UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
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Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation

National Marine Fisheries Service (NMFS) Evaluation of Three Hatchery and Genetic Management Plans for Skagit River Basin Chum Salmon under Limit 6 of the Endangered Species Act Section 4(d) Rule

NMFS Consultation Number: WCRO-2018-02183

Action Agencies: National Marine Fisheries Service (NMFS)
Bureau of Indian Affairs (BIA)
Unites States Fish and Wildlife Service (USFWS)

Affected Species and Determinations:

ESA-Listed Species	Status	Is the Action Likely to Adversely Affect Species?	Is the Action Likely To Jeopardize the Species?	Is the Action Likely Adversely Affect Critical Habitat?	Is the Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound Steelhead	Threatened	Yes	No	Yes	No
Puget Sound Chinook Salmon	Threatened	Yes	No	Yes	No

Fishery Management Plan That Describes EFH in the Project Area	Does the 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, Sustainable Fisheries Division

Issued By:

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Assistant Regional Administrator
Sustainable Fisheries Division

Date: October 26, 2022

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1. INTRODUCTION

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

The Proposed Action considered and reviewed in this document includes the following:

1. The National Marine Fisheries Service's (NMFS) determination under Limit 6 of the Endangered Species Act (ESA) 4(d) Rule for Puget Sound Chinook salmon and Puget Sound steelhead (50 CFR § 223.203(b)(6)), hereafter referred to as 4(d) Limit 6, concerning three chum salmon hatchery programs jointly managed by the Skagit River Fisheries Co-managers[1] in the Skagit River basin (Table 1);
2. The Bureau of Indian Affairs' (BIA) intermittent, discretionary funding and technical assistance to support two of these hatchery programs, as indicated in Table 1; and,
3. Funding by the U.S. Fish & Wildlife Service (USFWS) provided to the Washington Department of Fish and Wildlife (WDFW) through its Sport Fish Restoration Act (also called the Dingell-Johnson Act) grants program. USFWS provides grants to WDFW for hatchery facility operations, which include at least a portion of the funding for operation of the Marblemount Hatchery generally and one of these chum programs specifically.

All three of the programs are existing, ongoing programs. Each hatchery program is described in detail in a Hatchery and Genetic Management Plan (HGMP) submitted to NMFS for review (Sauk-Suiattle Indian Tribe 2018; Kirby 2022b; USIT 2022; WDFW 2022a). For HGMPs determined through NMFS review to satisfy the 4(d) Rule criteria, ESA section 9 take prohibitions will not apply to hatchery activities managed in accordance with the plans.

Collectively, NMFS, BIA, and USFWS are the "Action Agencies": NMFS because of its proposed determination on the plans; BIA because it on occasion provides discretionary funding and technical assistance; and, USFWS because of their funding of the programs. NMFS is the designated lead agency for the conduct of this consultation pursuant to BIA and USFWS request and mutual agreement between the agencies.

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 USC 1531 et seq.), and implementing regulations at 50 CFR 402, as amended. 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

[1] The Skagit River Fisheries Co-managers comprise the Upper Skagit Indian Tribe, the Sauk-Suiattle Indian Tribe, the Swinomish Indian Tribal Community, and the Washington Department of Fish and Wildlife. Throughout this document, these entities will collectively be referred to as the Skagit River Fisheries Co-managers, the Fisheries Co-managers, or as the co-managers.

Table 1. Skagit River watershed chum salmon hatchery programs (HGMPs) submitted to NMFS for ESA Section 4(d) authorization.

Program (HGMP)	ESA-listed	HGMP receipt	Program operator (funder)[a]	Program start year	Program type, purpose[b]
Upper Skagit Chum Salmon	no	October 10, 2022	USIT (USIT, BIA)	1990	integrated, education
Chum Salmon Remote Site Incubator (RSI)	no	May 29, 2018[c]	SSIT (SSIT, BIA)	2014	integrated, recovery
Skagit River Fall Chum Salmon	no	October 10, 2022	WDFW (WDFW, USFWS)	2020	integrated, recovery

[a] All programs are jointly managed by the Skagit River Fisheries Co-managers. Program operators and funders include the following: Bureau of Indian Affairs (BIA); Sauk-Suiattle Indian Tribe (SSIT); United States Fish and Wildlife Service (USFWS); Upper Skagit Indian Tribe (USIT); Washington Department of Fish and Wildlife (WDFW).

[b] NMFS defines integrated hatchery programs as those that are reproductively connected or "integrated" with a natural population, promote natural selection over hatchery-influenced selection, contain genetic resources that represent the ecological and genetic diversity of a species, and are included in a salmon ESU or steelhead DPS. When a hatchery program actively maintains distinctions or promotes differentiation between hatchery fish and fish from a native population, then NMFS refers to the program as "isolated" (or "segregated"). These types of programs promote domestication or selection in the hatchery over selection in the wild, and culture a stock of fish with phenotypes (e.g., different ocean migrations and spatial and temporal spawning distribution) that may differ from the natural population.

[c] NMFS received minor updates to the Chum Salmon RSI HGMP on October 7, 2022 (Kirby 2022b).

Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (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 two weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at Sustainable Fisheries Division (SFD) of NMFS in Portland, Oregon.

1.2. Consultation History

The first hatchery consultations in Puget Sound followed the listing of the Puget Sound Chinook Evolutionarily Significant Unit (ESU) under the ESA (64 FR 14308, March 24, 1999). In 2005, WDFW and the Puget Sound Tribes ("co-managers") completed two resource management plans (RMP) as the overarching frameworks for 114 HGMPs. The HGMPs described how each hatchery program would operate including effects on listed fish in the Puget Sound region. In 2004, the co-managers submitted the two RMPs and 114 HGMPs to NMFS for ESA review under limit 6 of the ESA 4(d) rule (50 C.F.R. 223.203). Of the 114 HGMPs, 75 were state operated including 27 Chinook salmon programs, 22 coho salmon programs, 2 pink salmon programs, 4 chum salmon programs, 2 sockeye salmon programs, and 18 steelhead programs. The Puget Sound Tribes submitted 38 HGMPs, including 14 for Chinook salmon, 13 for coho salmon, 9 for chum salmon, and 2 for steelhead. USFWS submitted one HGMP for its coho salmon program at Quilcene National Fish Hatchery.

Subsequent to the submittal of the plans to NMFS, the Puget Sound Steelhead Distinct Population Segment (DPS) was listed as “threatened” (72 FR 26722, May 11, 2007). On September 25, 2008, NMFS issued a final 4(d) rule adopting protective regulations for the listed Puget Sound steelhead DPS (73 FR 55451). In the final rule, NMFS applied the same 4(d) protections to steelhead as were already adopted for other ESA-listed Pacific salmonids in the region. Accordingly, the co-manager hatchery plans are now also subject to review for effects on listed steelhead.

Among the Puget Sound region HGMPs that have been submitted for NMFS’ consideration under the ESA are three plans developed by the Sauk-Suiattle Indian Tribe (SSIT), the Swinomish Indian Tribal Community (SITC), the Upper Skagit Indian Tribe (USIT), and the WDFW, describing three hatchery programs for chum salmon in the Skagit River watershed. On February 28, 2013, NMFS received an HGMP for the Upper Skagit Chum Salmon program with a request for review under limit 6 of the 4(d) rule. On August 27, 2015, NMFS received two HGMPs—an updated HGMP for the previously submitted Upper Skagit Chum Salmon program, and a new HGMP for a proposed Chum Salmon Remote Site Incubator (RSI) program—both submitted with a request for review under limit 6 of the 4(d) rule. On May 21, 2018, NMFS received a new HGMP for a proposed Skagit River Fall Chum Salmon (Marblemount Hatchery) program with a request for review under limit 6 of the 4(d) rule. On May 30, 2018, NMFS received a revised HGMP for the Chum Salmon RSI program with a request for review under limit 6 of the 4(d) rule. On October 7, 2022, NMFS received minor updates to the Chum Salmon RSI HGMP (Kirby 2022b). On October 10, 2022, NMFS received revised HGMPs for two of the previously submitted chum salmon programs—Upper Skagit Chum Salmon and Skagit River Fall Chum Salmon (Marblemount Hatchery)— with a request for review under limit 6 of the 4(d) rule. After reviewing these revised HGMPs, NMFS initiated formal consultation with itself on October 11, 2022. On October 13, NMFS received a revised Skagit River Fall Chum Salmon (Marblemount Hatchery) HGMP that corrected an error in one of the tables.

On June 11, 2018, NMFS conducted a site visit of hatchery and allied facilities associated with the consultation, including the Marblemount Hatchery, the Upper Skagit (Red Creek) Hatchery, and the Sauk-Suiattle RSI. This Biological Opinion is based on information provided in the most up-to-date HGMPs, the June 11, 2018 site visit, and subsequent meetings, telephone conversations, and email exchanges with the co-managers.

On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the 2019 regulations that were revised or added to 50 CFR part 402 in 2019 (“2019 Regulations,” see 84 FR 44976, August 27, 2019) without making a finding on the merits. On

September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. As a result, the 2019 regulations are once again in effect, and we are applying the 2019 regulations here. For purposes of this consultation, we considered whether the substantive analysis and conclusions articulated in the biological opinion and incidental take statement would be any different under the pre-2019 regulations. We have determined that our analysis and conclusions would not be any different.

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). 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).

As stated in Section 1.0 above, the Proposed Action includes the following:

1. NMFS ESA 4(d) Limit 6 determination on three chum salmon hatchery programs jointly managed by the Skagit River Fisheries Co-managers in the Skagit River basin (Table 1);
2. The Bureau of Indian Affairs' (BIA) intermittent, discretionary disbursement of funds and technical assistance for operation and maintenance of the two tribal hatchery programs (Upper Skagit Chum Salmon; Chum Salmon RSI); and,
3. Funding by the U.S. Fish & Wildlife Service (USFWS) provided to the Washington Department of Fish and Wildlife (WDFW) through its Sport Fish Restoration Act (also called the Dingell-Johnson Act) grants program. USFWS provides grants to WDFW for hatchery facility operations, which include at least a portion of the funding for operation of the Marblemount Hatchery generally and the Skagit River Fall Chum Salmon program specifically.

The Federal Actions considered in this consultation are subsumed within the effects of operating the hatchery programs pursuant to the HGMPs, including any associated research, monitoring and evaluation. See Table 1 for a list of the hatchery programs considered in this consultation, and see Figure 1 for the location of the facilities used to operate these programs. Details about these programs and facilities are provided in the following subsections. The purpose of the chum salmon programs is to supplement and rebuild the natural chum salmon population in the Skagit River, which experienced a substantial decline starting in 2007, and has remain depressed since. The USIT's Upper Skagit Chum Salmon program is also intended to support the cultural enrichment and environmental education awareness for the Upper Skagit Community and surrounding communities.

With regard to BIA and USFWS funding, the act of funding (and for BIA provision of technical assistance for) various hatchery activities does not have an immediate direct effect on listed salmonids beyond the operation of the programs themselves. NMFS finds that the indirect effects of Federal funding are coextensive with the proposed implementation of the HGMPs. The

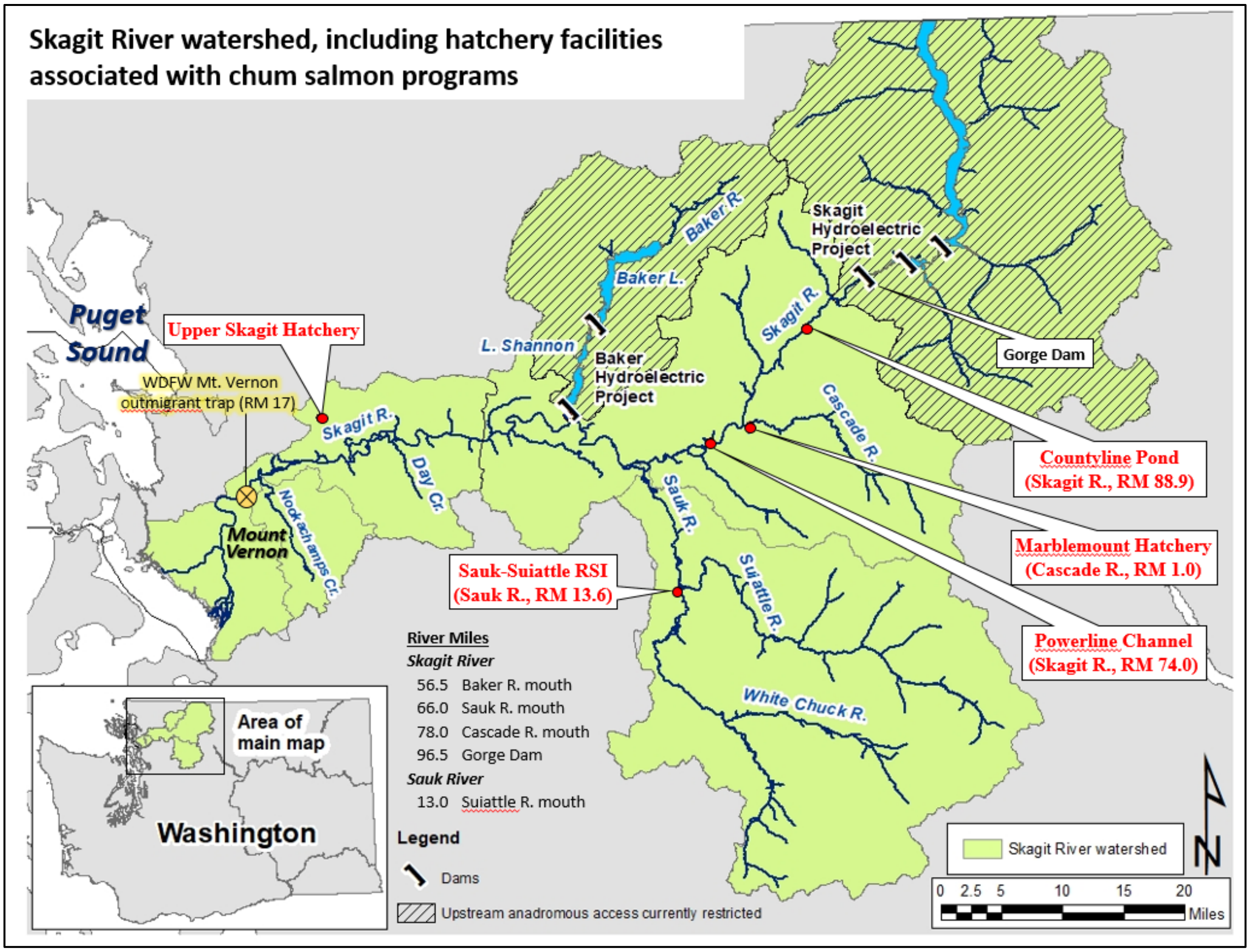

Figure 1. Map of Skagit River basin showing locations of hatcheries and related facilities relevant to this consultation (red dots and text). River miles (RM) are shown for hatchery facilities and other prominent features.

indirect effects from funding are evaluated and considered below in the context of NMFS' overall determination under Limit 6 of the ESA 4(d) rule (50 CFR § 223.203(b)(6)). Because the funding of the programs under consideration does not result in any actions or effects not already under consideration as part of NMFS' review of the programs themselves, this Opinion will not separately discuss the funding actions other than to note their inclusion in the consultation. Neither BIA nor USFWS has any other active role in the Proposed Action.

We considered, under the ESA, whether or not the Proposed Action would cause any other activities and determined that it would not, particularly because the proposed hatchery programs are not intended to nor do they support any fisheries.

The following sections comprise a description by the operators of the hatchery programs, as detailed in the submitted HGMPs.

1.3.1. Proposed Action for chum salmon hatchery programs

1.3.1.1. Marblemount Hatchery area streams, naming, and alignment

The WDFW's Marblemount Hatchery is one of the primary hatchery facilities associated with the Proposed Action. Relevant documentation and sources are inconsistent in both the naming and channel alignments of two particular streams in the vicinity of the hatchery which have a bearing on this consultation. To avoid confusion, this subsection summarizes these discrepancies, and details the stream naming and channel alignments that will be utilized throughout this document. Though detailed here in the Proposed Action section, there is relevance to the Environmental Baseline section as well.

One of the streams in question is a small spring-fed stream that runs through the Marblemount Hatchery (Stream A in Figure 2). This stream is called "Clark Creek" by WDFW staff and in hatchery documentation. The other stream in question originates at higher elevations to the southeast of the hatchery, and runs to the north, emptying into the Cascade River approximately one-half to one mile upriver from the hatchery (Stream B in Figure 2). Several sources, including the 2020 USGS topographic quadrangle map (Figure 2) and WDFW's SalmonScape website, label Stream B as "Clark Creek" and show that all or a portion of this stream runs to the west through the Marblemount Hatchery. This appears to be erroneous.

The 1995 Washington Department of Natural Resources' (WDNR) Jordan-Boulder Watershed Analysis, Appendix E: Stream Channel Assessment (WDNR 1995) provided an in-depth assessment of streams in this area. Their evaluation implies that these discrepancies have likely arisen from undocumented natural or human-caused alignment changes prior to 1995, and ongoing use of outdated maps that have not been field verified to reflect present-day conditions. The WDNR evaluation indicates that Streams A and B are currently disconnected at the surface (i.e., they appear at the surface as two separate streams), though they may have been connected historically. Stream B is referred to as "Shoemaker Creek" in the WDNR documents, as well as currently by local WDFW staff. WDNR (1995) notes that "Shoemaker Creek appears to have been channelized to its present-day location", that it is "a linear, excavated trough which lacks wood or channel bed structure", and that "[its] channel is artificially maintained in [its] present location." WDFW staff have indicated that the channel alignment described in WDNR (1995) (i.e., surface separation of Streams A and B) reflects present-day conditions. WDFW and the Marblemount Hatchery have no role in maintaining the current alignment of and surface separation between Streams A and B. Stream A is not labeled in the 1995 WDNR documents, but is referred to as "Clark Creek" in the historical hatchery documentation, including the water rights documents, and currently by hatchery staff.

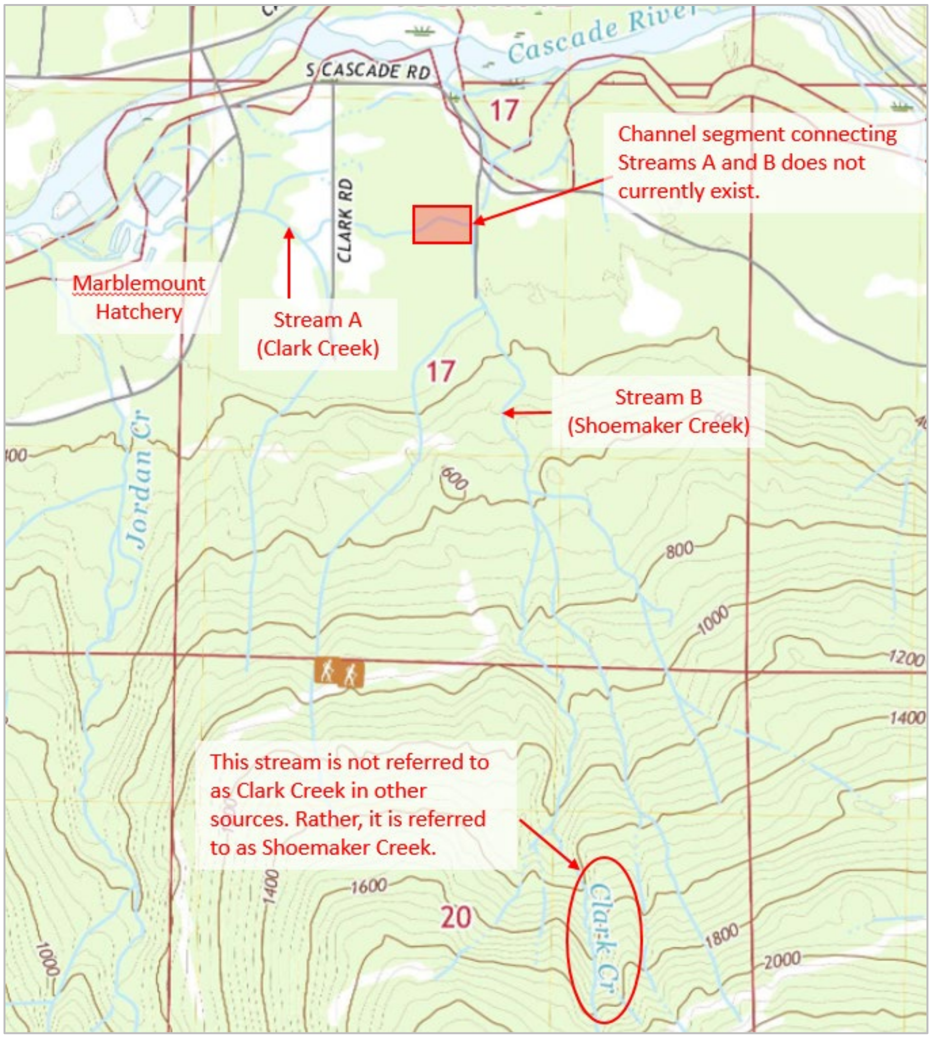

Figure 2. Marblemount Hatchery area stream alignments and names used in this consultation. The basemap, including channel alignments and stream names shown in light blue, is from the 2020 USGS topographic quadrangle map. Corrections are shown in red. See text for additional explanation.

