the possibility, combined with the minimal spatial and temporal overlap between SAFE-released fish and ESA-listed salmonids, and the lack of hatchery juveniles being released in large numbers or density, reinforce the conclusion that the risk of predation in any concerning amount is unlikely.

Competition

Competition occurs with salmonids when a resource is limited in space or time. A review by Weitkamp et al. (2014) found that the primary prey consumed by salmon and steelhead in tidal freshwater are aquatic and terrestrial insects (e.g., dipterans, hemipteran), amphipods, mysids, and freshwater crustaceans. In the brackish waters, the primary prey are larval and juvenile fish, amphipods, insects, krill (euphasiids), and copepods. In the estuary, the diets of Chinook and coho salmon and steelhead are dominated by amphipods and dipteran insects. Thus, diet overlap among salmon and steelhead in all estuarine zones is high. Actual impacts on natural-origin fish would depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward and Bjornn 1990). Not all populations within a given ESU or DPS may be affected by competition and predation. To the extent it does occur, it is further limited to instances of temporal and spatial overlap, which are limited as discussed above, for both lower river DPSs/ESUs and particularly more distant ones.

Given the proposed action occurs in the Lower Columbia River estuary, the behavior of juvenile salmonids is greatly different than when the fish are rearing in freshwater habitats prior to smolting. As smolts, the fish school together for protection and defending territories among conspecifics is not as prevalent as when in freshwater. Therefore, competition among hatchery- and natural-origin salmonids is not judged to be a negative effect; particularly in the estuary environment where salmonids are transitioning from freshwater to the ocean and no limiting resources have been identified.

Disease

The hatchery programs will be operated in compliance with regional fish health protocols pertaining to movement and monitoring of cultured fish which helps minimize risks associated with hatchery fish (IHOT 1995). When egg-to-release survival rates are high for fish propagated in the hatchery programs that are part of the proposed action, this indicates that protocols for monitoring and addressing the health of fish in hatcheries have been effective at limiting mortality. In addition, hatchery fish from these programs emigrate to the ocean relatively quickly, limiting exposure time and/or pathogen shedding in freshwater. Although fish are monitored monthly during rearing, there are situations where fish that may be infected with pathogens are released into the watershed. Sometimes this may occur as a measure to mitigate the spread of disease further in a hatchery environment. However, this practice also may contribute to increased pathogen levels in the natural environment if the disease does occur. This is rare and used only when preventive measures do not mitigate the outbreak.

Although a variety of pathogens have been detected in Oregon hatcheries over the last few years, no novel or exotic pathogens have been found and no devastating outbreaks have occurred in UWR hatchery programs in recent years. However, it is important to note that detection of a pathogen does not mean that disease was observed. It indicates the number of epizootics (20-30 per year) occurring from some pathogens is much less than the number of pathogen detections 3,000-4,000 per year. In addition, many of the epizootics are curable using treatments approved for use in fish culture such as formalin, hydrogen peroxide, and various antibiotics.

The low frequency of epizootics from native pathogens, in combination with frequent monitoring and treatment options under current fish health policies suggest that the amplification of pathogens during rearing of fish in hatcheries on natural-origin salmon and steelhead is likely indiscernible from natural pathogen levels in the natural environment. During an epizootic, hatchery fish can shed 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 and Bjornn 1990 (Bjornn and Steward 1990)); (Naish et al. 2007 (Naish et al. 2007)).

2.5.4 Research, monitoring, and evaluation

NMFS analyzes the incidental effects of the proposed research, monitoring, and evaluation (RM&E) on listed species. The HGMPs for the Proposed Action address the five factors that NMFS takes into account when it analyzes and weighs the beneficial and negative effects of hatchery RM&E (see Factor 4 in the Appendix). The Proposed Action includes RM&E activities that will continue to monitor the Performance Indicators identified in Section 1.10 of the HGMPs, ensure compliance with this opinion, and inform future decisions over how the hatchery programs can be adjusted to meet their goals while further reducing impacts on ESA-listed species.

No research specific to the SAFE spring Chinook salmon or coho programs is currently being conducted or proposed. The SAFE project has conducted or been involved in several studies with a goal of maximizing smolt survival, improving smolt quality, and minimizing impacts on endangered salmonids and their habitat. From 1995-2006, the programs spent considerable time investigating various rearing, feeding, and release strategies; the results of which are now incorporated into a preferred rearing and release regime.

Many of the monitoring activities of the SAFE spring Chinook salmon and coho programs are incorporated into routine ODFW and WDFW operations and in place to minimize risks to ESA-listed species. Spawning ground surveys, CWT recovery and analysis, as well as the monitoring of hatchery facilities and juvenile fish health occur regularly[23]. The HGMPs define the criteria and guidelines for these monitoring activities to ensure the actions are ceased if natural-origin fish encounters go above prescribed limits. The effects of these RM&E actions on the viability of ESA-listed spring Chinook salmon and winter steelhead are expected to be negligible. NMFS anticipates that greater than 99% of the RM&E activities specifically included in the proposed action for this project would be non-lethal observation and harassment of ESA-listed salmon and steelhead, as the net pens are maintained. Any ESA-listed fish near the project facilities would volitionally migrate away from the net pens as human presence occurs. Occasional handling (fewer than 10 juveniles and up to one adult per year) of listed fish may occur, with no lethal handling effects anticipated. In nearly all cases, the information and data gained from RM&E is critical to help inform the conservation and recovery of ESA-listed populations. The larger RM&E programs conducting spawning ground surveys and other activities are authorized by NMFS in separate consultations under the research limit of section 4(d), and are not included in this proposed action.

2.5.5 The operation, maintenance, and construction of hatchery facilities

The construction/installation, operation, and maintenance of hatchery facilities can alter fish behavior and harm all life stages of salmon and steelhead in the affected areas. Operation of the hatchery facilities can also degrade stream and riparian habitats near the hatcheries. The withdrawal of water from the stream in order to raise fish in the hatchery can reduce water in the stream between the inlet and outlet of the facilities.

All of the hatchery facilities that are part of the proposed action currently exist and are in operation. No new facilities or operations are proposed. All facilities are included in the environmental baseline. The Mitchell Act and Upper Willamette River opinions (NMFS 2019 and 2024) assessed the effects of the hatchery facilities used to collect broodstock, incubate eggs, and rear juvenile salmon prior to the transfer of fish to SAFE facilities. This includes all of the facilities used for SAFE broodstock collection and rearing facilities such as Clackamas Hatchery, Minto Fish Facility, Foster Fish Facility, and Dexter facilities for spring Chinook salmon and Big Creek, Klaskanine, S.F. Klaskanine, Beaver Creek, Cowlitz, Kalama Falls, Lewis River, Washougal, and Merwin fish collection facilities for coho salmon.

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[23] WDFW will discontinue any SAFE-specific monitoring after the final release of coho from Deep River.

This consultation includes the operation and maintenance of the SAFE net pens and associated hatchery facilities (or portions thereof) used to produce (rear) and release spring Chinook salmon and coho salmon specified in the proposed action.

Net pen complexes are sufficiently constructed to avoid accidents due to weather. Water system failure or flooding incidents are not possible since the pens and fish are immersed in large water bodies rather than supplied by an external source. In the event of net pen failure, fish would be capable of leaving the pens on their own and could not be recovered. Pen complexes are arranged to provide protection to the net pens and minimize the chances of early release.

