



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 N.E. Lloyd Boulevard, Suite 1100
Portland, Oregon 97232

Refer to NMFS No: **WCRO-2025-01705**

April 20, 2026

MJ Jordan
Environmental Compliance Biologist (Permit Specialist)
Leavenworth Fisheries Complex
U.S. Fish and Wildlife Service
12790 Fish Hatchery Road
Leavenworth, WA 98826

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Entiat National Fish Hatchery Summer Chinook Salmon Hatchery Program

Dear Ms. Jordan:

Thank you for requesting initiation of consultation with NOAA’s National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for Entiat National Fish Hatchery Summer Chinook Salmon Hatchery Program. The U.S. Fish and Wildlife Service (FWS) and Bureau of Reclamation fund and the FWS proposes to operate a hatchery program at the Entiat National Fish Hatchery (ENFH) that releases summer Chinook salmon into the Entiat River Basin.

Thank you also for your request for essential fish habitat (EFH) consultation. NMFS reviewed the proposed action for potential effects on EFH pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation.

We have concluded that the action would adversely affect EFH designated under the Pacific Coast Salmon Fishery Management Plan FMP. EFH conservation recommendations are provided.

After reviewing and analyzing the current status of the listed species and the critical habitat, the Environmental Baseline within the Action Area, the effects of the Proposed Action, the effects of other activities caused by the Proposed Action, and cumulative effects, it is NMFS’s biological opinion that the Proposed Action is not likely to jeopardize the continued existence of Upper Columbia River (UCR) spring-run Chinook salmon ESU and UCR steelhead DPS, or destroy or adversely modify their designated critical habitat. NMFS has also determined that, while the Proposed Action may affect Pacific eulachon; Lower Columbia River Chinook salmon, coho salmon, and steelhead; Middle Columbia River steelhead; Snake River spring/summer-run and fall-run Chinook and sockeye salmon, and steelhead; Columbia River chum; Upper Willamette River Chinook salmon and steelhead; Southern Resident Killer Whales, and green sturgeon; the Proposed Action is not likely to adversely affect these species.

Please contact Kathryn Blair in the Portland office (Kathryn.blair@noaa.gov; 503-231-6858) if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

A handwritten signature in blue ink that reads "Nancy L. Munn". The signature is written in a cursive style with a large initial "N".

Nancy Munn, Ph.D.
Assistant Regional Administrator for
Interior Columbia Basin Office

Enclosure

cc: Craig Chisam, Hatchery Manager
William Gale, Complex Manager

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bcc: CHRON File (pdf)
Division File copy

Endangered Species Act (ESA) Section 7(a)(2) Reinitiated Biological Opinion, Section 7(a)(2) Not Likely to Adversely Affect Determination, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Response

Entiat National Fish Hatchery Summer Chinook Salmon Hatchery Program

NMFS Consultation Number: *WCRO-2025-01705*

Action Agencies: United States Fish and Wildlife Service
United States Bureau of Reclamation

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	If likely to adversely affect, Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	If likely to adversely affect, is Action Likely to Destroy or Adversely Modify Critical Habitat?
Upper Columbia River steelhead (<i>Oncorhynchus mykiss</i>)	Threatened	Yes	No	Yes	No
Upper Columbia River spring-run Chinook salmon (<i>O. tshawytscha</i>)	Endangered	Yes	No	Yes	No
Pacific Eulachon/Smelt-Southern Distinct Population Segment (<i>Thaleichthys pacificus</i>)	Threatened	No	N/A	No	N/A
Lower Columbia River Chinook Salmon (<i>O. tshawytscha</i>)	Threatened	No	N/A	No	N/A
Snake River Spring/Summer-run Chinook Salmon (<i>O. tshawytscha</i>)	Threatened	No	N/A	No	N/A
Snake River Fall-run Chinook Salmon (<i>O. tshawytscha</i>)	Threatened	No	N/A	No	N/A

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	If likely to adversely affect, Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	If likely to adversely affect, is Action Likely to Destroy or Adversely Modify Critical Habitat?
Upper Willamette River Chinook Salmon (<i>O. tshawytscha</i>)	Threatened	No	N/A	No	N/A
Lower Columbia River Coho Salmon (<i>O. kisutch</i>)	Threatened	No	N/A	No	N/A
Columbia River Chum Salmon (<i>O. keta</i>)	Threatened	No	N/A	No	N/A
Snake River Sockeye Salmon (<i>O. nerka</i>)	Endangered	No	N/A	No	N/A
Lower Columbia River Steelhead (<i>O. mykiss</i>)	Threatened	No	N/A	No	N/A
Snake River Basin Steelhead (<i>O. mykiss</i>)	Threatened	No	N/A	No	N/A
Middle Columbia River Steelhead (<i>O. mykiss</i>)	Threatened	No	N/A	No	N/A
Upper Willamette River Steelhead (<i>O. mykiss</i>)	Threatened	No	N/A	No	N/A
Southern Resident Killer Whale (<i>Orcinus orca</i>)	Endangered	No	N/A	No	N/A
Sturgeon, green – Southern Distinct Segment (<i>Acipenser medirostris</i>)	Threatened	No	N/A	No	N/A

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes

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

Issued By: 

Nancy L. Munn, Ph.D.
Assistant Regional Administrator for Interior Columbia Basin Office

Date: April 20, 2026

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1. INTRODUCTION

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

The Proposed Action is funded by the United States Bureau of Reclamation (BOR) and the United States Fish and Wildlife Service (FWS). The FWS proposes to operate a hatchery program at the Entiat National Fish Hatchery (ENFH) that releases summer Chinook salmon into the Entiat River Basin. Summer Chinook salmon are not listed under the Endangered Species Act (ESA). Straying and redd superimposition by hatchery fish are issues in the Entiat River, which has the potential to adversely affect Upper Columbia River (UCR) Spring-run Chinook salmon Evolutionarily Significant Unit (ESU) and UCR steelhead distinct population segment (DPS).

The goal of the hatchery program is to compensate for lost fish production resulting from the construction of Grand Coulee Dam by producing summer Chinook salmon for commercial, sport, and tribal harvest in a manner that minimizes adverse impacts to the environment. The program is intended to function as a segregated program for harvest benefits. Fish from this program are not intended to spawn naturally and are not intended to establish, supplement, or support any summer Chinook salmon populations occurring in the natural environment.

1.1. BACKGROUND

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

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

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

1.2. CONSULTATION HISTORY

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 Fed. Reg. 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent

measures), were not intended to result in changes to the Services' existing practice in implementing section 7(a)(2) of the Act. 89 Fed. Reg. at 24268; 84 Fed. Reg. at 45015. We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this biological opinion and incidental take statement would not have been any different under the 2019 regulations or pre-2019 regulations.

The first hatchery consultations in the Columbia Basin followed the first listings of Columbia Basin salmon under the ESA in 1991. 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 was completed on April 7, 1994 (NMFS 1994; 2008a). 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 1995). 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 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).

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 FWS and by the Washington Department of Fish and Wildlife (WDFW). NMFS' opinion (NMFS 2007c) 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 2008a) and an opinion and RPAs for the FCRPS to avoid jeopardizing ESA-listed salmon and steelhead in the Columbia Basin (NMFS 2008d). 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 SCA 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 2008a, 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 2008). NMFS also “promised to share key considerations in analyzing HGMPs” and provided those materials to interested parties in February 2009 (Jones 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 Endangered Species Act (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....”

On July 31, 2009, the FWS submitted an HGMP and requested initiation of formal consultation under section 7 of the ESA to “cover the new summer Chinook salmon hatchery program at ENFH” (USFWS 2009). The HGMP described the Proposed Action and the potential effects of the action on UCR spring Chinook salmon and UCR steelhead.

NMFS completed its review of the HGMP and determined it sufficient for formal consultation on March 9, 2011 (Busack 2011). Subsequently, and during formal ESA consultation, NMFS received additional information and analysis, comments, and proposals from the FWS and the BOR. NMFS received an updated biological assessment dated February 13, 2012, on the potential effects of the ENFH on ESA-listed species and critical habitat under FWS jurisdiction (USFWS 2012). On February 15, 2012, FWS advised NMFS of a change in the Proposed Action as it related to the diversion of surface waters for hatchery operation and provided a “new, updated Section 4 Water Source to replace the Section 4 currently in the July 31, 2009, HGMP” (Irving 2012a). NMFS received additional information and analysis, and proposals in letters dated June 4, 2012 (Irving 2012b), September 11, 2012 (Irving 2012c), and September 13, 2012 (Puckett 2012).

On April 18, 2013, NMFS completed the Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion, Section 7(a)(2) Not Likely to Adversely Affect Determination, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation for the Entiat National Fish Hatchery Summer Chinook Salmon Hatchery Program (NMFS Consultation Number: NWR-2012-00841). This opinion concluded it was likely to adversely affect but not likely to jeopardize Upper Columbia River (UCR) spring Chinook salmon, and it was not likely to affect UCR steelhead. The action is not likely to destroy or adversely modify critical habitat. The FWS requested that the consultation be effective for up to ten years so that research, monitoring, and

evaluation (RM&E) included in the HGMP could provide meaningful results and inform future management decisions.

On May 14, 2025, NMFS reinitiated the opinion due to the reinitiation trigger of April 1, 2023, having been met. In addition, updated information on straying in the Entiat River and potential redd superimposition is also available. This new biological opinion supersedes the 2013 Entiat opinion.

On March 30, 2026, in *Center for Biological Diversity v. Burgum*, No. 24-cv-04651 (N.D. Cal.), the U.S. District Court for the Northern District of California vacated aspects of four provisions from the 50 CFR part 402 regulations governing interagency consultation under section 7 of the Endangered Species Act and reinstated the provisions that were previously in effect. Consistent with the Court's ruling, these are the governing provisions for this consultation:

“Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features.” (50 CFR 402.02 (2018)).

“Effects of the action refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.”¹ (50 CFR 402.02 (2018)).

50 CFR 402.14(g)(8): “In formulating its biological opinion, any reasonable and prudent alternatives, and any reasonable and prudent measures, the Service will use the best scientific and commercial data available and will give appropriate consideration to any beneficial actions taken by the Federal agency or applicant, including any actions taken prior to the initiation of consultation.” (50 CFR 402.14(g)(8) (2018)).

50 CFR 402.16(a): “(a) Reinitiation of consultation is required and shall be requested by the Federal agency or by the Service, where discretionary Federal involvement or control over the action has been retained or is authorized by law and” (50 CFR 402.16(a) (2023)).

¹ This definition includes the second sentence of the definition of “effects of the action.” That sentence provided the definition of “environmental baseline” in effect as of 2018. In the 2019 rule amending the 50 CFR part 402 regulations, the Services established “environmental baseline” as a stand alone definition. 84 Fed. Reg. 44976, 45016 (August 27, 2019). In the 2024 rule, the Services made minor revisions to the “environmental baseline” definition. 89 Fed. Reg. 24268, 24298 (April 5, 2024). The Court's ruling did not touch upon that definition of “environmental baseline,” and it therefore remains valid. The definition is also fully consistent with the definition of “effects of the action” from 2018

1.3. PROPOSED FEDERAL ACTION

Under the ESA, “action” means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies (see 50 CFR 402.02). We considered, under the ESA, whether or not the proposed action would cause any other interrelated or interdependent actions. “Interrelated actions” are those that are part of a larger action and depend on the larger action for their justification. “Interdependent actions” are those that have no independent utility apart from the action under consideration (50 CFR 402.02).

The Proposed Action is the FWS’ ongoing operation of a hatchery program that produces non-ESA-listed UCR summer Chinook salmon. It would use “a commingled stock destined for the UCR” but it would follow protocols and practices that promote the divergence of hatchery-origin stock at ENFH from the natural-origin UCR summer Chinook salmon ESU. The purpose or reason for the hatchery program is to mitigate losses in salmon production caused by the construction and operation of Grand Coulee Dam. The goal for the program is to provide summer Chinook salmon for harvest. On average, approximately 4,000 ENFH summer Chinook salmon could be harvested annually.

Under the MSA, “federal action” means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a federal agency (see 50 CFR 600.910).

1.3.1. Proposed Summer Chinook Hatchery Program

Proposed hatchery broodstock collection

Initially, hatchery broodstock for this program began with the commingled Upper Columbia River stock (not ESA listed) of summer Chinook salmon from the Wells Hatchery program. Since 2014, broodstock has been entirely from adult returns to ENFH. At least 150 pairs of ENFH adult summer Chinook salmon would continue to be collected for hatchery broodstock annually. No natural-origin broodstock are used, and only ENFH summer Chinook salmon (i.e., hatchery summer Chinook salmon only, not listed under the ESA), identifiable by an adipose fin clip, will be used for hatchery broodstock. A representative sample from throughout the hatchery fish return will be used for broodstock purposes. ENFH’s adult return ladder is operated throughout the entire run, and adults that voluntarily migrate back through the hatchery fish ladder is the preferred method of collection. In July, the highest adult return month, two-thirds of the adult returns necessary for broodstock are randomly selected for retention, and the remaining third is randomly selected through spawning in October. This secures enough broodstock from adults returning in July to allow for surplus events while fish and flesh quality remains high. Only in extreme situations (run collapse, brood year failure at the hatchery) would collection of surplus adults from another Wells stock program be considered. If this were to occur, hatchery managers would first coordinate with the fishery comanagers to determine the most appropriate course of action. Currently, spawning occurs on two consecutive days during the first week of October. The fish ladder remains open through October. Adults may be held up to three months before spawning.

Proposed mating protocols

A 1:1 female-to-male spawning ratio is the objective. There will be no selectivity in mating. The ELISA (Enzyme-Linked Immunosorbent Assay) method is used to detect BKD, which takes about 14 days to process. Egg lots are categorized by their risk level via the ELISA method, ranging from very high to below low. Eggs with high ELISA values are immediately discarded. Eyed eggs are physically shocked before egg picking begins. The undeveloped or infertile eggs remain tender and will rupture when shocked. Within a few hours, these eggs turn white and are easily identified.

Proposed protocols for each release group (annually)

The comanagers proposed to release a maximum of 400,000 ($\pm 10\%$) smolts² per year. The fish will be reared for about 18 months in the hatchery and forcibly released directly from the facility (RM 6.7) to the Entiat River in mid-April at the base of the fish ladder, where they will be later collected as returning adults.

The comanagers propose to release the smolts when they are within the range of 15 to 20 fish per pound (fpp). Each fish will be adipose fin-clipped, and at least 200,000 fish will receive a coded-wiretag (CWT). To evaluate post-release migration, passive integrated transponder (PIT) tags will be used as appropriate. Reporting and control of specific fish pathogens will be conducted in accordance with FWS' Fish Health Policy and Implementation Guidelines (USFWS 1995).

Proposed adult management

Comanagers estimate that > 4,000 adults could be harvested annually. This estimate includes the Entiat River fishery, which is a high priority for local stakeholders. Harvest from this program varies annually but has averaged 1,948 (721-4,258) for years 2015-2021. This harvest rate does not include the average 2,408 (1,330-4,184) hatchery recruitment nor natural escapement fish that were available for harvest as they swam past the fisheries into the hatchery (years 2015-2021) or escaped into the natural spawning grounds in the Entiat River.

All ENFH summer Chinook salmon that enter the fish ladder will be removed and they will not be returned to the river to spawn. This is intended to reduce the potential for superimposition on spring Chinook salmon redds. The adults collected in excess of broodstock needs are donated to various tribes for ceremonial and subsistence purposes. A small portion may also go to non-profit groups. The comanagers also propose to utilize excess hatchery fish in nutrient supplementation programs in the Entiat River subbasin or other appropriate locations.

Proposed research, monitoring, and evaluation

The FWS will monitor and report the abundance, distribution, and timing of ENFH summer Chinook salmon that spawn naturally and the incidence of superimposition of spring Chinook salmon redds. No sampling of juveniles is proposed.

Proposed operation, maintenance, and construction of hatchery facilities

The surface water intake is located on the Entiat River at RM 7.2 and water is returned to the river (minus any leakage and evaporation) at RM 6.7 (the program is non-consumptive). Surface water

² US v Oregon parties use a release goal $\pm 10\%$ to assess program performance.

diversion will not exceed 10% of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 100 cfs from November 1 through April 30, and 5% of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 200 cfs from May 1 through October 31. ENFH also has a water right for up to 7 cfs from Limekiln (Packwood) spring. In 2020, the USFWS requested and was granted a water right change authorization to Certificate No. 3058 to include a newly developed infiltration gallery. ENFH now has the ability to withdraw from among the groundwater wells, the infiltration gallery, and the surface water diversion in any combination, but not to exceed 22.5 cfs (10,098 gpm). All rights are primary, additive rights, with a combined authorized total instantaneous withdrawal/diversion of 15,340 gpm or 34.2 cfs, of which 27.2 cfs is associated with groundwater well, infiltration gallery, and Entiat River sources, and 7 cfs is associated with the Packwood Spring. The return water system operates under National Pollutant Discharge Elimination System (NPDES) permit number WAG-13-0000.

Table 1. Current water use rights for the Entiat National Fish Hatchery.

Water Right	Source(s)	Priority Date	Instantaneous (Qi)	Units	Annual (Qa)	Units
CS4-SWC3058	Entiat River, Well Nos. 1 through 6, and Infiltration Gallery	6/4/1943	22.5	cfs	---	afy
SWC3059	Packwood (Limekiln) Spring	6/4/1943	7	cfs	---	afy
4584-A	Well No. 1	8/25/1960	800	gpm	800	afy
G4-25874C	Well Nos. 2, 3, and 4	4/19/1978	1,300	gpm	699	afy

cfs = cubic feet per second, gpm = gallons per minute, afy = acre-feet per year

There are instream structures and associated armoring. There is a diversion structure at RM 7.2, a water return at RM 6.7, and the entrance to the fish ladder at RM 6.7. Minor armoring would be maintained at these three locations. The water intake at the diversion is screened in compliance with NMFS guidelines (NMFS 1994) to protect juvenile fishes. Screens are cleaned at least twice per day. There are no barriers or weirs to impair juvenile or adult passage and spatial distribution.

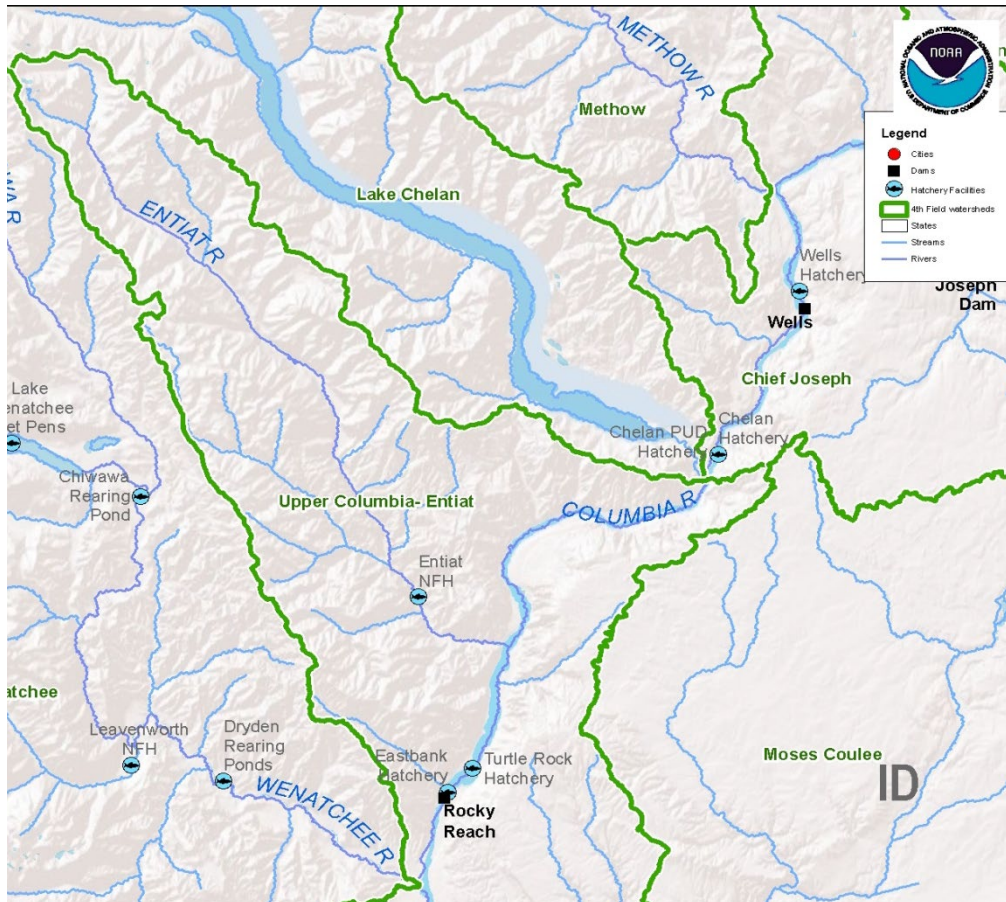


Figure 1. Location of ENFH (NMFS 2004b).

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 to 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 reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

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

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

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

2.2.1.1. Viability Approach

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

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

“Productivity,” as applied to viability factors, refers to the entire life cycle; i.e., the number of naturally-spawning adults (i.e., progeny). When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms “population growth rate” and

“productivity” interchangeably when referring to production over the entire life cycle. They also refer to “trend in abundance,” which is the manifestation of long-term population growth rate.

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

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

2.2.1.2. Listed Salmonids

In describing the range-wide status of listed salmon and steelhead species, we rely on viability assessments, status reviews, and criteria in 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 described above, the ESA allows a DPS (or in the case of salmon, an ESU) of a species to be listed as threatened or endangered. In terms of determining the status of a species, the Willamette Lower Columbia TRT (WLC TRT) developed a hierarchical approach for determining ESU-level viability criteria (Figure 1).

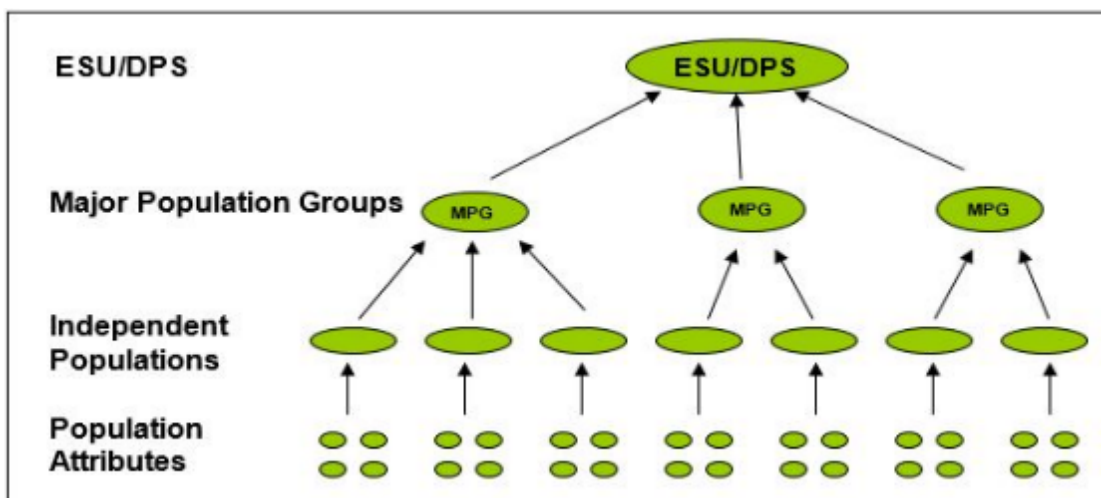


Figure 2. Hierarchical approach to ESU viability criteria.

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 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.

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. Often, this information exists in ESA recovery plans or annual performance reports from existing ESA authorizations. Recent information from recovery plans, which 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 reveals 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), as well as 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 essential 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 that encompasses all human impacts, which 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. 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.³

³ 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

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.

For this and other reasons, viability criteria vary among species, mainly in the number and type of metrics and the scales at which the metrics apply (i.e., population, MPG, or ESU/DPS) (Busch et al. 2008).

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

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

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

2.2.1.3. 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 2022).

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 2022)). Table 2 lists the hatchery and natural populations included (or excluded) in the ESU.

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.

Table 2. Upper Columbia River Spring-run Chinook Salmon ESU description and MPG (updated data from NMFS (2022)).

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 historical spring-run Chinook salmon habitat 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 3 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 migrating to saltwater in the spring of their second year of life.