Throughout this Biological Opinion, we will utilize the alignments and naming reflected in (WDNR 1995) and hatchery documentation, and confirmed by WDFW staff, as reflected in Figure 2 and summarized as follows:

- Stream A will be referred to as Clark Creek.
- Stream B will be referred to as Shoemaker Creek.
- Clark Creek and Shoemaker Creek will be considered to have no current or future surface hydrologic connection.

1.3.1.2. Proposed hatchery broodstock collection and spawning protocols

Broodstock collection will occur by a variety of means, as depicted in Table 2 and described below. The Marblemount Hatchery includes a weir and adult trap on Clark Creek. There is no broodstock collection infrastructure in the mainstem Skagit or Cascade Rivers. The Clark Creek adult trap consists of a fish ladder with v-trap that guides the fish directly into a collection pond. The pond is 200 feet long and 10 feet wide, totaling 2,000 square feet. The pond bottom is gently sloped along its length, measuring 4 feet deep at one end and 5 feet at the other. The pond is continuously fed with surface water and has cyclone fencing around its perimeter to prohibit predator entry. For purposes of chum broodstock collection, the trap will typically be operated continually (7 days per week, 24 hours per day) during November and December. The pond will be checked daily to observe general conditions, fish abundance, and fish behavior.

Under typical conditions, WDFW will sort the trap and remove any natural-origin fish present once per week. During sorting, natural-origin fish are held in a section of the pond until sorting is complete. Fish are then removed from the pond with bare hands and placed in large totes (approximately 250 gallon). Up to 5 fish may be loaded into a tote, and fish may spend up to 5 minutes in the tote prior to release into the river. Totes are filled with surface water from the adult pond intake immediately prior to placing fish in them. After fish are loaded into the tote, a lid is placed on and they are driven to the release location near the hatchery's Cascade River surface water intake. Fish are removed from the tote with bare hands and gently released with minimal in-air vertical drop into slow-moving water along the shoreline. Personnel that handle, transport, and release ESA-listed non-target fish will be fisheries professionals that are trained and knowledgeable on best practices for minimizing fish stress and maximizing fish safety.

All three of the programs will use in-river netting at locations in the Skagit and Sauk Rivers to collect some or all broodstock (Table 2). Netting activities will be conducted in a manner to collect live, healthy fish, and minimize harming or killing fish. These activities will be conducted by fisheries professionals trained and knowledgeable in the following: 1) proper net deployment, monitoring, and retrieval procedures; 2) identification of adult Chinook salmon and steelhead trout; 3) best practices for removing adult salmonids from net gear in a manner that minimizes fish stress and maximizes fish safety; and, 4) best practices for releasing excess or non-target adult salmonids back to the river in a manner that minimizes fish stress and maximizes fish safety. Net time in the water per deployment (soak time) will be short in duration—approximately 3–15 minutes—in order to minimize fish stress and injury to target and non-target species. Nets will be attended at all times while deployed in the river. Incidental catch may be held in mobile net pens to avoid repeat capture. Fish will be released from net pens once brood stocking activity is completed in the area on any given day.

Table 2. Broodstock collection and spawning (mating) details for Skagit River watershed chum salmon hatchery programs.

Program	Source[a]	Collection location(s)	Collection method[b,c,d]	Broodstock goal	Collection duration	Spawning[b]	pNOB[e]
Upper Skagit Chum Salmon	Skagit River NOR and HOR	Skagit River, RM 8–57	modified drift gill net/tangle net (5.5”)	500	mid October–December	matrix	0.99
Chum Salmon RSI	Sauk River NOR	Sauk River, RM 12–18	drift gill net; set gill net[f] (6.25–7.75”)	100	November	pairwise	varies
Skagit River Fall Chum Salmon	Skagit River NOR and HOR	Skagit River, > RM 69; Marblemount Hatchery Trap[g]	modified drift gill net/tangle net (6.75”), angling, snagging, beach seining, fish trap	4,900	November–December	matrix	0.5–1

[a] HOR indicates hatchery-origin fish; NOR indicates natural-origin.
[b] See text for additional detail.
[c] Net sizes are stretch size.
[d] For the Upper Skagit Chum Salmon and Skagit River Fall Chum Salmon programs, “modified drift gill net/tangle net” are re-purposed gill nets that are modified to function more as tangle nets. Single-wall, monofilament nets are hung loosely (2:1 ratio or more) rather than stretching along the cork and lead-lines so that fish become entangled in the mesh rather than attempting to swim through the net and becoming “gilled.” Net time in the water per deployment (soak time) will be short in duration—approximately 3–15 minutes—in order to minimize fish stress and injury to target and non-target species. Nets will be attended at all times while deployed in the river.
[e] Proportion of natural-origin brood, expressed as the proportion of all fish used for broodstock that are natural origin.
[f] Drift gill nets and set gill nets will be attended at all times while deployed in the river. For drift gill netting, net time in the water per deployment (soak time) will be short in duration—approximately 3–15 minutes. For set gill netting, nets will be retrieved at the first sign that a fish is captured. These measures minimize fish stress and injury to target and non-target species.
[g] Up to 50% of broodstock may be collected from the Marblemount Hatchery adult trap once adult return from the program begin returning to the watershed.

Hatchery programs will implement either matrix or pairwise mating (spawning) protocols, as indicated in Table 2. These protocols will be implemented as follows:

- *Matrix spawning*. Matrix spawning will occur by pooling eggs from two to five females (depending on availability) and distributing eggs equally into the same number of containers as the number of females. For example, two females' eggs will be combined and distributed equally among two containers, three females' eggs will be combined and distributed equally among three containers, and so forth. Eggs in each container will then be fertilized with milt from one male. After 60 seconds of fertilization time, milt from a secondary male will be added to ensure successful fertilization in the event the first (primary) male was sterile. The secondary male will be used as the primary male for fertilizing eggs in the subsequent container.

- *Pairwise spawning*. In pairwise spawning, eggs from one female will be mixed with milt from one male. After 30–60 seconds of fertilization time, milt from a secondary (back-up) male will be added. The secondary male will have been used as the primary male for fertilization of the previous female.

1.3.1.3. Proposed hatchery rearing and juvenile release

Details on the proposed rearing and release of fish for each program, including production (release) goals, marking and tagging regimes, and release locations are shown in Table 3. Inter-annual variability in fecundity and in-hatchery survival rates may result in excess juvenile fish at release time. Production overages greater than 10 percent of production targets in any given year are anticipated to be infrequent. If the running 5-year average production (beginning in the release year that NMFS makes a determination on the program) for a program is more than 105% of the level described, the co-managers will notify NMFS.

In general, the hatchery programs included in the Proposed Action will implement rearing and release practices that encourage rapid seaward migration and minimize the length of time hatchery-origin juveniles spend in freshwater. These include releasing fish only at natural outmigration times for their species. Release of hatchery juveniles prior to the target release date may be considered in the event of an emergency (e.g., loss of water). In such a situation, the co-managers will notify NMFS within 48 hours of the release and provide information on release location and size and number of released fish.

Table 3. Proposed annual release goals and protocols for Skagit River watershed chum salmon hatchery programs.

Program	Number and life stage[a] (size in fpp)	Marking and tagging	Egg incubation and juvenile rearing location	Acclimation site, duration (for off-station releases)	Volitional release?	Release location(s)	Release month(s)
Upper Skagit Chum Salmon	450,000 F (700)	none	Upper Skagit (Red Creek) Hatchery	none	no	Skagit River, below RM 57	April–May
Chum Salmon RSI	125,000 F (400–700)	none	Marblemount Hatchery (to eyed-egg; Sauk-Suiattle RSI (eyed-egg to fry)	none	no	Sauk River, RM 14.5 (50,000 fry); Hatchery Creek, RM 0.2 (50,000 fry); Lyle Creek, RM 0.5 (25,000 fry)	April–May
Skagit River Fall Chum Salmon	5 million FF (600–1,000)	100% otolith marked and/or parentage-based tagged	Marblemount Hatchery	none[b]	Yes for on-station releases; no for all others	Skagit River, RM 66–96[c] (≥ 60% of total release); Marblemount Hatchery on-station (≤ 40% of total release)	April

[a] Life stages are as follows: FF = fed fry; F = fry

[b] Acclimation and imprinting of off-station releases is intentionally avoided in order to maximize spatial distribution of returning adults throughout the natural range of Skagit River fall chum salmon.

[c] Fish may be released at one or more locations in the Skagit River, RM 67–96 based on localized chum spawner abundances and co-manager agreement. Currently identified potential and/or utilized sites include Skagit River Slough at Rockport Park (RM 66.5), County Line Ponds (RM 88.9), and Powerline Channel (RM 74.0). Additional or alternative release sites in the Skagit River may be utilized in the future.

1.3.1.4.Proposed pathogen prevention, monitoring, and control

Pursuant to the HGMPs, the co-managers propose to utilize best management practices for preventing, monitoring, and controlling pathogens in the hatchery environment, as detailed in "The Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State" (NWIFC and WDFW 2006). Robust pathogen prevention, monitoring, and control (PPMC) programs are recognized as crucial to ensuring high fish survival in the hatchery environment, as well as preventing pathogen amplification within the hatchery and transfer to natural waters. Both the WDFW and the Northwest Indian Fisheries Commission have trained and knowledgeable Fish Health professionals (Fish Health Specialists and Pathologists) on staff that will guide the design and implementation of PPMC programs for the hatchery facilities and programs included in the Proposed Action. PPMC programs include pertinent nutrition, water flow and chemistry, fish loading and density indices, handling, disinfecting procedures, and chemical and drug treatment standards, guidelines, and protocols. Hatchery managers and staff will be trained and knowledgeable in protocols for pathogen prevention and treatment, and in recognizing outward signs of pathogen presence. Suspected pathogen presence will be promptly reported to the appropriate Fish Health professionals, who will investigate and recommend corrective measures as necessary. In addition, Fish Health professionals will conduct routine monthly evaluations of rearing conditions and perform lethal sampling of small numbers of juvenile fish to assess the health status of the population and for early detection of pathogens of concern. Treatment plans will be developed and implemented as needed. Findings and results of pathogen monitoring and treatment will be documented and maintained.

Various disinfectants, antibiotics, medications, and anesthetics will be used at the hatchery facilities. Of these, disinfectants will be used the most. Disinfectants may include but not be limited to formalin, povidone-iodine, and iodophor.

Chemicals used in water that flows through a given hatchery facility will be used infrequently and/or intermittently, such that they will be absent from effluent at most times. Povidone-iodine will not be used in water that flow through the hatchery facilities, but rather may be used to treat eggs after fertilization and, less commonly, to disinfect small equipment such as nets and boots. Egg treatment will be infrequent (relatively few days per year) and will use small quantities of povidone-iodine. For gear treatment, containers of povidone-iodine solution will occasionally be made available in certain areas of the hatchery and used as needed. This solution degrades over time and as it gets used. After use, povidone-iodine solution will be disposed of on land.

Disposition of fish carcasses from euthanizing excess hatchery-origin adults or incidental mortality during broodstock collection may include nutrient enhancement (i.e., placed in natural waters), buried, or distributed for human consumption or other human uses (e.g., ceremonial). Approval from a Fish Health professional will be obtained prior to distributing carcasses for nutrient enhancement.

1.3.1.5. Proposed research, monitoring, and evaluation (RM&E)

A variety of research, monitoring, and evaluation activities and methodologies may be employed to assess effects of the hatchery programs on naturally-reproducing fish populations. These research, monitoring, and evaluation (RM&E) programs will provide data and information for adaptively managing the hatchery programs and their effects to both listed and unlisted fish species, and to meet HGMP performance criteria.

Some aspects of the proposed hatchery RM&E programs will be integrated with non-hatchery-related activities. Namely, the co-managers annually monitor adult spawner abundance in the Skagit River watershed to track trends in abundance and distribution of naturally-reproducing salmon and steelhead populations. Data collected during these surveys are also used to monitor hatchery performance criteria. Surveys may be performed by foot, boat, and/or snorkeling. Fish carcasses may be sampled for scales, otoliths, tissues for DNA analysis, and other similar types of biosampling. Similarly, the WDFW operates juvenile salmonid traps (rotary screw and/or incline plane) in the Skagit River at RM 17 to monitor abundance and productivity of naturally-reproducing salmonid populations. Data collected from the trapping operation is also used to monitor survival and outmigration time of hatchery-released fish. The trapping operation is covered under a separate ESA 4(d) authorization renewed annually by NMFS[2]. The co-managers propose to continue these spawner abundance and juvenile trapping activities into the foreseeable future.

The co-managers track, record, and maintain the following data to evaluate hatchery program performance and effectiveness:

- For all target and non-target salmonids (Pacific salmon, steelhead, bull trout) trapped at collection facilities or during in-river broodstock collection (e.g., gill netting), the co-managers may record the species, date and location of capture, sex (if possible), length (if possible), origin (hatchery or natural), mark/tag presence, and disposition. Chinook salmon with intact adipose fins will be interrogated for presence of coded wire tags.
- For each hatchery spawn day, the number of adult male, adult female, and jacks spawned, and number of eggs collected and fertilized will be recorded.
- Annual egg take and juvenile release numbers will be estimated and recorded in order to assess in-hatchery survival.

1.3.1.6. Proposed operation and maintenance of hatchery facilities

1.3.1.6.1. Marblemount Hatchery infrastructure in Clark Creek

The Marblemount Hatchery was constructed in-line with Clark Creek: as Clark Creek flows through the hatchery grounds it becomes highly integrated as part of the hatchery (Figure 3). A portion of Clark Creek is diverted to hatchery raceways via a surface water intake as the stream first enters the hatchery grounds. The remainder of Clark Creek flows into and through the hatchery by one of the following three pathways: 1) the adult trap and holding pond; 2) the steelhead channel; and, 3) the asphalt-lined rearing channels and release/bypass channel. There are three weirs at the hatchery: two on Clark Creek and one near the mouth of the bypass/release

[2] Recent NMFS permit numbers are as follow (year of permit coverage in parentheses): 22521 (2019), 21773 (2018), 20801 (2017), 19946 (2016), 19139 (2015), 18435 (2014), 17467 (2013), 16732 (2012), 15836 (2011), 14874 (2010).

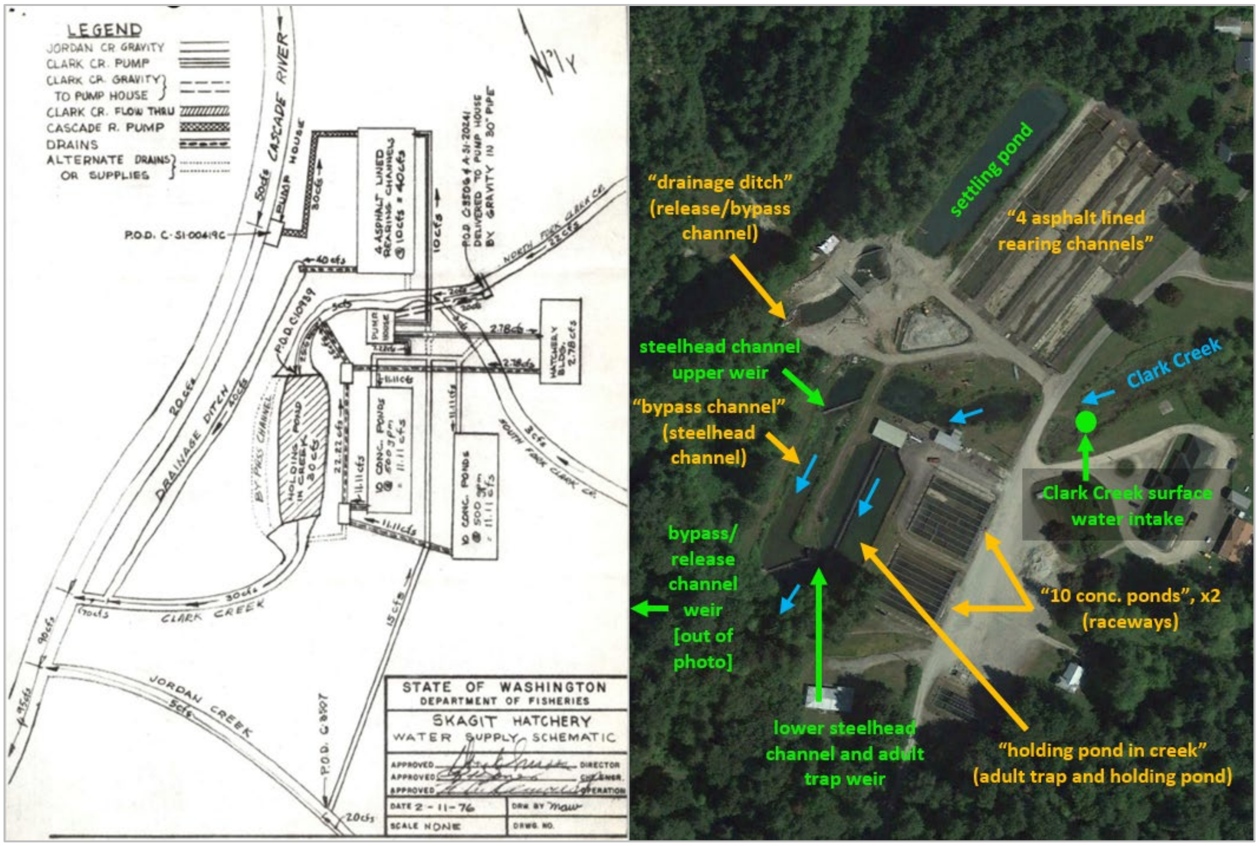

Figure 3. Marblemount Hatchery water supply schematic circa 1976 (left panel), and recent aerial view showing current terminology and additional hatchery features (right panel). Orange text in quotes correspond with terminology used in the left panel; current terminology is shown underneath in parentheses. Features labeled in green text are not shown or labeled in the left panel. Blue arrows show water flow direction.

channel (Figure 4). The two on Clark Creek are height and velocity barriers, and the one on the release/bypass channel is a picket-style weir (Figure 5). Upstream fish passage above the weirs is not provided.

1.3.1.6.2. Proposed water withdrawal and discharge

Water usage at all facilities will be non-consumptive. A National Pollutant Discharge Elimination System (NPDES) permit is required for effluent discharge from facilities that rear 20,000 pounds or more of fish annually or that feed 5,000 pounds or more of feed during any calendar month. Additional details regarding water withdrawal and effluent discharge from the facilities included in the proposed action are provided below.

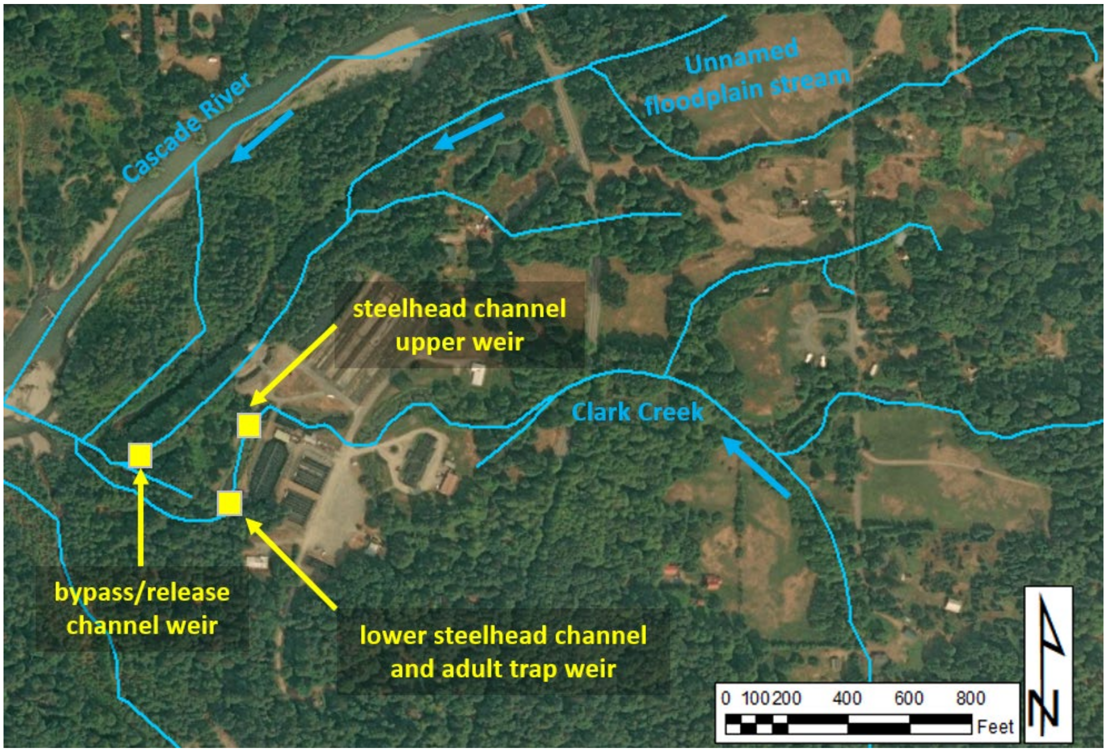

Figure 4. Locations of three weirs at the Marblemount Hatchery and associated streams. Source of stream and river channel locations (blue lines): USGS National Hydrography Dataset, NHDFlowline. Blue arrows show flow direction.