2.5.6 Fisheries

The proposed action does not include any effects related to fishing. Fisheries targeting adult salmon returning from the SAFE hatchery releases are managed under the auspices of the *U.S. v. Oregon* 2018-2027 management agreement and NMFS (NMFS 2018b)) section 7 Biological Opinion. This management agreement governs the allowable fishing impacts on ESA-listed salmon and steelhead from these fisheries, and the effects of these fisheries are included in the environmental baseline. See section 2.4.4 above for further details on these fisheries.

2.6 EFFECTS OF THE ACTION ON CRITICAL HABITAT

This consultation analyzes the Proposed Action for its effects on designated critical habitat and has determined that operation of the hatchery programs will have a negligible effect on PCEs in the Action Area. The net pen facilities in the action area were previously constructed and consulted upon in past ESA consultations and therefore are included as part of the environmental baseline. The only effects resulting from the Proposed Action are those associated with the continued release of hatchery fish annually from these net pens and routine operation and maintenance of the net pens. Operation and maintenance activities would include net pen maintenance, cleaning of debris and algae growth on the nets. These activities would not be expected to degrade water quality or adversely modify designated critical habitat, because they would occur infrequently, and only result in minor temporary effects. The effects of these actions on critical habitat are negligible given the scope of the actions.

Hatchery fish returning as adults can have a beneficial effect on critical habitat if the salmon are not harvested and end up spawning naturally in the environment. The beneficial effects on critical habitat, specifically freshwater spawning and rearing habitat, are from the conveyance of marine-derived nutrients from the carcasses of hatchery spawners and from conditioning of spawning gravel by hatchery spawners (Cederholm et al. 1999; Montgomery et al. 1996). Salmon 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. These marine-derived nutrients can increase the growth and survival of the ESA-listed species by increasing forage species (i.e., aquatic and terrestrial insects), aquatic vegetation, and riparian vegetation to name a few. Benefits to the natural environment from hatchery salmon carcasses are expected to be negligible for the proposed action because the vast majority of hatchery fish are harvested and do not spawn naturally.

2.7 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 and 402.17(a)). 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 changing environmental conditions 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 (Section 2.4).

The cumulative impacts from these programs contribute to the total impacts from hatcheries in the entire Columbia River Basin, which is noted in the Mitchell Act Biological Opinion ((NMFS 2024b)). Between those programs which have already undergone consultation and those for which consultation is underway, it is likely (though uncertain for ongoing consultations) that the type and extent of salmon and steelhead hatchery programs and the numbers of fish released in the Columbia River Basin will change over time. Although adverse effects will continue, these changes have already begun to reduce effects such as competition and predation on natural-origin salmon and steelhead compared to current levels, especially for those species that are listed under the ESA. This is because all salmon and steelhead hatchery programs funded and operated by non-federal agencies and tribes in the Columbia River Basin have to undergo review under the ESA to ensure that listed species are not jeopardized and that "take" under the ESA from salmon and steelhead hatchery programs is minimized or avoided. Although adverse effects on natural-origin salmon and steelhead will likely not be completely eliminated, the most recent 2024 Opinion (NMFS 2024b) showed that effects are decreasing and are expected to further decrease from current levels over time .Reductions in effects on listed salmon and steelhead are likely to continue occurring through changes in:

- 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
- Incorporation of new research results and improved best management practices for hatchery operations
- More accurate estimates of natural-origin salmon and steelhead abundance for abundance-based fishery management approaches

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 changing environmental conditions that are properly part of the environmental baseline versus cumulative effects. Our conclusion accounts for the environmental baseline, as well as the effects factors, so regardless of where changing environmental conditions are discussed, they will be reflected in our conclusion.

These potential changes to hatchery operations combined with the ongoing operations of the hatchery programs described in the proposed action result in a net beneficial change to current conditions. While the hatchery programs around the basin, and those under review here as well, lead to negative impacts on listed salmonid species as described above, when the beneficial changes to hatchery practices are also combined with the potential negative impacts from these hatchery programs and the rest of the operations in the Columbia River basin, an overall, basin-wide net beneficial result is expected as hatchery practices continue to improve and to reduce their negative impacts.

2.8 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 action. 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 biological opinion as to whether the proposed action is 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 diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

The Proposed Action is to provide federal funding to assist in on-going hatchery programs where hatchery fish are released from net pens in off-channel, slough areas of the in the Lower Columbia River specifically for fishery harvest upon return as adults. All other previous activities associated with this program are included in the environmental baseline. The primary areas affected by the proposed action include habitat areas where the net pens continue to rear and release hatchery fish, the release of hatchery fish, and the effects of hatchery fish not harvested and straying into nearby natural areas for spawning. As analyzed in section 2.5, above, there is little to no effect from the collection of broodstock associated with the proposed action. Straying by hatchery fish into adjacent habitat areas by spring Chinook salmon and coho salmon that were not harvested in the select area fisheries will not meaningfully affect the abundance, diversity or productivity of ESA-listed populations in the Lower Columbia River. Hatchery-origin coho salmon from the SAFE Deep River netpen release site, operated by WDFW, have been found to stray into the Grays and Elochoman rivers. However, the rates of straying from SAFE programs have been low, and these hatchery releases will be discontinued through the Proposed Action, with the last release of juvenile coho salmon from this site to occur in 2025. Therefore, the natural spawning of hatchery coho salmon released from the Deep River site will not occur, and these releases will not contribute to pHOS in the Grays River natural population following the final adult returns. Based on the best available information, there are similarly little to no pHOS issues identified for the SAFE spring Chinook salmon component.

The ecological effects from the continued release of hatchery fish from SAFE facilities in the Lower Columbia River are expected to be minimal and short-lived in space and time. The spatial distribution and diversity of Lower Columbia River natural populations will not be affected by the proposed action. In conclusion, the summation of effects on the VSP parameters of affected ESA-listed ESUs and DPSs is minimal to non-existent.

Overall, the proposed action poses low risks as discussed to several populations within the LCR Chinook and coho salmon ESUs. Those risks are not expected to significantly impact the receiving populations, and thus not expected to have more than a minimal effect at the species level. The affected populations are contributing or stabilizing, and because very few populations within each ESU will be impacted at all, the risks to the Lower Columbia River Chinook and coho salmon ESUs is similarly low. There is even less evidence of any effects from the proposed action to Columbia River chum or up-river salmon and steelhead ESUs.

The negative effects of the proposed action are being minimized by the continued implementation of best management practices of the SAFE program over the last two decades. The proposed action limits impacts from the release of hatchery fish by releasing hatchery fish that are ready to emigrate to the ocean as smolts, thus limiting the ecological effects. Habitat-related effects are minimized due to the location and limited scope of habitat affected by the continued operation of the net pens, even with the expected effects of changing environmental conditions in freshwater habitats. The adjacent natural population areas are not identified as primary populations needed for recovery. Therefore, any straying of hatchery salmon that are not harvested in fisheries would not compromise achievement of recovery goals of the Chinook salmon and coho salmon ESUs. The effects of fishery harvest on returning adult hatchery fish has proved to be within allowable fishery impacts under the ESA. Therefore, the proposed program has negligible impacts and all within the scope of ESA-approved limits.

Critical Habitat

The continued operation and maintenance of the net pens in the Lower Columbia River estuary and release of hatchery spring Chinook salmon and coho salmon pose a negligible effect on designated critical habitat in the Action Area. Since the net pens are small with localized effects diminished from the daily tide cycles, habitat effects are negligible. No new construction or expansion of the existing net pens is proposed; only the continued operation of existing facilities included in the environmental baseline.