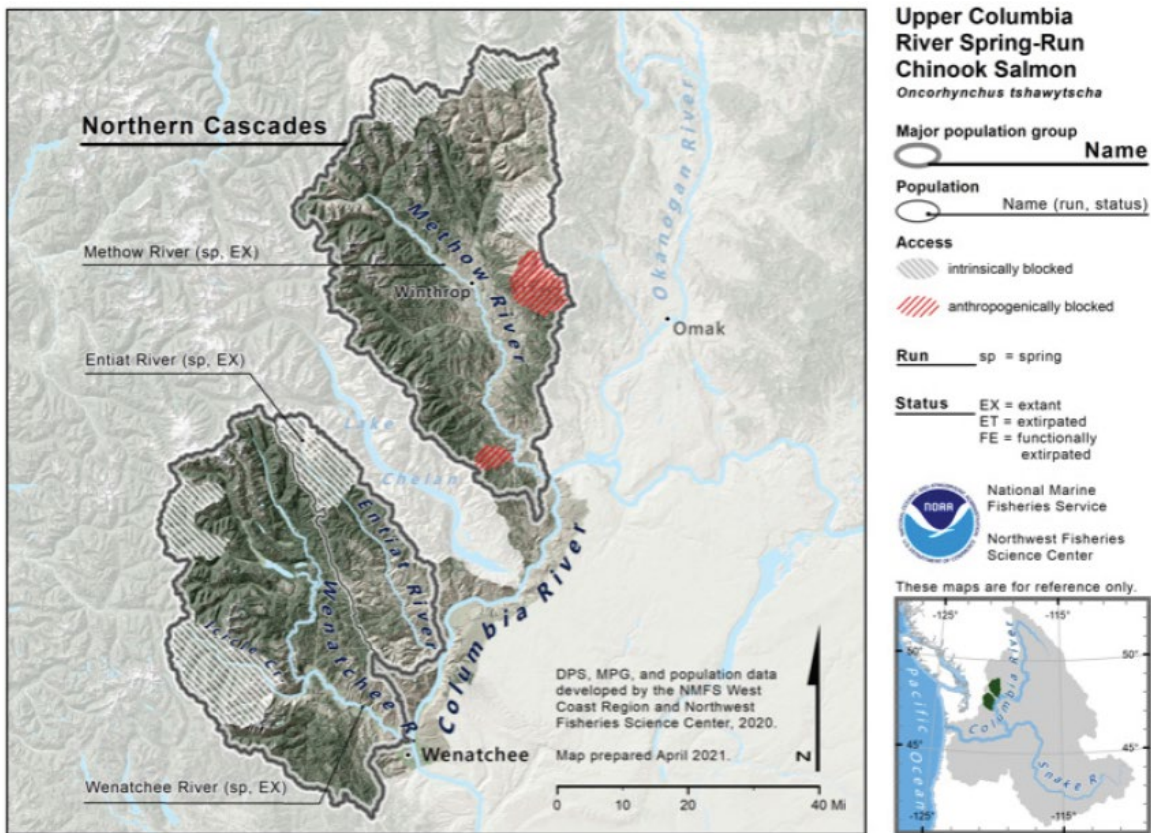


Figure 3. Map of the Upper Columbia River Spring-run Chinook Salmon ESU's spawning and rearing areas, illustrating populations and MPGs (Ford 2022).

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 2022). 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. Presently, 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 3) (UCSRB 2007).

Table 3. 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 (2022), data adapted from Table 5 in Ford (2022)).

Risk Rating for Abundance/Productivity	Risk Rating for Spatial Structure/Diversity			
	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 <i>Wenatchee</i> <i>Entiat</i> <i>Methow</i>

Abundance and Productivity

All three populations in the UCR Spring-run Chinook Salmon ESU remain at high overall risk (Table 3). Natural origin abundance has decreased over the levels reported in the prior review (NMFS 2016) for all populations in this ESU, in many cases sharply (Figure 4). 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 2022). However, natural abundance appeared to be improving from 2020-2022 (Streamnet.org data dashboard). 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 2022). 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 (NWFS 2015). Although the recent decline of population abundances is concerning, each population remains well above the abundance levels when they were listed. All three populations remain at high risk (Table 3).

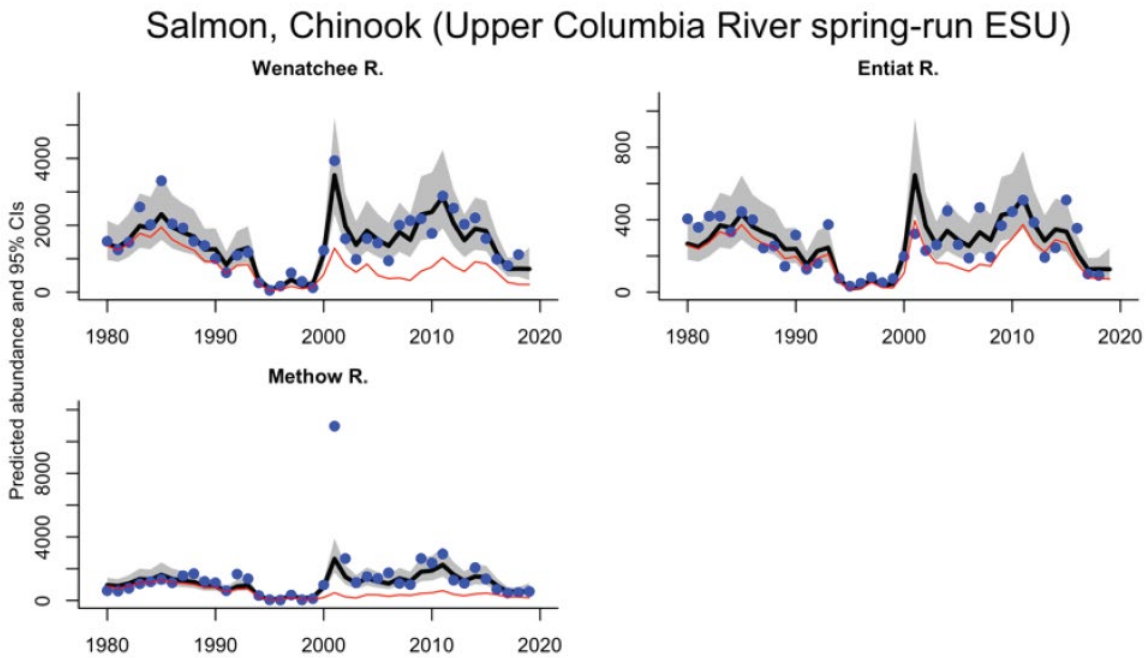


Figure 4. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other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

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- 17% (depending on run size) of UCR spring-run Chinook salmon returning to the Columbia River mouth (NMFS 2018). Actual incidental take has remained the same since the 2016 5-year review and averaged 11% for the years 2014–2019 (NMFS 2022). Exploitation rates have remained relatively low for non-treaty harvest, generally below the target rate of 2% (Figure 5).

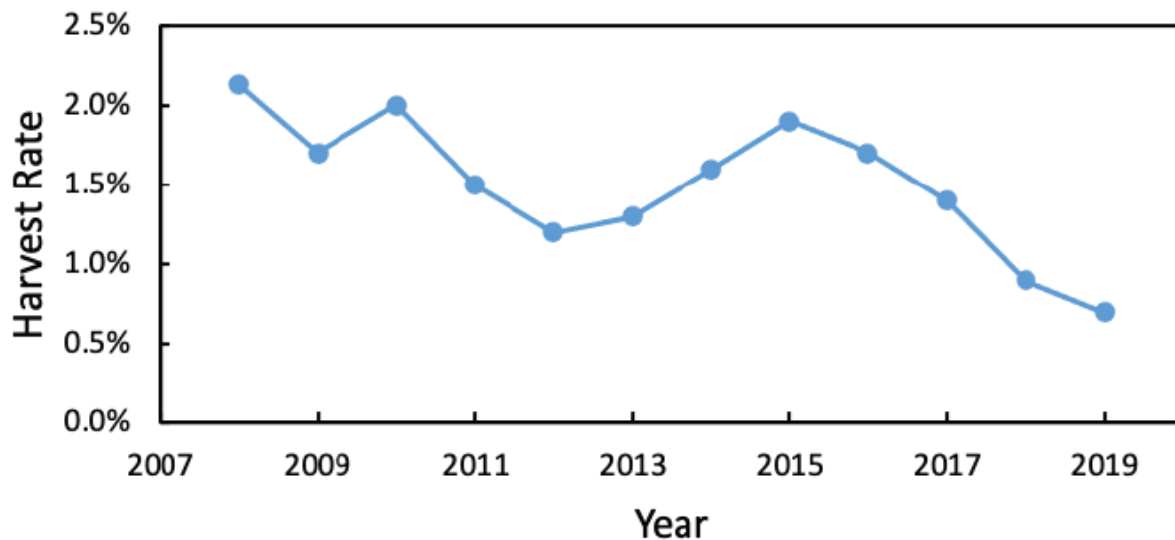


Figure 5. Non-treaty harvest rate for Upper Columbia River spring-run Chinook salmon. Data from the Columbia River Technical Advisory Committee (Figure reproduced from Ford (Ford 2022)).

Spatial Structure and Diversity

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

Hatcheries

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 2). Although several measures have been implemented to reduce risk, the proportion of hatchery-origin fish spawning naturally (pHOS) remains high in the Wenatchee and Methow Basins (Table 4). However, a better measure of hatchery genetic risk is the proportion of natural influence (PNI) within the population, which balances the incorporation of natural-origin fish into the broodstock with pHOS in the river as dual factors affecting genetic diversity. 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 2022). In the 2022 status review we concluded that hatchery effects have continued 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 2016) 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 2022).

The hatchery programs that have affected 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 2022).

Table 4. 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 (NWFSC 2015) for all three extant populations (Ford 2022). Productivities also continued to be very low, and both abundance and productivity remained well below the viable thresholds called for in the UCSRB Recovery Plan (UCSRB 2007) for all three populations. Short-term patterns in those indicators appear to be largely driven by year-to-year fluctuations in survival rates in areas outside of these watersheds—in particular, a recent run of poor ocean condition years. All three populations continued to be rated at low risk for spatial structure, but at high risk for diversity criteria (Ford 2022). Large-scale supplementation efforts in the Methow and Wenatchee Rivers are ongoing, intended to counter demographic risks given current average survival levels and the associated year-to-year variability (Ford 2022). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

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 2016). 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 2022).

2.2.1.4. 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 2022).

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 5, Figure 6) (Ford 2022); (NMFS 2022).

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 5 and Figure 6).

The life-history pattern of steelhead in the UCR Basin is complex (Chapman et al. 1994b). UCR steelhead exhibit a stream-type life with individuals exhibiting a yearling life history strategy (NMFS 2016). 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. 1994b; UCSRB 2007).

Table 5. Upper Columbia River Steelhead DPS description and MPGs (Ford 2022; NMFS 2022).

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
<i>MPG</i>	<i>Populations</i>
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
<i>Artificial production</i>	
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)

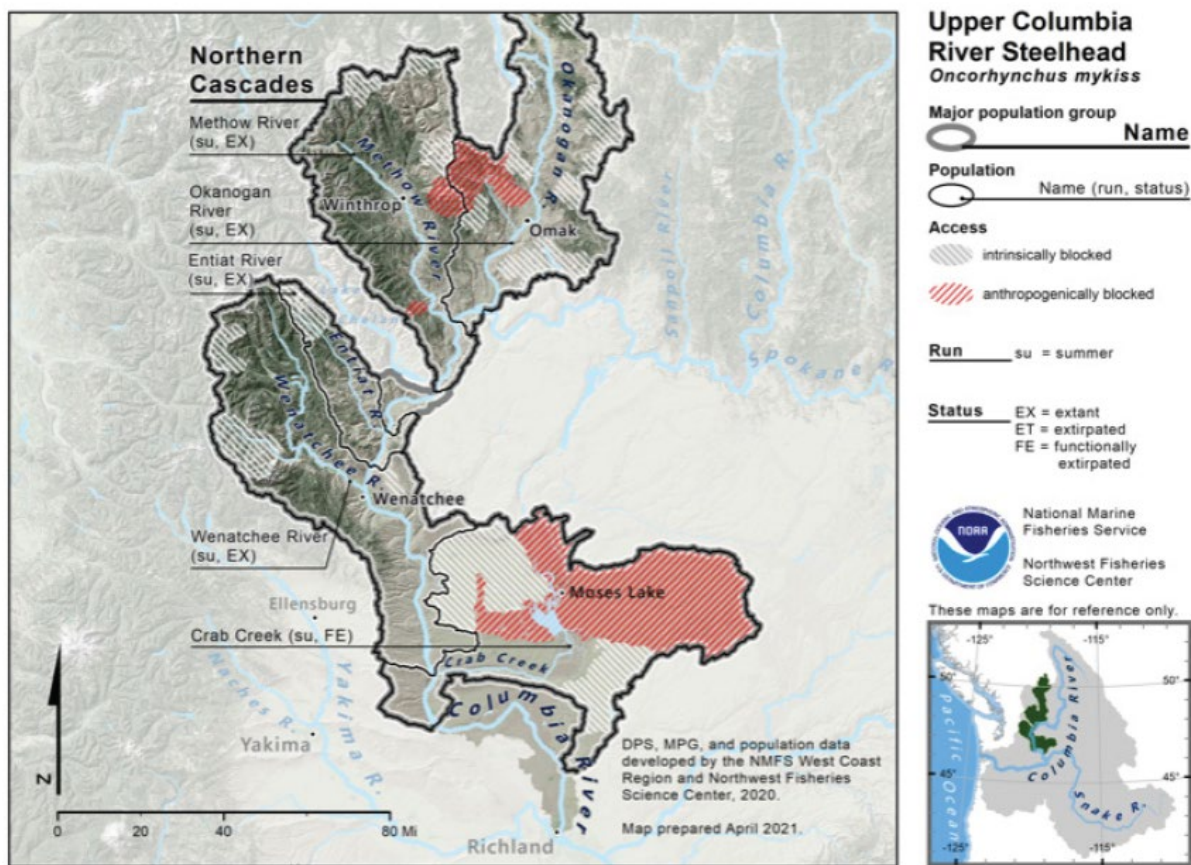


Figure 6. Map of the Upper Columbia River Steelhead DPS's spawning and rearing areas, illustrating natural populations and MPGs (Ford 2022).

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).

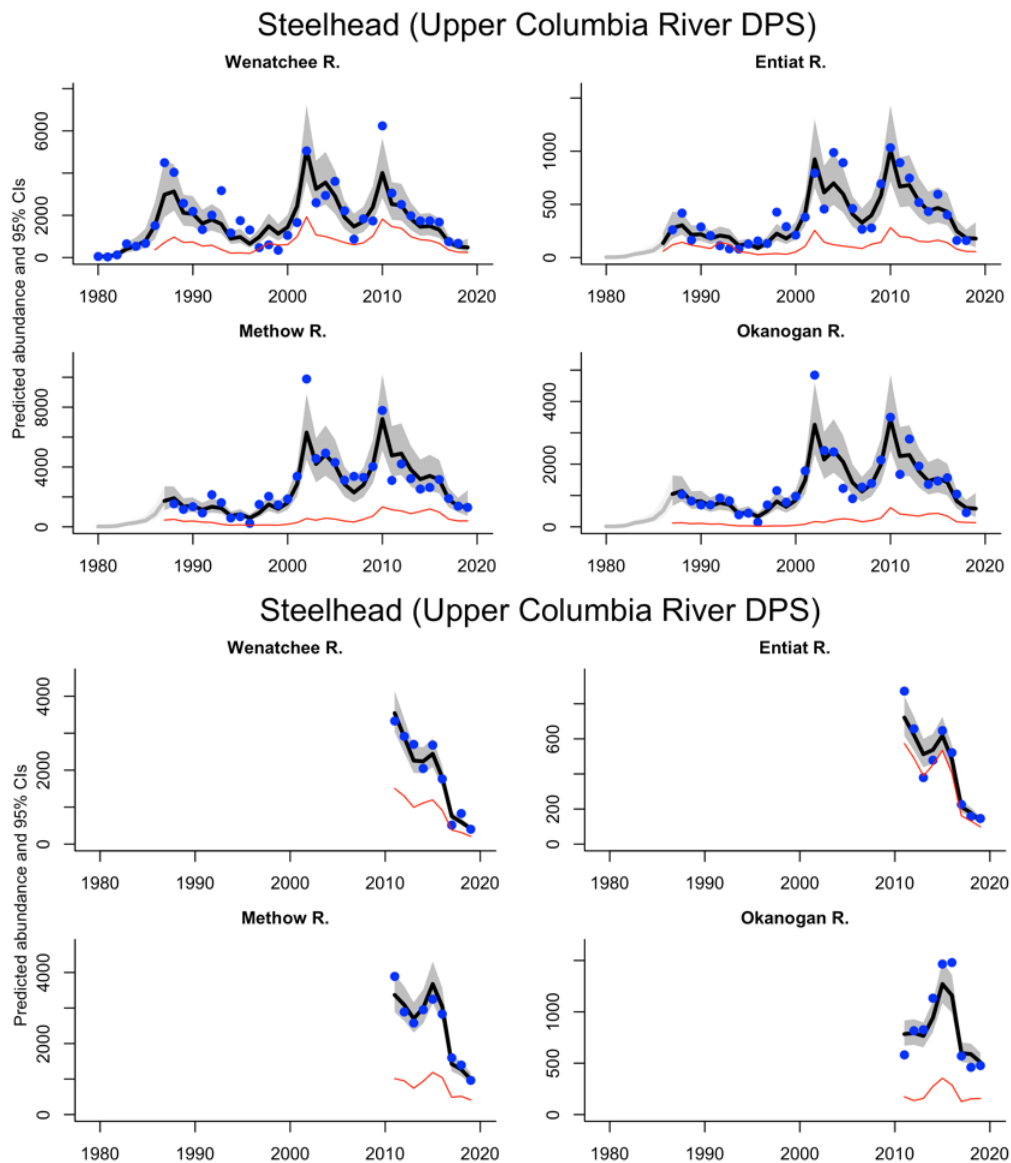


Figure 7. Smoothed trend in estimated total (thick black line, with 95% confidence interval in gray) and natural (thin red line) population spawning abundance. In portions of a time series where a population has no annual estimates but smoothed spawning abundance is estimated from correlations with other populations, the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends, the smoothed estimate may be influenced by earlier data points not included in the plot. 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 2022). Natural origin abundance has decreased over the levels reported in the prior review for all populations in this DPS, in many cases sharply (Figure 7). 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 7). However, natural abundance appeared to be improving from 2020-2022 (Streamnet.org data dashboard). 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 6). The overall diversity ratings remain unchanged at high risk (Table 6). 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 2022). Under the current recovery plan, habitat protection and restoration actions are being implemented that are directed at key limiting factors.

Table 6. 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 (2022), 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 <i>Wenatchee</i>
	High (>25%)	High Risk	High Risk	High Risk	High Risk <i>Entiat</i> <i>Methow</i> <i>Okanogan</i>

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 6).

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 from all regional DPSs each year) to very rare (NMFS 2022). The majority of harvest on UCR steelhead occurs in the mainstem Columbia River (NMFS 2022). Non-treaty fisheries in the Columbia River are limited to an incidental take of 2% of UCR steelhead during the combined winter, spring, summer period, and 2% during the fall management period (NMFS 2018). 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 8). 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 2018).

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% of listed UCR steelhead (Figure 8). As of 2012, rates are estimated over two management intervals per year, Fall and Winter/Spring/Summer (Figure 8).

Upper Columbia Steelhead Non-treaty Harvest

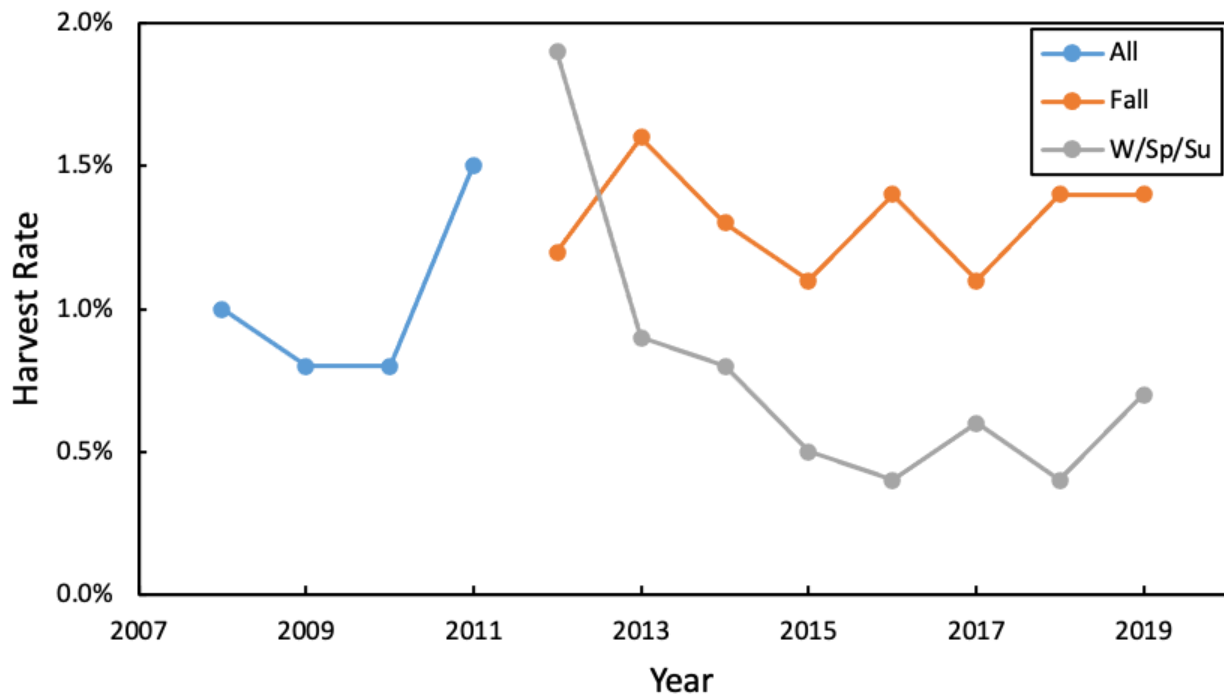


Figure 8. Harvest rates for non-treaty Upper Columbia River steelhead. As of 2012, reporting is generated across two management periods, Fall (orange line) and Winter/Spring/Summer (gray line). Prior to 2012, harvest rate reporting was across all of the calendar year (Figure from Ford Ford (2022)).

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 operations 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 releases of 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. The abundance boost also can help preserve genetic resources until other 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 2022).

The proportions of hatchery-origin returns in natural spawning areas remain high across the DPS, especially in the Methow and Okanogan river populations (Table 7), 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 2022). Given the changes in hatchery practices in the Wenatchee River (reduced production levels to reduce competition with natural origin populations, acclimation in the Wenatchee River to reduce straying as spawning adults, and a fishery or removal at dams to reduce the number of hatchery-origin adults on the spawning grounds) 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 7. 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 (2015) viability assessment, largely erasing gains observed over the past two decades for all four populations (Figure 7, Table 7). Recent declines are persistent and large enough to result in small, but negative 15-year trends in abundance for all four populations (Figure 7). 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 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 7). The improvements in natural returns in recent years largely reflect several years of relatively good natural survival in the ocean and tributary habitats. Tributary habitat actions called for in the Upper Columbia Salmon Recovery Plan are anticipated to be implemented over the

next 25 years, and the benefits of some of those actions will require some time to be realized (Ford 2022).

2.2.1.5. 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 both species affected by the Proposed Action. These critical habitat designations are described further below. 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 support⁴ 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 UCR spring Chinook and UCR steelhead 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.

⁴ The conservation value of a site depends upon: "(1) the importance of the populations associated with a site to the ESU [or DPS] conservation, and (2) the contribution of that site to the conservation of the population through demonstrated or potential productivity of the area" (NMFS 2005c).

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

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 2016).

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 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.

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 2016).

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

2.2.2. Freshwater Habitat for Salmon and Steelhead

The environmental baseline for listed salmon and steelhead and their designated critical habitat across the Action Area can be described along the following five dimensions: hydropower, habitat, hatcheries, harvest, and changing environmental conditions. In general, a wide array of human activities is responsible for the current condition of ESA-listed salmon and steelhead and critical habitat PBFs in the Action Area. It is difficult to overstate how much the quantity and quality of salmonid habitat has been diminished throughout the Entiat River Basin over the last 150 years. Habitat destruction, surface water management (damming, water withdrawal, flow modification), logging, urbanization, pollution, competition with and predation by non-native introduced species, fishing pressure, and genetic and ecological effects from hatchery production have influenced the condition of salmon and steelhead in the Action Area (NRC 1996). Many of these stressors are persistent, though some improvements have been made over the past several decades.

Baseline freshwater habitat conditions are described in detail in the documents cited in the following paragraphs. To summarize, many stream and riparian areas have been degraded by the effects of land and water use, including urbanization, road construction, forest management, agriculture, mining, transportation, and water development. Some streams have suffered little disturbance and maintain good habitat quality but are subject to the risk of new development in the floodplain. Other streams with high habitat quality are on federal lands and are not subject to industrial, commercial, or residential development. Development activities have contributed to a myriad of interrelated factors causing the decline of species considered in this opinion. Among the most important of these are changes in stream channel morphology; reduced instream roughness and cover; loss and degradation of off-channel areas, refugia, estuarine rearing habitats, riparian areas, spawning areas, and wetlands; degradation of water quality (e.g., temperature, sediment, dissolved oxygen, contaminants); and blocked fish passage. In addition to habitat loss, development has modified fluvial processes like channel migration, which has ecological consequences. The loss of mature riparian forests has reduced riparian functions and aquatic habitat quality due to decreases in habitat complexity (e.g., overhang banks, large wood), bank stability (i.e., increased erosion), shading (i.e., increased temperature), and prey sources.