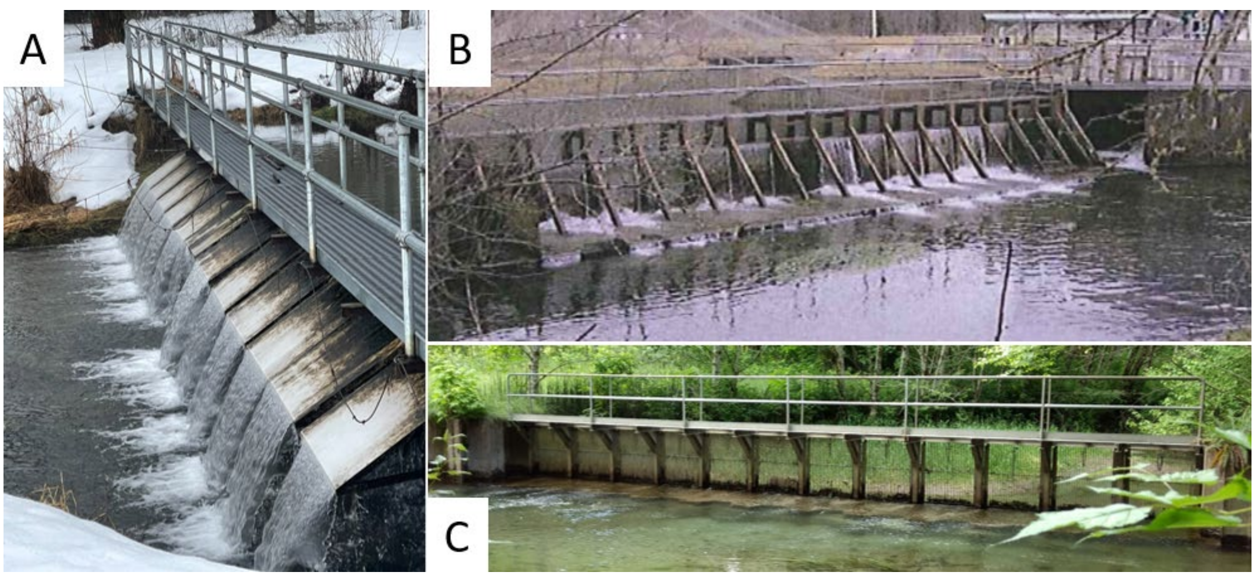

Figure 5. Photographs of the three Marblemount Hatchery weirs: A) steelhead channel upper weir; B) lower steelhead channel and adult trap weir; C) bypass/release channel weir.

- *Marblemount Hatchery*. The Marblemount Hatchery will withdraw water and discharge effluent all year. This facility uses water from both surface and groundwater sources. Groundwater is obtained from five on-site wells. Surface water is obtained from Clark Creek, the Cascade River, and Jordan Creek. Surface water intakes and flow pathways on Clark Creek are not screened for fish because they lie above barriers (weirs) that prohibit upstream movement of juvenile and adult fish into these areas. There is one surface water intake each on the Cascade River and Jordan Creek. Water may be withdrawn up to the following quantities, in accordance with current water rights: Cascade River, 30 cfs; Clark Creek, 25 cfs; Jordan Creek, 15 cfs; and, groundwater, 10 cfs.

  The Jordan Creek intake includes an in-channel water diversion structure with volitional upstream and downstream fish passage. The intake screening and passage structure was upgraded in 2018 to meet NMFS standards at the time (NMFS 2011a). The Cascade River intake screening does not meet recent (NMFS 2011a; 2022b) or previous (NMFS 1995; 1996) NMFS criteria. The surface area of the Cascade River screens is 307 ft^2. There is no in-channel diversion structure associated with the Cascade River intake. Water withdrawals affect 1,650 ft of the Cascade River, 1,310 ft of Jordan Creek, and 300 ft of Clark Creek (distance between mouth of the bypass/release channel and the lower steelhead channel and adult trap weir). Water withdrawn for use in the hatchery is not available to these creek and river reaches, with the exception of Clark Creek (some or all water may be returned in the vicinity of the lower steelhead channel and adult trap weir). Effluent is discharged from the hatchery in accordance with NPDES permit WAG 13-3015. All effluent is discharged into Clark Creek at or upstream of the weirs.

- *Upper Skagit (Red Creek) Hatchery*. The Upper Skagit Hatchery withdraws water and discharges effluent from November through May. This facility uses up to 0.56 cfs of surface water withdrawn from Red Creek, and up to 0.12 cfs of groundwater (Shannahan 2019). The surface water withdrawal affects approximately 700 ft of the creek (i.e., distance between intake and discharge). Screening at the intake is approximately 14 ft^2. The screening has clear openings of 3.18 mm, nearly twice as large as the 1.75 mm indicated in both recent (NMFS 2011a; 2022b) and previous (NMFS 1995; 1996) NMFS criteria, though sufficient in 1990 when the chum program that operates from here began. Other aspects of the screening—including an appropriate cleaning and maintenance plan—meet current criteria. The facility produces up to approximately 650 pounds of fish per year, and therefore does not require an NPDES permit.

- *Sauk-Suiattle RSI*. The Sauk-Suiattle RSI withdraws water and discharges effluent from November through May. This facility uses up to 0.1 cfs of surface or groundwater withdrawn from Hatchery Creek or an onsite well, respectively. The surface water withdrawal affects approximately 150 ft of the creek (i.e., distance between intake and discharge). Intake screening meets NMFS (2011a) standards. There is currently a barrier to anadromous fish passage (i.e., culvert, not associated with the hatchery) downstream from the intake. If the fish passage barrier is remedied and anadromous fish access is restored, the SSIT proposes to upgrade the intake to meet NMFS criteria in place at the time. The facility will produce up to approximately 320 pounds of fish per year, and therefore does not require an NPDES permit.

1.3.1.6.3. Other proposed operation and maintenance activities

Routine maintenance is required for "watered" facilities such as ponds, troughs, incubators, pumps, water diversions, outfalls, plumbing, and weirs, as well as buildings and grounds. Minor weir repairs and adjustments are also required on occasion. Removal of minor debris accumulations from surface water diversion structures and from discharge outfall structures is necessary to maintain their integrity and performance. Activities performed in or near surface waters that may harm fish or their habitat, including use of heavy equipment, are done in compliance with a WDFW Hydraulic Project Approval permit that specifies allowable in-water work windows and Best Management Practices to minimize introduction of pollutants into waterways. Activities that require a U.S. Army Corps of Engineers permit are not included in this consultation.

Maintenance of ponds and raceways at the Marblemount Hatchery is a regular occurrence. This involves the vacuuming and removal of accumulated sediment on the bottoms of hatchery ponds and raceways. A pollution abatement system consisting of a settling pond prevents sediment-laden water from reaching surface waters. Solids are periodically removed from the settling pond and disposed of at upland locations on the hatchery grounds or at commercial sites. This occurs approximately once every two years. Heavy equipment use for settling pond dredging is done in accordance with an existing WDFW Hydraulic Project Approval permit that specifies Best Management Practices to minimize introduction of pollutants into waterways.

Other facility maintenance includes building and grounds maintenance, including painting, minor building repairs, security repairs such as lighting and fence repair, and weeding and mowing. Typical chemicals that are used during grounds maintenance include Roundup and Rodeo. All applications are performed during dry conditions (i.e., not raining or expected to rain) using a backpack sprayer following the chemical manufacturer's label. Roundup is used around buildings and landscaped areas, and is not applied within 300 feet of water. Rodeo is used for applications closer to water.

Fish released from raceways exit via a pipe that discharges to an area in close proximity to the adult ladder and trap in Clark Creek. The pipe is outfitted with exclusionary grating at its outlet to prohibit natural fish from entering the pipe. The grating is hinged such that when hatchery fish are being released a rope is pulled which lifts the bottom of the grating so that juveniles can swim out freely. The grating is opened the morning of release and left open for up to 8 hours to allow fish to exit. This occurs approximately nine times per year during the months of May and June. The grating has rolled corners and no sharp edges so that potential for fish injury is minimized.

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

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

The 2019 regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the regulations (84 FR 44977), that definition does not change the scope of our analysis and in this opinion we use the terms "effects" and "consequences" interchangeably.

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

Identify the range-wide status of the species and critical habitat
This section describes the status of species and critical habitat that are the subject of this opinion. The status review starts with a description of the general life history characteristics and the population structure of the ESU/DPS, including the strata or major population groups (MPG)

where they occur. NMFS has developed specific guidance for analyzing the status of salmon and steelhead populations in a "viable salmonid populations" (VSP) paper (McElhany et al. 2000). The VSP approach considers four attributes, the abundance, productivity, spatial structure, and diversity of each population (natural-origin fish only), as part of the overall review of a species' status. For salmon and steelhead protected under the ESA, the VSP criteria therefore encompass the species' "reproduction, numbers, or distribution" (50 CFR 402.02). In describing the range-wide status of listed species, NMFS reviews available information on the VSP parameters including abundance, productivity trends (information on trends, supplements the assessment of abundance and productivity parameters), spatial structure and diversity. We also summarize available estimates of extinction risk that are used to characterize the viability of the populations and ESU/DPS, and the limiting factors and threats. To source this information, NMFS relies on viability assessments and criteria in technical recovery team documents, ESA Status Review updates, and recovery plans. We determine the status of critical habitat by examining its PBFs. Status of the species and critical habitat are discussed in Section 2.2.

Describe the environmental baseline in the action area

The environmental baseline includes the past and present impacts of Federal, state, or private actions and other human activities *in the action area* on ESA-listed species. It includes the anticipated impacts of proposed Federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in Section 2.4 of this opinion.

Analyze the effects of the proposed action on both the species and their habitat

Section 2.5 first describes the various pathways by which hatchery operations can affect ESA-listed salmon and steelhead, then applies that concept to the specific programs considered here.

Cumulative effects

Cumulative effects, as defined in NMFS' implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area. Future Federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in Section 2.6 of this opinion.

Integration and synthesis

Integration and synthesis occurs in Section 2.7 of this opinion. In this step, NMFS adds the effects of the Proposed Action (Section 1.3) to the status of ESA protected populations in the Action Area under the environmental baseline (Section 2.4) and to cumulative effects (Section 2.6). Impacts on individuals within the affected populations are analyzed to determine their effects on the VSP parameters for the affected populations. These impacts are combined with the overall status of the MGP to determine the effects on the ESA-listed species (ESU/DPS), which will be used to formulate the agency's opinion as to whether the hatchery action is likely to: (1) result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat.

Jeopardy and adverse modification
Based on the Integration and Synthesis analysis in Section 2.7, the opinion determines whether the proposed action is likely to jeopardize ESA protected species or destroy or adversely modify designated critical habitat in Section 2.8.

Reasonable and prudent alternative(s) to the proposed action
If NMFS determines that the action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, NMFS must identify a RPA or RPAs to the proposed action.

2.2. Range-wide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed action. The species and the designated critical habitat that are likely to be affected by the Proposed Action, and any existing protective regulations, are described in Table 4. 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" as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the function of the physical and biological features that are essential for the conservation of the species.

"Species" Definition

The ESA of 1973, as amended, 16 U.S.C. 1531 *et seq.* defines "species" to include any "distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature." To identify DPSs of salmon species, NMFS follows the "Policy on Applying the

Table 4. Federal Register notices for the final rules that list species, designate critical habitat, or apply protective regulations to ESA listed species considered in this consultation that are likely to be adversely affected.

SPECIES	LISTING STATUS	CRITICAL HABITAT	PROTECTIVE REGULATION
Chinook salmon (*O. tshawytscha*)			
Puget Sound	Threatened, March 24, 1999; 64 FR 14508	Sept 2, 2005; 70 FR 52630	June 28, 2005; 70 FR 37160
Steelhead (*O. mykiss*)			
Puget Sound	Threatened, May 11, 2007; 72 FR 26722	February 24, 2016; 81 FR 9252	September 25, 2008; 73 FR 55451

Definition of Species under the ESA to Pacific Salmon" (56 FR 58612, November 20, 1991). Under this policy, a group of Pacific salmon is considered a DPS and hence a "species" under the must satisfy two criteria to be considered an ESU: (1) It must be substantially reproductively isolated from other con-specific population units; and (2) It must represent an important component in the evolutionary legacy of the species. To identify DPSs of steelhead, NMFS applies the joint FWS-NMFS DPS policy (61 FR 4722, February 7, 1996). Under this policy, a DPS of steelhead must be discrete from other populations, and it must be significant to its taxon.

Status of Listed Species

For Pacific salmon and steelhead, 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 "viable salmonid population" (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 parameters or 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) produced per naturally spawning parental pair. 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, on habitat quality and spatial configuration, and on 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 DNA sequence variation at single genes to complex life history traits (McElhany et al. 2000).

In describing the range-wide status of listed species, we rely on viability assessments and criteria in NMFS Technical Recovery Team (TRT) documents and NMFS recovery plans, when available, that describe VSP parameters at the population, major population group (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 have 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).

2.2.1. Puget Sound Chinook Salmon ESU

Chinook salmon, *Oncorhynchus tshawytscha,* exhibit a wide variety of life history patterns that include: variation in age at seaward migration; length of freshwater, estuarine, and oceanic residence; ocean distribution; ocean migratory patterns; and age and season of spawning migration. Two distinct races of Chinook salmon are generally recognized: "stream-type" and "ocean-type" (Healey 1991; Myers et al. 1998). Ocean-type Chinook salmon reside in coastal ocean waters for 3 to 4 years, tending to not range very far northward in the Pacific Ocean prior to returning to their natal rivers. Stream-type Chinook salmon, predominantly represented by spring-run Chinook salmon populations, spend 2 to 3 years in the ocean and exhibit extensive offshore ocean migrations. Ocean-type Chinook salmon also enter freshwater later in the season upon returning to spawn than the stream-type fish; June through August compared to March through July (Myers et al. 1998). Ocean-type Chinook salmon use different areas—they spawn and rear in lower elevation mainstem rivers and they typically reside in freshwater for no more than 3 months. In comparison, spring Chinook salmon spawn and rear high in the watershed and often reside in freshwater for a year.

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 Puget Sound Chinook Salmon ESU is at high risk and is threatened with extinction (Ford 2022). The Puget Sound Technical Recovery Team (TRT) determined that 22 historical natural populations currently contain Chinook salmon and grouped them into five biogeographical regions (BGRs), based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity (Figure 6). Based on genetic and historical evidence reported in the literature, the TRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extirpated (Ruckelshaus et al. 2006). Nine of these 16 putatively extirpated spawning aggregations were thought to be early-type Chinook salmon, which are typically spring-run.

The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan de Fuca from the Elwha River eastward, and rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. We use the term "Puget Sound" to refer to this collective area of the ESU. Currently there are 25 artificial propagation programs producing Chinook salmon that are included as part of the listed ESU (85 FR 81822, December 17, 2020).

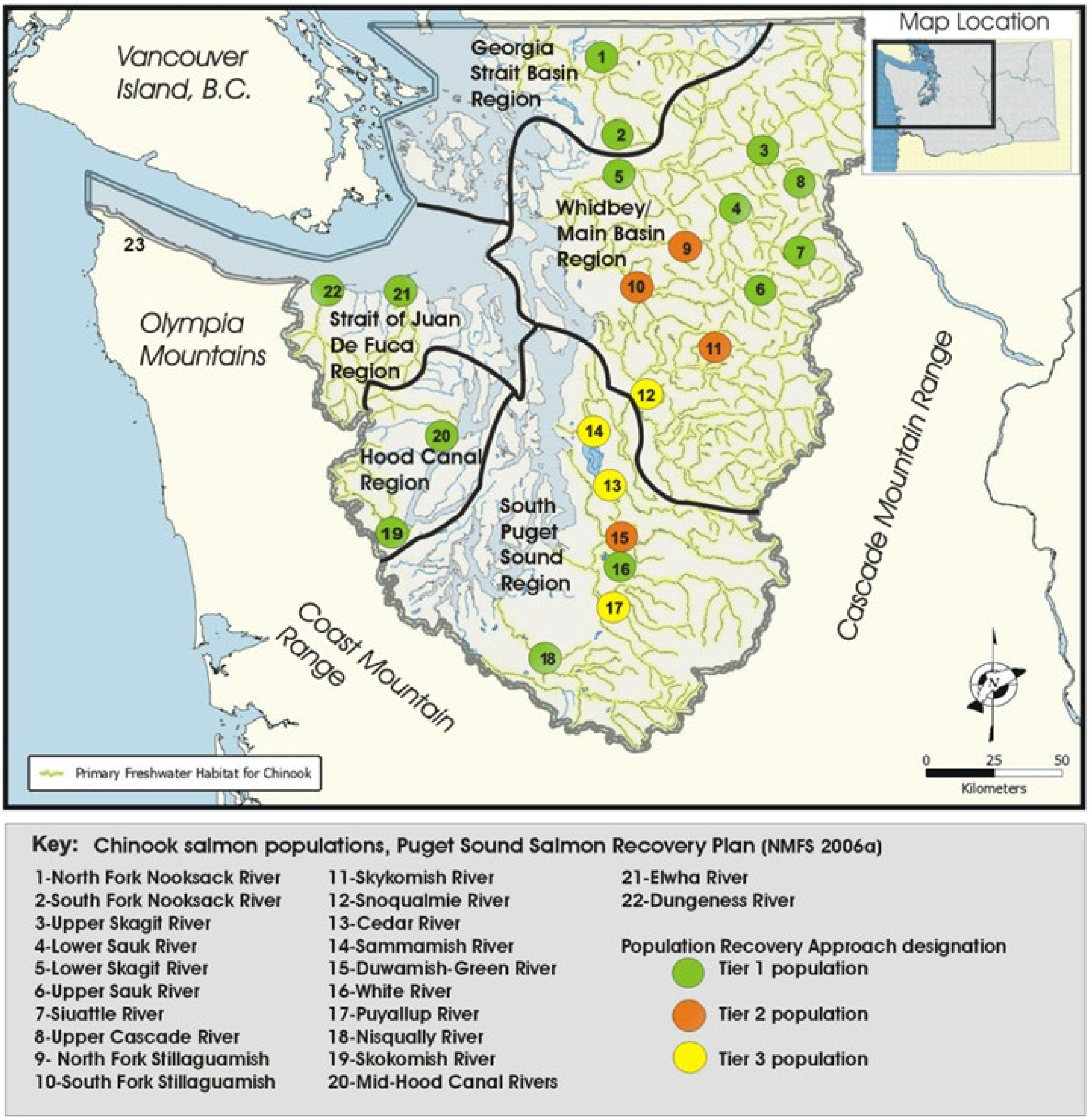

Figure 6. Puget Sound Chinook salmon ESU populations delineated by NMFS, including biogeographic region and assigned Population Recovery Approach tier status (SSDC 2007; NMFS 2010b)). The Upper Cascade population indicated on the map is referred to as Cascade throughout this document.

Pertinent information regarding the status of the species is described in detail in the NMFS 2022 Biological Viability Assessment Update (Ford 2022), and is summarized below. Sections of this document pertaining to the Puget Sound Chinook Salmon ESU are incorporated here by reference. Table 5 and Figure 7 summarize recent abundance and productivity for the Puget Sound Chinook salmon natural populations including NMFS' Critical and Rebuilding Escapement Thresholds and recovery plan targets for abundance and productivity. Most Puget Sound Chinook populations are well below escapement levels and productivity goals required for recovery, and many are below Critical and Rebuilding Escapement Thresholds. Since the last status review, abundance of natural-origin spawners increased across the ESU in all but two populations (Cascade and North Fork Stillaguamish), based on 5-year geometric means of 2015–2019 compared to those from 2010–2014 (Ford 2022). These 5-year geometric means increased by an average of 63% (range 1–223%) for the populations that increased, and decreased by 28% (North Fork Stillaguamish) and 38% (Cascade) for the two populations that declined. The 5-year geometric mean abundance for the entire ESU was 23,370 natural-origin adults for the 2015–2019 time period, and only 17,022 for the previous 5-year period; representing an overall increase of 37%. Recent natural-origin escapement abundance is above the NMFS-derived rebuilding threshold for 10 populations, between the critical and rebuilding thresholds for 4 populations, and below the critical threshold for 8 populations (Table 5). Productivity is negative for most populations (Figure 7).

Trends in long-term growth rate of natural-origin escapement are generally higher than growth rate of natural-origin recruitment (i.e., abundance prior to fishing) indicating some stabilizing influence on escapement, possibly from past reductions in fishing-related mortality (Ford 2022). Since 1990, 13 populations show long-term growth rates that are at or above replacement for natural-origin escapement including populations in four of five regions. Currently, only five populations, in two regions, show long-term neutral to positive growth rates in natural-origin recruitment. Additionally, most populations are consistently well below the productivity goals identified in the recovery plan. Although long-term trends (1990 forward) vary for individual populations across the ESU, currently 20 populations exhibit a stable or increasing long-term trend in total natural escapement. Thirteen of 22 populations show a growth rate in the 18-year geometric mean natural-origin spawner escapement that is greater than or equal to 1.00.

In addition to including additional recent years of spawning data compared to the 2015 status review, Ford (2022) also incorporates updates and corrections made in past escapement, age, and hatchery contribution data for many of the populations. Thus, trends represented here may be different than those discussed in previous Biological Opinions.

Despite the recent increases in natural-origin spawner abundances in the most recent five-year period, long-term trends in both abundance and productivity in most Puget Sound populations remain below the levels necessary for recovery. Indices of spatial distribution and diversity have not been developed at the population level, though diversity at the ESU level may be declining (Ford 2022).