2.9 CONCLUSION

After reviewing the current status of the listed species, the environmental baseline within the Action Area (including actions analyzed by NMFS (2018a, 2019, and 2024), the effects of the Proposed Action, and other cumulative effects, it is NMFS' biological opinion that the Proposed Action is not likely to jeopardize the continued existence of Lower Columbia River Chinook salmon ESU, Lower Columbia River coho salmon ESU, Lower Columbia River steelhead DPS, Columbia River chum salmon ESU, Upper Willamette River spring Chinook salmon ESU, Snake River spring/summer Chinook salmon ESU, or destroy or adversely modify designated critical habitat for these species.

2.10 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). “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.

2.10.1 Amount or Extent of Take

In section 2.5, above, NMFS analyzed six categories of effects for the Proposed Action, collectively including: (1) broodstock origin and collection, (2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds, (3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, mainstem rivers, estuary, and ocean, (4) research, monitoring, and evaluation (RM&E) supporting hatchery program implementation, (5) operation, maintenance, and construction of hatchery facilities (i.e., facility effects), and (6) fisheries that would not exist but for the availability of hatchery fish to catch. Take activities will conclude for WDFW after the SAFE Type-N Coho Salmon Program is terminated in 2025.

In the biological opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

2.11.1.1 Take from Hatchery Fish on the Spawning Grounds

SAFE hatchery programs may take natural-origin salmon in the Lower Columbia River if hatchery fish stray and spawn naturally in the wild with natural-origin fish, resulting in potential genetic introgression, which is a form of harm to listed salmonids The extent of take from genetic effects cannot be directly quantified, because such take is not observable and estimates of gene flow from this hatchery program into natural populations are not sufficiently available or reliable. Therefore, NMFS will rely on a commonly used surrogate metric, census pHOS measured in rivers where the effects would be potentially concerning, to estimate the overall extent of take from genetic effects attributable to the proposed action. Take from SAFE program hatchery fish on the spawning grounds will not be exceeded as long hatchery-origin fish originating from SAFE programs[24] do not exceed 5% of the naturally-spawning fish in “primary” and “contributing” populations of LCR Chinook and coho salmon ESUs, calculated as running four-year and three-year means for Chinook and coho salmon, respectively. For Chinook salmon, populations subject to this limit are the Elochoman/Skamokawa,

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[24] These populations may experience an overall pHOS rate that includes pHOS attributable to Mitchell Act-funded or other programs. The SAFE pHOS rate does not reflect the overall rate or the contribution of Mitchell Act programs to straying.

Mill/Abernathy/Germany, Grays/Chinook, Coweeman, Lower Cowlitz, Toutle, Kalama, Lewis, Washougal, and Clackamas river populations. For coho salmon, populations subject to this limit include the Grays/Chinook, Elochoman/Skamokawa, Clatskanie, Scappoose, Lower Cowlitz, Coweeman, South Fork Toutle, North Fork Toutle, East Fork Lewis, Washougal, Sandy, and Clackamas populations.

Census pHOS (enumeration of hatchery-origin spawners on natural-origin spawning grounds, reported as a proportion) measured in the streams listed above is an appropriate surrogate for take by genetic effects because it is rationally connected to those effects by measuring the extent to which hatchery and natural-origin salmon co-occur on the spawning grounds and have the opportunity to interbreed with these index populations. Census pHOS can be reasonably and reliably measured and monitored in the above rivers through spawning ground surveys conducted annually by ODFW and WDFW in the appropriate populations.

2.11.1.2 Take from Hatchery Fish in Juvenile Rearing Areas

The SAFE program releases hatchery salmon in the Lower Columbia River estuary where the ecological interactions between hatchery and natural salmon and steelhead can occur and cause take in the form of harm to threatened salmonid juveniles from predation and to threatened salmonid smolts through competition. It is impossible to quantify the take associated with competition and predation between SAFE releases and natural-origin fish; either modeled or direct measurements. Therefore, NMFS will rely on a take surrogate that relies on the ability of the program to meet several parameters, which tend to demonstrate whether take has stabilized to a level consistent with the analysis in this Opinion. Take is estimated to be that which would occur from ecological interactions under the following circumstances. Except as noted, failure to meet any one of the following parameters would suggest that the take associated with the proposed action has likely been exceeded.

Table 55. SAFE hatchery production levels.

Hatchery Program	Hatchery Program Operator	Five Year Average Production Level	Annual Maximum Production Level
SAFE Coho Salmon Program	ODFW, CCF	3,819,900	4,119,500
SAFE Spring Chinook Salmon Program	ODFW, CCF	3,519,000	3,795,000
SAFE Type-N Coho Salmon Program (terminating in 2025)	WDFW	714,000	770,000

Numbers of Hatchery Fish Released:

- Release of hatchery smolts in any given year must not exceed the smolt release goal for the hatchery program plus 10% for annual variability (Table 55). The 10% buffer allows for occasional overages based upon factors outside the direct control of the hatchery operators;

- The five-year rolling average of smolt releases for each hatchery program must not exceed 102% of the annual smolt release goal for that program (Table 55). This surrogate ensures the effects are within the scope analyzed in the opinion based upon the number of hatchery fish released, and reinforces that the buffer is not intended to be used annually;

Size of Hatchery Fish Released:

- The actual size of individual fish released should not be more than 10% larger than the planned release size for each program,

Location of Where Hatchery Fish are Released:

- Any change in release location from the locations identified in the HGMPs for the programs included in the proposed action must not expand the interaction area between hatchery and natural fish (releases will be from SAFE facilities).

This approach has a rational connection to the extent of take associated with ecological effects because the relative numbers of hatchery fish released and their physical size are commensurate with the extent of the risk, and the release location is a key factor in limiting that risk. All of these matters are reliably monitored by the co-managers annually as part of their regular hatchery monitoring and reporting to NMFS. All of these metrics are available each year for evaluation.

2.11.1.3 Take from Research, Monitoring, and Evaluation Activities

All of the hatchery programs conduct research, monitoring, and evaluation (RME) periodically to evaluate program performance, the effects of hatchery fish, and the status of natural-origin populations. These activities involve primarily incidental take by observation of salmon and steelhead, but may also occasionally collect fish for sampling. The majority of the expected take of natural-origin salmon and steelhead is non-lethal from observation, harassment and/or collection, where natural-origin fish may be incidentally captured, handled, and then released alive. Any mortality of salmon and steelhead would be inadvertent and accidental, unless the RME specifically needs natural-origin salmon or steelhead (e.g., direct take) for study.

The estimated take of natural-origin juvenile and adult salmon and steelhead associated with research, monitoring, and evaluation of the SAFE hatchery programs will be subject to the limits specified in the Mitchell Act and Willamette Opinions (NMFS 2024b, 2019b)because this program is interrelated with other activities authorized under this consultation. The applicable tables in NMFS 2024 can be found in Section 2.9.1.2.4 Research, monitoring, and evaluation that exists because of the hatchery program of the 2024 Mitchell Act Opinion, in particular Tables 126-128 and 130-133. Cumulative take associated with this consultation and the Mitchell Act Opinion (NMFS 2024b, 2019b) will be tracked by the operating agencies, who are required to report this to NMFS. This includes all incidental capture, handling, and mortality associated with monitoring and evaluation of the SAFE program in entirety (all funding sources). All capture and handling of juvenile and adult salmonids will be recorded and reported.

2.11.1.4 Take from Operation and Maintenance of SAFE Hatchery and Net Pen Facilities

No new construction or modification of the hatchery facilities or net pens is included in the proposed action.