Anadromous fish species have been greatly affected by land conversion due to urban and agricultural development. Dikes and levees constructed to protect infrastructure and agriculture have isolated floodplains from their river channels and restricted fish access. Development (e.g.,

urbanization, roads, agriculture) and their associated actions (e.g., shipping, dredging, roads, water withdrawals) have reduced and degraded anadromous fish habitat in numerous ways, including but not limited to the following:

- filling floodplains and wetlands,
- straightening and armoring rivers,
- reducing available in- and off-channel habitat,
- simplifying remaining habitat,
- restricting lateral channel movement,
- accelerating flow velocities,
- increasing erosion,
- decreasing cover,
- reducing prey sources,
- modifying stormwater runoff pathways,
- reducing groundwater infiltration,
- modifying subsurface flows,
- increasing flood elevations,
- contributing contaminants,
- increasing water temperatures,
- degrading water quality,
- reducing water quantity,
- removing riparian vegetation,
- modifying floodplain forest development, and
- reducing quantity and quality of in-channel shade and wood.

The existing transportation system also contributes to a poor environmental baseline condition in several ways. Many miles of roads and rail lines parallel streams, which has degraded stream bank conditions by encouraging bank armoring with rip rap, degraded floodplain connectivity by adding fill to floodplains, and discharge of untreated or marginally treated stormwater runoff to streams. Culvert and bridge stream crossings have similar effects and create additional problems for fish when they act as physical or hydraulic barriers that prevent fish access to spawning or rearing habitat, or contribute to adverse stream morphological changes upstream and downstream of the crossing itself.

Significant efforts to protect and restore habitat and habitat-forming processes by federal, state, local, and tribal entities across the Action Area have been ongoing for decades. These are summarized in the NMFS 5-year status review document (NMFS 2022), incorporated here by reference. These efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations. However, overall habitat improvement has been relatively modest compared to the extensive, persistent, and widespread nature of the loss and degradation. To date, habitat restoration efforts in the Pacific Northwest, much of which has occurred since initial ESA-listings in the mid-1990s, have not led to long-term population viability improvements necessary to achieve recovery targets (e.g., (Bilby et al. 2022; Jaeger and Scheuerell 2023)). Instead, it is generally expected to take up to five decades to demonstrate increases in viability resulting from habitat improvements. Ongoing habitat protection and restoration efforts are expected to continue to make incremental improvements at the scale of the Action Area and ESUs and DPSs, while increasing human population and changing environmental conditions are expected to exert negative pressures on habitat conditions across the region.

2.2.3. 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 1°C 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 an overall warming of 1.9–3.5 °C 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 °C 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 habitat elements 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 et al. 2010; Wade et al. 2013; Tohver et al. 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. (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 et al.)). 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. (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 (Ford 2022). Increases in water temperatures beyond their thermal optima will likely be detrimental through a variety of processes including: increased metabolic rates (and therefore food demand), decreased disease resistance, increased physiological stress, and reduced reproductive success. As trends progress toward warmer oceans and streams, more extreme winter flood events, summer low flows, loss of snowpack in the mountains, and ocean acidification, salmon face increasing challenges (Ford 2022). All of these processes are likely to reduce survival (Beechie et al. 2013; Wainwright 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. 2008b).

Salmonids require cold water for spawning and incubation. Increased temperatures at ranges well below thermal optima (i.e., when the water is cold) can increase growth and development rates. Examples of this include accelerated emergence timing during egg incubation stages, or increased growth rates during fry stages (Crozier et al. 2008b; Martins et al. 2011). Temperature is also an important behavioral cue for migration (Sykes et al. 2009), and elevated temperatures may result in earlier-than-normal migration timing. While there are situations or stocks where this acceleration in processes or behaviors is beneficial, there are also others where it is detrimental (Martins et al. 2012; Whitney et al. 2016).

As stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmonids with patches of suitable habitat while allowing them to undertake migrations through or to make foraging forays into areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile

rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

Changing environmental conditions in freshwater

As described previously, changing environmental conditions are predicted to increase the intensity of storms, reduce winter snowpack at low and middle elevations, and increase snowpack at high elevations in northern areas. Middle and lower elevation streams will have larger fall/winter flood events and lower late summer flows, while higher elevations may have higher minimum flows. How these changes will affect freshwater ecosystems largely depends on their specific characteristics and location, which vary at fine spatial scales (Crozier et al. 2008a; Martins et al. 2012). For example, within a relatively small geographic area (Salmon River Basin, Idaho), survival of some Chinook salmon populations was shown to be determined largely by temperature, while others were determined by flow (Crozier and Zabel 2006). Certain salmon populations inhabiting regions that are already near or exceeding thermal maxima will be most affected by further increases in temperature and perhaps the rate of the increases while the effects of altered flow are less clear and likely to be basin-specific (Crozier et al. 2008b; 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).

Uncertainty in Climate Predictions

There is considerable uncertainty in the predicted effects of changing environmental conditions and there is also the question of indirect effects of changing environmental conditions.

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. 2008b; 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. 2008a;

Waples et al. 2009). With their complex life cycles, it is also unclear how conditions experienced in one life stage are carried over to subsequent life stages, including changes to the timing of migration between habitats. Systems already stressed due to human disturbance are less resilient to predicted changes than those that are less stressed, leading to additional uncertainty in predictions (Bottom et al. 2011; Naiman et al. 2012; 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

“Action area” means all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area in this analysis is the Entiat River from RM 28.1 to its confluence with the Columbia River (at RM 484 on the Columbia River). RM 28.1 is the uppermost limit for spawning spring Chinook salmon in the Entiat River, and ENFH summer Chinook salmon have the potential to expand their spawning distribution into this area (Hamstreet 2013).

NMFS also includes the mainstem Columbia River from RM 484 to the mouth in the action area. The rationale for the inclusion of the Columbia River mainstem corridor is the potential effects from density-dependent interactions affecting salmon growth and survival.

2.4. ENVIRONMENTAL BASELINE

The “environmental baseline” refers to the condition of the listed species or its designated critical habitat in the Action Area, without the consequences to the listed species or designated critical habitat caused by the Proposed Action. The Environmental Baseline includes the past and present impacts of all federal, state, or private actions and other human activities in the Action Area, the anticipated impacts of all proposed federal projects in the Action Area that have already undergone formal or early section 7 consultations, and the impact of state or private actions which are contemporaneous with the consultation in process. The impacts to listed species or designated critical habitat from federal agency activities or existing federal agency facilities that are not within the agency’s discretion to modify are part of the environmental baseline (50 CFR 402.02).

In order to understand what is affecting a species, it is first necessary to understand the biological requirements of the species. Each stage in a species’ life-history has its own biological requirements (Groot and Margolis 1991; NRC 1996; Spence et al. 1996). Generally, anadromous fish require clean water with cool temperatures and access to thermal refugia, dissolved oxygen near 100 percent saturation, low turbidity, adequate flows and depths to allow passage over barriers to reach spawning sites, and sufficient holding and resting sites. Anadromous fish select spawning areas based on species-specific requirements of flow, water quality, substrate size, and groundwater upwelling. Embryo survival and fry emergence depend on substrate conditions (e.g., gravel size, porosity, permeability, and oxygen concentrations), substrate stability during high flows, and, for

most species, water temperatures of 13°C or less. Habitat requirements for juvenile rearing include seasonally suitable microhabitats for holding, feeding, and resting. Migration of juveniles to rearing areas, whether the ocean, lakes, or other stream reaches, requires free access to these habitats.

Wide varieties of human activities have affected UCR spring Chinook salmon, UCR steelhead and PCEs in the action area. These activities, more recently, include reclamation actions that are having beneficial effects. The Entiat subbasin encompasses 268,000 acres. The area is nearly 42 miles long and varies in width from five to fourteen miles. Approximately 224,000 acres of the subbasin is in public ownership, primarily the United States Forest Service (USFS), the Bureau of Land Management (BLM) and some lands are administered by the WDFW.

Historically, low-intensity wildfires maintained forests dominated by widely spaced, larger trees with little underbrush. Management practices of fire suppression, timber harvest, and livestock grazing have altered the forest ecology, increased tree density and underbrush, and changed the fire regime to high intensity, stand replacement, large wildfires. As a result, much of the Entiat River watershed has been susceptible to high intensity large fires. From 1970 to 1994, over 60% of the watershed was affected by large-stand-replacing wildfires, and in 1994 alone, the Tyee wildfire burned 33% of the watershed (Andonaegui 1999).

Starting in the uppermost areas of the Entiat watershed, riparian vegetation from the headwaters to Entiat Falls, near RM 34 (transport zone) consists of grand fir, Engelmann spruce, Douglas-fir, lodgepole pine, western red cedar, cottonwood, grasses, and forbs (USFS 1996). Riparian zone function as a buffer to stream sediment input is considered adequate where vegetative ground cover is good. Shade levels and the recruitment of large woody debris into riparian/aquatic habitat are good to excellent. About 6.6 miles of road in this zone is within 300 feet of a stream channel, with road densities below 1.0 mile per square mile. Riparian area impacts at developed campgrounds in this zone are localized and minimal, except for the concentrated use at Cottonwood Campground.

From Entiat Falls to McCrea Creek, near river-mile 25 (transitional zone), riparian species consist of Engelmann spruce and western hemlock at the higher elevations and cottonwood, red cedar, grand fir, dogwood, and alder at the lower elevations. Riparian zone function as a buffer to stream sediment is adequate where there is good vegetative ground cover. Large woody debris (LWD) recruitment and shade levels are fair to excellent. There are 43 miles of road within 300 feet of stream channels, with most of native surface with minimal surface water control features (USFS 1996).

The lower 20-25 miles of the Entiat River, representing more than 70% of the area accessible to anadromous fish, is predominately in private ownership. There are about 1,300 acres of orchard land in the lower valley, much of it classified as prime agricultural land. Riparian vegetation and function in the lower portion of the Entiat watershed (below the USFS boundary) has been affected by wildfire, agricultural encroachment on the floodplain, past flood control and channel straightening efforts, historic grazing, and rural residential development in the floodplain (Andonaegui 1999). Wildfires were noted as one of the primary disturbance factors affecting riparian vegetation. Vegetation from McCrea Creek to the river mouth (depositional zone) consists of primarily deciduous species, with alder, willow, cottonwood, aspen, elderberry, red osier dogwood, river birch, and maple as the dominant species. Conifers (Ponderosa pine and Douglas-fir) are also present. Shade and LWD recruitment is poor to good (USFS 1996). In some reaches, loss of vigorous shrubs in the riparian zone has reduced instream organic input and shade, and contributed to unstable stream banks and associated erosion. There are 205 miles of road identified within 300 feet of streams in this zone, with many having native surface with minimal surface water control

features. Roads adjacent to streams and associated road management have reduced LWD recruitment. Riparian zone function as a sediment delivery buffer is poor in the roaded segments and in some of the riparian area that is without roads.

The Lower Entiat River has been confined to a uniform channel and lacks habitat complexity. The Natural Resources Conservation Service Stream Team performed an extensive survey of the lower 20 RMs of the Entiat River in 1995. Beginning in the early 1970s, the construction of dikes and levees acted to disconnect the Entiat river from most of its floodplain. This resulted in the alteration of hydrologic and geomorphic processes that create and sustain conditions fish need to survive, including overwintering rearing habitat for juvenile fishes, and more generally, it reduced the ability of the Entiat River watershed to fully sustain salmon populations (Andonaegui 1999). The lower 14 miles of river have been transformed from rearing and refuge areas into mostly shallow riffles, with few pools and little habitat complexity. Habitat complexity (large pools, off-channel refugia, etc.) helps juvenile salmon avoid predators and provides shelter during flood flows, harsh winter conditions, and low instream flows. The quality and frequency of large-pool habitat was reduced by approximately 85 percent within the Lower Entiat River (NMFS 2004a). Adding to these problems and creating obstacles to juvenile and adult salmon spatial distribution have been push-up dams constructed to maintain surface water elevations for irrigation diversions. More recently, boulders, large wood, and root wads have been placed in the river reach where those habitat features are presently lacking.

Development in the lower subbasin has also increased the deposition of fine sediments, increased fertilizer and other pollutant inputs to the river, and decreased streamflows leading to increased water temperatures and potential barriers to fish passage. Restoration projects during the last five years will over time add streambank cover and complexity, filter pollutants, provide shade helping to moderate water temperature, reduce unusually high inputs of fine sediments, provide detritus to the aquatic habitat, and forage species, namely terrestrial insects for fish. The decommissioning of a surface water diversion is expected to increase flows and improve spring Chinook salmon spatial distribution during the summer-early fall seasons.

Another important aspect of the Environmental Baseline is hatchery effects – effects from hatchery programs located in the Entiat Basin and from fish that stray into the Entiat Basin from programs outside the basin. Hatchery spring Chinook salmon were first released into the Entiat River between 1942 and 1944 and then again on an annual basis starting in 1974. The program used non-local fish for broodstock that were a threat to the diversity and productivity of the natural spring Chinook salmon population (Table 5). Eggs for the program originated from the Cowlitz River (1974), Carson NFH (1975-1982), Little White Salmon NFH (1976-1979 and 1981), Leavenworth NFH (1979-1981 and 1994), and from Winthrop NFH (1988). In 2001, spawning ground surveys confirmed that spring Chinook salmon from ENFH were bypassing the hatchery and spawning naturally and genetic analysis indicated that it was likely that hatchery spring Chinook salmon were interbreeding with fish from the natural population. This led NMFS to conclude that the spring Chinook salmon hatchery program at ENFH was detrimental to preserving or restoring stock structure (NMFS 2004b) and the program was terminated in 2007. The last returns of these fish to the Entiat River were in 2010. Not as great a threat (these fish are largely from the same UCR Spring-run Chinook Salmon ESU) are fish from other hatchery programs that stray into the Entiat Basin. In 2011, 49 of the 54 hatchery fish carcasses recovered during spawning ground surveys in the Entiat River were stray hatchery-origin spring Chinook salmon from the Chiwawa spring Chinook salmon hatchery program in the Wenatchee River Basin (Hamstreet 2013).

Hatchery-origin spring-run Chinook salmon that stray into the Entiat River basin and successfully recruit into the natural-origin UCR spring-run Chinook salmon spawning population pose a risk to the natural population's spatial structure and diversity and therefore all hatchery-origin spring-run Chinook salmon that stray into ENFH are removed and prevented from spawning naturally. Although many of these HOR spring-run Chinook salmon are likely to be ESA-listed HOR strays from out-of-basin programs, NMFS believes the benefit of removing them from the natural spawning grounds outweighs the take of individual fish (no matter how many).

Recreational fishing occurs in the Entiat River. After termination of the spring Chinook salmon program at ENFH in 2007, fisheries were used, on several occasions, to remove hatchery spring Chinook salmon and prevent them from spawning naturally in the Entiat. The last returns from this program were in 2010 and there has not been a recreational spring Chinook fishery in the Entiat since. For summer Chinook, WDFW sets regulations for non-tribal fisheries to open the fishery once broodstock collection has been met. In 2024, the fishery opened July 9 with a daily limit of six Chinook, and closed August 16 after the non-tribal harvest share for summer Chinook had been met in the Columbia River above Priest Rapids Dam.

2.5. EFFECTS OF THE ACTION

Under the ESA, “effects of the action” refers to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration (50 CFR 402.02 (2018)).

The methodology and best scientific information NMFS follows and assembles for analyzing hatchery effects is summarized in Appendix A to this opinion, and the application of this methodology and our analysis of the Proposed Action is provided in Section 2.5.2. Appendix A is a reference document for NMFS's ESA hatchery consultations (revised May 2023) that guides the effects analysis of hatchery programs on salmon and steelhead populations. The effects analysis contained in Section 2.5.2 follows this guidance, including the evaluation of the six factors described in Appendix A and below. The effects of actions resulting from the Proposed Action are included in the analysis in this opinion to the extent they can be meaningfully evaluated.

2.5.1. Factors to Analyze When Analyzing Hatchery Effects

NMFS has substantial experience evaluating hatchery programs utilizing best available science (Hard et al. 1992; McElhany et al. 2000; NMFS 2004b; 2005d; Jones 2006; NMFS 2008b; 2012a). For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the individual and population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes—

abundance, productivity, spatial structure, and diversity—and then relates the effects of the Proposed Action at the population scale to the MPG level and ultimately to the survival and recovery of an entire ESU or DPS.

NMFS analyzes the effects of the Proposed Action in terms of effects we expect on ESA-listed species and on designated critical habitat based on the best scientific information available. This allows for quantification (wherever possible) of the effects of the six factors listed below and further described in Appendix A, to evaluate the impacts of hatchery operation on each listed species and their critical habitat. This factor-based analysis, in turn, allows NMFS to evaluate the combination of such effects with other non-hatchery-based impacts accruing to the species to determine whether or not the Proposed Action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.

The six factors that NMFS analyzes the Proposed Action against to evaluate its effects on ESA-listed species and their designated critical habitat are:

- 1) *The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock*
- 2) *Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities*
- 3) *Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, migratory corridor, estuary and ocean*
- 4) *Research, monitoring, and evaluation (RM&E) that exists because of the hatchery program*
- 5) *The operation, maintenance, and construction of hatchery facilities that exist because of the hatchery program*
- 6) *Fisheries that exist because of the hatchery program, including terminal fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds.*

NMFS's analysis assigns an effect category for each factor (negative, negligible, or positive/beneficial) on each ESU or DPS impacted by a hatchery program based on general salmon or steelhead population viability. The effect category assigned is based on: (1) an analysis of each factor weighed against the affected population(s) current risk level for abundance, productivity, spatial structure and diversity; (2) the role or importance of the affected natural population(s) in salmon ESU or steelhead DPS recovery; and (3) the target viability for the affected natural population(s).

For more information on each factor and how NMFS applies those factors in an ESA consultation, please see Appendix A. The analysis of these factors is contained in Sections 2.5.2.1 through 2.5.2.6 of this opinion.

2.5.2. Analysis of the Effects of the Proposed Action on ESA-listed Species

2.5.2.1. Factor 1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock

For Factor 1, we weigh the risks of removing natural-origin ESA-listed salmon from the natural population to be used as broodstock against the benefits of the hatchery-origin salmon and steelhead from those integrated programs returning to spawn naturally (see Appendix A, Section 1.1).

The Proposed Action utilizes ENFH stock, a non-ESA-listed hatchery-origin summer Chinook salmon, and does not remove any fish from the natural population for broodstock. Therefore, this factor is not implicated by the proposed action.

2.5.2.2. Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities

NMFS analyzes the effects of hatchery returns and the progeny of naturally-spawning hatchery fish on spawning grounds. There are three aspects to this analysis that separately consider the Proposed Action's likely genetic effects, ecological effects, and effects from adult collection facilities on ESA-listed species. Analysis of genetic effects focuses on three forms of risk: effects from hatchery-influenced selection, effects within-ESU diversity, and effects among-ESU diversity. Analysis of ecological effects focuses on competition for spawning habitat and redd superimposition. Lastly, NMFS analyzes the potential effects of handling ESA-listed salmon and steelhead that can be incidentally encountered at adult collection facilities.

In some cases, hatchery operations can provide genetic and ecological benefits. For example, hatchery programs can facilitate the *in situ* conservation of genetic resources for small populations and contribute to the delivery of marine-derived nutrients in natural environments. NMFS's analysis of genetic and ecological effects considers both potentially negative and positive effects from the hatchery operations associated with the Proposed Action.

Previously, NMFS (2013) predicted very little genetic interaction between ESA-listed UCR spring-run Chinook salmon and the UCR summer Chinook salmon produced by the ENFH. Similarly, NMFS (2013) predicted low levels of superimposition (< 15%) by hatchery-origin (HOR) summer Chinook salmon that might impact redds constructed by natural-origin (NOR) spring-run Chinook salmon. NMFS (2013) also predicted that very few spring-run Chinook salmon would be present at the time and location of summer-run Chinook salmon broodstock collection, such that few, if any, ESA-listed Chinook salmon would be inadvertently collected by ENFH. The predictions made by NMFS (2013) were largely based on records of adult spawning migration timing (i.e., run timing) and spawner distribution, but did not include such information for summer-run Chinook salmon produced by the ENFH program, which had only begun to produce and release summer Chinook salmon at the time NMFS conducted its analyses. Analyses presented here consider historical and recently collected data, including those for adult summer- Chinook salmon produced by ENFH.

Genetic and ecological effects on UCR steelhead, pursuant to the Proposed Action, are expected to be negligible or unlikely to occur. Interbreeding between steelhead and summer-run Chinook salmon does not occur, eliminating any potential for genetic effects from the Proposed Action on UCR steelhead. Moreover, there is little to no in-river co-occurrence or interaction between adult

UCR steelhead and summer-run Chinook salmon produced by ENFH, and adult UCR steelhead are not present near ENFH adult collection facilities when summer-run Chinook salmon are taken for hatchery broodstock. For these reasons, the effects of the proposed action on UCR steelhead under this factor are considered minimal, and no further evaluation of UCR steelhead is included in this section.

2.5.2.2.1. *Genetic interactions between hatchery- and natural-origin adults*

Hatchery programs, while having the ability to positively affect threatened populations by providing increased abundance, may pose genetic risks to natural populations in several ways, as discussed in Appendix A Section 5.2.1. Three forms of genetic risk from the ENFH summer-run Chinook salmon hatchery program are pertinent to our analyses: risk from hatchery-influenced selection, risk to within-ESU genetic diversity, and risk to among-ESU genetic diversity.

Hatchery-influenced selection

Hatchery-influenced artificial selection, intentional or inadvertent, can alter or diminish genetic diversity and impact the adaptive potential of hatchery-origin (HOR) salmon that spawn in the wild. Various studies have attributed shifts in adult body size (Gamble and Calsbeek 2023, Waters, 2015 #981), egg size (Heath et al. 2003), timing of reproduction ((Tillotson et al. 2019), (Quinn et al. 2002), and other biologically relevant traits to artificial selection that results from hatchery propagation and rearing. If HOR fish interbreed with naturally spawning ESA-listed species, their offspring will inherit hatchery-influenced genotypes and phenotypes, which could impact their performance and survival. Hatchery-influenced selection has also been identified as a possible cause for reduced fitness of hatchery fish that spawn in the wild (Koch and Narum 2021), which could impact the productivity of naturally spawning populations (Chilcote et al. 2011). In some cases, the relatively low fitness of HOR fish that spawn in the wild can be inherited by their naturally produced offspring ((Araki et al. 2009; Koch et al. 2025); but see Dayan et al. (2024)).

The magnitude of hatchery-influenced selection can be reduced by collecting hatchery broodstock that is representative of a local, natural population and by limiting factors that contribute to artificial selection during spawning and rearing. Regular integration of natural-origin (NOR) fish into the hatchery broodstock can also slow the rate of genotypic and phenotypic change that can occur in response to selection (Waters et al. 2015). The overall effect of hatchery-influenced selection on any local, NOR population(s) depends upon the degree to which these measures are implemented and, importantly, the proportion of HOR fish present on natural spawning grounds (pHOS).

The ENFH founded its summer-run Chinook salmon hatchery program in 2009 with eggs taken from HOR fish returning to the nearby Wells Hatchery, on the upper mainstem Columbia River. Since 2014, the ENFH's broodstock needs have been met entirely with marked (adipose fin clipped) HOR salmon released by and returning to the ENFH. Each year, up to 150 pairs of adult HOR summer-run Chinook salmon are collected from throughout the run (July – October), and these fish are used as hatchery broodstock. Artificial spawning of summer-run Chinook salmon at ENFH prioritizes single pair mating (1:1 male to female), but with contribution from a “secondary” male to ensure egg fertilization. This approach, also known as “overlapping pairwise spawning” (Busack and Knudsen 2007), serves to produce families of relatively equal size, limit potential for unintended artificial selection, and maintain effective population size (N_e) better than some commonly-used approaches (Busack 2007; Busack and Knudsen 2007). Efficient disease control is also facilitated by this mating design. The purpose of the ENFH's segregated summer-run Chinook

salmon hatchery program is to mitigate impacts from the construction and continued operation of Grand Coulee Dam on local fisheries. Unclipped, NOR Chinook salmon are rarely collected by the ENFH, but are immediately released to the river if collected. HOR summer-run Chinook produced by ENFH are not intended to spawn naturally (though some are not caught in the fishery or at the hatchery fish ladder), and marked Chinook salmon collected by the ENFH are not released back to the river (NMFS 2013). Together, these measures serve to limit the program’s impact on the abundance of ESA-listed spring-run Chinook salmon and reduce effects from hatchery-influence selection on the naturally spawning population.

In recent decades, the number of summer-run Chinook salmon redds has increased in the Entiat River (Figure 9), and pHOS for summer-run Chinook salmon has increased since 2017 to an average of 0.50 in 2019-2022 (Figure 10). Hatchery-origin summer Chinook Salmon were 51% of the spawning population upstream of the hatchery and 91% downstream of the hatchery. The NOR component of UCR summer-run Chinook salmon that spawn in the Entiat River is not an ESA-listed species, and this population has no established pHOS limit (NMFS 2013). The evaluation of this program is focused on the impact of summer Chinook on ESA-listed spring Chinook in the Entiat River via redd superimposition which has been closely monitored since 2013.