Table 5. Summary of selected recent spawner abundance data, and status thresholds for Puget Sound Chinook salmon. NO = natural-origin. Populations with recent 5-year geometric mean NO abundance at or below their critical escapement threshold are bolded. Populations with recent 5-year values exceeding their rebuilding NO escapement threshold are italicized.

Biogeographical region (BGR)	Population	Geometric mean NO spawner abundance, 2015–2019 (total spawners)[a]	% change in abundance from 2010–2014	Critical Escapement Threshold[b]	Rebuilding Escapement Threshold[c]	Recovery spawner target (productivity)[d]		Mean % NO fish in escapement, 2015–2019[e]
						at high productivity	at low productivity	
Georgia Basin	**NF Nooksack**	137 (1,553)	1 (29)	[200]	500	3,800 (3.4)	16,000 (1.0)	13
	SF Nooksack	42 (106)	223 (203)	[200]		2,000 (3.6)	9,100 (1.0)	45
Whidbey/ Main Basin	*Upper Skagit*	9,568 (10,521)	35 (41)	738	5,740	5,380 (3.8)	26,000 (1.0)	91
	Lower Sauk	635 (649)	69 (56)	[200]	371	1,400 (3.0)	5,600 (1.0)	98
	Lower Skagit	2,130 (2,640)	50 (71)	281	2,131	3,900 (3.0)	16,000 (1.0)	84
	Upper Sauk	1,318 (1,330)	54 (51)	130	470	750 (3.0)	3,030 (1.0)	99
	Suiattle	640 (657)	70 (74)	170	223	160 (2.8)	610 (1.0)	97
	Cascade	185 (223)	-38 (-30)	130	148	290 (3.0)	1,200 (1.0)	86
	NF Stillaguamish	302 (762)	-28 (-23)	300	550	4,000 (3.4)	18,000 (1.0)	45
	SF Stillaguamish	37 (96)	9 (41)	[200]	300	3,600 (3.3)	15,000 (1.0)	46
	Skykomish	1,736 (2,806)	3 (14)	400	1,491	8,700 (3.4)	39,000 (1.0)	62
	Snoqualmie	856 (1,146)	2 (6)	400	816	5,500 (3.6)	25,000 (1.0)	75
Central/ South Sound	*Cedar*	889 (1,253)	27 (37)	[200]	282*	2,000 (3.1)	8,200 (1.0)	71
	Sammamish	126 (879)	54 (-32)	[200]	[1,250]	1,000 (3.0)	4,000 (1.0)	16
	Duwamish/Green	1,822 (6,373)	132 (202)	400	1700	-	27,000 (1.0)	30
	White	895 (6,244)	37 (189)	[200]	488*	-	-	15
	Puyallup	577 (1,942)	28 (71)	[200]	797*	5,300 (2.3)	18,000 (1.0)	32
	Nisqually	766 (1,841)	59 (1)	[200]	1,200**	3,400 (3.0)	13,000 (1.0)	47
Hood Canal	**Skokomish**	265 (2,074)	95 (40)	452	1,160	-	-	16
	Mid-Hood Canal	196 (222)	145 (-25)	[200]	[1,250]	1,300 (3.0)	5,200 (1.0)	89
Strait of Juan de Fuca	**Dungeness**	114 (476)	73 (71)	[200]	925**	1,200 (3.0)	4,700 (1.0)	25
	Elwha	134 (2,810)	89 (108)	[200]	[1,250]	6,900 (4.6)	17,000 (1.0)	5

[a] Source: Ford (2022).
[b] The Critical Escapement Threshold represents a boundary below which uncertainties about population dynamics increase substantially. Values represent thresholds under current habitat and environmental conditions (McElhany et al. 2000; NMFS 2000b; 2018a). Values in brackets ([]) are based on generic VSP guidance (McElhany et al. 2000; NMFS 2006b).
[c] The Rebuilding Escapement Threshold represents an escapement level consistent with estimates of maximum sustainable yield (MSY) under the current productivity and capacity of the available habitat. Values represent thresholds under current habitat and environmental conditions (McElhany et al. 2000; NMFS 2000b; 2018a). Values in brackets ([]) are based on generic VSP guidance (McElhany et al. 2000; NMFS 2006b). Values with asterisks (*) are based on spawner-recruit assessment (Puget Sound Indian Tribes and WDFW 2017). Values with two asterisks (**) are based on alternative habitat assessment.
[d] Source: NMFS (2006b). Measured as recruits/spawner associated with the number of spawners at Maximum Sustained Yield under recovered conditions.
[e] Source: Ford (2022).

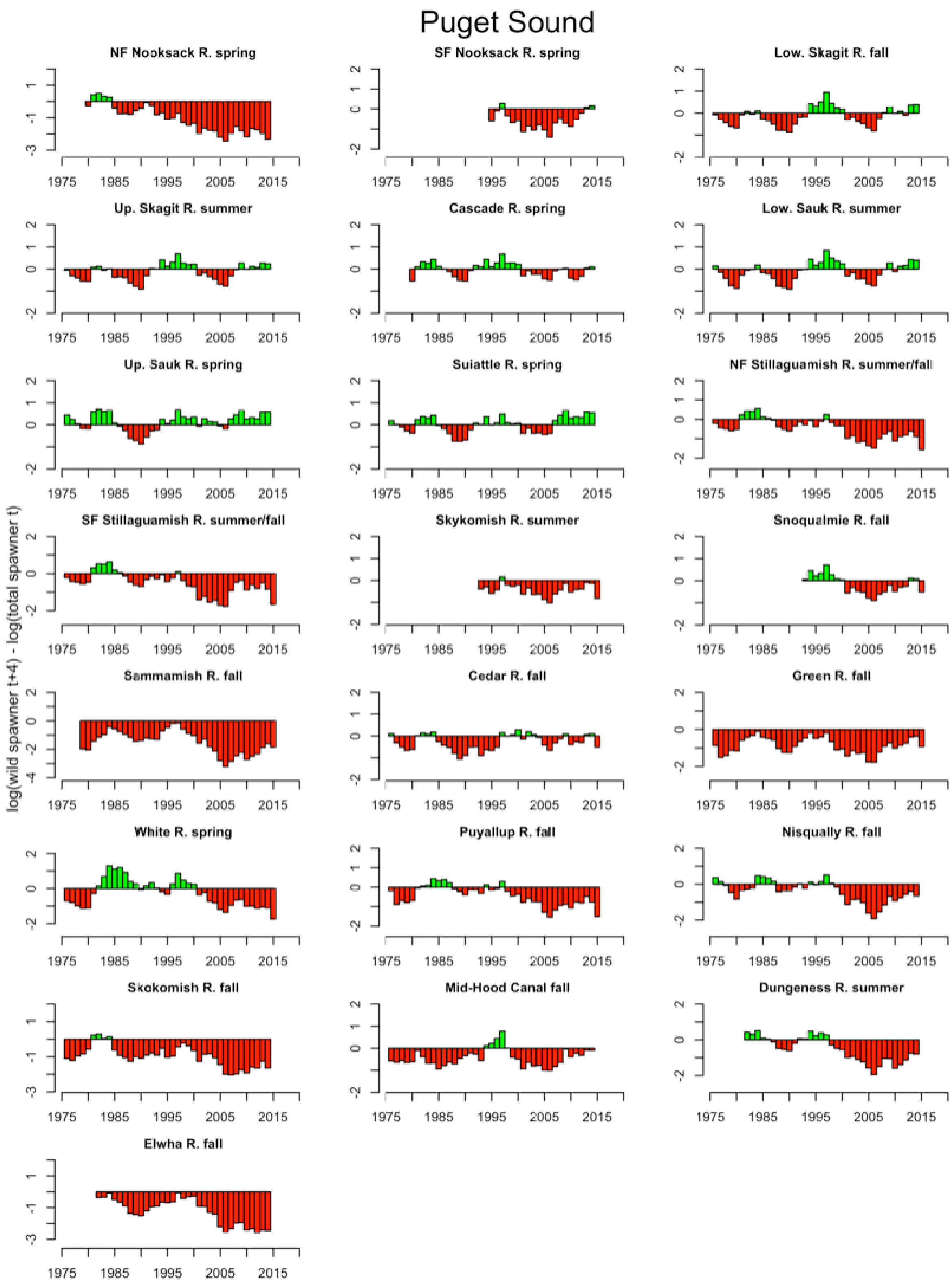

Figure 7. Trends in population productivity, estimated as the log of the smoothed natural-origin spawning abundance in year t minus the smoothed natural-origin spawning abundance in year (t – 4). From Ford (2022).

On January 19, 2007 (72 FR 2493), NMFS adopted the recovery plan for Puget Sound Chinook salmon (NMFS 2006b; SSDC 2007), which describes the ESU's population structure, identifies populations essential to recovery of the ESU, establishes recovery goals for most of the populations, and recommends habitat, hatchery and harvest actions designed to contribute to the recovery of the ESU. It adopts ESU and population level viability criteria recommended by the TRT (Ruckelshaus et al. 2002; NMFS 2006b; SSDC 2007), summarized as follows:

1) The viability status of all populations in the ESU is improved from current conditions. The final ESU-wide scenario for delisting will likely include populations with a range of risk levels, but when considered in the aggregate, the risks must be sufficiently low to assure persistence of the ESU.
2) Within each of the five Puget Sound biogeographical regions, at least two to four populations are viable[3] depending on the historical biological characteristics and acceptable risk levels within each region.
3) Within each of the five Puget Sound biogeographical regions, at least one population is viable from each of the major diversity groups historically present.
4) Tributaries to Puget Sound not identified as primary freshwater habitat (Figure 6) for any of the 22 identified natural populations are functioning in a manner that is sufficient to support ESU recovery.
5) Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery
6) Populations that do not meet viability criteria are sustained to provide ecological services and preserve options for ESU recovery. Furthermore, the indirect effects of habitat, hatchery, and harvest management actions targeted at non-viable populations are consistent with ESU recovery.

NMFS further classified Puget Sound Chinook salmon populations into three tiers (Figure 6) based on its draft Population Recovery Approach (PRA) using a variety of life history, production and habitat indicators, and the Puget Sound Recovery Plan biological delisting criteria (NMFS 2010a). NMFS understands that there are non-scientific factors, (e.g., the importance of a salmon or steelhead population to tribal culture and economics) that are important considerations in salmon and steelhead recovery. Tier 1 populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 populations play a secondary role in recovery of the ESU, and Tier 3 populations play a tertiary role. When NMFS analyzes proposed actions, it evaluates impacts at the individual population scale for their effects on the viability of the ESU. Accordingly, impacts on Tier 1 populations would be more likely to affect the viability of the ESU as a whole than similar impacts to Tier 2 or 3 populations.

[3] McElhany et al. (2000) defines a viable salmonid population "as an independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame."

The limiting factors described in SSDC (2007) and NMFS (2006b) include:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.
- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.
- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations.
- Salmon harvest management: Total fishery exploitation rates have decreased 14 to 63% from rates in the 1980s, but low natural-origin Chinook salmon population abundance in Puget Sound still require enhanced protective measures to reduce the risk of overharvest.

The severity and relative contribution of these factors varies by population. One theory for the declines in fish populations in Puget Sound in the 1980s and into the 1990s is that they may reflect broad-scale shifts in natural limiting conditions, such as increased predator abundances and decreased food resources in ocean rearing areas. These factors are discussed in more detail in the Environmental Baseline (Section 2.4).

Whidbey/Main Basin Biogeographical Region (BGR) and the Skagit River Populations

The Whidbey/Main Basin BGR contains 10 of the 22 Puget Sound ESU Chinook salmon populations, including 6 populations in the Skagit River watershed (Table 5). The Suiattle and one each of the early, moderately early, and late spawn-timing populations within the BGR need to be viable for ESU recovery. This BGR currently accounts for about 45% and 74% of natural spawners and natural-origin spawners[4] in the ESU, respectively (Ford 2022). The majority of extant ESU populations with early run-timing are in this BGR.

Considering abundance in a number of different ways—for example, short-term geometric means versus long-term population growth rates—the data do not support any particular conclusion across the BGR. Abundance varies greatly among the populations. The Skagit populations comprise the majority (approximately 83%) of natural-origin Chinook salmon in the BGR (Ford 2022). One population (Upper Skagit) has recent abundances within recovery targets (Table 5). Seven populations in the BGR, including 5 of 6 in the Skagit, are above their rebuilding thresholds (Table 5) based on estimates of the most recent 5-year geometric mean abundances (2015–2019), although one of these populations (Cascade) appears to be in decline (see below). Aside from the Cascade population, the remaining 5 Skagit populations increased in abundance by 35–70% from 2010–2014 to 2015–2019. One population in the BGR (SF Stillaguamish) is below its Critical Escapement Threshold with very low albeit seemingly stable abundances. One other population (NF Stillaguamish) is just above its Critical Escapement

[4] Natural spawners include all fish that spawn naturally regardless of origin (i.e., hatchery- or natural-origin). Natural-origin includes only fish originating from parents that spawned naturally.

Threshold and shows recent declines in abundance. The remaining 2 populations in the BGR (Skykomish, Snoqualmie) are both above their Rebuilding Escapement Thresholds with stable abundances. Long-term (1990-2019) escapement trends are increasing or stable for all but one population (SF Stillaguamish) (Ford 2022). Five of the 6 Skagit populations (all but the Cascade) have had productivities greater than zero in recent years, and are the only such populations in the BGR and in the ESU. All 6 Skagit populations are PRA Tier 1, and are the only Tier 1 populations in the BGR (Table 6). In summary, the Whidbey/Main Basin BGR generally, and the Skagit River basin in particular, are strongholds of the ESU in terms of life history diversity, spatial structure, and abundance.

Table 6. Extant Chinook salmon populations in the Whidbey/Main Basin biogeographical region, including PRA Tier Assignment and recovery criteria (NMFS 2010a).

Population	Run time	PRA Tier Assignment	Need to be at low risk for ESU viability
Upper Skagit	moderately early / summer	1	Suiattle and one each of the early, moderately early, and late forms
Lower Skagit	late / fall	1	
Upper Sauk	early / spring	1	
Lower Sauk	moderately early / summer	1	
Suiattle	very early / spring	1	
Cascade	moderately early / spring	1	
North Fork Stillaguamish	early / summer	2	
South Fork Stillaguamish	moderately early / fall	2	
Skykomish	late / summer	2	
Snoqualmie	late / fall	3	

The six Skagit River watershed Chinook salmon populations are defined and distributed across the basin as follows (Figure 8) (Marshall et al. 1995; SRSC and WDFW 2005; Ruckelshaus et al. 2006):

- *Upper Skagit River Summer Chinook*. This population spawns in the mainstem and certain tributaries of the Skagit River, from above the confluence of the Sauk River to Newhalem. Spawning also occurs in the lower five miles of the Cascade River, and in Diobsud, Bacon, Falls, Goodell, and Illabot Creeks. Gorge Dam, a hydroelectric facility operated by Seattle City Light, restricts access above RM 94, though anadromy above this point may have been limited due to natural obstructions (Smith 2003).
- *Lower Sauk River Summer Chinook*. This population spawns primarily in the Sauk River from its mouth to RM 27, separate from the Upper Sauk Spring Chinook salmon spawning areas above RM 31.
- *Lower Skagit River Fall Chinook*. This population spawns downstream of the mouth of the Sauk River and in the larger tributaries including Hansen, Alder, Grandy, Pressentin, Jackman, Jones, Nookachamps, O’Toole, Day, and Finney Creeks.

- *Upper Sauk River Spring Chinook*. This population spawns in the mainstem Sauk River above RM 31, in the lower North Fork Sauk River to the falls, and in the South Fork Sauk River to about RM 3.5–5. Included in this population are fish spawning in White Chuck River, and tributaries Camp, Pugh, and Owl Creeks.
- *Suiattle River Spring Chinook*. This population spawns in several Suiattle River tributaries including Buck, Downey, Sulpher, Tenas, Lime, Circle, Straight, Milk, and Big Creeks.
- *Cascade River Spring Chinook*. Sometimes referred to as Upper Cascade Springs, this population spawns in the mainstem Cascade River above RM 8.1, in the lower North and South Forks, and in tributaries Marble, Found, and Kindy Creeks. They are thus spatially separated from the Upper Skagit River Summer Chinook which use the lower 5 miles of the Cascade River.

The current abundance of Skagit River natural-origin Chinook salmon is substantially reduced from historical levels. For example, terminal net catch dropped from an average of 35,000 fish prior to 1945, to fewer than 5,000 fish during the 1990's (SRSC and WDFW 2005). Similarly, recruitment numbers ranged from 40,000 to more than 60,000 fish during much of the 1980's, then fell to 20,000 fish or less during the 1990's. Spatial distribution and diversity appear largely intact relative to historical conditions. There is some evidence that Chinook salmon used habitat above the Baker River dams, but there is no evidence that this area was used in large numbers by Chinook salmon or that an independent population existed here (Ruckelshaus et al. 2006). In the mainstem Skagit River, anadromy above Gorge Dam at RM 94 may have been limited due to possible natural barriers, though this is uncertain. Earlier reports did not identify evidence of appreciable spawning or independent populations above this point (Smith 2003; Ruckelshaus et al. 2006). Proportion of hatchery-origin fish in natural spawner escapements has typically been relatively low (Ford 2022), and is estimated to be 16 percent or less for all Skagit River populations for the most recent 5-year period (2015–2019) (Table 5).

Since the time of listing, natural spawner escapement abundances have increased or remained stable for five of the six Skagit River populations (Figure 9). Conversely, the Cascade Spring population appears to be in a steady, strongly statistically significant long-term decline (Figure 10) (Spearman correlation coefficient, 2001–2021 = -0.729; $p < 0.001$; $n = 21$). Recent abundances, beginning with 2018, are among the lowest on record. The geometric mean abundance for the most recent 4-year period (2018–2021), 140 fish, is the lowest for any 4-year period ever recorded (the previous low was 162 fish in 1987). These figures include hatchery-origin spawners because hatchery-origin spawners cannot be accurately accounted for in annual escapement estimates due to very low carcass sample sizes most years[5]. However, applying the most recent 5-year aggregate estimate of the proportion of hatchery-origin spawners (7.5%)[6], yields a mean natural-origin abundance of 129.5 fish—just below the Critical Escapement Threshold—for the most recent 4-year period (2018–2021). Though 5-year means, not 4-year,

[5] WDFW began sampling carcasses in the upper Cascade River where the natural spring Chinook population spawns in 2005. Since then (2005–2021), the mean annual number of carcasses sampled is 10, the median is 6, and the range is 0–35. Only 7 years (41%) have more than 6 carcasses sampled (2005, 2006, 2012, 2013, 2016, 2017, 2021).

[6] Aggregate carcass sampling data includes the following [year (number of carcasses sampled, number of hatchery-origin fish in the sample)]: 2017 (22,1), 2018 (2,0), 2019 (3,2), 2020 (0,0), 2021 (13,0). Carcass sample data from WDFW.

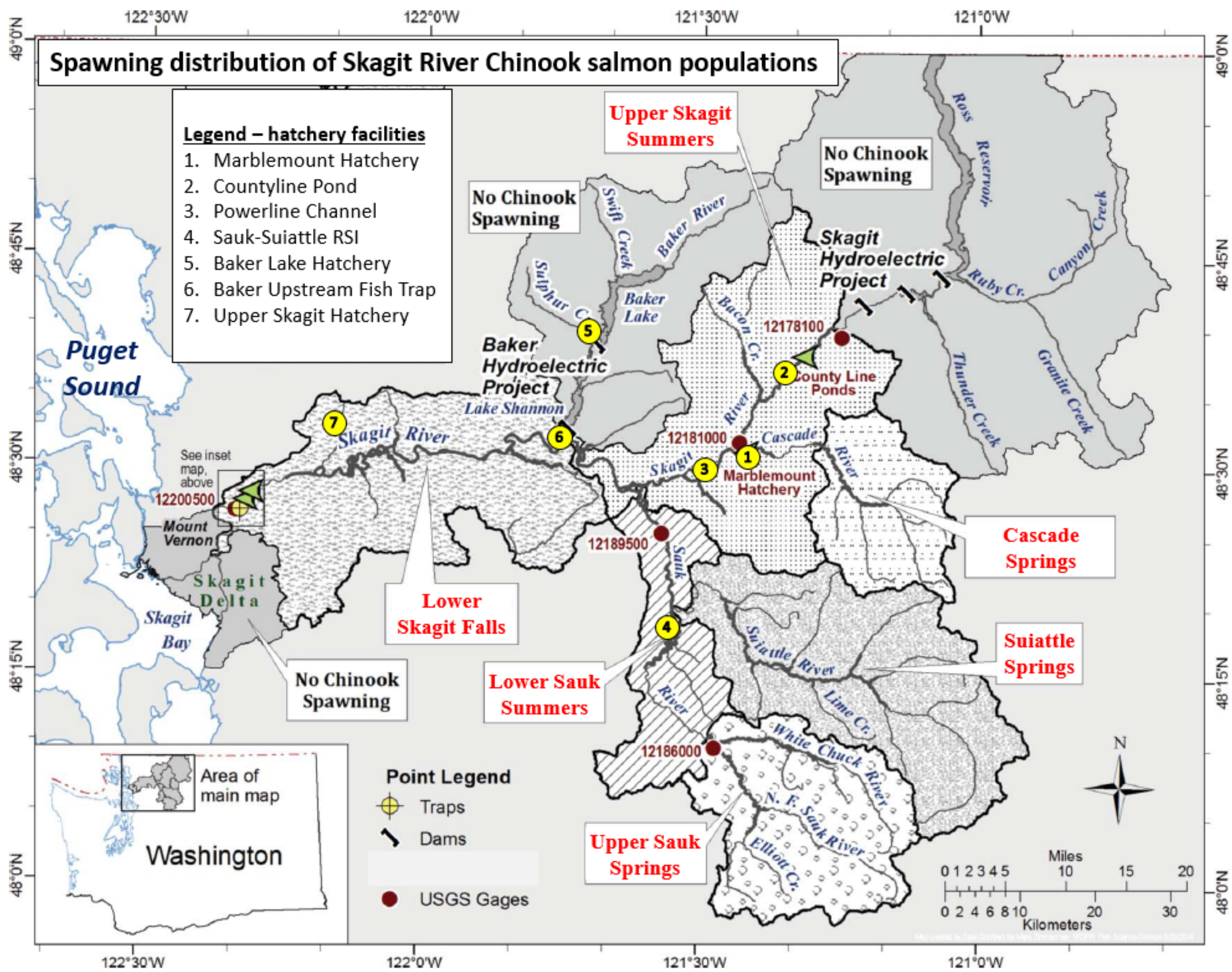

Figure 8. Spawning distribution of the six Skagit River Chinook salmon populations (red text), including approximate locations of hatcheries and related facilities relevant to this consultation (yellow circles numbered 1–4, 7). Rivers and tributaries shown are for reference only and are not intended to indicate Chinook salmon presence. Adapted from Zimmerman et al. (2015).

are typically used for evaluating a population's status (e.g., Ford 2022), these data and trends suggest that the Cascade River spring Chinook population is at imminent risk of falling below the Critical Escapement Threshold.