The SAFE net pens occur within established areas of the Lower Columbia River estuary where the net pens are naturally watered by the tides and river. No water is manipulated or altered. Take associated with the operation and maintenance of the net pens can occur through changes in water quality directly adjacent to the net pens through fish rearing and cleaning of algal growth from the nets. Increased turbidity plumes could occur during installation and removal of the net pens in the off-season when hatchery fish are not being reared. All of these effects are unquantifiable because they result in sub-lethal effects on ESA-listed salmon and steelhead through behavior modification if near the net pens and/or short-lived effects on water quality before being diluted. These potential effects cannot be reliably observed or measured.

Since take cannot be quantified, NMFS will rely on a surrogate measure of take. NMFS will consider the take limit associated with the operation of the SAFE net pens to have been exceeded if the net pen facilities are expanded greater than 30% from the existing production areas. This surrogate is rationally connected to the extent of take because modification of the proposed action to this extent (>30%) would increase the amount of habitat affected by the net pens, potentially increase the required maintenance activities of the net pens, and potentially exceed the effects analyzed in this Opinion. Our expectation is that take will be within the expectations of our opinion as long as the facilities are operated and maintained in accordance with the HGMPs for these programs.

2.10.2 Effect of the Take

In Section 2.9, NMFS determined that the level of incidental take, coupled with other effects of the Proposed Action, is not likely to jeopardize the continued existence of the LCR Chinook Salmon ESU, LCR Coho ESU, LCR Steelhead DPS, CR Chum ESU, UWR Chinook salmon, and SR spring/summer Chinook salmon, or result in the destruction or adverse modification of their designated critical habitat (section 2.5). In addition, for the other ESA-listed species that may be potentially affected when migrating through the Lower Columbia River estuary in the action area, NMFS has determined the proposed action is also not likely to jeopardize the continued existence of these species (section 2.5).

Section 2.12 includes the species that the proposed action is not likely to adversely affect and for which no take is expected.

2.10.3 Reasonable and Prudent Measures

“Reasonable and prudent measures” are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02).

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize incidental take. The action agencies (NMFS, USFWS, BPA), in cooperation with ODFW, WDFW, and CCF, shall ensure the following measures:

1. Fund and implement operation and maintenance and monitoring and evaluation of the three SAFE hatchery programs, and operation and maintenance of the SAFE facilities,

according to the Proposed Action specified above and in the SAFE spring Chinook salmon and coho salmon HGMPs (ODFW 2021a; ODFW 2021b; WDFW 2018).

2. Minimize the effects of the SAFE hatchery programs on ESA-listed natural-origin salmon and steelhead in the Lower Columbia River and its tributaries.

3. Provide periodic progress reports on the implementation of the HGMPs.

2.10.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the Action Agencies (or any other agencies associated with the proposed actions, i.e., ODFW, WDFW, CCF) must comply with them in order to implement the Reasonable and Prudent Measures specified above (50 CFR 402.14). The BPA, NMFS, USFWS, ODFW, WDFW, and CCF have 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 Opinion and Take Statement (50 CFR 402.14). However, these requirements will conclude for WDFW after the SAFE Type-N Coho Salmon Program is terminated in 2025. 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.

1a. Production and Release of SAFE hatchery spring Chinook salmon – In accordance with the proposed action, the BPA, NMFS, and USFWS shall ensure funding of acclimation and release and monitoring and evaluation activities, and facility operation and maintenance, at SAFE facilities in support of ODFW and CCF's implementation of the SAFE hatchery spring Chinook program. ODFW and CCF will provide non-federal funding for full implementation of the program, and will produce up to a maximum of 4.25 million smolts annually, as described in sections 1.3 and 1.3.1, above. This production level is authorized by the Incidental Take Statement in Section 2.10, above. Changes to the agencies' funding of the hatchery spring Chinook salmon production may occur in the future as long as the maximum annual production is not exceeded.

1b. Production and Release of SAFE hatchery coho salmon – In accordance with the proposed action, BPA, NMFS, and USFWS shall ensure funding of the acclimation and release of SAFE hatchery coho salmon at SAFE facilities, monitoring and evaluation, and operation and maintenance of the SAFE facilities. These programs will produce up to a maximum of 4.3 million smolts annually, as described in sections 1.3 and 1.3.1 above with the addition of non-federal funding. This production level is authorized by the Incidental Take Statement in section 2.9, above. Changes to the agencies' funding of the hatchery coho salmon production may occur in the future as long as the maximum annual production is not exceeded.

2a. Brood Sources, Production Caps, and Harvest Tools – NMFS, ODFW, and WDFW (as fish agency co-managers) will coordinate through other hatchery production and harvest forums and related consultations (NMFS 2024 for Clackamas stock, NMFS 2018a for *U.S. v. Oregon* harvest, NMFS 2019 for Willamette hatcheries) for the SAFE spring chinook and coho programs, to appropriately adjust broodstock sources, annual production levels, and incorporation of harvest-related tools to avoid or decrease effects on ESA-listed fish from SAFE hatchery production..

2b. NMFS has previously established pHOS limits for index populations of LCR Chinook and coho salmon (NMFS 2024). Related, NMFS further requires that salmon originating from SAFE hatchery programs represent no more than 5% of the naturally-spawning population in any one of these index populations or in extant LCR spring Chinook salmon populations, as determined through 4-year and 3-year running means for Chinook and coho salmon, respectively.

2c. In order to minimize the negative effects of ecological interactions between hatchery- and natural-origin fish in the Lower Columbia River and its tributaries, the program operators shall ensure high-quality juvenile salmon are transferred to and released from the SAFE net pen facilities. Juvenile salmon shall be transferred, reared, and released using the best management practices to produce healthy smolts ready to make the transition to saltwater.

2d. The program operators, with federal funding from the appropriate Action Agencies, shall monitor the straying and natural spawning of SAFE hatchery fish in the Lower Columbia River. The proportion of SAFE hatchery fish spawning naturally shall be kept to the lowest levels feasible, consistent with the pHOS levels described in NMFS ((NMFS 2024b)) for the affected natural populations.

3a. The program operators shall send to NMFS SFD (contact below) the annual production plans for SAFE facilities each year. All other funding and operating agencies for this program should also receive a copy.

3b. The funding agencies shall ensure funding for program operators to regularly produce written reports related to the SAFE program. The agencies may incorporate SAFE hatchery reporting into existing reporting requirements and schedules through BPA-funded and operator-authored reporting under BPA Project # 1993-060-00 and (NMFS 2024b)) Mitchell Act funding reporting (due January 31st for the previous fiscal year). These reports, once completed by the operators, shall be sent to NMFS SFD (contact below), specifically describing:

a. The number of hatchery fish, by species and run type, released from the SAFE facilities annually.
b. Monitoring of SAFE program hatchery fish on the natural spawning grounds.
c. Any proposed changes to the HGMPs and/or future hatchery production.
d. These reports in written form shall be sent to:

Natasha Preston, Branch Chief
NMFS – Sustainable Fisheries Division (SFD)
Anadromous Hatchery South Branch
1201 N.E. Lloyd Boulevard, Suite 1100
Portland, Oregon 97232

Technical Contact:
Kathryn Blair, kathryn.blair@noaa.gov
(503) 231-6858

2.11 CONSERVATION RECOMMENDATION

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 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 (50 CFR 402.02).

NMFS has not identified any conservation recommendations for this Proposed Action.

2.12 REINITIATION OF CONSULTATION

This concludes formal consultation on the SAFE hatchery programs.

As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

Among other considerations, NMFS may reinitiate consultation if there is significant new information indicating that impacts on ESA-listed species, beyond those considered in this opinion, are occurring from the operation of the proposed hatchery programs, including the operation of weirs and traps, and RM&E in support of the hatchery programs, or if the specific RM&E activities listed in the terms and conditions are not implemented.