Likely genetic effects of the hatchery program on ESA-listed spring-run Chinook salmon are discussed under “Among ESU diversity”.

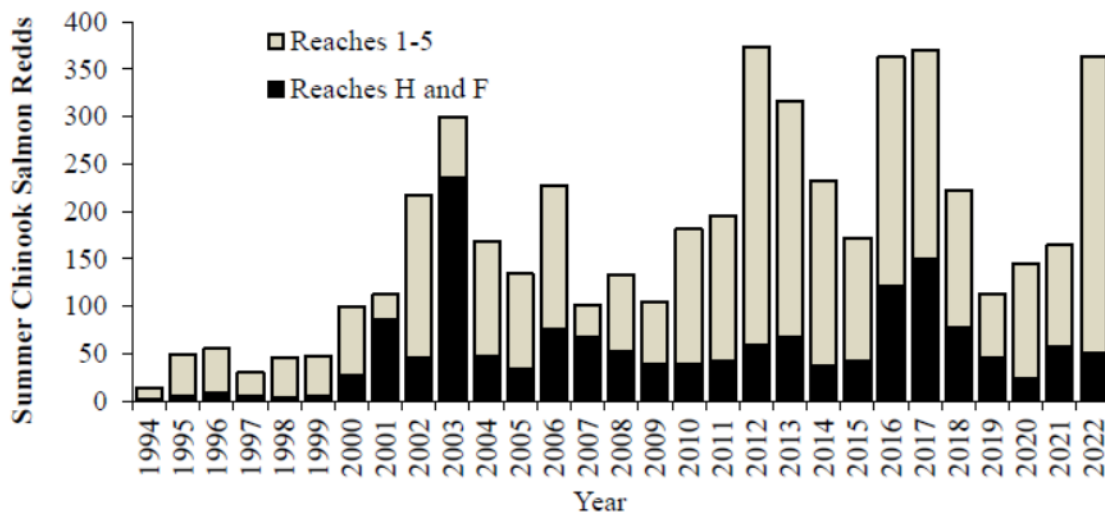


Figure 9. Annual Entiat River summer-run Chinook Salmon redd counts differentiated by upstream reaches 1–5 (rkm 26.6–48.1) and downstream reaches F and H (rkm 0.5–10.9). From Fraser and Cooper (2024).

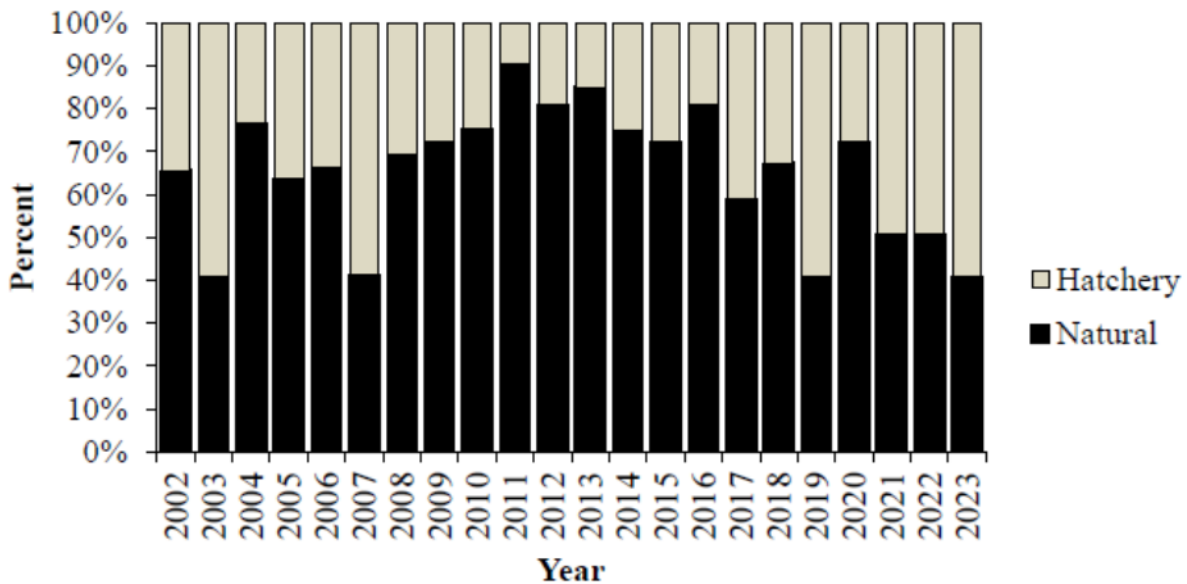


Figure 10. Percent of hatchery- and natural-origin summer-run Chinook Salmon spawning run escapement into the Entiat River. From Fraser and Cooper (2024)

Within-ESU diversity

Within-population genetic diversity is a general term for the quantity, variety, and combinations of genetic material in a population (Currens and Busack 1995). Within-population diversity is gained through mutations or gene flow from other populations, and is lost primarily due to genetic drift, a random loss of diversity that occurs because each new generation represents a finite amount of the genetic diversity present in the previous generation. The rate of diversity loss is determined by the population’s effective population size (N_e), which can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, N_e should be in the hundreds, as diversity loss can be severe if N_e drops to a few dozen (Lande and Barrowclough 1987; Waples 2002; Charlesworth 2009).

Hatchery programs, simply by virtue of creating more fish, can maintain or increase N_e . In very small populations, this can be a benefit, making selection more effective and reducing other small-population risks (Lacy 1987; Whitlock 2000; Willi et al. 2006). However, hatchery programs can also directly depress N_e in two ways. First, the collection of NOR fish for hatchery broodstock subjects those fish to hatchery management, and the effective size of the population can be reduced if the hatchery operation fails (Waples and Do 1994). As previously mentioned, the ENFH summer-run Chinook salmon broodstock was founded with and continues to use only HOR broodstock, and so this aspect of genetic risk is not relevant to the program. A second pathway to N_e reduction manifests when hatchery spawning involves a skewed sex ratio, as occurs when males are spawned multiple times (Busack 2007) or when gametes are pooled prior to fertilization. Pooling milt is especially problematic because when milt from several males is mixed and applied to eggs, a large portion of the eggs can be fertilized by a single male (Gharrett and Shirley 1985; Withler 1988). In contrast, factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_e (Fiumera et al. 2004; Busack and Knudsen 2007}. An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman and Laikre 1991; Ryman et al. 1995), when N_e is reduced through the return to the spawning grounds of large numbers of hatchery fish from very few parents.

Inbreeding depression, another N_e -related phenomenon, is caused by the mating of closely related individuals (e.g., sibs, half-sibs, cousins). The smaller the population, the more likely spawners will be related. Related individuals are likely to contain similar genetic material, and their resulting offspring may then have reduced survival as a result of lower genetic diversity or “double doses” of (i.e., homozygous for) deleterious mutations.

While empirical genetic data for the ENFH’s summer-run Chinook salmon population are not readily available, the relatively large census size of this program (150 mating pairs) and 1:1 mating protocols are likely to maintain an effective population size (N_e) capable of conserving the population’s genetic diversity. An evaluation of potential effects from interbreeding between NOR and HOR summer-run Chinook salmon in the Entiat River warrants consideration of the populations’ history. Importantly, summer-run Chinook salmon were not native to the Entiat River, as a large natural barrier near the river mouth once limited upstream fish migration during low summer flows (Craig and Suomela 1941). NOR summer-run Chinook salmon that now spawn in the Entiat River are likely descended from HOR and NOR strays that colonized the basin after the lower river channel was modified by human activities and a massive flood that occurred in 1948 (Fraser et al. 2020). Summer-run Chinook salmon produced by ENFH are themselves descended from the Wells Hatchery stock of summer-run Chinook salmon, which was founded with fall- and summer-run Chinook salmon collected at Wells Dam, beginning as early as 1967 (Myers et al. 1998). Accordingly, neither HOR nor NOR summer-run Chinook salmon are descended from a native Entiat River population. Instead, both are likely descended from neighboring populations of UCR summer-run Chinook salmon, which are not listed as threatened or endangered under the ESA.

Among-ESU diversity

Evolutionarily significant units (ESUs) are defined by important genetic diversity that is structured among population groups that have been reproductively isolated from one another over the course of their evolutionary histories. Among-ESU diversity can be lost when individuals from different ESUs interbreed, either within or outside hatchery settings. This can occur when fish from different ESUs are inadvertently spawned together in a hatchery, or when HOR fish stray onto natural spawning grounds and interbreed with fish from other ESUs. Such straying is most likely to occur at local scales (Pearsons and O'Connor 2024), but in some cases hatchery fish can stray far from their release sites, and in other cases potential effects from local straying can be mitigated by spatiotemporal differences between the spawning distributions of NOR and HOR fish.

As discussed in Appendix A Section 5.2.1, interbreeding of fish from different ESUs can result in outbreeding depression. This reduction in fitness occurs when locally co-adapted gene complexes of a native population are disrupted or replaced through genetic introgression from a genetically distinct, exogenous population. Because gene flow and introgression are often difficult or impossible to directly measure, NMFS typically evaluates hatchery effects to among-ESU genetic diversity through measures of straying by HOR fish and pHOS.

Although summer-run Chinook salmon are neither native to the Entiat River nor listed as endangered or threatened under the ESA, spring-run Chinook salmon are both native to this river and listed as threatened under the ESA. Prior to 2007, the ENFH produced and released HOR spring-run Chinook salmon that appeared on natural spawning grounds in relatively high proportions, which prompted ENFH to terminate its spring-run Chinook salmon program. Estimated pHOS for Entiat spring-run Chinook salmon averaged 0.50 in 2004-2009 (Fraser and Cooper 2024),

but dropped significantly following the program's discontinuation (mean pHOS = 0.12 for 2020-2023; (Fraser and Cooper 2024). The ENFH's transition to a summer-run Chinook salmon hatchery program was intended to reduce genetic interactions between fish released by the program and ESA-listed spring-run Chinook salmon. A recently published study indicates that, indeed, very little interbreeding occurs between summer- and spring-run Chinook salmon in the Entiat River. Fraser et al. (2020) used the program NEWHYBRIDS (Anderson and Thompson 2002) to analyze single nucleotide polymorphism data from a total 1,605 juvenile Chinook salmon collected from the Entiat River and found only 2.6% of individuals assigned as hybrids of spring- and summer-run Chinook salmon. Substantial spatiotemporal separation between naturally spawning spring- and summer-run Chinook salmon in the Entiat River likely limits genetic interactions, as spring-run Chinook salmon tend to spawn weeks earlier and higher in the watershed than summer-run Chinook salmon (Fraser and Cooper 2024). However, Fraser et al. (2020) also found that when hatchery-origin summer Chinook salmon spawned in lower quality habitat of the Entiat River, their progeny tended to move upstream into higher quality habitat. The authors speculated that hybridization could become a greater risk in subsequent generations if summer-run Chinook salmon continue to move further upstream into spring-run Chinook salmon spawning areas (Fraser et al. 2020). The ENFH program fish are not intended to spawn naturally, however some are not caught in the fishery or at the hatchery fish ladder. In 2023, 66 summer Chinook salmon carcasses were recovered, and 59% (39 fish) were hatchery-origin, with an estimated escapement of 133 fish {Fraser, 2024 #9403}. The observed proportion of hatchery-origin summer Chinook salmon carcasses does not present a concern because hybridization and redd superimposition on UCR spring Chinook (described below) is relatively rare due to temporal and spatial separation.

Straying by ENFH summer-run Chinook salmon into other populations is relatively rare. Of the 2,306,947 summer-run Chinook salmon that were (coded-wire) tagged and released by ENFH from 2010 to 2023, the Regional Mark Information System (<https://www.rmpec.org/>) includes records for a total of 13,459 that have been recovered. Of these, only 186 were recovered from natural spawning grounds, and of these, 122 were recovered from the Entiat River. Most of the remaining coded-wire tag (CWT) recoveries from spawning grounds were recorded in the Methow (n = 40) and Okanogan (n = 15) river basins. Based on a statistical expansion of the number of CWTs recovered from these basins in the years 2011-2023, the Methow and Okanogan summer-run Chinook salmon populations can be estimated to have received 172 and 87 strays, respectively, from the ENFH summer-run Chinook salmon hatchery program. During this same 12-year period, the Washington Department of Fish and Wildlife reports that the total abundance of NOR summer-run Chinook salmon summed to 14,919 and 71,448 in the Methow and Okanogan rivers, respectively (https://fortress.wa.gov/dfw/score/score/maps/map_wria.jsp), such that pHOS from the ENFH hatchery program has been 0.01 or less in these salmon populations. As previously noted, UCR summer-run Chinook salmon are not an ESA-listed species.

In summation, the overall genetic effects resulting from the ENFH summer-run Chinook salmon hatchery program, as described in the Proposed Action, do not constitute a serious threat to Entiat River spring Chinook. The program maintains a segregated broodstock, derived from an unlisted species, and genetic interactions with ESA-listed species are limited through hatchery management actions and natural spatiotemporal separation from ESA-listed species.

2.5.2.2.2. Ecological interactions between hatchery- and natural-origin adults

Adult HOR fish can have positive and negative ecological effects on natural ecosystems and ESA-listed species. Positive effects include contributions of marine-derived nutrients to freshwater

ecosystems and surrounding habitats. Negative ecological effects typically manifest when HOR fish compete with NOR fish for spawning sites or superimpose redds.

Nutrient contribution

To the extent that hatcheries contribute additional fish to the ecosystem, there can be positive ecological effects from hatchery operations. For example, when anadromous salmonids return to spawn, regardless of their origin, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a food source for juvenile salmonids and other fishes, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that can increase primary and secondary productivity (Kline et al. 1990; Gresh et al. 2000; Wipfli et al. 2003). As a result, the growth and survival of juvenile salmonids, including ESA-listed species, may increase in response to greater nutrient availability (Johnston et al. 1990; Larkin and Slaney 1996; Bradford et al. 2000; Gende et al. 2004).

Salmon and steelhead are important transporters of marine-derived nutrients, such as phosphorus, into freshwater and terrestrial systems through the decomposition of fish carcasses (Cederholm et al. 1999). Chinook salmon, in particular, can contribute large quantities of phosphorus per individual (Twining et al. 2017). Increased phosphorus can benefit NOR salmonids because it is typically a limiting nutrient for the growth of organisms that salmon prey upon. For example, growth rates in *Daphnia* (a prey source for salmonids) have been shown to increase with increased phosphorus in the algae (Boersma et al. 2009). This means that an increase in phosphorus in the ecosystem could provide a larger prey mass for native salmonids.

Fraser and Cooper (2024) reported that 66 summer-run Chinook salmon carcasses were recovered from the Entiat River during spawning grounds surveys in 2023. Of these 66 carcasses, 27 were HOR individuals, of which 25 originated from ENFH. Assuming an average adult fish weight of 5.67 kg and 0.0038 g of phosphorus per g of adult fish (see Twining et al. (2017)), these 25 HOR summer-run Chinook salmon contributed an estimated 539 g of phosphorus to the Entiat River ecosystem in 2023. Because phosphorus is often a key limiting nutrient to the productivity of river ecosystems, the addition of even small quantities of phosphorus by ENFH summer Chinook salmon can be expected to provide benefits for various species in the Entiat River basin, including spring-run Chinook salmon.

Competition for spawning habitat and redd superimposition

As described in the Status of Species, the Entiat population of UCR spring-run Chinook salmon is at an overall high risk for extinction. The five-year geometric mean abundance of this population decreased 46% between the 2010-2014 and 2015-2019 periods (Ford 2022). In recent years, adult spring-run Chinook salmon from hatchery supplementation programs in the Methow and Wenatchee rivers have also strayed into the Entiat River (Fraser and Hamstreet 2016). Strays from those programs, as well as strays from the ENFH summer-run Chinook salmon hatchery program, could pose ecological risks to Entiat River spring-run Chinook salmon.

Spring-run Chinook salmon spawn earlier in the year than summer-run Chinook salmon, which puts spring-run Chinook salmon redds at risk of superimposition by summer-run Chinook salmon that spawn later. Although spring- and summer-run Chinook salmon tend to spawn in different reaches of the Entiat River, there is some overlap of spatial distributions. More specifically, spring-run Chinook salmon do not spawn downstream of ENFH, which is sited at rkm 10.8 (6.7 RM), and

neither spring- nor summer-run Chinook salmon spawn between rkm 10.8 and 26.7, due to unsuitable spawning habitat (Fraser et al. 2020). However, the spatial distributions of spring- and summer-run Chinook salmon do overlap between rkms 26.6-48.1, even though most spring-run Chinook salmon spawn between rkms 35.0-48.1 and most summer-run Chinook salmon spawn between rkms 26.1-35.0.

From 2018 to 2022, approximately 80% of spring-run Chinook salmon spawning was between rkm 36 and 48 in the Entiat River, whereas 85% of summer-run Chinook salmon spawning occurred below rkm 36 (Fraser et al. 2020). The spatial distribution of HOR summer-run Chinook salmon spawning in the Entiat River averages 60% downstream of Entiat NFH, and 14% between rkm 26.6-48.1 (2013-2022; Fraser and Cooper 2024). However, in 2022, the proportion of HOR summer-run Chinook salmon spawning between rkm 26.6-48.1 increased to nearly 50%, coinciding with a large return of HOR Chinook salmon (Fraser and Cooper 2024). Therefore, spring-run Chinook salmon that spawned further upstream in the Entiat River were at lower risk for superimposition than those that spawned farther downstream, because relatively few summer-run Chinook salmon spawned in the upper reaches.

Per the management goals for ENFH, superimposition rates from ENFH summer-run Chinook salmon on spring-run Chinook salmon are to be less than 10% (NMFS 2013). For the 2023 spawning season, adult escapements were estimated at 154 spring-run Chinook salmon and 225 summer-run Chinook salmon to the Entiat River. An estimated 10.6% of the spring-run Chinook salmon redds were superimposed by summer-run Chinook salmon, yet only 5.3% of spring-run Chinook salmon redds were superimposed by summer-run Chinook salmon from the ENFH (Fraser and Cooper 2024). Rates of superimposition vary annually, but less than 10% of spring-run Chinook salmon redds are typically superimposed, and, from 2013 to 2023, an average 2.01% of spring-run Chinook salmon redds were superimposed by ENFH summer-run Chinook salmon (Fraser and Cooper 2024). Superimposition by ENFH fish for 2022 and 2023 was higher than previous years (6.4% and 5.3%, respectively); however, this percentage is based on 85 spring Chinook salmon redds, which is 90% of the 10-year average of 95 redds/year (Fraser and Cooper 2024). Nine instances of superimposition were noted in 2023, and not all superimpositions were from ENFH fish— Fraser and Cooper (2024) estimate ENFH superimposition at 5.3%, other hatchery-origin super imposition at 5.6%, and natural-origin summer on spring Chinook at 5%. These rates are not a concern, as management goals for the Entiat NFH state that the acceptable superimposition rates of Entiat NFH-origin Chinook salmon on spring Chinook salmon is to be less than 10% (NMFS 2013).

Overall, adult summer-run Chinook salmon produced by the ENFH, as described in the Proposed Action, are not likely to pose a serious ecological threat to Entiat River spring-run Chinook salmon.

Adult collection facilities

Handling of ESA-listed salmon and steelhead species at ENFH adult collection facilities is rare and likely to remain infrequent. When the ENFH fish collection ladder is opened for summer-run Chinook salmon (July), the vast majority of ESA-listed spring-run Chinook salmon have already migrated upriver past the hatchery and, therefore, spring-run Chinook salmon do not enter the ENFH adult holding ponds. Also, at the time of summer-run Chinook salmon collections, ESA-listed steelhead are not present in the vicinity of the hatchery.

From 2011 to 2023, only 11 adult spring-run Chinook salmon and one juvenile rainbow trout/steelhead have entered ENFH's fish ladder and holding pond. Approximately five or fewer

spring-run Chinook salmon adults and three or fewer juvenile rainbow trout/steelhead may be removed from the fish ladder and holding pond and returned to the Entiat River upstream of the fish ladder entrance per return year. Even though a few UCR spring Chinook may be handled during removal from the fish ladder or holding pond, no mortality is expected, and we do not expect the handling to reduce the ability of these fish to spawn. No lethal take has been recorded or is expected to occur. If mortality were to occur, the small number of fish is not expected to lower the abundance or productivity of the population.

2.5.2.3. Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas the migratory corridor

In addition to the factors discussed above, 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. This factor can have effects on the productivity of the natural population. Competition and a corresponding reduction in productivity and survival may result from direct interactions when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish or through indirect means, 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 naturally produced fry emerge from redds, and residualize. Predation by hatchery fish on juvenile salmon and steelhead, and transfer of disease pathogens from hatchery fish to juvenile salmon and steelhead are also considered in this factor. 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. 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 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.

ESA-listed natural-origin spring Chinook salmon and summer steelhead are both present in the Entiat River and may potentially overlap with ENFH summer Chinook salmon. Spring Chinook salmon fry emerge from the gravel in late winter or early spring at an average size of approximately 30mm (fork length (FL)), and most fry immediately move downstream to mainstem rearing areas (NMFS 2001). ESA-listed natural-origin spring-run Chinook salmon in the upper Columbia River initiate seaward migration as yearling fish between April and June at an average size of 87 to 127 mm FL (NMFS 2001). UCR steelhead fry emerge from the gravel in the late spring through August at a size of 30 to 33 mm (FL; NMFS 2001) and disperse to downstream rearing areas in the late summer and early fall. Upper Columbia River steelhead begin seaward migration at age 2+ (43.2%) or 3+ (46.4%) smolts (Peven 1990) during April and May at an average size of 136 to 188 mm (Chapman et al. 1994a). ENFH summer Chinook are released in mid-April at around 136 mm, and as described below, are expected to migrate to the Columbia River upon release. We expect limited interaction between juvenile steelhead and ENFH salmon due to the size and timing of release.

Summer Chinook salmon from ENFH (i.e., smolts) are expected to spend a limited time in the Entiat River before they reach the Columbia River and join tens of millions of natural-origin and hatchery smolts bound for the Pacific Ocean (Table 8). Hatchery fish are released only after reaching a physiological stage in their development (i.e., smoltification) that prompts them to leave freshwater for the ocean. Hatchery fish reach this stage and leave en masse, in contrast to ESA-listed natural-origin spring Chinook salmon that reach this physiological condition over a more prolonged period and begin leaving rearing areas far upstream in the Entiat River over the course of several months. The release site is 6.7 miles upstream from the Columbia River, downstream from the nearest spring Chinook salmon rearing areas. ENFH releases their fish when river flows are increasing or high, helping to flush the fish out of the area and into the Columbia River. Downstream migrating hatchery juveniles are thought to use different habitats than smaller steelhead and Chinook fry and fingerlings (Weber and Fausch 2004), minimizing the possibility of negative interactions or predation (Flagg et al. 2000) during downstream migration. ENFH summer Chinook salmon are released at a size range of 15 to 20 fish per pound (fpp) (average of 136 mm from broodyears 2016, 2017, 2019, and 2022) or less. There is a risk that hatchery juveniles released from ENFH may prey on smaller natural-origin salmonids that they encounter in the Entiat basin. Newly emerged Chinook salmon fry are at most risk of predation by hatchery fish.

Table 8. Entiat NFH summer Chinook Salmon juvenile migration passage data from release to Rocky Reach Dam, 2011–2024 (USFWS, 2025, pers.comm.).

Release Date	Passage Date				Days from release to passage			
	25%	50%	75%	90%	25%	50%	75%	90%
16-Apr-2024	18-Apr	19-Apr	20-Apr	23-Apr	2	3	4	7
12-Apr-2023	21-Apr	27-Apr	07-May	25-May	9	15	25	43
13-Apr 2022	27-Apr	09-May	22-May	02-Jun	14	26	39	44
15-Apr 2021	22-Apr	02-May	20-May	31-May	7	17	35	46
15-Apr 2020	19-Apr	23-Apr	06-May	15-May	4	8	21	30
14-Apr 2019	22-Apr	25-Apr	06-May	29-May	8	11	22	53
13-Apr 2018	16-Apr	17-Apr	19-Apr	29-Apr	3	4	6	16
13-Apr 2017	14-Apr	15-Apr	19-Apr	11-May	1	2	6	27
6-Apr 2016	9-Apr	10-Apr	25-Apr	4-May	3	4	19	28
13-Apr 2015	21-Apr	28-Apr	8-May	20-May	8	8	25	37
9-Apr 2014	10-Apr	12-Apr	16-Apr	7-May	1	3	7	28
16-Apr 2013	29-Apr	13-May	27-May	30-May	13	30	41	44
17-Apr 2012	19-Apr	19-Apr	20-Apr	30-Apr	2	2	3	13
15-Apr 2011	19-Apr	1-May	15-May	19-May	4	16	30	34

Rocky Reach Dam on the Columbia River is 11 miles downriver from the confluence of the Entiat and Columbia Rivers. ENFH is 6.7 miles from the Columbia/Entiat River confluence. As shown in Table 8, on average, it took 32 days for 90% of the ENFH summer Chinook to reach the Rocky Reach Dam (range of seven to 53 days), 18 miles from release. At this rate, ENFH summer Chinook travel 1.8 miles/day, and it would take 3.7 days to reach the Columbia River from ENFH.