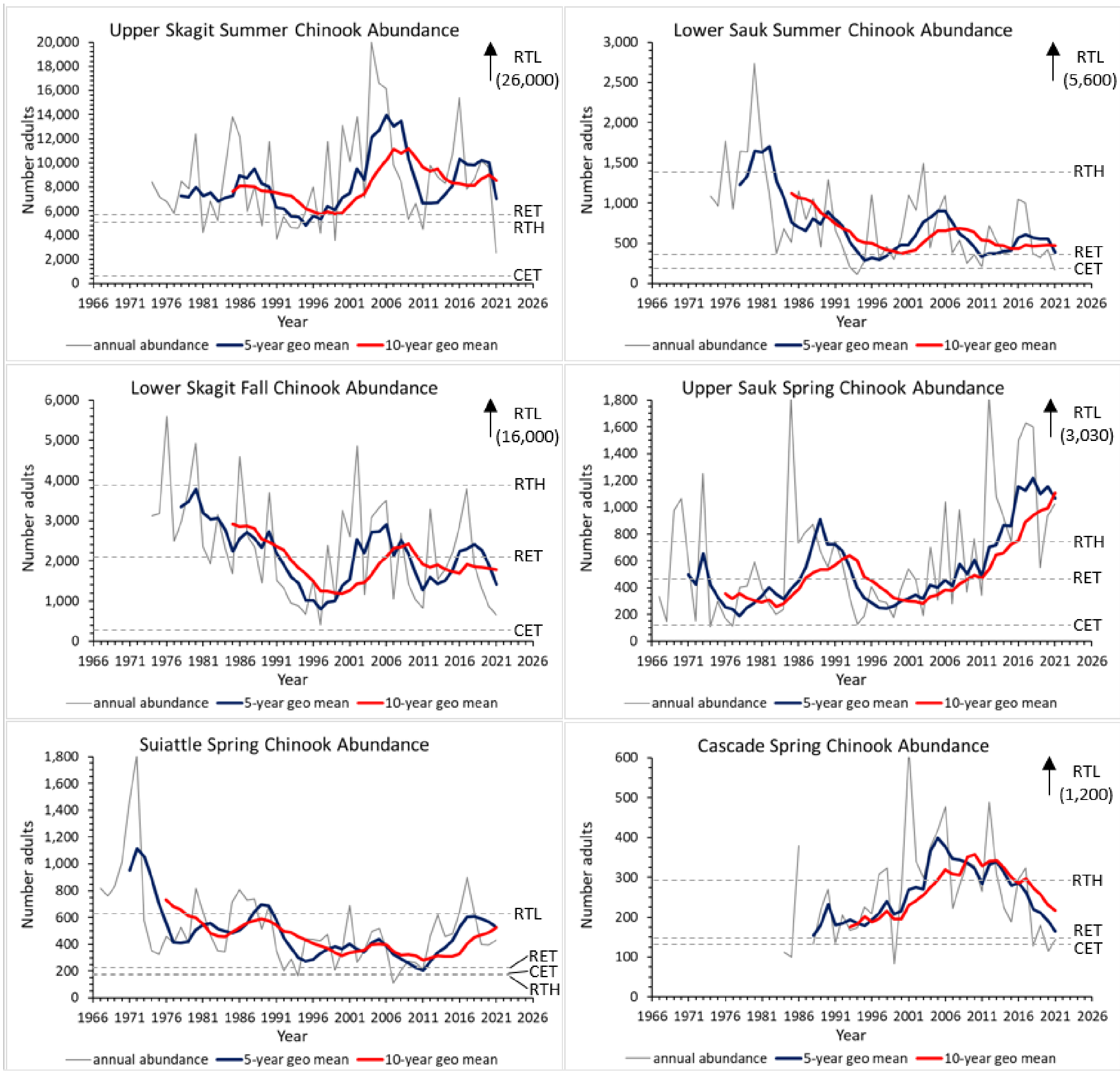

Figure 9. Natural spawner escapement estimates (NO+HO) for Skagit River Chinook salmon populations for the period of record. Recovery targets and escapement thresholds are shown for reference. Though these are applied to natural-origin fish only, abundance of hatchery-origin fish is typically a small proportion of each population (Table 5) (Ford 2022) and has little effect on the trends shown. CET = Critical Escapement Threshold; RET = Rebuilding Escapement Threshold; RTH = recovery spawner target at high productivity; RTL = recovery spawner target at low productivity. Escapement estimates from Skagit co-managers. The 2021 estimates are preliminary. See Table 5 for recovery targets and escapement thresholds.

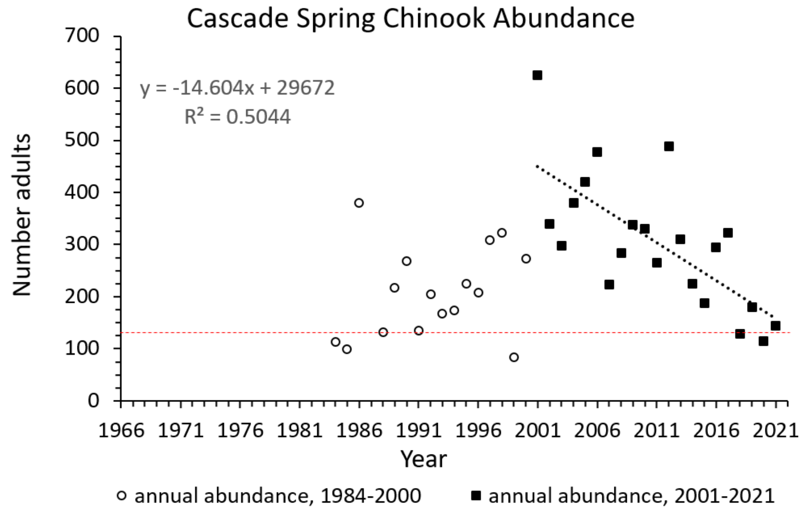

Figure 10. Annual Cascade River spring Chinook salmon natural spawner escapement estimates (NO+HO), and linear regression for the period 2001–2021. The 2021 estimate is preliminary. The Critical Escapement Threshold (red horizontal dashed line) is shown for reference. Though this is applied to natural-origin fish only, abundance of hatchery-origin fish is typically a small proportion of the escapement (Table 5) (Ford 2022) and has little effect on the trend shown. Escapement estimates from Skagit co-managers.

Spawn timing of the six Skagit Chinook populations is as follows (SRSC and WDFW 2005; SRSC and WDFW 2018; WDFW 2018b; 2019; 2022b):

- The three spring-run populations begin entering freshwater in April and spawn from late July to September or October.
- The two summer-run populations spawn from late August to October or early November.
- The Lower Skagit Fall population enters the river and spawns later, typically spawning from mid-September through mid-November.

In general, about two-thirds of spawners are 4-year-olds[7], and the remainder are mostly 3- and 5-year-olds (PSIT and WDFW 2010). Juveniles of all populations may exhibit either ocean- or stream-type life histories, though the relative proportions of each vary by adult return timing. Fish in the Summer and Fall populations are predominantly ocean-type (82–97 ocean-type; 3–18% stream-type), whereas the Spring populations have a much larger proportion of stream-type fish (49–56% ocean-type; 45–51% stream-type), based on analysis of scales collected from adults on the spawning grounds (SRSC and WDFW 2005).

[7] Adult spawner age is defined as its spawning year minus its parent spawning year. For example, a fish that spawned in 2020 whose parents spawned in 2016 is considered a 4-year-old fish. This is a different ageing system than that used to define juvenile ages in freshwater. Juvenile age in freshwater is based on fry emergence timing from redds. For example, Skagit River Chinook salmon typically emerge early in the calendar year, and are considered age-0 juveniles for the remainder of the calendar year. For fish that remain in freshwater, the next calendar year they are considered age-1 juveniles.

Juvenile Chinook salmon outmigrants in the Skagit River basin exhibit the following four life history types, as described in SRSC and WDFW (2005) and (Greene et al. 2016), and updated with recent data as indicated:

- *Bay-rearing fry migrants*. These fry emerge from egg pockets and migrate quickly downstream to Skagit Bay, usually in February and March (Kinsel 2019b) at an average length of 41 mm FL (range 30–48 mm FL) (Kinsel 2019a). Fry migrants do not rear extensively in delta habitat. Some fry migrants take up residence in pocket estuary habitat. These areas are thought to provide fry migrants with a survival or growth advantage over other nearshore habitats.

- *Delta-rearing fry migrants*. Delta rearing fry emerge from egg pockets and migrate downstream at the same time as fry migrants. Instead of directly entering Skagit Bay, they reside in tidal delta[8] habitat for a period ranging from several weeks up to several months, reaching an average size of 74 mm FL (observed range from otoliths is 49–126 mm FL). The average delta residence period for delta rearing Chinook salmon in 1995 and 1996, combined, was 34.2 days. Following the delta rearing period, these fish migrate to Skagit Bay, usually starting in late May or June.

- *Subyearling (or "parr") migrants*[9,10]. These fish rear for a short period of time in freshwater—weeks to months—achieving a similar size as their delta-rearing cohorts over the same time period. Following freshwater residence, subyearling migrants outmigrate from February to July, peaking in May and June (Kinsel 2019b). The average size of recent subyearling migrants is 61 mm FL (range 48–99 mm FL) (Kinsel 2019a). Subyearling migrants do not reside in tidal delta habitats, instead moving through the delta to Skagit Bay. Some of these fish may reside in off-channel habitat within the large river floodplain areas of the Skagit River. Depending on the total outmigration population size, subyearling migrants make up approximately 15% to over 60% of the age-0 outmigration each year (fry and subyearlings combined) (Zimmerman et al. 2015).

- *Yearling migrants*. These fish rear in freshwater for one year prior to outmigrating. Movement patterns and habitat preferences within freshwater are largely unknown. Yearlings migrate to the estuary mostly from March through May, but may migrate from mid-January into July (Kinsel 2019b). The average size of recent yearling migrants is 100 mm FL (range 69–135 mm FL) (Kinsel 2019a). Yearlings do not reside in tidal delta habitats for an extended period of time like delta-rearing migrants. Yearlings seem to

[8] The tidal delta is generally defined as downriver from RM 9 (SRSC and WDFW 2005).

[9] Throughout this document, we use the following three mutually exclusive categories to define life-history stage of juvenile salmonids in freshwater: "fry" for age-0 fish that have recently emerged from redds (typically on the order of days to weeks); "subyearlings" for age-0 fish that are older and larger than fry; and, "yearlings" as age-1 fish. Further, we use the term "parr" for freshwater-rearing juvenile salmonids of any age class that are no longer fry but have not yet begun smoltification (the series of physiological changes that juvenile salmonids undergo to prepare them to survive in sea water).

[10] The term "parr migrant" is often used for these fish in the Skagit River. However, this may be confusing as the term "parr" is typically applied to juvenile salmonids that are rearing in freshwater, not those that are actively migrating to saltwater (Quinn 2018). Thus, we use the term "subyearling migrant" in place of "parr migrant" to avoid confusion.

pass through delta habitats, possibly lingering briefly, before they move to nearshore areas. Yearlings are rarely found in shallow intertidal environments, and are most commonly detected in deeper subtidal or offshore habitats. Residence in nearshore areas of Skagit Bay by yearlings appears to be shorter than ocean type life histories.

Juvenile outmigration abundance is dominated by fry outmigrants (bay- and delta-rearing combined), which typically account for 78% of all outmigrants, followed by subyearings at 22%, and yearlings at less than 1% (Figure 11), based on WDFW outmigrant trapping near Mount Vernon at RM 17 from 2008 to 2017 (Figure 8) (Seiler et al. 2001; 2002; Seiler et al. 2003; 2004; Kinsel 2019b). The relative abundance of bay- to delta-rearing fry is not known, though a 2005 capacity evaluation estimated that the delta could support about 1.5 times more fry than the bay (Beamer et al. 2005). From 2008 to 2017, outmigrant abundance averaged 2,440,445 fry (range 801,667–4,603,262), 677,917 subyearlings (range 116,601–1,216,100), and 17,794 yearlings (range 4,256–26,266), respectively (Kinsel 2019b). Subyearling and delta-rearing fry outmigrants appear to account for the substantial majority of adult returns (Beamer et al. 2005).

Based on WDFW outmigrant trapping near Mount Vernon at RM 17 (Figure 8), juvenile Chinook salmon outmigrate from the Skagit River basin primarily from January through July. Peaks occur in February–March for fry, May–June for subyearling, and April–May for yearling outmigrants (Figure 12) (Seiler et al. 2001; 2002; Seiler et al. 2003; 2004; Kinsel 2019b). For life histories that rear in freshwater (subyearling and yearling migrants), movement within the river system between fry emergence and marine outmigration is not well known. Some individuals likely remain relatively near spawning grounds, while others likely disperse to downstream freshwater areas to rear (subyearling and yearling migrants) and overwinter (yearling migrants only) (e.g., Daum and Flannery 2011, and references therein; Shrimpton et al. 2014, and references therein).

2.2.2. Critical Habitat for Puget Sound Chinook Salmon

Designated critical habitat for the Puget Sound Chinook salmon ESU includes localized estuarine areas and specific river reaches associated with the following subbasins: Strait of Georgia, Nooksack, Upper Skagit, Sauk, Lower Skagit, Stillaguamish, Skykomish, Snoqualmie, Snohomish, Lake Washington, Green, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha (70 FR 52630, September 2, 2005). The designation also includes some nearshore areas extending from extreme high water out to a depth of 30 meters and adjacent to watersheds occupied by the 22 extant natural populations because of their importance to rearing and migration for Chinook salmon and their prey, but does not otherwise include offshore marine areas. There are 61 watersheds (HUC5 basins) within the range of this ESU. Twelve watersheds received a low rating, nine received a medium rating, and 40 received a high rating of conservation value to the ESU (NMFS 2005a). All nineteen nearshore marine areas also received a rating of high conservation value. Of the 4,597 miles of stream and nearshore habitat eligible for designation, 3,852 miles are designated critical habitat (NMFS 2005a). Of the 11 watersheds within the Skagit River basin, 10 received a “high” conservation value rating, and one (Baker River) received a “medium” rating (NMFS 2005a).

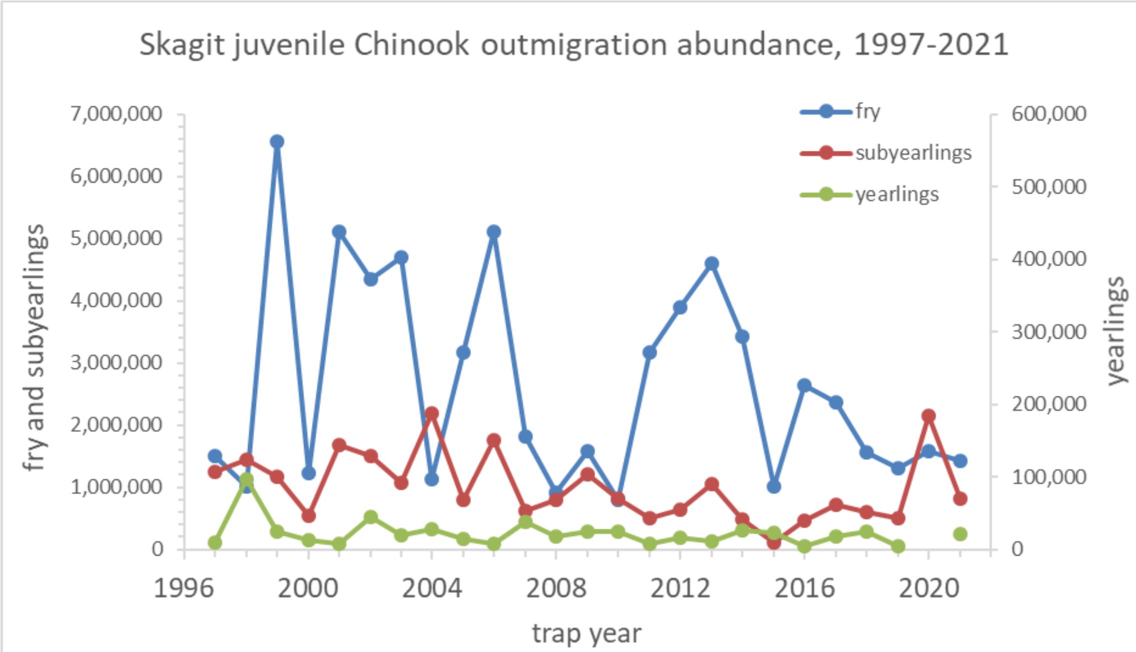

Figure 11. Annual abundance of Skagit River natural-origin juvenile Chinook salmon outmigrants, as determined from WDFW outmigrant trapping at Skagit River RM 17, 1997–2021. Abundance estimates from WDFW.

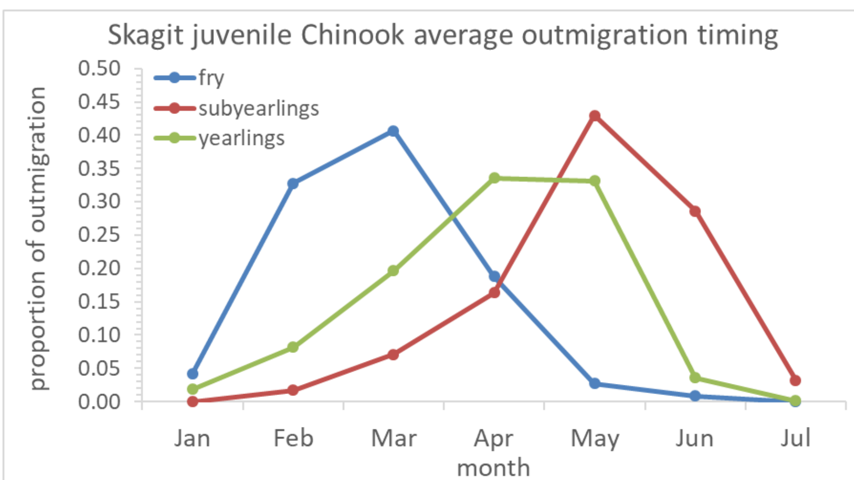

Figure 12. Average outmigration timing of Skagit River natural-origin juvenile Chinook salmon, as determined from WDFW outmigrant trapping at Skagit River RM 17, 2014–2018. Traps were operated from late January through mid-July all years. Previous work indicates that little outmigration occurs outside of this time. Sources: Seiler et al. (2001; 2002); Seiler et al. (2003; 2004); Kinsel (2019b).

NMFS determines the range-wide status of critical habitat by examining the condition of its primary constituent elements (PCEs) identified when the 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). PCEs for Puget Sound Chinook salmon (70 FR 52731, September 2, 2005), including the Skagit River watershed salmon populations, include:

1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
2. Freshwater rearing sites with: (i) Water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) Water quality and forage supporting juvenile development; and (iii) Natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
3. Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
4. Estuarine areas free of obstruction and excessive predation with: (i) Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and (iii) Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.
5. Nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.
6. Offshore marine areas with water-quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Critical habitat is designated for Puget Sound Chinook salmon within the Skagit River watershed action area. Critical habitat includes the estuarine areas and the stream channels within the proposed stream reaches of the Skagit River watershed, and includes a lateral extent as defined by the ordinary high-water line (33 CFR 319.11). The Puget Sound Critical Habitat Analytical Review Team identified the following management activities that may affect the PCEs in one or more of the Skagit River basin watersheds: agriculture, channel modifications (e.g., rip rap, diking), dams, forestry, urbanization, road building and maintenance, and wetland loss and removal (NMFS 2005a).