If the amount or extent of take considered in this opinion is exceeded, NMFS may reinitiate consultation. SFD will consult with the operators to determine specific actions and measures that can be implemented to address the take or implement further analysis of the impacts on listed species. If the amount and extent of take cannot be reduced to levels considered in this opinion, NMFS will reinitiate consultation.

2.13 “NOT LIKELY TO ADVERSELY AFFECT” DETERMINATIONS

There are ESA-listed species considered in this consultation for which NMFS determined the proposed action “may affect, but not likely to adversely affect” these species. For these determinations, the effects of the proposed action are expected to be discountable, insignificant, or completely beneficial. Discountable effects are those effects that are extremely unlikely to occur. Insignificant effects relate to the magnitude of the impact where the action should never reach the scale where "take" occurs. Beneficial effects are contemporaneous positive effects without any adverse effects on the species. Refer to the biological opinion for a description of the proposed action and action area. The following species in Table 36 are included as may affect, but not likely to adversely affect, determinations for this consultation.

All of these species may potentially be in the Lower Columbia River estuary near the net pens when SAFE hatchery fish are also present. A further assessment of these determinations is included below.

Table 56. Listing status and critical habitat designations for species considered in this opinion. (Listing status: 'T' means listed as threatened under the ESA; 'E' means listed as endangered.)

SPECIES	LISTING STATUS	CRITICAL HABITAT
Chinook salmon (*Oncorhynchus tshawytscha*)		
Snake River fall-run	T: 6/28/05 (NMFS 2005c)	12/28/93 (NMFS 1993)
Upper Columbia River	E: : 6/28/05 (NMFS 2005c)	09/02/05 (NMFS 2005d)
Sockeye salmon (*O. nerka*)		
Snake River	E: 6/28/05 (NMFS 2005c)	12/28/93 (NMFS 1993)
Steelhead *(O. mykiss)*		
Upper Willamette River	T: 1/5/06 (NMFS 2006b)	09/02/05 (NMFS 2005d)
Middle Columbia River	T: 1/5/06 (NMFS 2006b)	09/02/05 (NMFS 2005d)
Upper Columbia River	T: 8/24/09	09/02/05 (NMFS 2005d)
Snake River Basin	T: 1/5/06 (NMFS 2006b)	09/02/05 (NMFS 2005d)
Green Sturgeon *(Acipenser medirostris)*		
Southern DPS of Green Sturgeon	E: 4/7/06 (NMFS 2006c)	10/09/09
Killer Whales *(Orcinus orca)*		
Southern Resident DPS Killer Whales	E: 11/18/05 (NMFS 2005e)	11/29/06 (NMFS 2006d)
Eulachon *(Thaleichthys pacificus)*		
Southern DPS	T: 3/18/10	10/20/11

Other ESA-listed Salmon and Steelhead

ESA-listed salmon and steelhead produced in the Upper Willamette, Middle Columbia, Upper Columbia, and Snake Basin may be present in the Lower Columbia River estuary when SAFE hatchery fish are also present. However, the co-occurrence of these species near the SAFE facilities and when hatchery fish are present is extremely unlikely due to their off-channel location and/or timing of the release of juvenile SAFE hatchery fish when the other upriver stocks are not likely to be present in the estuary. All of the potential interaction would be ecological and no competition or predation is expected due to the larger size of these smolts compared to SAFE releases. ESA-listed fish from the Lower Columbia ESUs and DPS and chum salmon are evaluated in the opinion above.

For the adult life stage, adult hatchery fish from the SAFE project may be present with adults migrating back to other production areas in the Columbia River. Due to the limited overlap in space and time (February through June), these ecological interactions are not expected to be adverse and entirely negligible. There is no information suggesting hatchery fish migrating upriver with natural-origin fish in the Lower Columbia would cause an adverse effect on listed salmon and steelhead.

Green sturgeon

The southern green sturgeon DPS includes all natural populations of green sturgeon that spawn south of the Eel River in Humboldt County, California. Critical habitat is designated for the lower Columbia River up to RKm 74. The proposed action would increase the prey base of salmonids potentially available to green sturgeon from the release of hatchery fish (both juvenile and adult hatchery fish). Negative ecological impacts from the proposed action are not likely due to the size of green sturgeon (sub-adult and adult), differential habitat use, and life histories. Water quality and quantity effects from the operation of the hatchery facilities on green sturgeon critical habitat in estuarine waters is discountable due to the short-lived effect of hatchery effluent in upstream streams and rivers. We conclude green sturgeon may be affected, but are not adversely affected by the proposed action.

Eulachon

Eulachon are present in the Lower Columbia River and some of the larger tributaries. Critical habitat is designated for eulachon in the lower Columbia River and SAFE hatchery fish are present only in this area. The overlap between eulachon and these hatchery fish is from February through June in the lower Columbia River. Eulachon would be migrating up the lower Columbia River to spawn and the hatchery fish would emigrating to the ocean as juveniles and upstream as adults. Potential adverse effects are unlikely due to differences in habitat use and behavior between eulachon and hatchery fish. Hatchery fish are readily emigrating to the ocean and not rearing in the river. The operation of the SAFE facilities will not affect eulachon because the fish are not likely to be present for any extent of time in these off-channel net pen areas. Given the potential for interaction between hatchery fish and eulachon is entirely ecological in the action area, eulachon may be affected, but not likely to be adversely affected.

Southern Resident Killer Whales

Southern resident killer whales reside predominantly in the Strait of Juan de Fuca and Puget Sound regions during late spring through summer. During this period, these killer whales feed predominantly on returning Chinook salmon to the region, with selective preference given to consuming the older and largest Chinook salmon (Hanson et al. 2010). During the fall and winter periods, southern resident killer whales have been observed outside the Puget Sound Region, ranging from central California to northern Vancouver Island, Canada (Hilborn et al. 2012). While Chinook salmon still continues to be the preferred prey species of these killer whales, other marine species such as lingcod, greenling, sole, sablefish, and squid have also been observed in their diet (NMFS 2014[25]). The limited data available suggest the highest likelihood

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[25] Information available from: https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/southern-resident-killer-whale-orcinus-orca. Accessed February 7, 2025.

of southern resident killer whales being found potentially off the mouth of the Columbia River is from late fall through early spring. The occurrence of killer whales along the Oregon-Washington coasts likely varies from year to year, but known southern resident killer whales have been observed off these coasts several times over the last decade. During the period when killer whales are most likely to be present along the Oregon-Washington coasts (late fall through early spring), a mixture of Chinook salmon stocks originating from California to southeast Alaska have been found (Weitkamp 2010). Therefore, Chinook salmon potentially consumed by killer whales would not be solely from the SAFE hatchery programs, and only a small percentage of the total abundance of Chinook salmon would be from the proposed hatchery programs described herein, based on the abundance of hatchery-origin Chinook salmon relative to total Chinook salmon. In addition to Chinook salmon, a variety of other salmonids and marine species are also available for consumption by killer whales along the Oregon-Washington coasts.

The proposed action includes the release of hatchery Chinook salmon which are a preferred prey source for these killer whales. Therefore, NMFS has determined the proposed action may affect killer whales, but the effects are not likely to be adverse. The proposed action will affect the natural production of salmon (the effects of hatcheries on natural-origin salmon), as evaluated above, and the proposed action increases the prey base of Chinook salmon for killer whales. Based on this, NMFS believes in total, the proposed action will not adversely affect Southern Resident killer whales.

3. Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation

The consultation requirement of section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or Proposed Actions that may adversely affect EFH. The MSA (Section 3) defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Adverse effects include the direct or indirect physical, chemical, or biological alterations 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 on EFH may result from actions occurring within EFH or outside EFH, and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on descriptions of EFH for Pacific Coast salmon (PFMC 2003) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

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 physical, biological, and chemical 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 on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-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 [CFR 600.905(b)]

The effects of hatchery programs funded by the Proposed Action can occur 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), Pacific Coast groundfish (PFMC 2023c), coastal pelagic species (CPS) (PFMC 2023a), and highly migratory species (HMS)(PFMC 2023b).

The Proposed Action is the implementation of a spring Chinook salmon and coho salmon hatchery programs in Oregon and coho salmon hatchery program in Washington for fisheries enhancement, as described in Section 1.3. The Action Area includes the Columbia River estuary in the United States (U.S.), habitat described as EFH for Chinook and coho salmon (PFMC 2003). Because EFH has not been described for steelhead, the analysis is restricted to the effects of the Proposed Action on EFH for Chinook and coho salmon.

It is still reasonable to consider EFH impacts as described by PFMC (2003). As laid out there, the freshwater EFH for Chinook and coho salmon has five habitat areas of particular concern (HAPCs): (1) complex channels and floodplain habitat; (2) thermal refugia; (3) spawning habitat; (4) estuaries; and (5) marine and estuarine submerged aquatic vegetation. HAPC 1 and 3 are potentially affected by the Proposed Action.

3.2 ADVERSE EFFECTS ON ESSENTIAL FISH HABITAT

The Proposed Action has negligible, if any, effects on the major components of EFH. The net pens where hatchery fish are released have been in operation for years and are located in tidal, off-channel backwater areas of the Lower Columbia River. The amount of EFH habitat affected by the placement of net pens is insignificant. Nearshore habitat is not affected as the net pens are in deeper waters and secured by existing piling structures. The proposed hatchery programs include designs to minimize each of these effects.

The PFMC (2003) recognized concerns regarding the “genetic and ecological interactions of hatchery and wild fish… [which have] been identified as risk factors for wild populations.” The biological opinion describes in considerable detail the impacts the hatchery programs might have on natural populations of Chinook and coho salmon. Ecological effects of juvenile and adult hatchery-origin fish on natural-origin fish are discussed in Sections 2.5 and 2.6. Hatchery fish returning to the Lower Columbia River are expected to be caught at side stream/terminal fisheries and not spawn naturally. Coho salmon are more likely to stray and spawn naturally than spring Chinook salmon due to their life history differences. The areas where hatchery fish are likely to spawn near the SAFE terminal areas are not the core populations needed for recovery of the ESUs and thus not consequential to salmon recovery.

3.3 ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

For each of the potential adverse effects by the Proposed Action on EFH for Chinook and coho salmon, NMFS believes that the Proposed Action, as described in the HGMPs, supplemental information, and the ITS (Section 2.10) includes the best approaches to avoid or minimize those adverse effects. Thus, NMFS has no conservation recommendations specifically for Chinook and coho salmon EFH.

3.4 STATUTORY RESPONSE REQUIREMENT

As required by section 305(b)(4)(B) of the MSA, NMFS, BPA, and the USFWS must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5 SUPPLEMENTAL CONSULTATION

The action agencies must reinitiate EFH consultation if the Proposed Action is substantially revised by the applicants 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

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) ("Data Quality Act") 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, document compliance with the Data Quality Act, 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. NMFS has determined, through this ESA Section 7 consultation that operation of Select Area Fisheries Enhancement spring Chinook salmon and coho salmon programs as proposed will not jeopardize ESA-listed species and will not destroy or adversely modify designated critical habitat. Therefore, NMFS can issue an ITS. The intended users of this opinion are the NMFS (permitting entity), and the BPA (funding entity), and WDFW and ODFW (program operators). The scientific community, resource managers, and stakeholders benefit from the consultation through the anticipated increase in returns of salmonids, and through the collection of data indicating the potential effects of the operation on the viability of natural populations of ESA-listed salmon and steelhead in the Columbia River Basin. This information will improve scientific understanding of hatchery salmon and steelhead effects that can be applied broadly within the Pacific Northwest area for managing benefits and risks associated with hatchery operations.

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 600.920(j).

Best Available Information: This consultation and supporting documents use the best available information, as described in the references section. The analyses in this biological opinion/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.

5. Appendix A: Hatchery Production Tables for the Safe Program

Table A-1. Proposed annual production/release numbers, rearing and release locations for ODFW SAFE spring Chinook salmon program.

Select Area Site	Size Range	Release Number	Marking	Rel. Loc	Rel. Month
Youngs Bay	12-18 fpp	1,300,000	100% ad clip, Minimum of 2% CWT	Youngs Bay	February-April
		500,000		North Fk. Klaskanine R.	February-April
Tongue Point	12-18 fpp	450,000	100% ad clip, Minimum of 2% CWT	Columbia River at Tongue Point	February-April
Blind Slough	12-18 fpp	250,000	100% ad clip, Minimum of 2% CWT	Big Creek	February-April
		275,000		Gnat Creek	February-April
		675,000		Blind Slough	February-April
Total		3,450,000			

Table A-2. Proposed annual production/release numbers, rearing and release locations for ODFW and WDFW SAFE coho salmon program.

Select Area Site	Size Range	Release Number	Marking	Rel. Loc	Rel. Month
Youngs Bay	10-17 fpp	825,000	100% ad clip, Minimum of 2% CWT	Youngs Bay	March-May
		1,430,000		North Fork Klaskanine R.	March-May
		385,000		South Fork Klaskanine R.	March-May
Tongue Point	10-17 fpp	705,000	100% ad clip, Minimum of 2% CWT	Columbia River at Tongue Point	March-May

Blind Slough	10-17 fpp	400,000	100% ad clip, Minimum of 2% CWT	Blind Slough	March-May
Deep River	15 fpp	700,000	100% ad clip, Minimum of 45,000 CWT	Deep River	April-May
Total		4,445,000			

6. APPENDIX B: Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations (Revised May 2023)[26]

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 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

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[26] This version of the appendix supersedes all earlier dated versions and the NMFS (2012a) standalone document of the same name.

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.

6.1 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

6.2 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.

6.2.1 Genetic effects

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, BIA, and USFWS 2011). 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, Naish, and Primmer 2020).

Four general processes determine the genetic composition of populations of any plant or animal species (e.g., Falconer and MacKay 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[27] 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 47):

- Within-population genetic diversity
- Among-population genetic diversity/outbreeding
- Hatchery-influenced selection

The first two areas are well-known major concerns of conservation biology (Allendorf, Luikart, and Aitken 2013); (Frankham, Ballou, and Briscoe 2010), but our emphasis on hatchery-influenced selection— what conservation geneticists would likely call "adaptation to captivity" (Allendorf, Luikart, and Aitken 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.

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[27] For example, the probability of a random base substitution in a DNA molecule in coho salmon is .000000008 (Rougemont et al. 2020).

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.

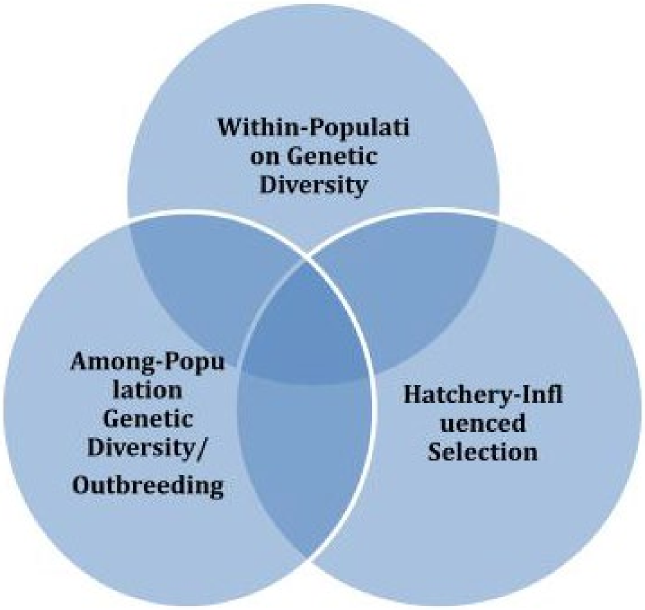

Figure 47. Major categories of hatchery program genetic effects analyzed by NMFS.