For the short period (up to three months) that summer Chinook salmon occur in freshwater, they largely occupy different areas of the Entiat River than ESA-listed UCR spring-run Chinook salmon. Hatchery-origin summer Chinook salmon that return as adults and do not volunteer into the hatchery are expected to home to and spawn near the hatchery where they were reared, acclimated, and released since this location is almost ten miles downstream from the nearest areas where ESA-listed UCR spring-run Chinook salmon spawn, the progeny of naturally spawning hatchery-origin summer Chinook salmon are not expected to use the same areas for juvenile rearing as ESA-listed spring-run Chinook salmon.

PCDRisk

Our analysis of juvenile competition and predation in the Entiat River to the confluence of the Columbia River uses the PCDRisk ecological interactions model developed by Pearsons and Busack (2012). This model is used to understand the risks to natural-origin salmon and steelhead from predation by, and direct (contest) competition with, released hatchery fish from the point of release to the Entiat/Columbia River confluence. It does not estimate interactions among natural fish or among hatchery fish, although both interaction scenarios are likely to occur. While this model uses some quantitative estimates of ecological interactions, the estimates are derived from parameters based on best available science and professional judgment on qualitative information. Therefore, the most appropriate way to think of these estimates is as a relative measure of UCR spring Chinook salmon and UCR summer steelhead adversely affected by the release of hatchery fish from ENFH.

The logic used in the PCD Risk model was described by Lauver et al. (2012), but since that time, it has been modified to increase supportability and reliability. Notably, the current version no longer operates in a stand-alone graphical user interface environment and no longer has a probabilistic mode. NMFS also further refined the model by allowing for multiple hatchery release groups of the same species to be included in a single run and by allowing both natural-origin and hatchery-origin fish to grow over the modeled residence period. Modification to the model logic included an elimination of competition equivalents and replacement of the disease function with a delayed mortality metric in 2018. The 2023 version also changed the way delayed mortality was calculated.

The rationale behind the changes described above was to make the model more realistic. In previous uses of the model, competition rarely directly resulted in death because it takes many competitive interactions for a fish to suffer enough weight loss to cause mortality by starvation. Weight loss is how adverse competitive interactions were captured in the model. However, fish that experience competition and resulting weight loss are likely more vulnerable to mortality from other factors, such as disease. In the revised application, at the end of each model run, the competitive impacts for each fish are assessed, and the fish has a probability of delayed mortality based on the amount of growth lost due to competitive impacts. This function will be subject to further refinement based on the availability of new research. For now, the probability of delayed mortality is equal to the proportion of a fish's weight relative to the potential increase in weight without competitive interactions.

Similar to the use of models for biological systems elsewhere, this model cannot possibly account for all the variables that could influence competition and predation on natural-origin juveniles. For example, the model assumes that if a hatchery fish is piscivorous and stomach capacity is available, the hatchery fish will consume natural-origin prey. In reality, hatchery-origin fish could choose to eat a wide variety of fauna, such as other fish species (e.g., minnows) or aquatic and terrestrial insects, in addition to natural-origin juveniles. However, NMFS believes that with this model we are generating, to the best of our ability, and based on the best available science, a reasonable estimate of the effects on natural-origin juvenile salmon and steelhead.

For this consultation, NMFS assumed some of the parameter inputs consistent with other consultations in which we use this model (Table 9). We assumed that habitat complexity was low, at only 10 percent, to conservatively account for habitat degradation in the lower Entiat River. We used habitat segregation estimates of 0.3 for conspecifics (spring Chinook salmon), and 0.6 for other salmon and steelhead (UCR steelhead); a dominance mode of 3; and maximum encounters per day of 1, based on what was decided in the (HETT 2014) database for hatchery programs of the same life stage and species.

Table 9. Parameters in the PCD Risk model.

Parameter	Value
Habitat Complexity	0.1
Population overlap	1.0
Habitat segregation	0.3 for spring Chinook, 0.6 steelhead
Dominance mode	3
Probability dominance results in weight loss	0.05
Proportion of weight loss causing death	0.5
Maximum encounters per day	1
Predatory:prey length ratio for predation	0.25

Natural and Hatchery Origin Input Parameters

Model inputs of abundance and size on hatchery and natural-origin juveniles are found in Table 10. In addition, we input the survival rate and residence time of the hatchery-origin fish. We used a survival rate of 0.98: USFWS provided juvenile data, which established an average 0.57 survival rate to McNary Dam from 2011-2024, which is 199 km from the release site at ENFH. Therefore, we get a mortality rate of 0.003 juveniles per mile, resulting in a 0.98 survival rate from release to the confluence of the Entiat and Columbia Rivers. For residence time, we calculated 3.7 days, based on data from Table 8, above, and rounded up to 4 days, as PCDRisk only uses whole values.

Table 10. Total abundance and size of natural-origin and ENFH salmon and steelhead used as PCDRisk inputs.

	Number of Fish	Mean Length (mm)	CV length

Spring Chinook yearling ⁵	11,950	97	0.10
Spring Chinook subyearling ⁵	6,435	83	0.13
Steelhead	18,169	160	0.19
Summer Chinook (ENFH)	440,000	136	0.098

Results

Neither UCR steelhead nor spring Chinook experienced direct competition or predation effects from the hatchery releases of summer Chinook. UCR steelhead had delayed mortality of 20.6 juveniles. UCR spring Chinook had delayed mortality of 54 juveniles, with 32.8 yearlings and 21.2 subyearlings accounting for the total mortality. Based on the smolt-to-adult return (SAR) survival rates (Desgroseillier et al. 2024), spring Chinook SAR was estimated at 0.63% for yearling smolts and 0.72% for subyearling outmigrants. The combined spring Chinook SAR estimate was 0.65% for the 2017 brood year, the most recent data available. This results in adult mortality of 0.351 adults. For UCR steelhead, we used a SAR value from TAC (2017) of 0.88%. This equates to adult mortality of 0.181 adults. Therefore, barring circumstances which depart from the model, we find the mortality of ESA-listed species from the ENFH summer Chinook to not affect the abundance or productivity of the population.

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 in freshwater, and this analysis may be an overestimation. Based on the variables described above, risk to individual affected populations is not expected to reach a level that would lower the abundance or productivity of the population.

We also discuss below other aspects of salmon and steelhead biology that influence ecological interactions based on current scientific literature that were not considered in the model, or otherwise require more elaboration. These are: (1) diet composition; (2) predation; and (3) disease. All of these aspects must be considered when assessing the effects of hatchery fish on natural populations of salmon and steelhead, and these factors assist in understanding the uncertainty in our modeled estimates of direct competition and predation.

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 prey upon younger-aged fish that are smaller, especially larger hatchery steelhead co-occurring in microhabitats with younger, smaller salmonids (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

⁵ Abundance data of spring Chinook differ from (Desgroseillier et al. 2025), due to rounding the proportion of each age class and the total number of juvenile spring Chinook.

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 other populations of fry and fingerlings that are encountered during the downstream migration. Studies (Melnichuk et al. 2014; Berejikian et al. no date) 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.

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 UCR spring Chinook salmon or UCR steelhead in the action area. The minimal spatial and temporal overlap between ENFH-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. 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 (Bjornn and Steward 1990). ENFH summer Chinook salmon are “ocean-type” and spend up to 3 months in their natal area before leaving for the ocean. Summer Chinook salmon prefer estuarine and ocean areas for rearing compared to spring Chinook salmon, which prefer freshwater tributary habitats for early rearing. This results in fewer instances where competition impacts by ENFH hatchery fish on natural-origin UCR species can potentially occur. To the extent competition does occur, it is further limited to instances of temporal and spatial overlap, which are limited as discussed above. As modeled above, UCR steelhead had delayed mortality of 20.6 juveniles (0.1%) and UCR spring Chinook had delayed mortality of 54 juveniles (0.3%), and this is combined predation and competition. We reach the same conclusion for competition as for predation, based on the same rationale: this risk is not likely to be a significant overall concern for UCR spring Chinook salmon or UCR steelhead in the action area because spatial and temporal overlap between ENFH-released fish and ESA-listed salmonids is minimal, and the lack of hatchery juveniles being released in large numbers or density, reinforce the conclusion that the risk of competition in any concerning amount is unlikely.

Disease

The hatchery program will continue to 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 ENFH summer Chinook egg-to-release survival rates are high, 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 this program 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 USFWS hatcheries over the last few years, no novel or exotic pathogens have been found, and no devastating outbreaks have occurred, in UCR hatchery programs in recent years. However, it is important to note that the detection of a pathogen does not mean that the 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, suggests 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 event, hatchery fish can shed pathogen(s) 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 (Bjornn and Steward 1990; Naish et al. 2007).

Residualism

Chinook salmon hatchery programs can have high rates of precocial maturation in males (Beckman and Larsen 2005; Harstad et al. 2014; Larsen et al. 2004; Larsen et al. 2013). Precocial males may forgo ocean migration, thus increasing their potential for competition and predation on natural-origin salmon and steelhead in juvenile rearing areas. Harstad et al. (2014) found that for the Carson spring Chinook salmon program, an average of 25 percent (from the 2010-2011 release years) of the males matured precocially. For the Similkameen summer Chinook salmon program from the 2008-2011 release years, an average of 12 percent of the males matured precocially. The precocious maturation rates for summer Chinook salmon reared at Entiat NFH are variable: Gonadosomatic Index (GSI) sampling results (which only estimates male maturation) for the most recent five-year period of analysis at ENFH range from 6.5 to 27.7 percent with a five-year average of 16.2 percent. To assess precocity of the release year cohort, divide the GSI percent maturation in half, assuming an equal sex ratio of the smolts released. As described above, adverse impacts of residual hatchery Chinook salmon on natural-origin salmonids can occur. However, the issue of residualism has not been as widely investigated compared to steelhead. Therefore, monitoring in the vicinity of the hatchery release point 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 (Bjornn and Steward 1990); California HSRG, 2012 #1559}.
- 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.

Conclusion

The entire Action Area is the lowermost 28.1 miles of the Entiat River before entering the Columbia River. The potential spatial overlap would only occur at the release site at RM 6.7 of the Entiat River to the confluence with the Columbia River. All fish occupying habitats upriver of the hatchery would not be affected by the proposed action because hatchery fish rarely occur there.

For the reasons described above, hatchery-released fish will readily out-migrate 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 6.7 mile area of potential spatial overlap.

2.5.2.4. Factor 4. Research, monitoring, and evaluation that exists because of the hatchery program

NMFS analyzes the incidental effects of the proposed research, monitoring, and evaluation (RM&E) on listed species. This factor can also affect the productivity VSP parameter of the natural population. The Proposed Action addresses the five factors that NMFS takes into account when it analyzes and weighs the beneficial and negative effects of hatchery RM&E. It includes RM&E to monitor compliance with this opinion and to inform future decisions over how the hatchery program can make adjustments that further reduce risks to ESA-listed spring Chinook salmon and steelhead.

RM&E includes surveys, annually, to determine the prevalence of hatchery-origin summer Chinook salmon in spring Chinook salmon natural spawning areas and the location and extent of superimposition of spring Chinook salmon redds by summer Chinook salmon. Interactions with listed species during these surveys are not expected, therefore the potential for lethal or sub-lethal effects to UCR spring Chinook salmon and UCR steelhead are negligible.

2.5.2.5. Factor 5. The operation, maintenance, and construction of hatchery facilities that are associated with 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. It can also degrade habitat function and reduce or block access to spawning and rearing habitats altogether. Here, NMFS discusses changes to riparian habitat, channel morphology, and habitat complexity, in-stream substrates, and water quantity and water quality attributable to operation, maintenance, and construction activities and confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

Operations, maintenance, and construction activities included in the Proposed Action will have a negligible effect on ESA-protected spring Chinook salmon and steelhead and on designated critical habitat. The existing facility is located high in the floodplain and has not led to altered channel

morphology and stability, reduced and degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity, and no new facilities are proposed.

Broodstock collection facilities do not affect fish passage and the spatial distribution of juvenile and adult spring Chinook salmon because there is no barrier in the river and there is no evidence that flows from the fish ladder delay upstream migrations.

The water supply system is designed and operated such that groundwater extraction and surface water diversion are not expected to reduce the spatial distribution and productivity of the Entiat spring Chinook salmon population. In NMFS' opinion, flows in the bypass reach, between RM 6.7 and 7.2 will not impair juvenile or adult spring Chinook salmon passage. The FWS will also monitor and report on juvenile and adult passage conditions between the upstream diversion site and the location downstream where water is returned to the river. ENFH's combined groundwater and surface water withdrawal does not exceed 22.5 cfs. All of the water used by the hatchery is returned to the Entiat River, less any leakage and evaporation.

The diversion intake is screened and meets NMFS criteria for protecting anadromous salmonids. The return water system operates under NPDES permit number WAG-13-0000, and effluent is monitored weekly to ensure compliance with permit requirements. The ESA recovery plan does not identify effluent from ENFH as a threat to spring Chinook salmon survival and recovery. While effluent discharge from hatchery facilities can adversely affect water quality mainly by raising temperatures and total suspended solids (TSS) concentrations, ENFH consults with the Washington Department of Ecology (WDOE) and the US Environmental Protection Agency (EPA) to make sure appropriate regulations are followed when the pollution abatement ponds are cleaned and the sediment is disposed of.

Surface water diversion, as described in the Proposed Action, is expected to have a negligible effect on ESA-listed UCR spring-run Chinook salmon or UCR summer steelhead, and FWS will monitor Entiat River stream-flows and fish passage conditions to validate this conclusion and ensure that the spatial distribution of UCR spring-run Chinook salmon or UCR summer steelhead are not affected.

2.5.2.6. Factor 6. Fisheries that exist because of the hatchery program

Fisheries are not a part of the Proposed Action. However, there is a fishery that exists because of the Proposed Action. The terminal fishery on the Entiat River meets the "but for" test, meaning the fishery would not occur "but for" the Proposed Action. Recreational fisheries in the Entiat River are managed by WDFW with a daily bag limit based on projected escapement. The fishery is closed when the non-tribal harvest share is projected to have been met. In 2024, the fishery opened July 9 with a daily limit of six summer Chinook in the Entiat, and closed August 16 after the non-tribal harvest share for summer Chinook had been met in the Columbia River above Priest Rapids Dam. Harvest from this basin-wide program varies annually but has averaged 1,948 (721-4,258) for years 2015-2021.

The ENFH summer Chinook fishery may impact listed natural-origin species that are inadvertently and incidentally caught (and must be released). These fisheries could negatively affect the abundance VSP parameter of the affected populations (Section 2.5). Fisheries are strictly regulated based on ESA-authorized management, including catch and release take allowance. The incidental take limits in Table 11 are for the ESU/DPSs; data for impacts to listed species during the summer Chinook on the Entiat River is not available. In the 2021-2022 fishing year (the most recent available), eight Chinook salmon were caught in the Entiat River, and 91,044 Chinook (0.009%)

were caught in all Washington freshwater fisheries (Table 23 from Kraig and Scalici 2023). We can assume a proportional amount of incidental take is caused by the fishery due to ENFH hatchery production, meaning that at single-digit totals the number of incidental catch of spring Chinook is negligible if not nonexistent. Fisheries catching ENFH summer Chinook salmon in the mainstem Columbia River and the Pacific Ocean would exist with or without the Proposed Action and have previously been evaluated in separate biological opinions (NMFS 2012b; 2018). While NMFS can analyze the effects of this fishery, we are not authorizing it through this consultation.

Table 11. Incidental take limits of listed salmonids for non-treaty and treaty Indian fisheries under the 2018 Agreement expressed in terms of harvest rates unless otherwise indicated (from Table 2-102) {NMFS, 2018 #7718}.

ESU or DPSs Total	Take Limits (%)	Treaty Indian (%)	Non-Treaty (%)
UCR Spring-Run Chinook Salmon	5.5-17.0 ^{6,7}	5.0-14.3 ^{6,7}	0.5-2.7 ⁶
UCR steelhead			
<i>Natural-origin component</i>	4.0 ⁸	8	4.0 ⁸
<i>Hatchery-origin component</i>	⁹	⁹	⁹

2.5.3. Effects on Critical Habitat

This consultation analyzed the Proposed Action for its effects on designated critical habitat and has determined that operation of the hatchery program will have a negligible effect on PBFs in the action area.

Existing hatchery facilities have not led to altered channel morphology and stability, reduced and degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity and no new facilities are proposed. Except for the ladder entrance and water diversion, hatchery facilities are located away from the river and do not affect designated critical habitat.

Proposed surface water diversion for rearing juvenile fish in the hatchery and the return of that water to the Entiat River will not affect the spatial distribution of adult or juvenile ESA-protected spring Chinook salmon or steelhead. The Proposed Action includes strict criteria for diverting water from the river and will not have any discernible effect or result in any adverse modification to critical habitat. This reach of the Entiat River, RM 6.7 to 7.2, is strictly a migration corridor for ESA-listed spring Chinook salmon and steelhead, and flow requirements specified in the HGMP will provide safe passage for adult and juvenile salmon. Surface water diversion will not exceed 10 percent of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 100 cfs from November 1 through April 30, and 5 percent of the mean daily flow

⁶ Allowable take depends on run size.

⁷ Impacts in treaty fisheries on listed natural-origin fish can be up to 0.8% higher than the river mouth runsize harvest rates (indicated in table above) due to the potential for changes in the proportion natural-origin to hatchery-origin between the river mouth and Bonneville Dam due to mark selective fisheries.

⁸ Applies to non-treaty fisheries only. 2% in summer seasons below the I-395 Bridge to the mouth of the Columbia River, this includes the following year's winter/spring fisheries upstream of The Dalles Dam from January 1 through June 30 into the Snake River up to the Washington/Idaho border. A 2% limit also applies in the fall season in the same area below the I-395 Bridge to the mouth of the Columbia River from August 1 to October 31, and upstream of The Dalles Dam from November 1 through December 31. There is no specific harvest rate limit proposed for treaty fisheries on A-Index summer steelhead, but they are expected to remain within recent (2008 – 2016) average rates (0.5 – 3.0%).

⁹ There is no take prohibition on ad clipped hatchery fish even if they part of a listed group.

whenever the combination of flow minus the amount of hatchery surface diversion is less than 200 cfs from May 1 through October 31. Hatchery diversion screens protect juvenile fish from entrainment and injury and satisfy NMFS screen criteria.

Operation of the facility is not expected to degrade water quality. Water will be treated before it is returned to the river and the program has a current NPDES permit.

2.6. CUMULATIVE EFFECTS

“Cumulative effects” are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation [50 CFR 402.02]. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the Action Area. However, it is difficult if not impossible, to distinguish between the Action Area’s future environmental conditions caused by 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 earlier in the discussion of the Environmental Baseline (Section 2.4).

Some types of human activities, such as development and harvest, contribute to cumulative effects and are generally expected to have adverse effects on salmon and steelhead populations and PBFs. Many of these activities have occurred in the recent past, and their effects are therefore included in the Environmental Baseline. Some of these activities are also considered reasonably certain to occur in the future because they occurred frequently in the recent past (especially if authorizations or permits have not yet expired), and those future effects are addressed as cumulative effects.

Within the Action Area, non-federal actions are likely to include human population growth (e.g., expansion of the built environment; conversion of forests and open space to residential, commercial, and industrial uses; increased effluent discharge from municipal wastewater treatment), water withdrawals (i.e., those pursuant to senior state water rights), and land use practices (e.g., forestry, agriculture). All of these activities can contaminate local or larger areas with hydrocarbon-based materials and other pollutants. State, tribal, and local government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, shoreline growth management, and resource permitting. Private activities include continued resource extraction, vessel traffic, development, and other activities that contribute to poor water quality and continued vessel and construction noise in the freshwater environment. Although these activities and their effects are ongoing to some extent and likely to continue in the future, past occurrence is not a guarantee of a continuing level of activity. That will depend on the pace at which human population growth and its corresponding environmental ramifications continue, as well as the emergence, adoption, implementation, and/or effectiveness of economic, administrative, and legal impediments to activities with adverse effects, and safeguards to minimize or prevent adverse effects. Therefore, NMFS finds it likely that the cumulative effects of these activities will have adverse effects commensurate with those of similar past activities, as described in the Environmental Baseline. Additionally, relevant state, tribal, and local government actions may include fishing permits. These continuing upstream commercial and

sport fisheries, which have some incidental catch of listed species, will have adverse impacts through the removal of fish that would contribute to spawning populations.

We expect salmon and steelhead spawning and rearing habitat, foraging and migration habitat, and water quality to continue to be negatively affected by the following: forestry; agriculture and grazing; channel and bank modifications; road building and maintenance; urbanization; sand and gravel mining; dams; irrigation impoundments and withdrawals; boat traffic in rivers; wetland loss; forage fish/species harvest; and, changing environmental conditions.

While we may anticipate some trend of beneficial changes to hatchery operations not covered by the Proposed Action in this Opinion, we cannot assume at this time that these changes would occur or would result in specific changes in effects on ESA-listed species. We anticipate that reductions in future effects on listed salmon and steelhead are likely to occur 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,
- Increased use of marking and/or tagging of hatchery-origin fish,
- More accurate estimates of natural-origin salmon and steelhead abundance for abundance-based fishery management approaches.

The general improving trend in reducing the impacts of hatcheries is encouraging but is too uncertain to attribute specific changes at this time. Therefore, our opinion expressed below is not predicated on changes to hatchery operations not covered by the Proposed Action

With respect to harvest, within the Action Area, sport fisheries, which have some incidental catch of listed species, will have adverse impacts through the removal of fish that would contribute to spawning populations. Future tribal, state, and/or local government actions will likely be in the form of legislation, administrative rules, policy initiatives, and fishing permits. These actions may include changes in increases or decreases in the types of activities that currently occur, including changes in fishing activities or resource extraction, either of which could impact ESA-listed species or their habitat. These actions are subject to political, legislative, and fiscal uncertainties. These realities, added to the geographic scope, which encompasses several entities exercising various authorities, and the changing economies of the region, make the analysis of cumulative effects speculative.

2.7. INTEGRATION AND SYNTHESIS

The Integration and Synthesis section is the final step in assessing the Proposed Action's risk to species and critical habitat. 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 for the conservation of the species.

2.7.1. UCR Spring Chinook Salmon

Best available information indicates that UCR Spring-run Chinook Salmon ESU is at high risk and remains at endangered status. Based on the combined ratings for abundance/productivity and spatial structure/diversity, all three extant populations and the ESU remain at high risk of extinction.

As described in the Environmental Baseline (Section 2.4), the degraded habitat conditions and hatchery-origin adult strays in the Action Area pose a risk to the Entiat River basin's ESA-listed spring-run Chinook salmon population. The primary habitat conditions in the Entiat Basin that currently limit abundance, productivity, spatial structure, and diversity of salmon and steelhead include stream channel configuration and complexity that has been reduced due to logging in the riparian zone, flood control measures that straightened the channel and removed large wood from the river channel. These historic and ongoing activities have led to a condition with low instream habitat diversity including few pools, lack of large wood accumulations, and disconnected side channels, wetlands, and floodplains. The result is a reduction in resting and rearing areas for both adult and juvenile salmon and steelhead throughout the Entiat River (UCR TT 2014). Since the previous 5- year review (NWFSC 2015), the habitat concerns remain essentially unchanged. However, there has been a focused effort to assess the impacts of summer-run Chinook salmon on spring-run Chinook salmon in the Entiat River. There have been observations of redd superimposition and hybridization between spring-run Chinook salmon and summer-run Chinook salmon. Hatchery-origin spring Chinook salmon strays into the basin, primarily from programs out of the basin, will continue threatening the spatial structure and diversity of the Entiat River UCR spring-run Chinook salmon population (Ford 2022).

The Entiat spring Chinook salmon population is the smallest of the UCR spring-run populations with the lowest viability threshold of 500 fish (Wenatchee and Methow River populations have thresholds of 2,000 fish) (Ford 2022). The factors analyzed in Section 2.5 and on designated critical habitat would predominately affect Entiat River spring Chinook population critical habitat. Effects to the quality of rearing and spawning habitat are expected to be minor at the action area scale.

Hatchery fish and the progeny of naturally spawning hatchery fish in spawning grounds, along with encounters between natural and hatchery-origin fish at adult collection facilities, are likely to have adverse effects. However, as described in (Section 2.5.2), the overall effects of the ENFH summer-run Chinook salmon hatchery program are not expected to reduce the abundance or productivity of Entiat River spring-run Chinook or steelhead.