2.2.3. Puget Sound Steelhead DPS

Oncorhynchus mykiss has an anadromous form, commonly referred to as steelhead. Steelhead differ from other Pacific salmon in that they are iteroparous (capable of spawning more than once before death). Adult steelhead that have spawned and returned to the sea are referred to as kelts. Averaging across all West Coast steelhead populations, 8% of spawning adults have spawned previously, with coastal populations containing a higher incidence of repeat spawning compared to inland populations (Busby et al. 1996). Steelhead express two major life history types—summer and winter. Puget Sound steelhead are dominated by the winter life history type and typically migrate as smolts to sea at age two. Seaward emigration occurs from April to mid-May, with fish typically spending one to three years in the ocean before returning to freshwater. They migrate directly offshore during their first summer, and move southward and eastward during the fall and winter (Hartt and Dell 1986). Adults return from December to May, and peak spawning occurs from March through May. Summer steelhead adults return from May through October and peak spawning occurs the following January to May (Hard et al. 2007). Temporal overlap exists in spawn timing between the two life history types, particularly in northern Puget Sound where both summer and winter steelhead are present, although summer steelhead typically spawn farther upstream above obstacles that are largely impassable to winter steelhead (Behnke and American Fisheries Society 1992; Busby et al. 1996).

The Puget Sound steelhead DPS was listed as threatened on May 11, 2007 (72 FR 26722), and the most recent NMFS status review (NMFS 2016) determined that the DPS should remain threatened. The DPS includes all naturally spawned anadromous winter and summer steelhead populations within the river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington, bounded to the west by the Elwha River (inclusive) and to the north by the Nooksack River and Dakota Creek (inclusive) (Figure 13). Also included as part of the ESA-listed DPS are five hatchery-origin stocks derived from local natural steelhead populations and produced for conservation purposes (85 FR 81822, December 17, 2020). Non-anadromous "resident" *O. mykiss* occur within the range of Puget Sound steelhead, but are not part of the DPS due to key differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007). Puget Sound steelhead populations are aggregated into three extant Major Population Groups (MPGs) containing a total of 32 Demographically Independent Populations (DIPs) based on genetic, environmental, and life history characteristics (Myers et al. 2015) (Table 7). For simplicity, the term "population" will be used interchangeably with "DIP" throughout this document when referring to Puget Sound steelhead trout.

Pertinent information regarding the status of the species is described in detail in the NMFS 2022 Biological Viability Assessment Update (Ford 2022), and is summarized below. Sections of these status review documents pertaining to the Puget Sound Steelhead DPS are incorporated here by reference. Table 7 and Figure 14 summarize recent abundance and productivity for Puget Sound steelhead trout populations, including NMFS' recovery plan targets and results of the 2015 risk assessment. Abundance information is either insufficient or lacking entirely for approximately one-third of the populations, disproportionately so for summer-run populations. In most cases where no information is available it is assumed that abundances are very low.

All monitored Puget Sound steelhead populations are below escapement and productivity goals required for recovery—most are well below these goals—and many are at high risk of extirpation (Table 7) (Ford 2022). Since the 2016 status review, abundance of natural spawners increased by 25% across the DPS, based on 5-year geometric means of 2015–2019 compared to those from 2010–2014 (Ford 2022), although 7 of the 20 monitored populations declined in abundance. Abundances increased by an average of 62% (range 2–187%) for the 13 populations that increased, though abundances generally remained within the observed long-term range of

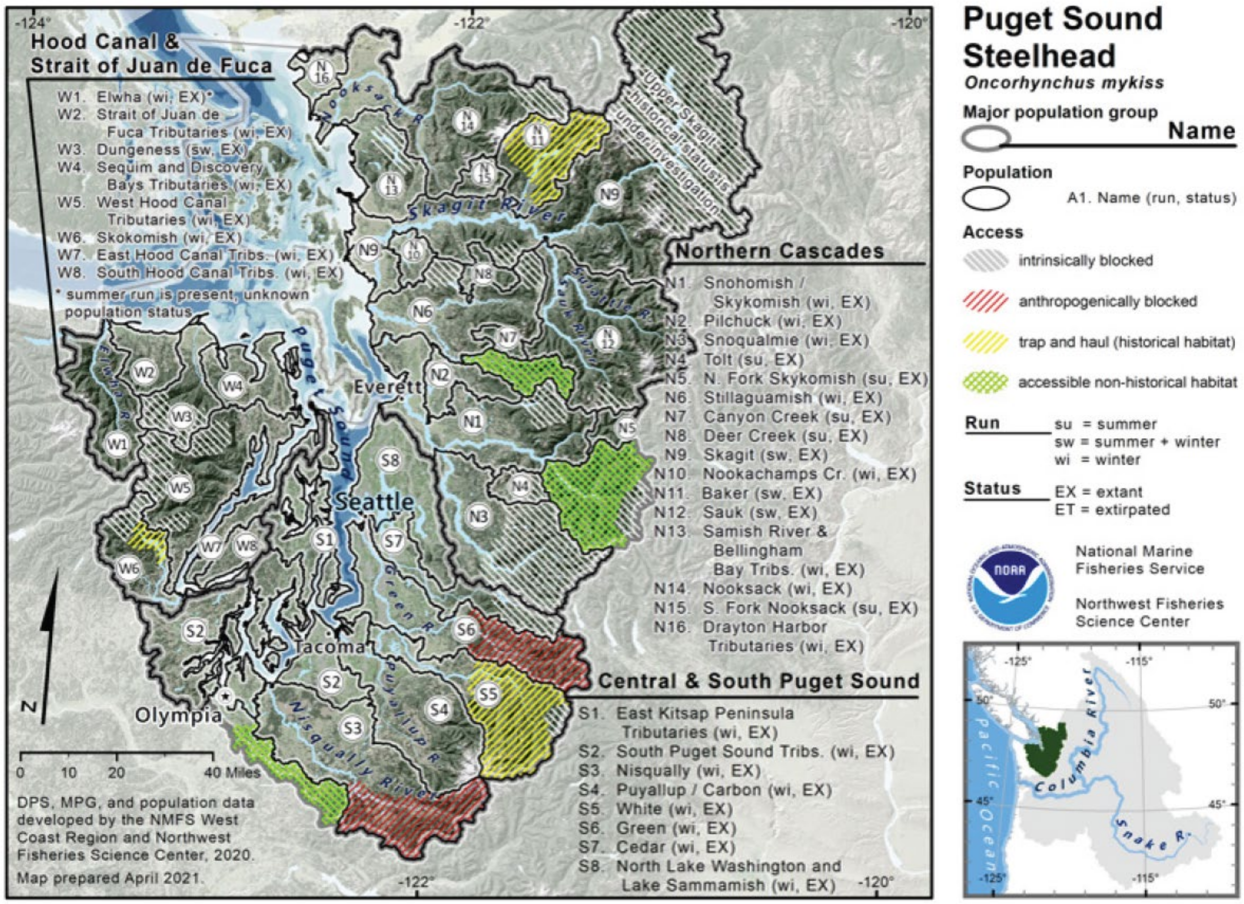

Figure 13. Puget Sound steelhead trout DPS populations delineated by NMFS, including Major Population Groups. From Ford (2022).

variability, with some exceptions. Abundances decreased by 28% (range 10–63%) for the 7 populations that declined. The 5-year geometric mean abundance for the entire DPS was 19,814 spawners for the 2015–2019 time period, and 15,865 spawners for the previous 5-year period; representing an overall increase of 25%. Recent productivities across the DPS have generally been mixed and variable with no clear and consistent trends (Figure 14). Indices of spatial distribution and diversity have not been developed at the population level, although recent improvements at passage barriers and changes in hatchery programs have enhanced DPS spatial structure and diversity, respectively (Ford 2022).

Table 7. Summary of selected recent abundance and productivity data, and status thresholds for Puget Sound Steelhead trout. NO = natural-origin.

Region	Population	Geometric mean spawner abundance, 2015–2019[a]	% change in abundance from 2010–2014	Extinction risk estimated in 2015 (QET)[b]	Recovery spawner target[c] at high productivity (R/S=2.3)	Recovery spawner target[c] at low productivity (R/S=1.0)
Northern Cascades MPG	Drayton Harbor Tbs.	-	-	-	1,100	3,700
	Nooksack R.	1,906	9	-	6,500	21,700
	SF Nooksack R. (S)	-	-	-	400	1,300
	Samish R. & Tbs.	1,305	74	L: 30% w/in 100 yrs (31)	1,800	6,100
	Skagit R.	7,181	12	L: 10% w/in 100 yrs (157)	15,000[d]	15,000
	Sauk R.			(103)		
	Nookachamps Cr.			(27)		
	Baker R.	-	-	(36)	1,100	3,800
	Stillaguamish R.	487	26	H: 90% w/in 25 yrs (67)	7,000	23,400
	Canyon Cr. (S)	-	-	-	100	400
	Deer Cr. (S)	-	-	-	700	2,300
	Snohomish/ Skykomish R.	690	-29	L: 40% w/in 100 yrs (73)	6,100	20,600
	Pilchuck R.	638	2	L: 40% w/in 100 yrs (34)	2,500	8,200
	Snoqualmie R.	500	-29	H: 70% w/in 100 yrs (58)	3,400	11,400
	Tolt R. (S)	40	-63	H: 80% w/in 100 yrs (25)	300	1,200
	NF Skykomish R. (S)	-	-	-	200	500
Central and South Puget Sound MPG	Cedar R.	6	50	H: 90% w/in few yrs of 2015 (36)	1,200	4,000
	N. Lake WA Tbs.	-	-	-	4,800	16,000
	Green R.	1,289	95	MH: 50% w/in 100 yrs (69)	5,600	18,700
	Puyallup/Carbon	936	150	H: 90% w/in 25–30 yrs	4,500	15,100
	White R.	451	-12	L: 40% w/in 100 yrs (64)	3,600	12,000
	Nisqually R.	1,368	187	H: 90% w/in 25 yrs (55)	6,100	20,500
	E. Kitsap Tbs.	-	-	-	2,600	8,700
	S. Sound Tbs.	-	-	-	6,300	21,200

Region	Population	Geometric mean spawner abundance, 2015–2019[a]	% change in abundance from 2010–2014	Extinction risk estimated in 2015 (QET)[b]	Recovery spawner target[c]	
					at high productivity (R/S=2.3)	at low productivity (R/S=1.0)
Hood Canal and Strait of Juan de Fuca (SJF) MPG	Elwha R.	1,241	82	H: 90% in 2015 (41)	2,619	2,619
	Dungeness R.	448	-13	H: 90% w/in 20 yrs (30)	1,200	4,100
	SJF Ind. Tbs.	95	-37	H: 90% w/in 60 yrs[e] (26)	1,000	3,300
	Sequim & Discovery Bay Tbs.	27[f]	-	H: 90% w/in 100 yrs[g] (25)	500	1,700
	Skokomish R.	938	76	H: 70% w/in 100 yrs (50)	2,200	7,300
	W. Hood Canal Tbs.	150	9	L: 20% w/in 100 yrs (32)	2,500	8,400
	E. Hood Canal Tbs.	93	-10	L: 40% w/in 100 yrs (27)	1,800	6,200
	S. Hood Canal Tbs.	91	32	H: 90% w/in 20 yrs (30)	2,100	7,100

[a] Source: Ford (2022). A "-" indicates that no estimate is available because the population is not monitored.
[b] Defined as the probability of decline to an established quasi-extinction threshold (QET), in number of spawners, for each population. Source: (Hard et al. 2015). Abbreviations: H = high; MH = moderately high; L = low. A "-" indicates that data were insufficient to estimate extinction risk.
[c] Source: NMFS (2019c).
[d] Interim target for the three aggregated Skagit River populations is 15,000 with an intrinsic productivity at least equal to that during 1978–2017.
[e] Established for Morse and McDonald Creeks only.
[f] There are no monitoring data available for 2018 or 2019 for the Sequim and Discovery Bay Tributaries population. The figure shown here is the geometric mean of the following years: 2015, 2016, 2017, 2020.
[g] Established for Snow Creek only.

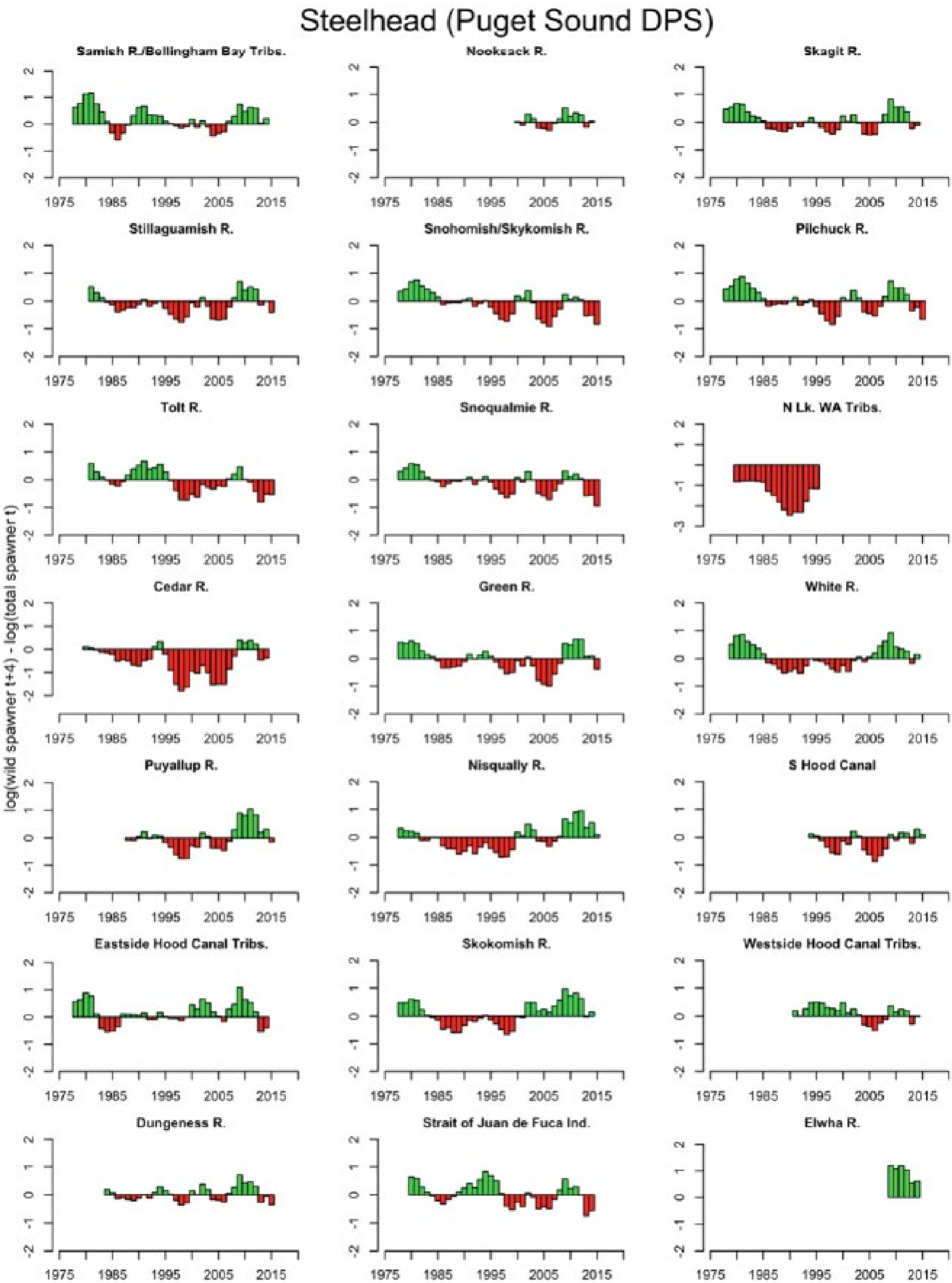

Figure 14. Trends in population productivity of Puget Sound steelhead, estimated as the log of the smoothed natural spawning abundance in year t minus the smoothed natural spawning abundance in year (t – 4). From Ford (2022).

On December 27, 2019 (84 FR 71379), NMFS adopted the recovery plan for the Puget Sound steelhead DPS, which describes the DPS's population structure, identifies populations and other criteria essential to recovery of the DPS, establishes recovery goals for each population, and recommends strategies and actions designed to contribute to the recovery of the DPS. DPS and MPG-level viability criteria are summarized as follows:

1) All 3 MPGs must be viable, as outlined below, and there must be sufficient data available for NMFS to make such a determination.
2) At least 50% of the steelhead populations within each of the three Puget Sound MPGs are viable.
3) Specific populations—detailed in the Recovery Plan—within each MPG must be viable.
4) Within each MPG, all populations must combine to achieve a minimum MPG-level viability score (defined in the Recovery Plan) thereby ensuring MPG resilience.
5) Natural production of steelhead trout from tributaries to Puget Sound not identified in any of the 32 identified populations provides sufficient ecological diversity and productivity to support DPS-wide recovery.
6) Populations are distributed geographically throughout each MPG to reduce risk of catastrophic extirpation.
7) Diverse habitat types are present within each MPG.

The primary pressures contributing to the decline and ongoing suppression of Puget Sound steelhead, as detailed in the Recovery Plan, include the following:

- Fish passage barriers at road crossings;
- Dams, including fish passage and flood control;
- Floodplain impairments, including agriculture;
- Residential, commercial, industrial development (urbanization);
- Timber harvest management;
- Water withdrawals and altered flows;
- Climate change;
- Ecological and genetic interactions between hatchery- and natural-origin fish;
- Harvest pressures (including selective harvest) on natural-origin fish; and,
- Early marine survival (juvenile mortality in estuary and marine waters of Puget Sound).

Northern Cascades MPG and the Skagit River Populations

The Northern Cascades MPG contains half (16) of the 32 Puget Sound DPS steelhead trout populations, including 4 populations in the Skagit River watershed (Table 7). The Puget Sound steelhead TRT concluded that population viability is greatest for the Northern Cascades MPG relative to the other Puget Sound MPGs (Hard et al. 2015). The Northern Cascades MPG currently accounts for about 64% of spawners in the ESU (Ford 2022). Across the MPG, spawner abundances increased by 9% from the 2010–2014 to the 2015–2019 period, although notable declines across the Snohomish River basin populations, including the Tolt River summer population, are concerning (Ford 2022). Within the Northern Cascades MPG, both of the following must be met for DPS recovery: 1) 5 of the 11 populations with winter or winter/summer runs must be viable, including one from the Skagit (Skagit River or Sauk River population); and, 2) 3 of the 5 summer-run populations must be viable (NMFS 2019c). All of the extant DPS populations with summer run-timing are in this MPG.

The four Skagit River watershed steelhead trout populations are defined and distributed across the basin as follows (Figure 15) (Myers et al. 2015; NMFS 2019c):

- *Skagit River Summer Run and Winter Run*. This population includes all steelhead spawning in the mainstem Skagit River and its tributaries—excluding the Baker and Sauk Rivers and Nookachamps Creek—from the mouth to the historical location of a series of cascades located near Gorge Dam. This population is one of the predominant steelhead populations in Puget Sound, accounting annually for several thousand spawning steelhead. Winter-run steelhead predominate in the mainstem and lower tributaries, with summer-run steelhead having historically been reported in Day and Finney Creeks and the Cascade River.
- *Sauk River Summer Run and Winter Run*. This population spawns in the Sauk and Suiattle Rivers and their tributaries, and likely accounts for a substantial proportion of total Skagit River watershed steelhead, though precise estimates are lacking.
- *Nookachamps Creek Winter Run*. This population spawns in the small, lowland subbasin of Nookachamps Creek, and accounts for a small proportion of steelhead in the Skagit River watershed.
- *Baker River Summer Run and Winter Run*. Historically, the Baker River was likely a major contributor to Skagit River basin steelhead runs. However, the construction and operation of the two Baker River hydroelectric dams were severely detrimental to this population. Many TRT members and reviewers considered this population extirpated, although resident *O. mykiss* in the Baker River basin may retain some of the historical genetic legacy. Anadromous adult steelhead have not been passed above the dams since 2006.

The current abundance of Skagit River watershed steelhead trout is substantially reduced from historical levels. Historical abundance was estimated at about 94,000–189,000 adults for all four Skagit River watershed populations combined, distributed as follows: Skagit River, 69%; Sauk River, 25%; Baker River, 5%; Nookachamps Creek, 1% (Myers et al. 2015). In contrast, recent basin-wide abundance estimates (2012–2021) have ranged from about 3,000 to 9,000 adults, representing 2–10% of estimated historical abundances. These abundance estimates include winter-run fish only, which are believed to currently make-up the substantial majority of spawners. Available information indicates that summer-run fish in the Skagit River watershed are at low (Sauk River) to critically low (Skagit River) abundance levels, and that summer-run fish in the Sauk River basin were a minor contributor to total abundance (Myers et al. 2015).

The Skagit River steelhead populations have been monitored and forecasted as an aggregate population. Because of this, most of the available information about the status, trends, and distribution are not available at the population level. The interim recovery target is 15,000 fish for this Skagit River aggregate with an intrinsic productivity at least equal to that during 1978–2017 (NMFS 2019c).