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 2009c).

- **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)

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 and Currens 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.

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 and MacKay 1996; Allendorf, Luikart, and Aitken 2013)[28].

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 and Barrowclough 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 and Allendorf 2012) concluded the rule still provided valuable guidance; another (Frankham, Bradshaw, and Brook 2014) concluded that larger values are more appropriate, basically suggesting a 100/1000 rule. See Frankham, Ballou, and Briscoe (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, Bradshaw, and Brook (2014) suggested a N_eN_c range of ~0.1-0.2

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[28] There are technically two subcategories of Ne: inbreeding effective size and variance effective size. The distinction between them is usually not a concern in our application of the concept.

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 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, Buskirk, and Hoffmann 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 and Do 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 and Shirley 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 (Busack and Knudsen 2007; Fiumera et al. 2004) 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 and Knudsen 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, Utter, and Hindar 1995; Ryman 1991). 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 and Bernatchez (2002), Tufto and Hindar (2003), and Wang and Ryman (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 and Hindar (2003) method that yield identical answers to the Duchesne and Bernatchez (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, Ballou, and Briscoe 2010; Allendorf, Luikart, and Aitken 2013; Rollinson et al. 2014; Hedrick and Garcia-Dorado 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 and Hard 2009). Inbreeding concerns in salmonids related to hatcheries have been reviewed by Wang, Hard, and Utter (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, Buskirk, and Hoffmann 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, Ford, and Blouin 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.

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 and Ellis 2006). Ironically, random mating, a common spawning guideline for conservation of genetic diversity has been hypothesized to be effectively selecting for younger, smaller fish (Hankin, Fitzgibbons, and Chen 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, NPT, and USFWS 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 and Maisse 1985; Myers, Hutchings, and Gibson 1986), Chinook salmon (Larsen et al. 2004; Bernier et al. 1993), coho salmon (Silverstein and Hershberger 1992; Iwamoto, Alexander, and Hershberger 1984), steelhead (Schmidt and House 1979; McMillan et al. 2012) , sockeye salmon (Ricker 1959), as well as several salmonid species in Asia and Europe (Kato 1991; Munakata et al. 2001; Dellefors and Faremo 1988; Morita, Tsuboi, and Nagasawa 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, Beckman, and Cooper 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 et al. 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 0.

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 and Caudill 2012; Westley, Quinn, and Dittman 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 (Goodman 2005; Grant 1997; Jonsson, Jonsson, and Hansen 2003; Quinn 1997), 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, Quinn, and Dittman (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 2.11

Gene flow from other populations can increase genetic diversity (e.g., Ayllon, Martinez, and Garcia-Vazquez 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 and Naish 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 (ICTRT 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, Quinn, and Hendry 2011; Satterthwaite and Carlson 2015). Eldridge, Myers, and Naish (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 2.11 pHOS[29] 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 (Blankenship et al. 2007; e.g., Saisa, Koljonen, and Tahtinen 2003). 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 (Leider et al. 1990; Reisenbichler and McIntyre 1977; Williamson et al. 2010).

Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[30]), 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 intentional selection for desired characteristics (Waples 1999), but in this section, for the most

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[29] 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.

[30] 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, Lohmueller, and Wayne 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; Fisch et al. 2015; Allendorf, Luikart, and Aitken 2013) 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.

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[31]. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

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, 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:

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[31] 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.

- 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 (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 and Christie 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, Flagg, and Kline 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, Shedd, and Dann 2019; Shedd et al. 2022). The RRS was 0.42 for females and 0.28 for males (Lescak, Shedd, and Dann 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 (Williamson et al. 2010; Ford, Murdoch, and Howard 2012; Ford, Murdoch, and Hughes 2015; Ford and Williamson 2009; Hess et al. 2012; Janowitz-Koch et al. 2018)
- Steelhead (Araki et al. 2007; Araki, Cooper, and Blouin 2009; Christie, Marine, and Blouin 2011; Berntson et al. 2011)
- Pink salmon (Lescak, Shedd, and Dann 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; Ford et al. 2016; Christie et al. 2011), but the two conducted with "stream-type" Chinook salmon (Ford, Murdoch, and Howard 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[32]. 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.

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 and O'Hely (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)foot[33]. (Table 55). In considering the guidelines, we equate "primary" with a recovery goal of "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.

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[32] 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, Weir, and Bernatchez 2012).

[33] Development of conservation importance classifications varied among technical recovery teams (TRTs); for more information, documents produced by the individual TRT's should be consulted.

Table 56. HSRG gene flow guidelines (HSRG 2009a).

	Program classification	
Population conservation importance	**Integrated**	**Segregated**
Primary	**PNI $\geq$ 0.67 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 0.05**
Contributing	**PNI $\geq$ 0.50 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 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).[34]

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, Burgess, and Waples (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 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 0).

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

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[34] 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%.

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.

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 2009b, 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 (2004) 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.

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.

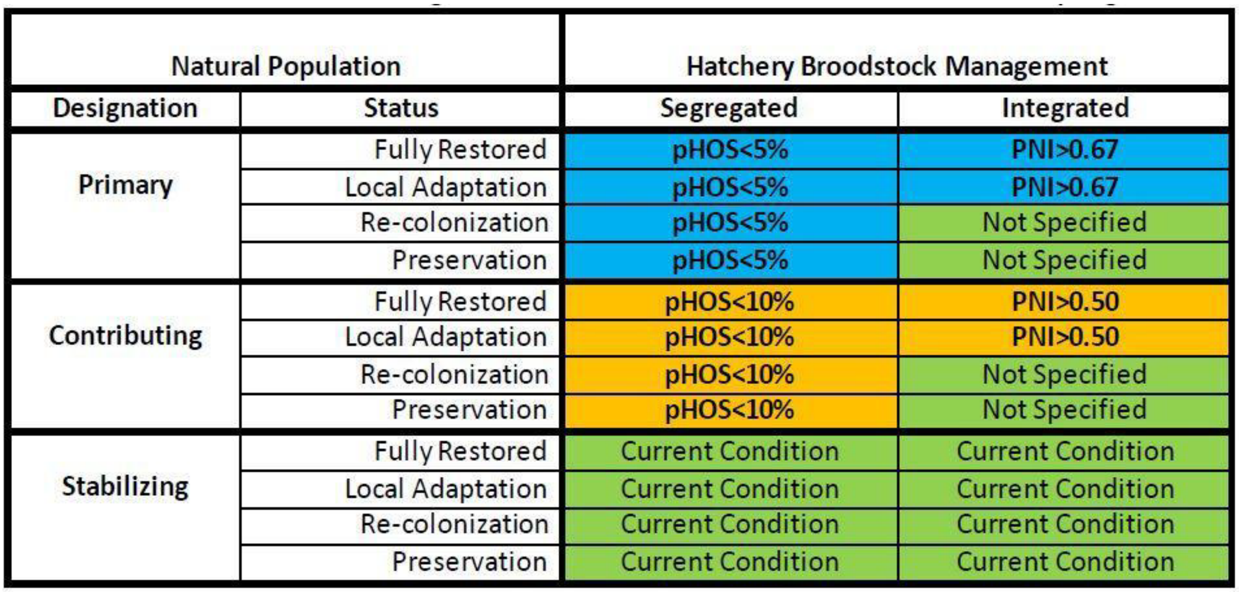
Gene flow guidelines in phases of recovery

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 2017, 2014, 2015). 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 56). 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 57. 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[35]. 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 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.*

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 47**. 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[36] (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.