NMFS analyzed the remaining factors and determined that they will have negligible or inconsequential effects, and beneficial effects in one case, on the UCR spring-run Chinook salmon ESU. It is not possible to detect any competitive interactions caused by ENFH summer Chinook salmon in the migration corridor, and therefore they are not included in this analysis, but rather considered to be reflected in the species status descriptions. The proposed RM&E does not include any handling of ESA-listed fish, and effects from hatchery facility operations are insignificant to the species as the facilities are constructed and operated in compliance with standards designed to protect both juvenile and adult salmon. Further, none of these factors are identified in the recovery plan as a factor limiting UCR spring-run Chinook salmon recovery. All of these effects are at not expected to alter the abundance, productivity, spatial structure or diversity of the population or the MPG.

Added to the Environmental Baseline and effects of the Proposed Action are the effects of future state, private, or tribal activities, not involving federal activities, within the Action Area. We assume the activities are reasonably certain to occur in the future and at levels similar to what has already occurred, and include them in the Cumulative Effects analysis. Many of the state and private activities identified in the Environmental Baseline are anticipated to occur at similar levels of intensity into the future. The Recovery Plan for UCR Spring-run Chinook Salmon and steelhead (UCSRB 2007) describes the ongoing and proposed state, tribal, and local government actions that are targeted to reduce known threats to UCR spring-run Chinook salmon in the Entiat River. It is acknowledged, however, that such future state, tribal, and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives, and land use and other types of permits, and that government actions are subject to political, legislative, and fiscal uncertainties.

Thus, it is NMFS' opinion that when the effects of the action and cumulative effects are added to the environmental baseline, and in light of the status of the species, the effects of the action will not cause reductions in reproduction, numbers, or distribution that would reasonably be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of UCR spring-run Chinook salmon

2.7.2. UCR Steelhead

Best available information indicates that UCR steelhead DPS is at high risk and remains at threatened status. Based on the combined ratings for abundance/productivity and spatial structure/diversity, all four extant populations and the DPS remain at high risk of extinction.

Generally, there is little to no co-occurrence or interaction between UCR steelhead and summer Chinook salmon from ENFH. There is no overlap in the spawning and rearing distribution or adult migration timing. Steelhead are not present in the Action Area during hatchery broodstock collection and, thus, they are not encountered by the hatchery. UCR steelhead do not spawn or rear in close proximity to the location in the lower Entiat River where hatchery-origin fish are released or in proximity to the hatchery facilities themselves, hatchery-origin smolts leave the Entiat River soon after release, and the hatchery diversions are screened to protect juvenile fish from entrainment and injury as they move through the lower river on their way to the ocean. Therefore, with minimal effects from the hatcheries in the action area, we conclude that those effects are similarly minimal at the DPS level.

Thus, it is NMFS' opinion that when the effects of the action and cumulative effects are added to the environmental baseline, and in light of the status of the species, the effects of the action will not cause reductions in reproduction, numbers, or distribution that would reasonably be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of UCR steelhead

2.7.3. Critical Habitat

After reviewing the Proposed Action and conducting the effects analysis, NMFS has determined that the Proposed Action will not impair PBFs designated as essential for spawning, rearing, and adult migration purposes.

The hatchery water diversion and the discharge pose only a negligible effect on designated critical habitat in the action area (Section 2.5.3). Existing hatchery facilities have not contributed to altered

channel morphology and stability, reduced and degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity, and no new facilities or changes to existing facilities are proposed. The Proposed Action includes strict criteria for diverting water from the river and will not impair PBFs. ESA-listed spring Chinook salmon and steelhead do not spawn or rear in the vicinity of the water diversion or in that reach of the river between the point of diversion and the point of water return. This reach of the Entiat River, RM 6.7 to 7.2, is strictly a migration corridor for ESA-listed spring Chinook salmon and steelhead, and flow requirements specified in the HGMP will provide safe passage for adult and juvenile salmon. Up to 10 juvenile steelhead per return year may be removed from the fish ladder and holding pond and returned to the Entiat River upstream of the fish ladder entrance. This may temporarily impair safe passage through the migratory corridor for those few juvenile steelhead at the scale of the action area. This is not expected to be meaningful at the scale of the designation.

The recovery plan for UCR spring-run Chinook salmon and steelhead (NMFS 2007b) identified a number of limiting factors and threats to the Entiat River spring Chinook salmon and steelhead critical habitat, including water quality, sediment routing dysfunction, blocked and impaired fish passage, degraded floodplain and channel structure, and hydrologic alterations (Section 2.2.).

Conclusion

After reviewing and analyzing the current status of the listed species and the critical habitat, the Environmental Baseline within the Action Area, the effects of the Proposed Action, the effects of other activities caused by the Proposed Action, and cumulative effects, it is NMFS's biological opinion that the Proposed Action is not likely to jeopardize the continued existence of UCR spring-run Chinook salmon ESU and UCR steelhead DPS, or destroy or adversely modify their designated critical habitat.

2.8. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Harass" is further defined by guidance as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

2.8.1. Amount or Extent of Take

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

NMFS analyzed six factors and identified two that are likely to result in take: Factor 2, hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities; and Factor 3, hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas.

Factor 2

Encounters with natural-origin and hatchery fish at adult collection facilities:

In the course of collecting hatchery summer Chinook salmon for hatchery broodstock, the Proposed Action is expected to handle, annually, up to five adult UCR spring-run Chinook salmon. These are fish that volunteer into ENFH. All natural-origin spring-run Chinook salmon handled during broodstock collection must be released, immediately, back into the Entiat River. In addition, NMFS expects up to 10 juvenile steelhead may be removed from the fish ladder and holding pond and returned to the Entiat River upstream of the fish ladder entrance per return year.

Spring Chinook salmon redd superimposition:

ENFH summer Chinook salmon that are not intercepted at the hatchery may cause take of UCR spring-run Chinook salmon by ecological interactions on the spawning grounds where summer Chinook salmon from ENFH have the potential to superimpose redds (i.e., disturb or destroy embryos and/or alevins) made by ESA-listed spring-run Chinook salmon in the Entiat River.

It is not possible to accurately quantify the take of species caused by redd superimposition; specifically, we cannot quantify how many salmon embryos or alevins will be disturbed as a result of redd superimposition. NMFS will therefore rely on a surrogate take indicator that relates to the take of salmon embryos or alevins as a result of redd superimposition: the number of redds affected. Superimposition, caused by ENFH summer Chinook salmon, is not expected to affect more than 10 percent of the total number of redds produced by naturally spawning spring-run Chinook salmon in the Entiat River annually, and, therefore, the surrogate take indicator is superimposition of more than 10 percent of spring Chinook salmon redds in the Entiat River. This surrogate take indicator is capable of measurement, and is rationally connected to the take of species identified above, since the number of redds correlates closely with the number of embryos or alevins in the river, and with the number of alevins or embryos affected by hatchery fish.

Factor 3:

Take Caused by Juvenile Releases

Incidental take of ESA-listed salmon are expected to occur in the form of interactions between juvenile hatchery and natural-origin fish in juvenile rearing and migratory areas within the Entiat River. This form of take concerns interactions (predation, competition, or pathogen transmission, collectively referred to as ecological interactions) between juvenile salmon and juvenile hatchery fish. This occurs as smolts emigrate from hatcheries and acclimation ponds and likely transit through the migratory waters of the Action Area or as hatchery fish residualize and remain behind.

However, it is difficult to quantify this take because ecological interactions cannot be observed directly. NMFS will, therefore, rely on a series of surrogate take indicators, each which will apply as described below. These surrogates all work in conjunction with each other; exceedance of any one of these surrogates is an exceedance of take.

Timing Surrogate:

The first take surrogate is the date of release. This standard has a rational connection to the amount of take expected from ecological interactions, because the potential for adverse ecological interactions increases as more overlap occurs between hatchery and natural-origin fish, for the reasons discussed in Section 2.5.2.3. For this take surrogate, NMFS considers that the incidental take associated with the release date will have been exceeded if hatchery smolts are released before April 1st unless the operator has previously obtained NMFS concurrence that the early release will not increase the temporal overlap with natural-origin fish. If NMFS receives information that the emigration of most natural-origin juveniles has shifted to a later time, NMFS will revisit this take surrogate or its associated timing to determine whether the take levels analyzed in this opinion have been exceeded.

Numbers of Hatchery Fish Released:

The second take surrogate is compliance with the production levels. As the number of smolts released increases, so does the extent of potential interaction, so exceeding the expected production levels would increase the incidental take beyond the levels analyzed in this opinion.

- 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 12). The 10% buffer allows for occasional overages based upon factors outside the direct control of the hatchery operators.

Table 12. Production target, maximum annual and five-year average production levels for the ENFH Summer Chinook Salmon Hatchery Program.

Hatchery Program	Hatchery Program Operator	Proposed Production Target Limit	Annual Maximum Production Level
ENFH summer Chinook salmon	USFWS	400,000	440,000

Size of Hatchery Fish Released:

- The actual size of individual fish released should not be more than 10% larger than the planned release size (15-20 fpp; 140-154 mm). If, at the time of release, it is determined that the production falls outside this range, the applicants will notify NMFS.

Take caused by Residualism:

Take may occur through ecological interactions where hatchery fish residualize and remain in freshwater. This, too, cannot be reliably observed and quantified; therefore, NMFS will rely on a take surrogate consisting of the proportion of hatchery-origin fish that are visually identified as precociously mature prior to release by sampling a subset of the release. This standard has a rational connection to the amount of take expected from ecological interactions because precocious fish are

more likely to residualize after release from the hatchery, which would place them in contact with natural-origin fish of a size that makes them vulnerable to predation. This take surrogate can be reliably measured and monitored by assessing precocious maturation rates before each proposed release.

The incidental take through residualization will be exceeded if the percent of releases that are determined to be precocially mature using Gonadosomatic Index (GSI) sampling exceeds 30 percent in any one year, or if the 5-year average exceeds 30% at any time, or if the release year cohort exceeds 15 percent. However, if it is apparent from numbers observed in years prior to the fifth year that the average is certain to exceed 30 percent after five years, co-managers will contact NMFS in the year the likely exceedance is discovered. Additionally, this take surrogate can be monitored by either of the following methods: 1) lethal visual assessment that would look for precocially mature fish; or 2) non-lethal visual assessment that would look for precocially mature males and parr (as defined by the unlikelihood of it smolting; i.e., if there is any indication that it would smolt, it would not be considered a parr). For the second method, the nonlethal visual assessments are likely to detect a lower rate of potentially residualizing fish, adding parr to the sampling would lead to a higher detection rate than visually assessing for precocially mature males alone.

These surrogates can be reliably measured and monitored through the enumeration and tracking of release dates and numbers for hatchery salmon. Each of these surrogates represents an independent threshold, meaning that exceedance of any one of these surrogates would result in the applicable program having exceeded the incidental take limits included in this statement, potentially necessitating the reinitiation of consultation.

2.8.2. Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the Proposed Action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.8.3. Reasonable and Prudent Measures

“Reasonable and prudent measures” refer to those actions the Director considers necessary or appropriate to minimize the impact of the incidental take on the species (50 CFR 402.02).

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize incidental take. This opinion requires that Action Agencies, FWS, and BOR:

1. Minimize the number of natural-origin UCR spring-run Chinook salmon that enter the hatchery, and the impacts of handling such fish in the course of broodstock collection.
2. Minimize the number of stray hatchery-origin spring-run Chinook salmon that spawn in the Entiat River.
3. Document spring-run Chinook salmon redd superimposition and minimize the number of ENFH hatchery-origin summer Chinook salmon that spawn in the Entiat River.
4. Minimize risk associated with competitive interactions between hatchery- and natural-origin fish, including residualism.

2.8.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The USFWS or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the Proposed Action would likely lapse.

1. The following terms and conditions implement reasonable and prudent measure 1:
 - a. *Operate the fish ladder, to the extent possible, to limit the number of natural-origin spring-run Chinook salmon that volunteer into the hatchery and return natural-origin spring-run Chinook salmon that enter ENFH back into the river without delay and in the best possible condition. Monitor the number of these fish, annually, that enter ENFH – and advise NMFS immediately if more than five enter in a given year.*
 - b. *Monitor stream-flows at the USGS gage site #12452990 to ensure that surface water diversion: (1) does not exceed 10% of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 100 cfs from November 1 through April 30; and (2) does not exceed 5% of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 200 cfs from May 1 through October 31.*
2. The following terms and conditions implement reasonable and prudent measure 2:
 - a. *Remove all hatchery-origin spring-run Chinook salmon that enter ENFH and prevent them from returning to the river to spawn naturally.*
 - b. *Monitor the origin and number of stray hatchery-origin spring-run Chinook salmon that annually enter ENFH.*
3. The following terms and conditions implement reasonable and prudent measure 3:
 - a. *Operate the fish ladder, to the extent possible, to attract and capture as many hatchery-origin summer Chinook salmon as possible. Remove all hatchery-origin summer Chinook salmon that enter ENFH and prevent them from returning to the river to spawn naturally.*
 - b. *Conduct surveys, annually, to determine the timing, abundance, and distribution of ENFH summer Chinook salmon that spawn naturally and the prevalence of hatchery-origin summer Chinook salmon spawning in spring-run Chinook salmon natural spawning areas.*
 - c. *Conduct surveys annually to determine the location and extent of superimposition of UCR spring-run Chinook salmon redds by hatchery-origin summer Chinook salmon.*
4. The following terms and conditions implement reasonable and prudent measure 4:
 - a. *Release hatchery smolts that are physiologically ready to migrate.*
 - b. *Rear hatchery fish to a size sufficient to ensure that smoltification occurs in nearly the entire population.*

- c. *Release hatchery smolts in lower river areas, below areas used for stream-rearing by naturally produced juveniles.*
- d. *Monitor 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.*
- e. *The FWS shall implement the hatchery program as described in the HGMP. NMFS' SMD must be notified in advance of any change in hatchery program operation and implementation that potentially would result in increased take of ESA-listed species. The FWS shall provide one comprehensive annual report to the SMD, on or before April 1 of each year, that includes the RM&E described in Terms and Conditions numbers 1, 2b, 3b, 3c, 4d and 4e, as well as any other relevant reports (juvenile abundance, spawning ground surveys, etc.). The numbers of fish released, release dates, and locations, and tag/mark information shall be included in the annual report. All reports, as well as all other notifications required in the permit, shall be submitted electronically to the NMFS point of contact for this program:*

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2.9. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, “conservation recommendations” are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

The USFWS, in cooperation with the NMFS and other entities, should continue to investigate the level of ecological interactions between hatchery-produced salmon and ESA-listed spring-run Chinook salmon within the Entiat River basin to identify additional methods to minimize these interactions.

2.10. REINITIATION OF CONSULTATION

This concludes formal consultation for Entiat National Fishery Hatchery Summer Chinook Salmon Program.

Under 50 CFR 402.16(a): “Reinitiation of consultation is required and shall be requested by the federal agency or by the Service, where discretionary federal involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written

concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action.”

2.11. “NOT LIKELY TO ADVERSELY AFFECT” DETERMINATIONS

NMFS has determined that the Proposed Action may affect but is not likely to adversely affect Pacific eulachon; Lower Columbia River Chinook salmon, coho salmon, and steelhead; Middle Columbia River steelhead; Snake River Spring/Summer-run and Fall-run Chinook and sockeye salmon, and steelhead; Columbia River chum; Upper Willamette River Chinook salmon and steelhead; Southern Resident Killer Whales, and green sturgeon.

The potential concern with the Proposed Action and the species listed above is the relationship between hatchery production and density-dependent interactions affecting salmon growth and survival in the mainstem Columbia River. However, NMFS has determined that, based on best available science and the relatively small number of releases (400,000 ($\pm 10\%$) smolts) in the Columbia River and estimated returns of 4,000 adults, while there may be some affect, the effects are not likely to be significant for Pacific eulachon; Lower Columbia River Chinook salmon, coho salmon, and steelhead; Middle Columbia River steelhead; Snake River Spring/Summer-run and Fall-run Chinook and sockeye salmon, and steelhead; Columbia River chum; Upper Willamette River Chinook salmon and steelhead; Southern Resident Killer Whales, and green sturgeon. The rationale for this conclusion is there are no meaningful causal connections between hatchery production on the scale anticipated in the Proposed Action and any such effects.

3. MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species’ contribution to a healthy ecosystem. For the purposes of the MSA, EFH means “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity”, and includes the associated physical, chemical, and biological properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects may result from actions occurring within EFH or outside of it and may include direct, indirect, site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH (50 CFR 600.905(b)).

EFH Affected by the Proposed Action

The proposed project occurs within EFH for various federally managed fish species within the Pacific Coast salmon (PFMC 2024) fishery management plan (FMP) developed by the Pacific Fisheries Management Council (PFMC), and approved by the Secretary of Commerce.

In addition, the project occurs within, or in the vicinity of the Entiat River and hatchery facilities where hatchery-origin salmon and steelhead occur or are anticipated to occur, which is designated as a habitat area of particular concern (HAPC) for federally managed fish species within the Pacific Coast salmon FMP (PFMC 2024). HAPC are described in the regulations as subsets of EFH which are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area. Designated HAPC are not afforded any additional regulatory protection under the MSA; however, federal projects with potential adverse impacts on HAPC will be more carefully scrutinized during the consultation process.

Freshwater EFH for Pacific salmon includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to Chinook salmon in Washington, except areas upstream of certain impassible man-made barriers, and longstanding, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years). Freshwater EFH for Chinook salmon consists of four major components, (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and (4) adult migration corridors and adult holding habitat. A more detailed description and identification of EFH for salmon is found in Appendix A of the Pacific Coast Salmon Fishery Management Plan (PFMC 2024).

Adverse Effects on EFH

The Proposed Action is likely to have a negligible effect on freshwater EFH for Chinook salmon. Potential effects on freshwater EFH by the Proposed Action (particularly through water withdrawal, effluent discharge, and increased competition for spawning and rearing sites) are only likely to occur in areas that Chinook salmon spawn naturally and within the migration corridor of the Entiat River.

The direct discharge of hatchery facility effluent is regulated by the EPA under the CWA through NPDES permits. The water is treated before it returns to the river, and minimized to the maximum extent, such that the Proposed Action is unlikely to affect freshwater EFH for Chinook salmon through the effluent discharge from the hatchery facilities. The proposed hatchery programs minimize each of these effects through compliance with the NPDES permits.

The Proposed Action may affect freshwater EFH for Chinook salmon through hatchery facilities that withdraw streamflow. The Proposed Action includes strict criteria for diverting water from the river and will not have any discernible effect. This reach of the Entiat River, RM 6.7 to 7.2, is strictly a migration corridor for ESA-listed spring Chinook salmon, and flow requirements specified in the HGMP will provide safe passage for adult and juvenile salmon. Surface water diversion will not exceed 10 percent of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 100 cfs from November 1 through April 30, and 5 percent of the mean daily flow whenever the combination of flow minus the amount of hatchery surface diversion is less than 200 cfs from May 1 through October 31. Hatchery diversion screens protect juvenile fish from entrainment and injury and satisfy NMFS screen criteria.

The Proposed Action may affect freshwater EFH for Chinook salmon through increased competition for spawning and rearing sites (redd superimposition) and predation. The (PFMC 2024) recognized that these effects pertain to EFH because of the concerns about “genetic and ecological interactions

of hatchery and wild fish ... [which have] been identified as risk factors for wild populations.” The Opinion describes in considerable detail the impacts hatchery programs might have on natural populations; greater detail on possible effects of hatchery programs can be found in Section 2.5.2. Hatchery fish returning to the Entiat River are expected to largely spawn and rear near the hatchery and not compete for space with spring Chinook salmon, though some redd superimposition on spring Chinook by hatchery summer Chinook occurs. Some summer Chinook from ENFH will stray into other rivers but not in numbers that would cause the carrying capacities of natural production areas to be exceeded, or that would result in increased incidence of disease or increases in predators. To the extent that hatchery fish from ENFH and from other hatcheries volunteer into ENFH, they will be removed and prevented from returning to the Entiat River in order to reduce adverse ecological and genetic effects on extant Entiat River natural populations.

Predation by adult hatchery-origin fish on juvenile natural-origin salmonids will be limited because of timing differences, because adult salmon stop feeding by the time they reach spawning areas, and because predation by juvenile offspring of hatchery-origin fish on juvenile natural-origin salmonids would not occur for reasons discussed in Section 2.5.2.

Spawning and rearing locations and adult holding habitat are not expected to be affected by operation of the program, as no modifications to these areas would occur, and no structures that would impede migration are included or proposed to be constructed.

3.1 EFH CONSERVATION RECOMMENDATIONS

For the potential adverse effects by the Proposed Action on EFH for Chinook salmon, NMFS believes that the Proposed Action, as described in Section 1.3 and the ITS (Section 2.10, above) includes the best approaches to avoid or minimize those adverse effects. The Reasonable and Prudent Measures (1-3) and Terms and Conditions (1.a-b, 2.a-b, 2.a-c) included in the ITS constitute NMFS’s recommendations to address potential EFH effects, and are briefly summarized below--

- 1) Minimize the number of natural-origin UCR spring-run Chinook salmon that enter the hatchery, and the impacts of handling such fish during broodstock collection by:
 - a. Operating the fish ladder, to the extent possible, to limit the number of natural-origin spring-run Chinook salmon that volunteer into the hatchery
 - b. Monitoring stream flows to ensure that surface water diversion does not exceed the mean daily flows specified
- 2) Minimize the number of stray hatchery-origin spring-run Chinook salmon that spawn in the Entiat River by:
 - a. Removing all hatchery-origin spring-run Chinook salmon that enter ENFH and prevent them from returning to the river to spawn naturally.
 - b. Monitoring the origin and number of stray hatchery-origin spring-run Chinook salmon that annually enter ENFH.
- 3) Document spring-run Chinook salmon redd superimposition and minimize the number of ENFH hatchery-origin summer Chinook salmon that spawn in the Entiat River by:
 - a. Operating the fish ladder, to the extent possible, to attract and capture as many hatchery-origin summer Chinook salmon as possible. Remove all hatchery-origin summer Chinook salmon that enter ENFH and prevent them from returning to the river to spawn naturally.

- b. Conducting surveys, annually, to determine the timing, abundance, and distribution of ENFH summer Chinook salmon that spawn naturally and the prevalence of hatchery-origin summer Chinook salmon spawning in spring-run Chinook salmon natural spawning areas.
- c. Conducting surveys annually to determine the location and extent of superimposition of UCR spring-run Chinook salmon redds by hatchery-origin summer Chinook salmon

3.2 STATUTORY RESPONSE REQUIREMENT

As required by section 305(b)(4)(B) of the MSA, NMFS 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)).

3.3 SUPPLEMENTAL CONSULTATION

FWS and BOR must reinstate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920(l)).

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1. UTILITY

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the FWS and the BOR (funding entity). The scientific community, resource managers, and stakeholders benefit from the consultation through the anticipated increase in returns of salmonids to the Columbia and Entiat Rivers, and through the collection of data indicating the potential effects of the operation on the viability of natural populations of UCR steelhead and Chinook salmon. This information will improve scientific understanding of hatchery-origin Chinook salmon effects that can be applied broadly within the Pacific Northwest area for managing benefits and risks associated with hatchery

operations. The document will be available within 2 weeks at the NOAA Library Institutional Repository [<https://repository.library.noaa.gov/welcome>]. The format and naming adhere to conventional standards for style.

4.2. INTEGRITY

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, ‘Security of Automated Information Resources,’ Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3. OBJECTIVITY

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR part 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

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6. APPENDIX

Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations (Revised May 2023)¹⁰

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 information not cited in the appendix will be cited in the other sections of the opinion that detail our analyses of effects.

¹⁰ This version of the appendix supersedes all earlier dated versions and the NMFS (2012) standalone document of the same name.

In choosing the literature we cite in this Appendix, our overriding concern is our mandate to use “best available science”. Generally, “best available science” means recent peer-reviewed journal articles and books. However, as appropriate we cite older peer-reviewed literature that is still relevant, as well as “gray” literature. Although peer-review is typically considered the “gold standard” for scientific information, occasionally there are well-known and popular papers in the peer-reviewed literature we do not cite because we question the methodology, results, or conclusions. In citing sources, we also consider availability, and try to avoid sources that are difficult to access. For this reason, we generally avoid citing master’s theses and doctoral dissertations, unless they provide unique information.

1.1. Factor 1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock

A primary consideration in analyzing and assessing effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the biological benefits and risks of using ESA-listed fish (natural or hatchery-origin) for hatchery broodstock. It considers the maximum number of fish proposed for collection and the proportion of the donor population collected for hatchery broodstock. “Mining” a natural population to supply hatchery broodstock can reduce population abundance and spatial structure

1.2. Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural and hatchery fish at adult collection facilities.

There are three aspects to the analysis of this factor: genetic effects, ecological effects, and encounters at adult collection facilities. We present genetic effects first. For the sake of simplicity, we discuss genetic effects on all life stages under factor 2.

1.2.1. Genetic effects

1.2.1.1. Overview

Based on currently available scientific information, we generally view the genetic effects of hatchery programs as detrimental to the ability of a salmon population’s ability to sustain itself in the wild. We believe that artificial breeding and rearing is likely to result in some degree of change of genetic diversity and fitness reduction in hatchery-origin. Hatchery-origin fish can thus pose a risk to diversity and to salmon population rebuilding and recovery when they interbreed with natural-origin fish. However, conservation hatchery programs may prevent extinction or accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford et al. 2011).