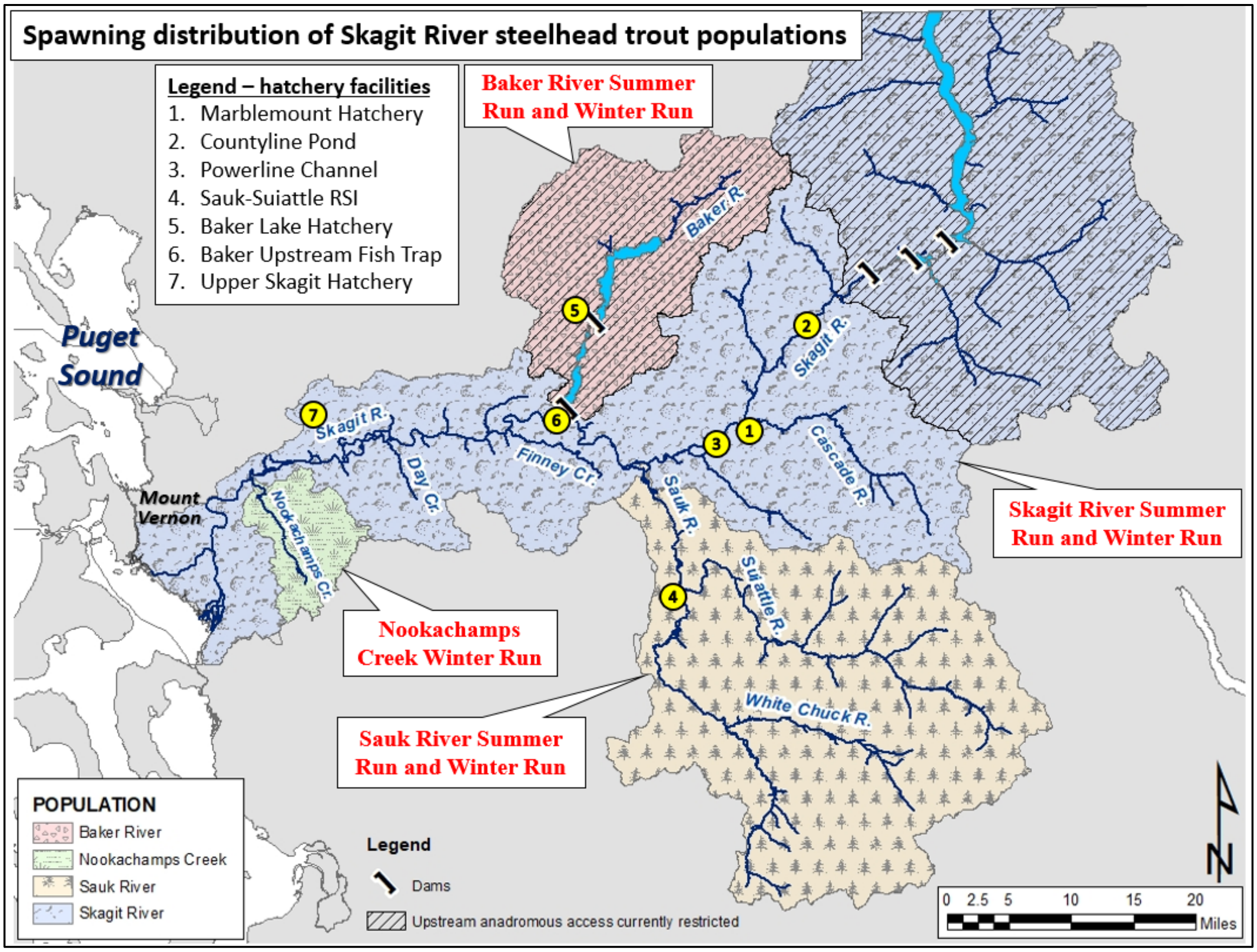

Figure 15. Spawning distribution of the four Skagit River steelhead trout populations (red text), including approximate locations of hatcheries and related facilities relevant to this consultation (yellow circles numbered 1–4, 7). Rivers and tributaries shown are for reference only, and are not intended to indicate *O. mykiss* presence. Sources: Myers et al. (2015); (NMFS 2019c).

Similar to many Puget Sound steelhead trout populations, steelhead in the Skagit River watershed, in aggregate, have experienced reductions in spawning abundance relative to higher levels in the 1980s (Figure 16). From 1978 to 1990, Skagit steelhead abundance approximately doubled, increasing from about 5,000 to about 11,000 fish. This trend was strongly statistically significant (Spearman correlation coefficient = 0.819, $p < 0.001$, $n = 13$). However, abundance declined early in the 1990s and has remained largely stable since, albeit with an apparent gradual but not statistically significant decline (Spearman correlation coefficient = -0.217, $p = 0.258$, $n = 29$). Recently, abundance steadily declined from a high of 9,084 fish in 2014, to just above 3,000 fish in both 2020 and 2021, which were 2 of the 3 lowest years since 1991, and 2 of the 4 lowest on record. Nonetheless, the most recent 5-year geometric mean (2017–2021) of 4,429 fish remains within the range of variability for the 1991–2021 period (Figure 16). Since the time of

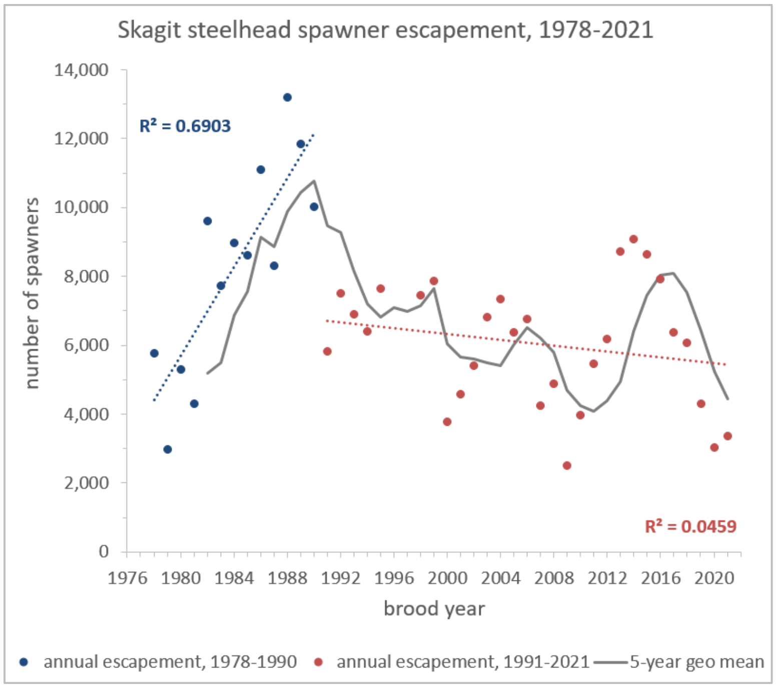

Figure 16. Estimated abundance of steelhead trout spawners in the Skagit River watershed, separated into two time periods (1978–1990, blue; 1991–2021, maroon) based on apparent trends during each period (see text for more detail). Linear regression lines and associated R^2 values are shown for each time period. The 5-year geometric mean (gray line) is shown for the entire period of record. Abundance data from WDFW.

listing, the geometric mean abundance is 5,256 fish with no apparent trend (Spearman correlation coefficient = -0.046, p = 0.870, n = 15), despite fluctuating widely.

Despite the general stability in spawner abundance since 1991, the number of steelhead smolts captured in the WDFW's outmigrant traps at RM 17 has declined during this time (Figure 17). During the early- to mid-1990's catch was typically around 1,000 to 2,000 smolts, whereas in recent years catch has generally been around 200 to 500 smolts. This decline is statistically significant (Spearman correlation coefficient = -0.755; p < 0.001). The catch data do not account for discharge-based variability in trap efficiency or trap outages, though general trap methods have not changed.

In general, winter-run steelhead return to freshwater during the winter and early spring months and spawn relatively soon thereafter. In contrast, summer-run steelhead return to freshwater during late spring and early summer in a relatively immature state and hold there until spawning the following winter/spring. In the Skagit River, steelhead have been observed to spawn between mid-February and mid-July (Barkdull 2020b), though the majority of spawning typically occurs from April through mid-June (Sauk-Suiattle Indian Tribe et al. (2018) cited in NMFS (2018b)). Though spawning and rearing occurs throughout the Skagit River mainstem and tributaries, the

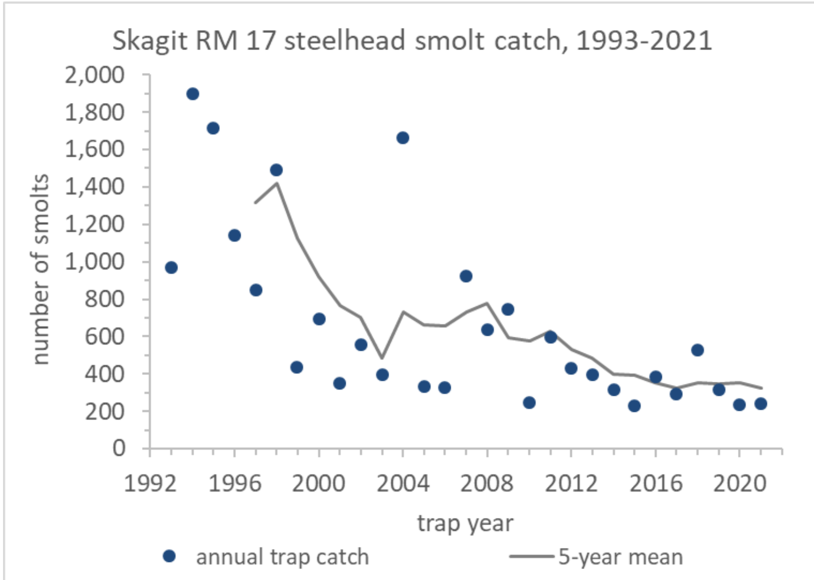

Figure 17. Unadjusted (raw) catch of steelhead trout smolts at the WDFW Skagit River RM 17 (Mount Vernon) outmigrant trap, 1993–2021. Catch data from WDFW.

majority appears to occur in the tributaries (Beamer et al. 2010; Barkdull 2020a). For example, Skagit River mainstem redds accounted for 13% of all redds observed despite making up 25% of miles surveyed during basin-wide redd surveys from 2005 to 2019 (Barkdull 2020a).

While there is considerable information that summer-run steelhead existed historically in the Skagit River tributaries, recent surveys suggest that the summer-run component is at a critically low level. Locations where summer-run fish have been reported include Finney Creek, Day Creek, the Cascade River, the upper Sauk River, and the South Fork Sauk River. However, despite extensive surveys by the co-managers, river miles 8.0 to 11.6 of Finney Creek is the only location where summer-run fish are currently known to spawn. The summer-run steelhead enter Finney Creek in October and November, with spawning occurring primarily from February through March (Sauk-Suiattle Indian Tribe et al. (2018) cited in NMFS (2018b)).

Scott and Gill (2008) reported that repeat steelhead spawners averaged 6% (range: 0–12%) of the total number of spawners in the Skagit River from the mid 1980's through the mid-2000's. The substantial majority of kelts[11] (87%) leave the Skagit River watershed in May and June, based on tagging and tracking studies completed as part of a larger experiment (Pflug et al. 2013). The remaining 13% leave shortly before (December–April) or after (July).

The WDFW does not routinely estimate abundance of steelhead smolts passing their RM 17 smolt trapping operation, presumably due to low catch and low capture efficiency of steelhead. However, the WDFW implemented additional measures to be able to estimate steelhead abundance at this location for 7 years, from 2008 through 2014. The average estimated

[11] The term "kelt" refers to an adult steelhead that survives after spawning.

abundance of steelhead outmigrants during these years was 155,249 fish (range: 80,499–240,533 fish), though the authors assert that these estimates must be viewed with caution due to wide confidence intervals caused by small total catch (Kinsel et al. 2015a). Outmigrants are predominantly age-2 (65%) and age-3 (30%), though some are age-1 (3%) and age-4 (2%) (Kinsel et al. 2015a; Kinsel 2018). Steelhead trout smolts outmigrate from the Skagit River primarily from mid-April through mid-June (Figure 18) (Kinsel et al. 2013; Kinsel et al. 2014; Kinsel et al. 2015a). Movement within the river system between fry emergence and marine outmigration is not well known. Some trout fry and parr outmigrate from tributaries in the spring, while other individuals appear to remain within their natal tributaries until smolting (Kinsel et al. 2014; Kinsel et al. 2015a; Kinsel et al. 2015b; Kinsel et al. 2016). Fry and parr outmigrants presumably continue rearing in freshwater areas for another year or more prior to smolting (e.g., Leider et al. 1986, and references therein).

2.2.4. Critical Habitat for Puget Sound Steelhead

Designated critical habitat for the Puget Sound steelhead DPS includes specific river reaches associated with the following subbasins: Strait of Georgia, Nooksack, Upper Skagit, Sauk, Lower Skagit, Stillaguamish, Skykomish, Snoqualmie, Snohomish, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha (81 FR 9252, February 24, 2016). The designation does not include any marine nearshore areas in Puget Sound or offshore marine areas. There are 18 subbasins (HUC4 basins) containing 66 occupied

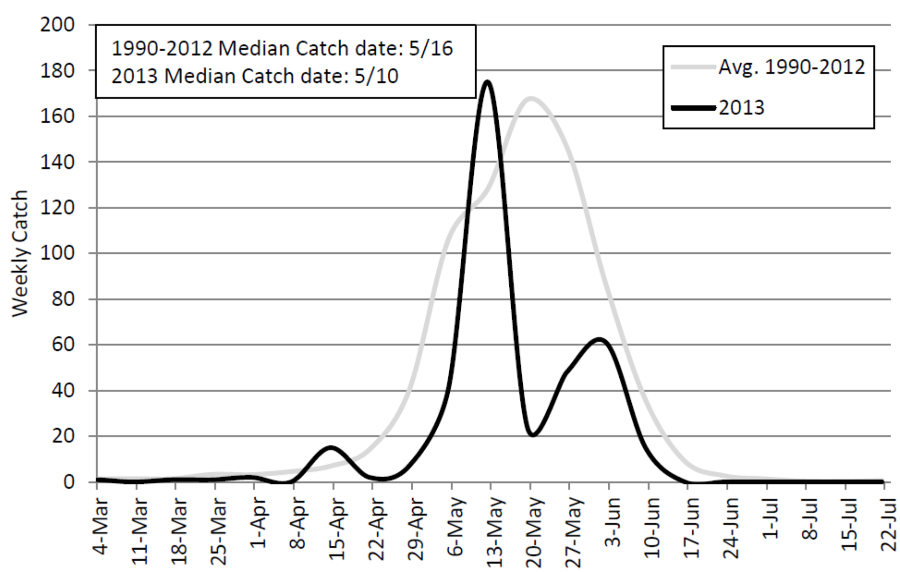

Figure 18. Average outmigration timing of Skagit River steelhead trout smolts, as determined from WDFW outmigrant trapping at Skagit River RM 17, 1990–2013. Source: Kinsel et al. (2014).

watersheds (HUC5 basins) within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS (78 FR 2726, January 14, 2013). Of the 11 watersheds within the Skagit River basin, 9 received a "high" conservation value rating, and two (Baker River, Upper Suiattle River) received a "medium" rating (NMFS 2015). PCEs are the same as those detailed above for Puget Sound Chinook salmon (subsection 2.2.1.2). The Puget Sound Critical Habitat Analytical Review Team identified the following management activities that may affect the PCEs in one or more of the Skagit River basin watersheds: agriculture, channel modifications (e.g., rip rap, diking), dams, forestry, urbanization, road building and maintenance, and wetland loss and removal (NMFS 2015).

2.3. Action Area

The "action area" means all areas to be affected directly or indirectly by the Proposed Action, in which the effects of the action can be meaningfully detected, measured, and evaluated (50 CFR 402.02). The action area associated with this analysis includes the places within or near the Skagit River watershed where salmon and steelhead originating from the proposed hatchery programs would migrate and spawn naturally (Figure 1). Generally, this includes anadromous-accessible areas of the Skagit River watershed downstream from Gorge Dam. The action area also includes the marine waters of the Salish Sea to Cape Flattery off the Washington Coast in the Pacific Ocean.

2.4. Environmental Baseline

Under the Environmental Baseline, NMFS describes what is affecting listed species and designated critical habitat before including any effects resulting from 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 and the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation (50 CFR 402.02).

2.4.1. General Features and Characteristics of the Action Area

The Skagit River watershed is located in the northwest corner of Washington (Figure 1). It is the largest drainage flowing into Puget Sound, covering 3,100 square miles and providing over 20% of the water flowing into Puget Sound. The headwaters of the river are located in the steep, rugged terrain of the Cascade Mountains, mostly on public lands and protected areas. The watershed can be divided into five subbasins. Three correspond with the largest tributaries that feed the Skagit River: the Baker River (297 square miles), the Cascade River (185 square miles), and the Sauk River (732 square miles). The other two subbasins are the upper and lower Skagit River. For the purposes of this document, the upper Skagit River is that part of the Skagit River drainage upstream from the Baker River confluence, excluding the Cascade and Sauk subbasins. The lower Skagit River is that portion of the watershed downstream from the Baker River confluence. There are five major impoundments (hydroelectric dams) within the system, all of which are found within the Baker (two dams; Baker Hydroelectric Project) and upper Skagit (three dams; Skagit Hydroelectric Project) subbasins. The Cascade and the Sauk Rivers are not impounded.

The watershed includes steep, mountainous terrain in headwater areas, foothills in the middle, and a broad valley and alluvial fan adjacent to Puget Sound. Upper watershed areas to the east lie on the west slope of the Cascade Mountains, and include the headwaters of the Skagit, Cascade, Baker, and Sauk Rivers. Most of the watershed downstream from Gorge Dam (the lowermost dam on the mainstem Skagit River) is characterized by a hydrologic regime transitional between snowmelt- and rainfall-dominated, with both rainfall- and snowmelt-driven peaks, and low flows in August–September (Beechie et al. 2006). The Suiattle and Cascade Rivers are exceptions, both exhibiting a snowmelt-dominated hydrologic regime with peak flows in May–July and low flows in late winter or early spring.

Four of the subbasins—all except the lower Skagit—are primarily in federal ownership, including large protected areas within North Cascades National Park, Glacier Peak Wilderness, and Mount Baker Wilderness. Lower areas of these four subbasins are mostly in private ownership, comprised primarily of agriculture and rural residential in valley bottoms, and privately-owned commercial timberlands and second growth forests in the uplands. The lower Skagit River subbasin is predominantly comprised of agriculture, rural residential, and urban development within and near the cities of Mount Vernon, Burlington, and Sedro-Woolley. Most of the wetlands within the original floodplain in the lower Skagit have been drained, filled, or channeled to accommodate development and farming.

2.4.2. Habitat

The information in this section summarizes habitat conditions in the Skagit River watershed, and factors responsible for those conditions, as detailed in SRSC and WDFW (2005) and Smith (2003). Generally speaking, habitat conditions are best in upper watershed areas and progressively degrade through middle- to lower-watershed areas. Upper watershed tributary habitat is generally in good condition, though many mainstem reaches have been affected by roads, hydromodification (levees), dam operations, riparian deforestation, and historical logging practices. The lower Skagit subbasin is the most heavily degraded. Historical, nearly ubiquitous transformation of the lower watershed from a densely forested large river delta and adjoining estuary to its current state has substantially diminished the quantity and quality of salmonid habitat. Habitat and habitat-forming processes have been substantially impacted by the extensive network of sea dikes and channel-confining levees, removal of large wood from the river channel, and conversion of the natural delta to agriculture, residential, and urban development. Consequences include the following, which are discussed in the following paragraphs:

- the river is disconnected from the floodplain, severely diminishing the abundance of highly-productive side channel and off-channel habitat;
- there is little mature riparian forest vegetation;
- water velocities are increased, and refuge habitat from elevated water velocities is scarce;
- sediment transport is altered;

- the ability of the river to retain large wood is impaired; and,
- the abundance of distributary and tidal channels in the estuary is greatly reduced. These are discussed in more detail below.

Most areas in the Skagit River watershed have some level of riparian degradation. In the lower Skagit subbasin, riparian areas have been heavily degraded. The loss of riparian forests has reduced suitable spawning habitat in some tributaries and the resulting increase in temperatures has created thermal barriers to Chinook salmon migration. In the mainstem, a majority of the river has at least moderately impaired riparian function. In the upper Skagit subbasin, with the exception of Illabot Creek, riparian function is substantially to moderately impaired. In the lower Sauk River, logging and ongoing agricultural practices have substantially diminished riparian forests in areas, resulting in less in-channel large wood. In the upper Sauk River, riparian degradation is moderate. Significant riparian degradation has occurred along the mainstem of the Suiattle River. There has been little riparian degradation in the Cascade River, with degradation almost entirely limited to coho tributaries.

Increases in sediment levels in freshwater habitat are largely due to mass wasting events associated with logging roads and timber harvest. A sediment budget created for the Skagit watershed has shown that sediment levels are greater than historical levels, which contributes to increasing scour and fill of the channel bed. Hence, salmon and steelhead eggs are more easily and more frequently dislodged or buried, and fry emergence can be blocked. For freshwater rearing fry, increased sediment reduces benthic invertebrate production and the value of edge habitat cover by filling the spaces between cobbles, boulders, and large woody debris.