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[35] 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).

[36] 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.

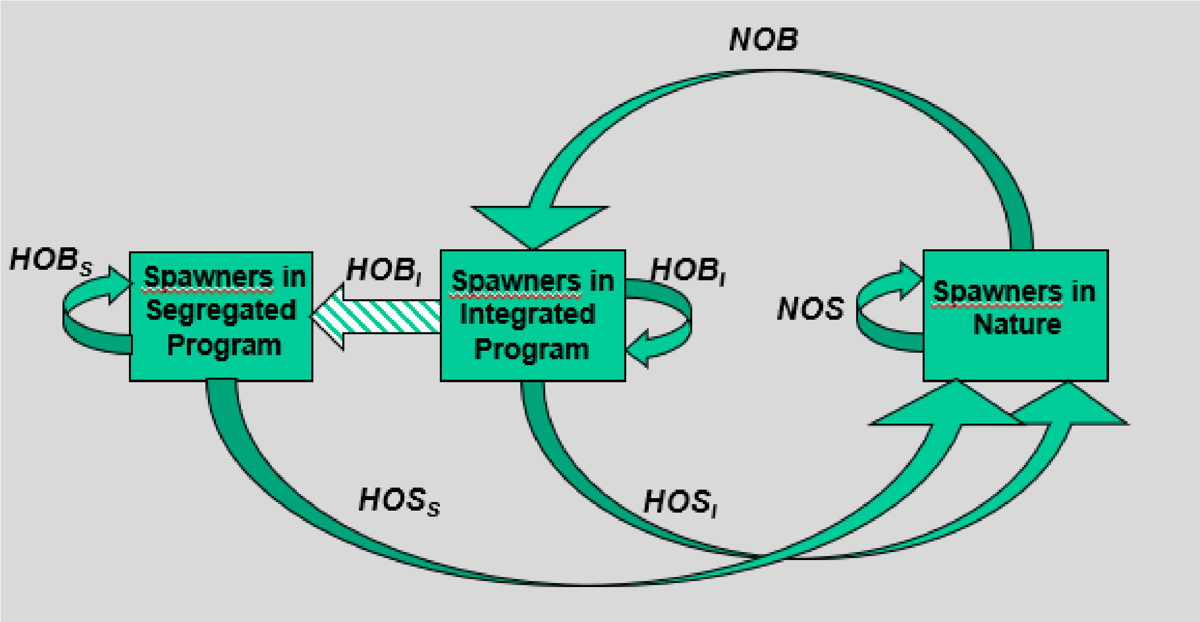

Figure 48. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOS$_I$) and a segregated program (HOS$_S$). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOB$_I$) as broodstock, but the 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.

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.

6.2.2 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 (Gresh, Lichatowich, and Schoonmaker 2000; Kline et al. 1990; Larkin and Slaney 1996; Murota 2003; Piorkowski 1995; Quamme and Slaney 2003; Wipfli et al. 2003). As a result, the growth and survival of juvenile salmonids may increase (Bell 2001; Bilton, Alderdice, and Schnute 1982; Bradford, Pyper, and Shortreed 2000; Brakensiek 2002; Hager and Noble 1976; Hartman and Scrivener 1990; Holtby 1988; Johnston et al. 1990; Larkin and Slaney 1996; Quinn and Peterson 1996; Ward and Slaney 1988).

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, Quinn, and Ewert (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, Quinn, and Smoker 1998).

6.2.3 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.

6.3 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.

6.3.1 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 and Mullan 1989; Steward and Bjornn 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 and Mullan 1989; Steward and Bjornn 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 and Bjornn 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 and Iwata 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 and Berejikian 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, Reimers, and Hall 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, 2004; Hasegawa et al. 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 and Berejikian 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 (California HSRG 2012; Steward and Bjornn 1990)
- 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[37], 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, distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

6.3.2 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

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[37] “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.

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 (HSRG 2004 and references therein; Pearsons and Hopley 1999; Hargreaves and LeBrasseur 1986), but other studies have concluded that salmonid predators prey on fish up to 1/3 their length (Beauchamp 1990; Cannamela 1992; CBFWA 1996; Hillman and Mullan 1989; Horner 1978; Daly, Brodeur, and Weitkamp 2009). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Bachman 1984; Olla, Davis, and Ryer 1998; Sosiak, Randall, and McKenzie 1979).

Size is an important determinant of how piscivorous hatchery-origin fish are. Keeley and Grant (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

6.3.3 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 and Bjornn 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, Beamish, and Kent 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; WDFW and PSTIT 2006; ODFW 2003; USFWS 2004). 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 (WDFW and PSTIT 2006) divides the state into 14 Fish Health Management Zones[38] (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

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[38] Puget Sound consists of five FHMZs, the Columbia basin only 1.

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).

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

6.3.4 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. (2009). 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.

6.3.5 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 and Quinn (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 and Quinn 2008; Keefer and Caudill 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 (Dunnigan 1999; Quinn 1997; YKFP 2008).

Dittman and Quinn (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 (Beckman et al. 2000; Hoar 1976). 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 (Bentzen et al. 2001; Fulton and Pearson 1981; Hard and Heard 1999; Kostow 2009; Quinn 1997; Westley, Quinn, and Dittman 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., (Clarke et al. 2011; Kenaston, Lindsay, and Schroeder 2001).

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.

6.4 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.

6.4.1 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.

6.4.2 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 2000, 2008a) 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).

6.4.3 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 and Brynildson 1967; Gjerde and Refstie 1988). Mortality among fin-clipped fish is variable, but can be as high as 80 percent (Nicola and Cordone 1973). In some cases, though, no significant difference in mortality was found between clipped and un-clipped fish (Gjerde and Refstie 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 and Cordone 1973), probably because the adipose and pelvic fins are not as important as other fins for movement or balance (McNeil and Crossman 1979). However, some work has shown that fish without an adipose fin may have a more difficult time swimming through turbulent water (Buckland-Nicks, Gillis, and Reimchen 2011; Reimchen and Temple 2003).

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.[39] CWTs are small pieces of wire that are detected magnetically and may contain codes[40] 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.

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[39] The same technology, more commonly called RFID (radio frequency identification), is widely used in inventory control and to tag pets.

[40] Tags without codes are called blank wire tags (BWTs).

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, Flagg, and McCutcheon 1987; Prentice and Park 1984; Rondorf and Miller 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, Haw, and Bergman 1987; Peltz and Miller 1990). This latter effect can create problems for species like salmon because they use olfactory clues to guide their spawning migrations (Morrison and Zajac 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 and Hoyt 1982; Matthews and Reavis 1990; Moring 1990). Tagging may also reduce fish growth by increasing the energetic costs of swimming and maintaining balance.

6.4.4 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 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.

6.5 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.

6.6 FACTOR 6. FISHERIES THAT EXIST BECAUSE OF THE HATCHERY PROGRAM

There are two aspects of fisheries that are potentially relevant to NMFS' analysis:

1. 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.
2. 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 2005c). In any event, fisheries must be carefully evaluated and monitored based on the take, including catch and release effects, of ESA-listed species.

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