We recognize that there is considerable debate regarding aspects of genetic risk. The extent and duration of genetic change and fitness loss and the short- and long-term implications and consequences for different species (i.e., for species with multiple life-history types and species subjected to different hatchery practices and protocols) remain unclear and should be the subject of further scientific investigation. As a result, we believe that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that

harmonize conservation with the implementation of treaty Indian fishing rights and other applicable laws and policies (NMFS 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 et al. 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

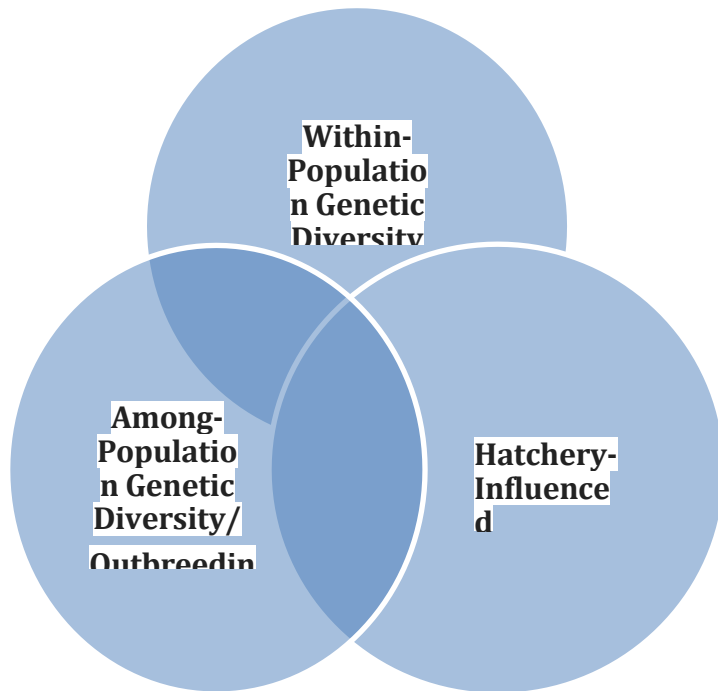
Mutations are changes in DNA sequences that are generally so rare² that they can be ignored for relatively short-term evaluation of genetic change, but the other three processes are considerations in evaluating the effects of hatchery programs on the productivity and genetic diversity of natural salmon 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 1):

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

The first two areas are well-known major concerns of conservation biology (e.g., Frankham et al. 2010; Allendorf et al. 2013), but our emphasis on hatchery-influenced selection— what conservation geneticists would likely call “adaptation to captivity” (Allendorf et al. 2013, pp. 408-409)— reflects the fairly unique position of salmon and steelhead among ESA-listed species. In the case of ESA-listed Pacific salmon and steelhead, artificial propagation in hatcheries has been used as a routine management tool for many decades, and in some cases the size and scope of hatchery programs has been a factor in listing decisions.

In the sections below we discuss these three major areas of risk, but preface this with an explanation of some key terms relevant to genetic risk. Although these terms may also be listed in a glossary in the biological opinion to which this appendix accompanies, we felt that it was important to include them here, as this appendix may at times be used as a stand-alone document.

² For example, the probability of a random base substitution in a DNA molecule in coho salmon is .000000008 (Rougemont et al. 2020).



• **Figure 1. Major categories of hatchery program genetic effects analyzed by NMFS**

1.2.1.1.1. Key Terms

The terms “wild fish” and “hatchery fish” are commonly used by the public, management biologists, and regulatory biologists, but their meaning can vary depending on context. For genetic risk assessment, more precise terminology is needed. Much of this terminology, and further derivatives of it, is commonly attributed to the Hatchery Scientific Review Group (HSRG), but were developed in 2004 technical discussions between the HSRG and scientists from the Washington Department of Fish and Wildlife (WDFW) and the Northwest Indian Fisheries Commission (HSRG 2009a).

- **Hatchery-origin (HO)**- refers to fish that have been reared and released by a hatchery program, regardless of the origin (i.e., from a hatchery or from spawning in nature) of their parents. A series of acronyms has been developed for subclasses of HO fish:
 - **Hatchery-origin recruits (HOR)** – HO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature, used for hatchery broodstock, or surplus.
 - **Hatchery-origin spawners (HOS)**- hatchery-origin fish spawning in nature. A very important derivative term, used both in genetic and ecological risk, is **pHOS**, the proportion of fish on the spawning grounds of a population consisting of HO fish. pHOS is the expected maximum genetic contribution of HO spawners to the naturally spawning population.
 - **Hatchery-origin broodstock (HOB)**- hatchery-origin fish that are spawned in the hatchery (i.e., are used as broodstock). This term is rarely used.

- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms parallel to those for HO fish has been developed for subclasses of NO fish:
 - **Natural-origin recruits (NOR)** – NO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature or used for hatchery broodstock.
 - **Natural-origin spawners (NOS)**- natural-origin fish spawning in nature.
 - **Natural-origin broodstock (NOB)**- natural-origin fish that are spawned in the hatchery (i.e., are used as broodstock). An important derivative term is **pNOB**, the proportion of a hatchery program’s broodstock consisting of NO fish.

Hatchery programs are designated as either as “integrated” or “segregated”. In the past these terms have been described in various ways, based on purpose (e.g., conservation or harvest) or intent with respect to the genetic relationship between the hatchery fish and the natural population they interact with. For purposes of genetic risk, we use simple functional definitions based on use of natural-origin broodstock:

- **Integrated hatchery programs**- programs that intentionally incorporate natural-origin fish into the broodstock at some level (i.e., pNOB > 0)
- **Segregated hatchery programs**- programs that do not intentionally incorporate natural-origin fish into the broodstock (i.e., pNOB = 0)

1.2.1.2. Within-population diversity effects

Within-population genetic diversity is a general term for the quantity, variety, and combinations of genetic material in a population (Busack 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.

1.2.1.2.1. Genetic drift

Genetic drift is random loss of diversity due to population size. The rate of drift is determined not by the census population size (N_c), but rather by the effective population size (N_e). The effective size of a population is the size of a genetically “ideal” population (i.e., equal numbers of males and females, each with equal opportunity to contribute to the next generation) that will display as much genetic drift as the population being examined (e.g., Falconer and MacKay 1996; Allendorf et al. 2013)³.

³ There are technically two subcategories of N_e : inbreeding effective size and variance effective size. The distinction between them is usually not a concern in our application of the concept.

This definition can be baffling, so an example is useful. A commonly used effective-size equation is $N_e = 4 * N_m * N_f / (N_m + N_f)$, 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 et al. 2014) concluded that larger values are more appropriate, basically suggesting a 100/1000 rule. See Frankham et al. (2010) for a more thorough discussion of these guidelines.

Although N_e can be estimated from genetic or demographic data, often-insufficient information is available to do this, so for conservation purposes it is useful to estimate effective size from census size. As illustrated by the example above, N_e can be considerably smaller than N_c . This is typically the case. Frankham et al. (2014) suggested a N_e/N_c range of ~0.1-0.2 based on a large review of the literature on effective size. For Pacific salmon populations over a generation, Waples (2004) arrived at a similar range of 0.05-0.3.

In salmon and steelhead management, effective size concerns are typically dealt with using the term effective number of breeders (N_b) in a single spawning season, with per-generation N_e equal to the generation time (average age of spawners) times the average N_b (Waples 2004). We will use N_b rather than N_e where appropriate in the following discussion.

Hatchery programs, simply by virtue of being able to create more progeny than natural spawners are able to, can increase N_b in a fish population. In very small populations, this increase can be a benefit, making selection more effective and reducing other small-population risks (e.g., Lacy 1987; Whitlock 2000; Willi et al. 2006). Conservation hatchery programs can thus serve to protect genetic diversity; several programs, such as the Snake River sockeye salmon program, are important genetic reserves. However, hatchery programs can also directly depress N_b by three principal pathways:

- Removal of fish from the naturally spawning population for use as hatchery broodstock. If a substantial portion of the population is taken into a hatchery, the hatchery becomes responsible for that portion of the effective size, and if the operation fails, the effective size of the population will be reduced (Waples 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 (Fiumera et al. 2004; Busack and Knudsen 2007) over what would be achievable with less structured designs. Considerable benefit in N_b increase over what is achievable by 1-to-1 mating can be achieved through a factorial design as simple as a 2 x 2 (Busack 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 and Laikre 1991; Ryman et al. 1995). The key factors determining the magnitude of the effect are the numbers of hatchery and natural spawners, and the proportion of natural spawners consisting of hatchery returnees.

The initial papers on the R-L effect required knowledge of N_b in the two spawning components of the population. Waples et al. (2016) have developed R-L equations suitable for a wide variety of situations in terms of knowledge base. A serious limitation of any R-L calculation however, is that it is a snapshot in time. What happens in subsequent generations depends on gene flow between the hatchery broodstock and the natural spawners. If a substantial portion of the broodstock are NO fish, the long-term effective size depression can be considerably less than would be expected from the calculated per-generation N_b .

Duchesne 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 et al. 2010; Allendorf et al. 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 et al. (2002) and Naish et al. (2007).

N_e affects the level of inbreeding in a population, as the likelihood of matings between close relatives is increased in populations with low numbers of spawners. Populations exhibiting high levels of inbreeding are generally found to have low N_e (Dowell Beer et al. 2019). Small

populations are at increased risk of both inbreeding depression and genetic drift (e.g., Willi et al. 2006). Genetic drift is the stochastic loss of genetic variation, which is most often observed in populations with low numbers of breeders. Inbreeding exacerbates the loss of genetic variation by increasing genetic drift when related individuals with similar allelic diversity interbreed (Willoughby et al. 2015).

Hatchery populations should be managed to avoid inbreeding depression. If hatcheries produce inbred fish which return to spawn in natural spawning areas the low genetic variation and increased deleterious mutations can lower the fitness, productivity, and survival of the natural population (Christie et al. 2014). A captive population, which has been managed so genetic variation is maximized and inbreeding is minimized, may be used for a genetic rescue of a natural population characterized by low genetic variation and low N_e .

1.2.1.2.2. Biased/nonrepresentational sampling

Even if effective size is large, the genetic diversity of a population can be negatively affected by hatchery operations. Although many operations aspire to randomly use fish for spawning with respect to size, age, and other characteristics, this is difficult to do. For example, male Chinook salmon that mature precociously in freshwater are rarely if ever used as broodstock because they are not captured at hatchery weirs. Pressure to meet egg take goals is likely responsible for advancing run/spawn timing in at least some coho and Chinook salmon hatcheries (Quinn et al. 2002; Ford et al. 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 et al. 2009).

The sampling examples mentioned thus far are more or less unintentional actions. There are also established hatchery practices with possible diversity consequences that are clearly intentional. A classic example is use of jacks in spawning, where carefully considered guidelines range from random usage to near exclusion of jacks (e.g., Seidel 1983; IDFG et al. 2020). Another is the deliberate artificial selection in the hatchery of summer and winter steelhead to smolt at one year of age, which has resulted in early spawning stocks of both ecotypes (Crawford 1979).

Another source of biased sampling is non-inclusion of precocious males in broodstock. Precociousness, or early male maturation, is an alternative reproductive tactic employed by Atlantic salmon (Baglinière and Maisse 1985; Myers et al. 1986), Chinook salmon (Bernier et al. 1993; Larsen et al. 2004), coho salmon (Iwamoto et al. 1984; Silverstein and Hershberger 1992), steelhead (Schmidt and House 1979; McMillan et al. 2012), sockeye salmon (Ricker 1959), as well as several salmonid species in Asia and Europe (Dellefors and Faremo 1988; Kato 1991; Munakata et al. 2001; Morita et al. 2009).

Unlike anadromous males and females that migrate to the ocean to grow for a year or more before returning to their natal stream, precocious males generally stay in headwater reaches or migrate shorter distances downstream (Larsen et al. 2010) before spawning. They are orders of magnitude smaller than anadromous adults and use a ‘sneaker’ strategy to spawn with full size anadromous females (Fleming 1996). Precocious males are typically not subject to collection as broodstock, because of either size or location. Thus, to the extent this life history is genetically

determined, hatchery programs culturing species that display precociousness unintentionally select against it.

The examples above illustrate the overlap between diversity effects and selection. Selection, natural or artificial, affects diversity, so could be regarded as a subcategory of within-population diversity. Analytically, here we consider specific effects of sampling or selection on genetic diversity. Broodstock collection or spawning guidelines that include specifications about non-random use of fish with respect to age or size, spawn timing, etc. (e.g., Crawford 1979) are of special interest. We consider general non-specific effects of unintentional selection due to the hatchery that are not related to individual traits in Section 1.2.1.4.

1.2.1.3. Among-population diversity/ Outbreeding effects

Outbreeding effects result from gene flow from other populations into the population of interest. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1997; Keefer and Caudill 2012; Westley et al. 2013). Natural straying serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources.

Hatchery fish may exhibit reduced homing fidelity relative to NO fish (Grant 1997; Quinn 1997; Jonsson et al. 2003; Goodman 2005), resulting in unnatural levels of gene flow into recipient populations from strays, either in terms of sources or rates. Based on thousands of coded-wire tag (CWT) recoveries, Westley et al. (2013) concluded that species propagated in hatcheries vary in terms of straying tendency: Chinook salmon > coho salmon > steelhead. Also, within Chinook salmon, “ocean-type” fish stray more than “stream-type” fish. However, even if hatchery fish home at the same level of fidelity as NO fish, their higher abundance relative to NO fish can cause unnaturally high gene flow into recipient populations.

Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997). Based on fundamental population genetic principles, a 1995 scientific workgroup convened by NMFS concluded that aggregate gene flow from non-native HO fish from all programs combined should be kept below 5 percent (Grant 1997), and this is the recommendation NMFS uses as a reference in hatchery consultations. It is important to note that this 5% criterion was developed independently and for a different purpose than the HSRG’s 5% PHOS criterion that is presented in Section 1.2.1.4.

Gene flow from other populations can increase genetic diversity (e.g., Ayllon et al. 2006), which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population’s level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland 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 et al. 2011; Satterthwaite and Carlson 2015). Eldridge et al. (2009) found that among-population genetic diversity had decreased in Puget Sound coho salmon populations during several decades of intensive hatchery culture.

As discussed in Section 1.2.1.4, pHOS⁴ is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze outbreeding effects.

- Adult salmon may wander on their return migration, entering and then leaving tributary streams before spawning (Pastor 2004). These “dip-in” fish may be detected and counted as strays, but may eventually spawn in other areas, resulting in an overestimate of the number of strays that potentially interbreed with the natural population (Keefer et al. 2008). On the other hand, “dip-ins” can also be captured by hatchery traps and become part of the broodstock.
- Strays may not contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (e.g., Saisa et al. 2003; Blankenship et al. 2007). The causes of poor reproductive success of strays are likely similar to those responsible for reduced productivity of HO fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Reisenbichler and McIntyre 1977; Leider et al. 1990; Williamson et al. 2010).

1.2.1.4. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication⁵), the third major area of genetic effects of hatchery programs that NMFS analyzes, occurs when selection pressures imposed by

⁴ 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.

⁵ 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 and Fuller 2014), and show evidence of large-scale genetic change (e.g., Freedman et al. 2016). By this standard, the only domesticated fish species is the carp (*Cyprinus carpio*) (Larson and Fuller 2014). “Adaptation to captivity”, a term commonly used in conservation biology (e.g., Frankham 2008), and becoming more common in the fish literature (Christie et al. 2011; Allendorf et al. 2013; Fisch et al. 2015) is more precise for species that have been

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 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 fish⁶. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

subjected to semi-captive rearing for a few decades. We feel “hatchery-influenced selection” is even more precise, and less subject to confusion.

⁶ 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.

1.2.1.4.1. Relative Reproductive Success Research

Although hundreds of papers in the scientific literature document behavioral, morphological and physiological differences between NO and HO fish, the most frequently cited research has focused on RRS of HO fish compared to NO fish determined through pedigree analysis. The influence of this type of research derives from the fact that it addresses fitness, the ability of the fish to produce progeny that will then return to sustain the population. The RRS study method is simple: genotyped NO and HO fish are released upstream to spawn, and their progeny (juveniles, adults, or both) are sampled genetically and matched with the genotyped parents. In some cases, multiple-generation pedigrees are possible.

RRS studies can be easy to misinterpret (Christie et al. 2014) for at least three reasons:

- RRS studies often have little experimental power because of limited sample sizes and enormous variation among individual fish in reproductive success (most fish leave no offspring and a few leave many). This can lead to lack of statistical significance for HO:NO comparisons even if a true difference does exist. Kalinowski and Taper (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 and Ford 2004). Researchers and managers wondered if these results were applicable to species and life-history types with shorter hatchery residence, as it seemed reasonable that the selective effect of the hatchery environment would be less on species with shorter hatchery residence times (e.g., RIST 2009). Especially lacking was RRS information on “ocean-type” Chinook. Recent RRS work on Alaskan pink salmon, the species with the shortest hatchery residence time has found very large differences in reproductive success between HO and NO fish (Lescak et al. 2019; Shedd et al. 2022). The RRS was 0.42 for females and 0.28 for males (Lescak et al. 2019). This research suggests the “less residence time, less effect” paradigm should be revisited.

Collectively, some RRS results are now available for all eastern Pacific salmon species except sockeye salmon. Note that this is not an exhaustive list of references:

- Coho salmon (Theriault et al. 2011; Neff et al. 2015)

- Chum salmon (Berejikian et al. 2009)
- “Ocean-type” Chinook salmon (Anderson et al. 2012; Sard et al. 2015; Evans et al. 2019)
- “Stream-type” Chinook salmon (Ford et al. 2009; Williamson et al. 2010; Ford et al. 2012; Hess et al. 2012; Ford et al. 2015; Janowitz-Koch et al. 2018)
- Steelhead (Araki et al. 2007; Araki et al. 2009; Berntson et al. 2011; Christie et al. 2011)
- Pink salmon (Lescak et al. 2019; Shedd et al. 2022)

Although the size of the effect may vary, and there may be year-to-year variation and lack of statistical significance, the general pattern is clear: HO fish have lower reproductive success than NO fish.

As mentioned above, few studies have been designed to detect unambiguously a genetic component in RRS. Two such studies have been conducted with steelhead and both detected a statistically significant genetic component in steelhead (Araki et al. 2007; Christie et al. 2011; Ford et al. 2016), but the two conducted with “stream-type” Chinook salmon (Ford et al. 2012; Janowitz-Koch et al. 2018) have not detected a statistically significant genetic component.

Detecting a genetic component of fitness loss in one species and not another suggests that perhaps the impacts of hatchery-influenced selection on fitness differs between Chinook salmon and steelhead.⁷ The possibility that steelhead may be more affected by hatchery-influenced selection than Chinook salmon by no means suggest that effects on Chinook are trivial, however. A small decrement in fitness per generation can lead to large fitness loss.

1.2.1.4.2. Hatchery Scientific Review Group (HSRG) Guidelines

Key concepts concerning the relationship of gene flow to hatchery-influenced selection were developed and promulgated throughout the Pacific Northwest by the Hatchery Scientific Review Group (HSRG), a congressionally funded group of federal, state, tribal, academic, and unaffiliated scientists that existed from 2000 to 2020. Because HSRG concepts have been so influential regionally, we devote the next few paragraphs to them.

The HSRG developed gene-flow guidelines based on mathematical models developed by Ford (2002) and by Lynch 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.

⁷ This would not be surprising. Although steelhead are thought of as being quite similar to the “other” species of salmon, genetic evidence suggests the two groups diverged well over 10 million years ago (Crête-Lafrenière et al. 2012).

2003).⁸ (Table 1). 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.

- **Table 1. HSRG gene flow guidelines (HSRG 2009b).**

Population conservation importance	Program classification	
	Integrated	Segregated
Primary	PNI > 0.67 and pHOS < 0.30	pHOS < 0.05
Contributing	PNI > 0.50 and pHOS < 0.30	pHOS < 0.10
Stabilizing	Existing conditions	Existing conditions

Although they are controversial, the HSRG gene flow guidelines have achieved a considerable level of regional acceptance. They were adopted as policy by the Washington Fish and Wildlife Commission (WDFW 2009), and were recently reviewed and endorsed by a WDFW scientific panel, who noted that the “...HSRG is the primary, perhaps only entity providing guidance for operating hatcheries in a scientifically defensible manner...” (Anderson et al. 2020). In addition, HSRG principles have been adopted by the Canadian Department of Fisheries and Oceans, with very similar gene-flow guidelines for some situations (Withler et al. 2018)⁹.

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 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 1.2.1.4.3).

⁸ Development of conservation importance classifications varied among technical recovery teams (TRTs); for more information, documents produced by the individual TRT’s should be consulted.

⁹ 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%.

At minimum, we consider the HSRG guidelines a useful screening tool. For a particular program, based on specifics of the program, broodstock composition, and environment, we may consider a pHOS or PNI level to be a lower risk than the HSRG would but, generally, if a program meets HSRG guidelines, we will typically consider the risk levels to be acceptable. However, our approach to application of HSRG concepts varies somewhat from what is found in HSRG documents or in typical application of HSRG concepts. Key aspects of our approach warrant discussion here.

1.2.1.4.2.1. PNI and segregated hatchery programs

The PNI concept has created considerable confusion. Because it is usually estimated by a simple equation that is applicable to integrated programs, and applied in HSRG guidelines only to integrated programs, PNI is typically considered to be a concept that is relevant only to integrated programs. This in turn has caused a false distinction between segregated and integrated programs in terms of perceptions of risk. The simple equation for PNI is:

$$PNI \approx pNOB / (pNOB + pHOS).$$

In a segregated program, pNOB equals zero, so by this equation PNI would also be zero. You could easily infer that PNI is zero in segregated programs, but this would be incorrect. The error comes from applying the equation to segregated programs. In integrated programs, PNI can be estimated accurately by the simple equation, and the simplicity of the equation makes it very easy to use. In segregated programs, however, a more complicated equation must be used to estimate PNI. A PNI equation applicable to both integrated and segregated programs was developed over a decade ago by the HSRG (HSRG 2009a, equation 9), but has been nearly completely 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.

1.2.1.4.2.2. **The effective pHOS concept**

The HSRG recognized that HO fish spawning naturally may on average produce fewer adult progeny than NO spawners, as described above. To account for this difference, the HSRG (2014) defined *effective* pHOS as:

$$\text{pHOS}_{\text{eff}} = (\text{RRS} * \text{HOS}_{\text{census}}) / (\text{NOS} + \text{RRS} * \text{HOS}_{\text{census}}),$$

where RRS is the reproductive success of HO fish relative to that of NO fish. They then recommend using this value in place of $\text{pHOS}_{\text{census}}$ 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 $\text{RRS} < 1$ (compared to natural fish) due to selection in the hatchery. A component of reduced RRS of hatchery fish is therefore already incorporated in the model and by extension the calculation of PNI. Therefore, reducing pHOS values by multiplying by RRS will result in underestimating the relevant pHOS and therefore overestimating PNI. Such adjustments would be particularly inappropriate for hatchery programs with low pNOB, as these programs may well have a substantial reduction in RRS due to genetic factors already incorporated in the model.

In some cases, adjusting pHOS downward may be appropriate, particularly if there is strong evidence of a non-genetic component to RRS. Wenatchee spring Chinook salmon (Williamson et al. 2010) is an example case with potentially justified adjustment by RRS, where the spatial distribution of NO and HO spawners differs, and the HO fish tend to spawn in poorer habitat. However, even in a situation like the Wenatchee spring Chinook salmon, it is unclear how much of an adjustment would be appropriate.

By the same logic, it might also be appropriate to adjust pNOB in some circumstances. For example, if hatchery juveniles produced from NO broodstock tend to mature early and residualize (due to non-genetic effects of rearing), as has been documented in some spring Chinook salmon and steelhead programs, the “effective” pNOB might be much lower than the census pNOB.

It is important to recognize that PNI is only an approximation of relative trait value, based on a model that is itself very simplistic. To the degree that PNI fails to capture important biological information, it would be better to work to include this biological information in the underlying models rather than make ad hoc adjustments to a statistic that was only intended to be a rough guideline to managers. We look forward to seeing this issue further clarified in the near future. In the meantime, except for cases in which an adjustment for RRS has strong justification, we feel that census pHOS, rather than effective pHOS, is the appropriate metric to use for genetic risk evaluation.

1.2.1.4.2.3. Gene flow guidelines in phases of recovery

In 2012 the HSRG expanded on the original gene flow guidelines/standards by introducing the concept of recovery phases for natural populations (HSRG 2012), and then refined the concept in later documents (HSRG 2014; 2015; 2017). They defined and described four phases:

1. Preservation
2. Re-colonization
3. Local adaptation
4. Fully restored

The HSRG provided guidance on development of quantitative “triggers” for determining when a population had moved (up or down) from one phase to another. As explained in HSRG (2015), in the preservation and re-colonization phase, no PNI levels were specified for integrated programs (Table 1). 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 2. 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 phases¹⁰. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020). In response, the HSRG 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.*

1.2.1.4.3. Extension of PNI modeling to more than two population components

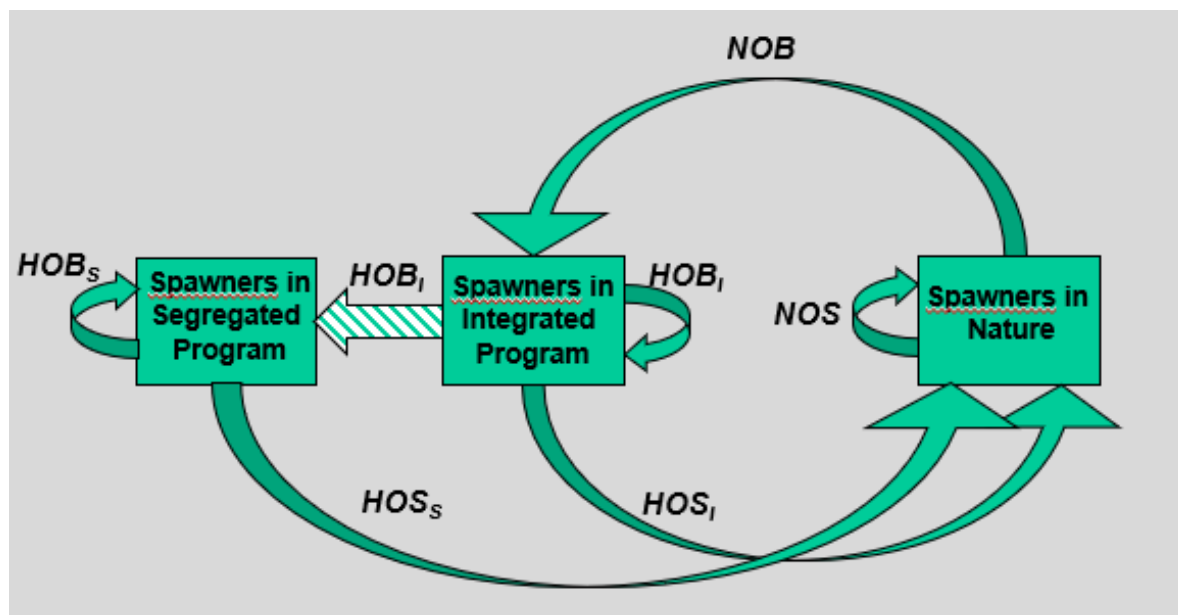
The Ford (2002) model considered a single population affected by a single hatchery program—basically two population units connected by gene flow—but the recursion equations underlying the model are easily expanded to more than two populations (Busack 2015). This has resulted in tremendous flexibility in applying the PNI concept to hatchery consultations.

A good example is a system of genetically linked hatchery programs, an integrated program in which returnees from a (typically smaller) integrated hatchery program are used as broodstock for a larger segregated program, and both programs contribute to pHOS (Figure 3). 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 significantly¹¹(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.

¹⁰ 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).

¹¹ 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 2. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOS_i) and a segregated program (HOS_s). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOB_i) as broodstock, but the segregated uses returnees from the integrated program (HOB_i above striped arrow) as all or part of its broodstock, genetically linking the two programs. The system illustrated here is functionally equivalent to the HSRG’s (HSRG 2014) “stepping stone” concept.**

1.2.1.4.4. California HSRG

Another scientific team was assembled to review hatchery programs in California and this group developed guidelines that differed somewhat from those developed by the “Northwest” HSRG (California HSRG 2012). The California team:

- Felt that truly isolated programs in which no HO returnees interact genetically with natural populations were impossible in California, and was “generally unresponsive” of the concept of segregated programs. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5 percent.
- Rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as “the amount of spawning by NO fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between HO and NO fish, and societal values, such as angling opportunity.”
- Recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50 percent in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5 percent, even approaching 100 percent at times.

- Recommended for conservation programs that pNOB approach 100 percent, but pNOB levels should not be so high they pose demographic risk to the natural population by taking too large a proportion of the population for broodstock.

1.2.2. Ecological effects

Ecological effects for this factor (i.e., hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds) refer to effects from competition for spawning sites and redd superimposition, contributions to marine-derived nutrients, and the removal of fine sediments from spawning gravels. Ecological effects on the spawning grounds may be positive or negative.

To the extent that hatcheries contribute added fish to the ecosystem, there can be positive effects. For example, when anadromous salmonids return to spawn, hatchery-origin and natural-origin alike, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production (Kline et al. 1990; Piorowski 1995; Larkin and Slaney 1996; Gresh et al. 2000; Murota 2003; Quamme and Slaney 2003; Wipfli et al. 2003). As a result, the growth and survival of juvenile salmonids may increase (Hager and Noble 1976; Bilton et al. 1982; Holtby 1988; Ward and Slaney 1988; Hartman and Scrivener 1990; Johnston et al. 1990; Larkin and Slaney 1996; Quinn and Peterson 1996; Bradford et al. 2000; Bell 2001; Brakensiek 2002).

Additionally, studies have demonstrated that perturbation of spawning gravels by spawning salmonids loosens cemented (compacted) gravel areas used by spawning salmon (e.g., Montgomery et al. 1996). The act of spawning also coarsens gravel in spawning reaches, removing fine material that blocks interstitial gravel flow and reduces the survival of incubating eggs in egg pockets of redds.

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences, such as increased competition, and potential for redd superimposition. Although males compete for access to females, female spawners compete for spawning sites. Essington et al. (2000) found that aggression of both sexes increases with spawner density, and is most intense with conspecifics. However, females tended to act aggressively towards heterospecifics as well. In particular, when there is spatial overlap between natural-and hatchery-origin spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of ESA-listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (e.g., Fukushima et al. 1998).

1.2.3. Adult Collection Facilities

The analysis also considers the effects from encounters with natural-origin fish that are incidental to broodstock collection. Here, NMFS analyzes effects from sorting, holding, and handling natural-origin fish in the course of broodstock collection. Some programs collect their broodstock from fish voluntarily entering the hatchery, typically into a ladder and holding pond,

while others sort through the run at large, usually at a weir, ladder, or sampling facility. The more a hatchery program accesses the run at large for hatchery broodstock – that is, the more fish that are handled or delayed during migration – the greater the negative effect on natural- and hatchery-origin fish that are intended to spawn naturally and on ESA-listed species. The information NMFS uses for this analysis includes a description of the facilities, practices, and protocols for collecting broodstock, the environmental conditions under which broodstock collection is conducted, and the encounter rate for ESA-listed fish.

NMFS also analyzes the effects of structures, either temporary or permanent, that are used to collect hatchery broodstock, and remove hatchery fish from the river or stream and prevent them from spawning naturally, on juvenile and adult fish from encounters with these structures. NMFS determines through the analysis, for example, whether the spatial structure, productivity, or abundance of a natural population is affected when fish encounter a structure used for broodstock collection, usually a weir or ladder.

1.3. Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the migratory corridor, estuary, and ocean (Revised June 1, 2020)

NMFS also analyzes the potential for competition, predation, and disease when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas.

1.3.1. Competition

Competition and a corresponding reduction in productivity and survival may result from direct or indirect interactions. Direct interactions occur when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish, and indirect interactions occur when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (Rensel et al. 1984). Natural-origin fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, take up residency before natural-origin fry emerge from redds, and residualize. Hatchery fish might alter natural-origin salmon behavioral patterns and habitat use, making natural-origin fish more susceptible to predators (Hillman 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 et al. 1972; Taylor 1991). Taylor (1991) found that coho salmon were much more aggressive toward size-matched *ocean*-type Chinook salmon (early outmigrants), but only moderately more aggressive toward size-matched *stream*-type Chinook salmon (later outmigrants). Similarly, the findings of Hasegawa et al. (2014) indicate that masu salmon (*O. masou*), which spend 1 to 2 years in streams before outmigrating, dominate and outcompete the early-migrating chum salmon.

A few exceptions to this general stream residence-aggression pattern have been observed (e.g., Lahti et al. 2001; Young 2003; Hasegawa et al. 2004; Young 2004), but all the species and migratory forms evaluated in these studies spend one year or more in stream habitat before outmigrating. Other than the Taylor (1991) and Hasegawa et al. (2014) papers noted above, we are not aware of any other studies that have looked specifically at interspecific interactions between early-outmigrating species (e.g., sockeye, chum, and pink salmon) and those that rear longer in streams.

En masse hatchery salmon and steelhead smolt releases may cause displacement of rearing natural-origin juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations, or to premature out-migration by natural-origin juveniles. Pearsons et al. (1994) reported small-scale displacement of naturally produced juvenile rainbow trout from stream sections by hatchery steelhead. Small-scale displacements and agonistic interactions observed between hatchery steelhead and natural-origin juvenile trout were most likely a result of size differences and not something inherently different about hatchery fish, such as behavior.

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a time near the release point. These non-migratory smolts (residuals) may compete for food and space with natural-origin juvenile salmonids of similar age (Bachman 1984; Tatara 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 (Steward and Bjornn 1990; California HSRG 2012)
- Rearing hatchery fish to a size sufficient to ensure that smoltification occurs
- Releasing hatchery smolts in lower river areas, below rearing areas used by natural-origin juveniles
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location, and release timing if substantial competition with natural-origin juveniles is likely

Critical information for analyzing competition risk is quality and quantity of spawning and rearing habitat in the action area,¹² 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.

1.3.2. Predation

Predation is another potential ecological effect of hatchery releases. Predation, either direct (consumption by hatchery fish) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Here we consider predation by hatchery-origin fish, by the progeny of naturally spawning hatchery fish, and by birds and other non-piscine predators attracted to the area by an abundance of hatchery fish.

Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish released at a later stage that are more likely to migrate quickly to the ocean, can still prey on fry and fingerlings that are encountered during the downstream migration. Some of these hatchery fish do not emigrate and instead take up residence in the stream where they can prey on stream-rearing juveniles over a more prolonged period, as discussed above. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat.

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to natural-origin fish (Rensel et al. 1984). Due to their location in the stream, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is greatest immediately upon emergence from the gravel and then decreases as they move into shallow, shoreline areas

¹² “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.

(USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are as large as 1/2 their length (Hargreaves and LeBrasseur 1986; Pearsons and Fritts 1999; HSRG 2004 and references therein), but other studies have concluded that salmonid predators prey on fish up to 1/3 their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996; Daly et al. 2009). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak et al. 1979; Bachman 1984; Olla et al. 1998).

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

1.3.3. Disease

The release of hatchery fish, as well as hatchery effluent, into juvenile rearing areas can lead to pathogen transmission; and contact with chemicals, or altering environmental conditions (e.g., dissolved oxygen) can result in disease outbreaks. Fish diseases can be subdivided into two main categories:

- Infectious diseases are those caused by pathogens such as viruses, bacteria, and parasites.
- Noninfectious diseases are those that cannot be transmitted between fish and are typically caused by environmental factors (e.g., low dissolved oxygen), but can also have genetic causes.

Pathogens can be categorized as exotic or endemic. For our purposes, exotic pathogens are those that have little to no history of occurrence within the boundaries of the state where the hatchery program is located. For example, *Oncorhynchus masou* virus (OMV) would be considered an exotic pathogen if identified anywhere in Washington state because it is not known to occur there. Endemic pathogens are native to a state, but may not be present in all watersheds.

In natural fish populations, the risk of disease associated with hatchery programs may increase through a variety of mechanisms (Naish et al. 2007), discussed below:

- Introduction of exotic pathogens
- Introduction of endemic pathogens to a new watershed
- Intentional release of infected fish or fish carcasses
- Continual pathogen reservoir
- Pathogen amplification

The last two terms above require some explanation. A continual pathogen reservoir is created when a standing crop of susceptible hosts keeps the pathogen from burning itself out. For example, stocking certain susceptible strains of trout can ensure that the pathogen is always present. Pathogen amplification occurs when densities of pathogens that are already present increase beyond baseline levels due to hatchery activities. A good example is sea lice in British Columbia (e.g., Krkošek 2010). The pathogen is endemic to the area and is normally present in wild populations, but salmon net pens potentially allow for a whole lot more pathogen to be produced and added to the natural environment.

Continual pathogen reservoir and pathogen amplification can exist at the same time. For example, stocked rainbow trout can amplify a naturally occurring pathogen if they become infected, and if stocking occurs every year, the stocked animals also can act as a continual pathogen reservoir.

Pathogen transmission between hatchery and natural fish can occur indirectly through hatchery water influent/effluent or directly via contact with infected fish. Within a hatchery, the likelihood of transmission leading to an epizootic (i.e., disease outbreak) is increased compared to the natural environment because hatchery fish are reared at higher densities and closer proximity than would naturally occur. During an epizootic, hatchery fish can shed relatively large amounts of pathogen into the hatchery effluent and ultimately, the environment, amplifying pathogen numbers. However, few, if any, examples of hatcheries contributing to an increase in disease in natural populations have been reported (Steward 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 et al. 2000), which are often endemic and ubiquitous (e.g., *Renibacterium salmoninarum*, the cause of Bacterial Kidney Disease).

Several state, federal, and tribal fish health policies, in some cases combined with state law, limit the disease risks associated with hatchery programs (IHOT 1995; ODFW 2003; USFWS 2004; WWTIT and WDFW 2006). Specifically, the policies govern the transfer of fish, eggs, carcasses, and water to prevent the spread of exotic and endemic pathogens. For example, the policy for Washington (WWTIT and WDFW 2006) divides the state into 14 Fish Health Management Zones¹³ (FHMZs), and specifies requirements for transfers within and across FHMZs. Washington state law lists pathogens for which monitoring and reporting is required (regulated pathogens), and the Washington Department of Fish and Wildlife typically requires monitoring and reporting for additional pathogens. Reportable pathogen occurrence at a Washington hatchery is communicated to the state veterinarian, but also to fish health personnel at a variety of levels: local, tribal, state, and federal.

For all pathogens, both reportable and non-reportable, pathogen spread and amplification are minimized through regular monitoring (typically monthly) removing mortalities, and disinfecting all eggs. Vaccines may provide additional protection from certain pathogens when available (e.g., *Vibrio anguillarum*). If a pathogen is determined to be the cause of fish mortality, treatments (e.g., antibiotics) will be used to limit further pathogen transmission and amplification. Some pathogens, such as *infectious hematopoietic necrosis virus* (IHNV), have no known treatment. Thus, if an epizootic occurs for those pathogens, the only way to control pathogen amplification is to cull infected individuals or terminate all susceptible fish. In addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

In addition to the state, federal, and tribal fish health policies, disease risks can be further minimized by preventing pathogens from entering the hatchery through the treatment of incoming water (e.g., by using ozone), or by leaving the hatchery through hatchery effluent (Naish et al. 2007). Although preventing the exposure of fish to any pathogens before their release into the natural environment may make the hatchery fish more susceptible to infection after release into the natural environment, reduced fish densities in the natural environment

¹³ Puget Sound consists of five FHMZs, the Columbia basin only 1.

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 unsetttable solids, temperature, and dissolved oxygen in the hatchery effluent to ensure compliance with environmental standards and to prevent fish mortality.

In contrast to infectious diseases, which typically are manifest by a limited number of life stages and over a protracted time period, non-infectious diseases caused by environmental factors typically affect all life stages of fish indiscriminately and over a relatively short time period. Because of the vast literature available on rearing of salmon and trout in aquaculture, one group of non-infectious diseases that are expected to occur rarely in current hatchery operations are those caused by nutritional deficiencies

1.3.4. Ecological Modeling

While competition, predation, and disease are important effects to consider, they are events which can rarely, if ever, be observed and directly measured. However, these behaviors have been established to the point where NMFS can model these potential effects to the species based on known factors that lead to competition or predation occurring. In our Biological Opinions, we use the Predation, Competition, and Delayed Mortality (PCD) Risk model version 4.1.0 based on Pearsons and Busack (2012). PCD Risk is an individual-based model that simulates the potential number of ESA-listed natural-origin juveniles lost to competition, predation, and delayed mortality (from disease, starvation, etc.) due to the release of hatchery-origin juveniles in the freshwater environment.

The PCD Risk model has undergone considerable modification since 2012 to increase supportability, reliability, transparency, and ease of use. Notably, the current version no longer operates as a compiled FORTRAN program in a Windows environment. The current version of the PCD Risk model (Version 4.1.0) is an R package (R Core Team 2019). A macro-enabled Excel workbook is included as an interface to the model that is used as a template for creating model scenarios, running the model, and reporting results. Users with knowledge of the R programming language have flexibility to develop and run more complex scenarios than can be created by the Excel template. The current model version no longer has a probabilistic mode for

defining input parameter values. We also further refined the model by allowing for multiple hatchery release groups of the same species to be included in a single run.

There have also been a few recent modifications to the logic and parameterization of the model. The first was the elimination of competition equivalents and replacement of the disease function with a delayed mortality parameter. The rationale behind this change was to make the model more realistic; competition rarely directly results in death in the model because it takes many competitive interactions to suffer enough weight loss to kill a fish. Weight loss is how adverse competitive interactions are captured in the model. However, fish that lose competitive interactions and suffer some degree of weight loss are likely more vulnerable to mortality from other factors such as disease or predation by other fauna such as birds or bull trout. Now, at the end of each run, the competitive impacts for each fish are assessed, and the fish has a probability of delayed mortality based on the competitive impacts. This function will be subject to refinement based on research. For now, the probability of delayed mortality is equal to the proportion of a fish's weight loss. For example, if a fish has lost 10% of its body weight due to competition and a 50% weight loss kills a fish, then it has a 20% probability of delayed death, ($0.2 = 0.1/0.5$).

Another change in logic was to the habitat segregation parameter to make it size-independent or size-dependent based on hatchery species. Some species, such as coho salmon, are more aggressive competitors than other species, such as chum and sockeye salmon. To represent this difference in behavior more accurately in the model, for less aggressive species such as chum and sockeye salmon, hatchery fish segregation is random, whereas for more aggressive species, segregation occurs based on size, with the largest fish eliminated from the model preferentially.

1.3.5. Acclimation

One factor that can affect hatchery fish distribution and the potential to spatially overlap with natural-origin spawners, and thus the potential for genetic and ecological impacts, is the acclimation (the process of allowing fish to adjust to the environment in which they will be released) of hatchery juveniles before release. Acclimation of hatchery juveniles before release increases the probability that hatchery adults will home back to the release location, reducing their potential to stray into natural spawning areas.

Acclimating fish for a time also allows them to recover from the stress caused by the transportation of the fish to the release location and by handling. Dittman 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 (Quinn 1997; Dunnigan 1999; 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 (Hoar 1976; Beckman et al. 2000). Salmon species with more complex life histories (e.g., sockeye salmon) may imprint at multiple times from emergence to early migration (Dittman et al. 2010). Imprinting to a particular location, be it the hatchery, or an acclimation pond, through the acclimation and release of hatchery salmon and steelhead is employed by fisheries managers with the goal that the hatchery fish released from these locations will return to that particular site and not stray into other areas (Fulton and Pearson 1981; Quinn 1997; Hard and Heard 1999; Bentzen et al. 2001; Kostow 2009; Westley et al. 2013). However, this strategy may result in varying levels of success in regards to the proportion of the returning fish that stray outside of their natal stream. (e.g., (Kenaston et al. 2001; Clarke et al. 2011).

Increasing the likelihood that hatchery salmon and steelhead home to a particular location is one measure that can be taken to reduce the proportion of hatchery fish in the naturally spawning population. When the hatchery fish home to a particular location, those fish can be removed (e.g., through fisheries, use of a weir) or they can be isolated from primary spawning areas.

Factors that can affect the success of acclimation as a tool to improve homing include:

- Timing acclimation so that a majority of the hatchery juveniles are going through the parr-smolt transformation during acclimation
- A water source distinct enough to attract returning adults
- Whether hatchery fish can access the stream reach where they were released
- Whether the water quantity and quality are such that returning hatchery fish will hold in that area before removal and/or their harvest in fisheries.

1.4. Factor 4. Research, monitoring, and evaluation that exists because of the hatchery program

NMFS analyzes proposed research, monitoring, and evaluation (RM&E) activities associated with proposed hatchery programs for their effects on listed species and designated critical habitat. Such activities include, but are not limited to, the following:

- Observation during surveying (in-water or from the bank)
- Collecting and handling (purposeful or inadvertent)
- Sampling (e.g., the removal of scales and tissues)
- Tagging and fin-clipping, and observing the fish (in-water or from the bank)

Some RM&E actions may capture fish, induce injury, cause behavioral changes, and affect redds. Any negative effects from RM&E are weighed against the value of new information, particularly information that tests key assumptions and that reduces uncertainty. NMFS also considers the overall effectiveness of the RM&E program. There are five factors that we consider when assessing the beneficial and negative effects of hatchery RM&E:

- Status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat
- Critical uncertainties concerning effects on the species

- Performance monitoring to determine the effectiveness of the hatchery program at achieving its goals and objectives
- Identifying and quantifying collateral effects
- Tracking compliance of the hatchery program with the terms and conditions for implementing the program.

After assessing the proposed hatchery RM&E, and before making any recommendations to the action agency(s), NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost. The following subsections describe effects to listed fish species associated with typical RM&E activities and risk mitigation measures.

1.4.1. Observing

For some activities, listed fish and redds of listed fish are observed in-water (e.g., by snorkel surveys, wading surveys, or observation from the banks). Direct observation is the least disruptive method for determining a species' presence/absence and estimating its relative numbers. Effects of direct observation are also generally the shortest-lived and least harmful of the research activities discussed in this section because a cautious observer can effectively obtain data while only slightly disrupting fish behavior and causing minimal to no disturbance to redds. Fish frightened by the turbulence and sound created by observers are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type and then return when observers leave the area. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors, and are typically not expected to significantly disrupt normal behavioral patterns or create the likelihood of injury.

Redds may be observed or encountered during some RM&E activities. Trained and knowledgeable surveyors are typically aware of risk reduction measures, such as not walking on redds, avoiding disturbance to nearby sediments and gravel, affording disturbed fish time and space to reach cover, and minimizing time present.

1.4.2. Capturing/handling

Any physical handling or psychological disturbance is known to be stressful to fish (Sharpe et al. 1998). Primary contributing factors to stress and death from handling are excessive doses of anesthetic, differences in water temperatures (between the river and holding vessel), dissolved oxygen conditions, the amount of time fish are held out of the water, and physical trauma. Stress increases rapidly if the water temperature exceeds 18°C 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; 2008) that have been incorporated as terms and conditions into

section 7 opinions and section 10 permits for research and enhancement. Additional monitoring principles for supplementation programs have been developed by Galbreath et al. (2008).

1.4.3. Fin clipping and tagging

Many studies have examined the effects of fin clips on fish growth, survival, and behavior. Although the results of these studies vary somewhat, it appears that generally fin clips do not alter fish growth (Brynildson 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 (Reimchen and Temple 2003; Buckland-Nicks et al. 2011).

In addition to fin clipping, two commonly available tags are available to differentially mark fish: passive integrated transponder (PIT) tags, and coded-wire tags (CWTs). PIT tags consist of small radio transponders that transmit an ID number when interrogated by a reader device.¹⁴ CWTs are small pieces of wire that are detected magnetically and may contain codes¹⁵ that can be read visually once the tag is excised from the fish.

PIT tags are inserted into the body cavity of the fish just in front of the pelvic girdle. The tagging procedure requires that the fish be captured and extensively handled. Thus, tagging needs to take place where there is cold water of high quality, a carefully controlled environment for administering anesthesia, sanitary conditions, quality control checking, and a recovery tank.

Most studies have concluded that PIT tags generally have very little effect on growth, mortality, or behavior. Early studies of PIT tags showed no long-term effect on growth or survival (Prentice and Park 1984; Prentice et al. 1987; 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

¹⁴ The same technology, more commonly called RFID (radio frequency identification), is widely used in inventory control and to tag pets.

¹⁵ Tags without codes are called blank wire tags (BWTs).

deeply in the snout of a fish, it may kill the fish, reduce its growth, or damage olfactory tissue (Fletcher et al. 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.

1.4.4. Masking

Hatchery actions also must be assessed for risk caused by masking effects, defined as when hatchery fish included in the Proposed Action are not distinguishable from other fish. Masking undermines and confuses RM&E, and status and trends monitoring. Both adult and juvenile hatchery fish can have masking effects. When presented with a proposed hatchery action, NMFS analyzes the nature and level of uncertainties caused by masking, and whether and to what extent listed salmon and steelhead are at increased risk as a result of misidentification in status evaluations. The analysis also takes into account the role of the affected salmon and steelhead population(s) in recovery and whether unidentifiable hatchery fish compromise important RM&E.

1.5. Factor 5. Construction, operation, and maintenance, of facilities that exist because of the hatchery program

The construction/installation, operation, and maintenance of hatchery facilities can alter fish behavior and can injure or kill eggs, juveniles, and adults. These actions can also degrade habitat function and reduce or block access to spawning and rearing habitats altogether. Here, NMFS analyzes changes to: riparian habitat, channel morphology, habitat complexity, in-stream substrates, and water quantity and quality attributable to operation, maintenance, and construction activities. NMFS also confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

1.6. Factor 6. Fisheries that exist because of the hatchery program

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

- 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 2005). 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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