Spawning habitat in the lower Skagit River is believed to be very poor for egg incubation and survival. Aerial surveys of the mainstem have shown extensive fine sediment accumulation in areas that were formerly graveled. The recent heavy accumulation of silt in the mainstem and mass wasting and loss of pool-riffle sections in the tributaries have caused both a loss of spawning area and poor egg-to-fry survival. In contrast, habitat in the upper Skagit River is relatively good for egg incubation. In the lower Sauk River, it is believed that spawning habitat is among the poorest in the system for incubation survival due to recent heavy accumulation of silt in the mainstem, and mass wasting and loss of pool-riffle sections in the tributaries. This problem is compounded by accelerating glacial melt from Glacier Peak, which has deposited large amounts of silt on the spawning grounds downstream of the Suiattle River, further impairing incubation survival. In addition, fish that migrate through the lower Sauk River and/or that come to the lower Sauk River from other areas to rear or forage (e.g., Upper Sauk Spring Chinook salmon) are subject to the sediment problems in this area. The upper Sauk River is considered impaired because of forest management activities and geology. Most streams in the Suiattle River system are in relatively pristine condition, although past forest practices and geological instability have caused sediment impairment in a few areas.

Flooding greatly impacts egg-to-fry survival. While floods are natural events, human activities, such as increasing impervious surfaces, land clearing, and extending drainage networks associated with roads can increase the severity and frequency of floods. The flooding problem is especially severe in the lower Skagit River basin, which absorbs the full brunt of floods, and where stresses due to flooding are amplified because of the alterations to lower basin hydrology.

Additionally, hydromodification has a particularly large impact in the Skagit River watershed as the Skagit River was naturally a highly dynamic system. Historically, flooding periodically created productive new channels for both spawning and rearing. However, high levels of hydromodification have prevented the formation of new channels. In the lower and upper Skagit River, high levels of hydromodification have reduced the area of natural banks and backwaters by about 60% and have prevented the formation of new channels. The Sauk River is still highly dynamic, but in some cases now has decreased new channel formation and limited re-opening of old channels. Parts of the mainstem, mainly between Darrington and the Suiattle River, have also experienced a loss of preferred spawning habitat due to hydromodification. In the Suiattle River, four locations in the mainstem channel are impaired due to stream bank hardening. There is no known hydromodification in the upper Cascade River.

Water consumption for agricultural irrigation Competition is an ongoing issue in the Skagit River basin. Salmon and steelhead need a continuous supply of cool, oxygen-rich water to survive and must compete with other water users for the limited supply of water in the Skagit River Basin. A 1996 Memorandum of Understanding between the Skagit tribes and several other government entities, and a 2001 instream flow rule, are intended to limit water withdrawals so that fish have sufficient water available. However, instream flow studies demonstrate that existing flows are often below optimum, and there is pressure for additional withdrawals from exempt wells, over-appropriation of water rights, and illegal withdrawals. Such withdrawals, in addition to those due to dam operations, can cause dewatering of off-channel habitat, increased predation, reduction of available rearing habitat, and exacerbation of existing problems such as water quality impairment (particularly temperature) and habitat simplification.

In the Skagit River delta, post-settlement diking, dredging, and filling have severely decreased the historical extent of habitat. Currently, the contiguous habitat area that is exposed to tidal and river hydrology is approximately 3,118 hectares, whereas the historical area was 11,483 hectares. This represents a 73% loss of tidal delta habitat (wetlands and channels). These estimates of net delta habitat loss account for increases in habitat from progradation (growth of the delta farther out into the sea) that occurred between the 1860s and 1991. Progradation has added 68 hectares of tidal delta habitat over the last 50 years.

Pocket estuaries are partially enclosed, measurably diluted marine bodies of water that are smaller in scale and discontinuous from Chinook salmon natal river systems. Approximately 80% of Whidbey Basin pocket estuaries have been lost. Historical pocket estuaries in close proximity to the Skagit delta have seen a net loss of 86%. Lost pocket estuary habitat limits nearshore habitat capacity and juvenile Chinook salmon survival by reducing areas for fish to forage and seek refuge. Juvenile Chinook salmon are over 100 times and 10 times more abundant in pocket estuary habitat than in offshore and nearshore habitat, respectively, during the period from February through May.

The Puget Sound region, including the Skagit River basin, has experienced rapid population growth in recent years. The Skagit River basin spans three counties: Whatcom County, Skagit County, and Snohomish County. These counties have experienced 5.8–10.4% increases in population from 2010 to 2016. Population growth generally leads to increased impervious surface, habitat loss, and more habitat fragmentation due to commercial and residential construction, and infrastructure expansion and development.

NMFS has completed several ESA section 7 consultations on large scale projects affecting listed species in Puget Sound and the Skagit River. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006a), and consultations on Washington State Water Quality Standards (NMFS 2008c), Washington State Department of Transportation Preservation, Improvement, and Maintenance Activities (NMFS 2013), and the National Flood Insurance Program (NMFS 2008d). These documents considered the effects of Proposed Actions that would occur during the next 50 years on the ESA listed salmon and steelhead species in the Puget Sound basin. Information on the status of these species, the environmental baseline, and the effects of the Proposed Actions are reviewed in detail. The environmental baselines in these documents consider the effects from timber, agriculture and irrigation practices, urbanization, and hatcheries, and tributary habitat, estuary, and large scale environmental variation. These Biological Opinions and Habitat Conservation Plans, in addition to the watershed specific information in the Puget Sound Salmon Recovery Plan mentioned above, provide a current and comprehensive overview of baseline habitat conditions in Puget Sound and are incorporated here by reference.

Stream alignments in the vicinity of the Marblemount Hatchery have been modified, as described in subection 1.3.1.1. The lack of current surface connection between Clark Creek and Shoemaker Creek is considered part of the Environmental Baseline.

2.4.3. Hydropower

The information below summarizes the effects of hydroelectric projects in the Skagit River watershed, and was adapted from Smith (2003) and SRSC and WDFW (2005).

Within the Skagit River basin, there are mainstem hydroelectric dams on the Baker River (two dams) and on the Skagit River upstream of Newhalem (three dams). All five Skagit and Baker River dams were constructed in the early- to mid-1900s. The three Skagit mainstem dams completely block salmon migration. Whether or not an historical anadromous barrier existed near the lower-most dam is currently the subject of debate. Fish passage at the two Baker Dams is managed with a trap-and-haul system. Construction of the Baker dams inundated spawning and rearing habitat for Chinook salmon, steelhead trout, and other anadromous salmonid species. The United States Forest Service estimated that 117 acres of wetlands and ponds, 5 miles of side-channel habitat, and 52 miles of tributaries were lost by creation of the reservoirs.

Dam operations have substantial effects on habitat and habitat forming processes downstream. About 29% of the flow in the Skagit River goes through the mainstem Skagit River dams, and another 17% through the Baker dams. Water storage occurs behind each of the dams in the mainstem Skagit River and Baker River, and because of dam storage and operations, it is estimated that the magnitude of peak flows has been reduced by about 50%. Flow regulation in the mainstem Skagit River may have led to loss of important side channel habitat, and inhibits formation of new side channels. Mitigation funds from Seattle City Light, which operates the three mainstem Skagit River dams, have been used to reconstruct side channel habitat in this part of the river basin. Sediment and large wood transport is also impaired by the dams. Conversely, flow regulation may increase egg-to-fry survival by diminishing the intensity, frequency, and duration of redd-scouring flows. Mainstem areas nearest the downstream side of the projects are more directly influenced by flow regulation than more downriver areas, which have more flow buffer from tributary inputs. Hydroelectric operations associated with the Baker River dams has been considered one of the greatest problems in the Baker River and nearby segments of the Skagit River.

Fry stranding studies conducted in the 1970s and 1980s in conjunction with relicensing the mainstem Skagit River dams (Seattle City Light projects) demonstrated that downramping (reducing river flows) can strand and kill large numbers of fry. This problem was addressed by restricting the downramping rate for the mainstem Skagit River dams. An additional impact of hydropower operations is an increase in potential Chinook salmon redd stranding over natural rates. This can occur when project flow releases are increased over natural basin inflow during spawning and minimum flow releases are at or below natural inflows during egg incubation and fry emergence. The mainstem Skagit dams have largely dealt with redd-dewatering as a potential source of mortality through the establishment of minimum flows appropriate for each species.

In October 2008, the Federal Energy Regulatory Commission (FERC) issued Puget Sound Energy (PSE) a new 50-year operating license for the Baker River Hydroelectric Project. The license contains specific requirements about many aspects of the hydroelectric project, including structures, equipment, water quality, and other environmental issues, wildlife and fisheries programs, operating procedures, stream flow, and more. NMFS (FERC et al. 2008) concluded that, in the long term, the relicensed dam operations will continue to have negative effects on listed species, but the mitigation measures detailed in the license minimize these effects. As a consequence, current operation of the dams poses less of a threat to reduce the abundance or productivity of the Skagit River Chinook salmon and steelhead populations than past operations.

2.4.4. Climate Change

Climate change has broad and substantial negative implications for salmonids and salmonid habitat in the Pacific Northwest (e.g., Climate Impacts Group 2004; Beechie et al. 2006; Zabel et al. 2006; Battin et al. 2007; ISAB 2007; Mantua et al. 2010; Wade et al. 2013; Tohver et al. 2014; Mauger et al. 2015; Crozier et al. 2019), including the Skagit River system (e.g., Lee and Hamlet 2011; Rybczyk et al. 2016; Austin et al. 2021). Climate in the Puget Sound region has been changing for several decades, as has climate-related elements of freshwater and marine aquatic habitats. Climate change is expected to continue for many decades into the future, with substantial negative implications to freshwater and marine habitats and the species that currently inhabit these waters. 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 the region, including the Skagit River watershed. Related long-term negative effects include but are not limited to the following: depletion of cool water habitat and refugia; detrimental alterations to adult and juvenile migration patterns; increased egg and fry mortality from increased flooding and sediment loads; increased competition among species; greater vulnerability to predators; and, increased disease susceptibility. Climate change is also expected to detrimentally affect marine habitats and salmonid survival through warmer water temperatures, loss of coastal and estuary habitat from sea level rise, ocean acidification, and changes in water quality and freshwater inputs.

The distribution and productivity of salmonid populations in the region are likely to be affected by climate change (Beechie et al. 2006). Average annual Pacific Northwest air temperatures have increased by approximately 1ºC since 1900, or about 50% more than the global average over the same period (ISAB 2007). The latest climate models project a warming of 0.1 ºC to 0.6 ºC per decade over the next century. According to the Independent Scientific Advisory Board (ISAB), these effects pose the following impacts over the next 40 years:

- Warmer air temperatures will result in diminished snowpacks and a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.
- With a smaller snowpack, these watersheds will see their runoff diminished earlier in the season, resulting in lower stream-flows in the June through September period. River flows in general and peak river flows are likely to increase during the winter due to more precipitation falling as rain rather than snow.
- Water temperatures are expected to rise, especially during the summer months when lower stream-flows co-occur with warmer air temperatures. As climate change progresses and stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmon and steelhead with patches of suitable habitat to recover in after spending time in more stressful temperatures (e.g., during migration or foraging forays). 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).

Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids (e.g., Battin et al. 2007; ISAB 2007; Beechie et al. 2013; Crozier et al. 2019). For example, restoring connections to historical floodplains, off-channel freshwater habitats, and currently-blocked estuarine areas would increase rearing area, provide refugia, and increase floodwater storage. Protecting and restoring riparian buffers would ameliorate stream temperature increases, reduce sediment inputs, and minimize erosion. Purchasing or applying easements to lands that provide important cold water or refuge habitat would also be beneficial. Harvest and hatchery actions can respond to changing conditions associated with climate change by incorporating greater uncertainty in assumptions about environmental conditions, and conservative assumptions about salmon survival, in setting management and program objectives and in determining rearing and release strategies (Beer and Anderson 2013; Crozier et al. 2019).

2.4.5. Hatcheries

The history of hatchery operations in the Skagit River, including some programs that are currently operating and comprise the Proposed Action, extend decades into the past. Some historical programs are no longer in operation (e.g., Skagit River Hatchery Winter Steelhead). Of those that are still operating, some have changed very little since their inception, others have changed considerably, and some have started, stopped, and started again. This section provides a summary of the pertinent aspects of historical and current hatchery operations in the Skagit River watershed. Much of the information in this section was obtained from HGMPs. Additional information is cited as appropriate.

Upper Skagit Chum Salmon, past operations

The Upper Skagit chum salmon program is an ongoing program that would continue pursuant to the Proposed Action of this Biological Opinion. This section describes the program's past operations. The program has been operated as an integrated recovery program since its inception in 1990 (USIT 2015). The goal of the program is to provide cultural enrichment and environmental education and awareness programs for the Upper Skagit Indian Tribe and surrounding communities. Skagit chum salmon is an integral component of cultural identity, and the hatchery program has provided a unique educational experience highlighting Tribal Resource Management. The program has a release goal of up to 450,000 fry from the Upper Skagit (Red Creek) Hatchery, though release numbers have often been less.

Chum Salmon Remote Site Incubator (RSI), past operations

The Chum Salmon RSI program is an ongoing program that would continue pursuant to the Proposed Action of this Biological Opinion. This section describes the program's past operations. The program has been operated as an integrated recovery program since its inception in 2014 to supplement the declining Skagit River watershed natural population (Sauk-Suiattle Indian Tribe 2018). The objective and purpose of the program is to increase abundance, retain diversity, and indirectly provide overall chum salmon harvest opportunities in the Skagit River basin by recovering the population to pre-decline levels (i.e., those prior to 2007). All fry have been released into the Sauk River watershed. Though the release goal of the program is 125,000 fry, the program is still ramping up and no releases have yet exceeded 20,000 fry.

Skagit River Fall Chum Salmon, past operations

The Skagit River Fall Chum Salmon program is an ongoing program that would continue pursuant to the Proposed Action of this Biological Opinion. This section describes the program's past operations. The program was started as an integrated recovery program in 2020 to supplement the declining natural population in the Skagit River watershed (WDFW 2022a). The goal of the program is to provide a demographic boost that links hatchery production to natural spawning abundance until consistent spawning abundance and harvestable natural chum salmon production is restored. This program will be on-going until chum natural returns (NOR) stabilize at levels which meet or exceed watershed escapement goals of 45,500 for odd- and 122,000 for even-years (based on a five-year geometric mean for even/odd years), inclusive of 5,500 annual broodstock collection goal. The program will be reevaluated when these watershed escapement goals are achieved. The first fry releases from the program occurred in 2021 with approximately 317,000 fry released into the Cascade River and the Skagit River Slough (RM 66.5). The release goal of the program is 5 million fry.

Skagit River Spring Chinook Salmon

The Skagit River spring Chinook program is an ongoing program. Effects from past and present activities associated with this program are thus included here as part of the environmental baseline. The program is currently being reviewed by NMFS as part of a separate consultation for ESA 4(d) Limit 6 determination, which is expected to be completed in the near future. This program was founded from natural-origin Skagit River fish, though the exact origins and composition of all contributing broodstock are uncertain (HSRG 2003; McKinney and Seamons 2021). Possible contributors include the following:

- Natural-origin spring Chinook from several Suiattle River tributaries that were collected during 1974–1986. This is believed to be the dominant brood source.
- Hatchery-origin volunteers to the Marblemount Hatchery from a program that operated during the 1950s, 1960s, and early 1970s, and that may have been founded from native Cascade River fish.
- Natural-origin spring and summer Chinook salmon volunteering to the hatchery prior to the implementation of mass-marking in 1995; likely a relatively small component.
- Early-returning Marblemount Hatchery-origin summer Chinook salmon; likely a relatively small component.

Hatchery-origin returns have been used exclusively for broodstock since at least 1995. The program has thus been operated as segregated since that time. Genetic assessments have shown that Skagit Hatchery spring Chinook salmon are genetically distinguishable from all other Skagit natural populations (Marshall et al. 1995; McKinney and Seamons 2021), which may be caused by artificial propagation practices (e.g., hatchery mating and rearing practices) (HSRG 2003) and/or mixing of multiple broodstock sources (McKinney and Seamons 2021).

All hatchery releases have been on-station from Marblemount Hatchery, except for a group of 300,000 subyearlings released from the Baker Stress Relief Ponds in 2022. Program production goals were 250,000 subyearlings and 150,000 yearlings through 2011. After the 2011 releases, the yearling component was discontinued and, to compensate, the subyearling component was increased to 587,500 fish. A yearling component was re-started beginning with release year 2020 at a production goal of 400,000 yearlings. This represented a substantial increase in overall spring Chinook production as the subyearling release goal was kept constant at 587,500 fish. Since 2003, average actual release numbers have been within 5.4% of the production goals, though exceedances as high as 84% have occurred.

This program is operated as a segregated harvest program (WDFW 2018b). Anthropogenic influences have resulted in decreased and degraded aquatic and terrestrial habitat which has resulted in decreased natural production of Chinook salmon in the Skagit basin. Marblemount Hatchery (Skagit River) spring Chinook salmon stock is part of the Puget Sound Chinook salmon ESU, but not essential for recovery (85 FR 81822, December 17, 2020). This program serves as a terminal harvest program and supplements the natural return as mitigation for lost production, in addition to serving as an indicator stock for supporting domestic and international management objectives.

Skagit River Summer Chinook Salmon

The Skagit River summer Chinook program is an ongoing program. Effects from past and present activities associated with this program are thus included here as part of the environmental baseline. The program is currently being reviewed by NMFS as part of a separate consultation for ESA 4(d) Limit 6 determination, which is expected to be completed in the near future.

This program started releasing juvenile fish in 1995 and has changed little, if any, since its inception. It started, and continues to operate, as an integrated program that targets natural-origin Upper Skagit River summer Chinook salmon for broodstock. Minor proportions of marked (hatchery origin) fish have been included in the broodstock during low return years to meet broodstock goals. The proportion of natural-origin brood (pNOB) has averaged 0.91 since 2002, and 0.96 for the most recent 10-year period (2011–2020). Fewer than 100 natural-origin fish have been collected for broodstock each year; the recent 10-year mean (2011–2020) is 76 fish per year. All hatchery juvenile fish have been reared at Marblemount Hatchery and released from County Line Ponds (Skagit River RM 88.9). The program production goal has been 200,000 subyearlings. Since 2003, the average actual release has been 199,600 fish annually, though releases in individual years have varied from -45% (109,284 fish in 2009) to +24% (248,047 fish in 2007) of the production goal. Prior to this program, a summer Chinook program operated in the Skagit River watershed from the 1970s until 1993 (last juvenile release). This older program was founded from native Skagit River fish, but Green River-origin fall Chinook salmon being propagated at Marblemount Hatchery were also mixed in with the broodstock.

This is an integrated fisheries management and research program (SRSC and WDFW 2018). It serves as an indicator stock that provides information for assessment of regional and distant fisheries, on exploitation and marine survival rates, and monitoring and evaluating fish migration patterns, timing, and distribution representative of Skagit River natural summer and fall Chinook salmon populations. Skagit River Summer Chinook salmon have been impacted by the loss of rearing and spawning habitat, habitat impacts resulting from construction and operation of 5 dams in the Skagit River watershed, and other environmental issues that have impeded production and recovery efforts.

Skagit River Fall Chinook Salmon

From 1947 through brood year (BY) 1992 release, hatchery fall Chinook salmon of various Puget Sound and Columbia River ancestries were released from the Marblemount Hatchery (SRSC and WDFW 2005). After these were terminated, a new program was founded in 1998 (first broodstock collection) with natural Skagit River fall Chinook salmon (WDFW 2019). This program operated through 2009 (last juvenile release). It was as an integrated program targeting natural-origin Skagit River fall Chinook salmon for broodstock, though hatchery-origin fish were often included. Fish were gillnetted from the lower Skagit River mainstem below RM 42. The proportion of natural-origin brood (pNOB) averaged 0.77 (range 0.39–1) during much of the program (2001–2008). Fewer than 100 natural-origin fish were used as broodstock each year; the 2001–2008 mean was 60 natural-origin fish per year. The program production goal was 222,000 subyearlings, though this was achieved only once. Mean production was 142,800 fish annually across all years of operation. All hatchery juvenile fish were reared at Marblemount Hatchery and released from the Baker River Stress Relief Ponds (RM 0.7).

Skagit River Coho Salmon

The Skagit River coho salmon program is an ongoing integrated harvest program that was started in 1947 (WDFW 2018a). Effects from past and present activities associated with this program are included here as part of the environmental baseline. The program is currently being reviewed by NMFS as part of a consultation for ESA 4(d) Limit 6 determination, which is expected to be completed in the near future. This program was designed to serve as an indicator stock for natural coho salmon production in the Skagit River and provide essential information for assessment of regional (e.g., mixed-stock pre-terminal) and distant (e.g., Canadian) fisheries as well as marine survival, migration patterns, timing, and distribution. A secondary goal is to augment the population providing harvestable fish (in support of treaty rights, commercial, and recreational fisheries), although harvest management in the region is focused on natural production. Hatchery production goals have varied, recently ranging between 250,000 and 530,000 yearlings. Most fish have been released directly from the Marblemount Hatchery, though release locations have included Indian Slough, Telegraph Slough, and the Oak Harbor Marina. Current production goals are 500,000 yearlings from Marblemount Hatchery and 30,000 yearlings from Oak Harbor Marina.

Baker River Coho Salmon

The ongoing Baker River coho salmon program was started in 1992 as an integrated harvest program for providing mitigation for lost production due to the two Baker River dams (PSE and WDFW 2018a). Effects from past and present activities associated with this program are included here as part of the environmental baseline. The program is currently being reviewed by NMFS as part of a separate consultation for ESA 4(d) Limit 6 determination, which is expected to be completed in the near future. The program has also provided fish for evaluating efficacy of the Floating Surface Collectors (FSC) in Baker Lake and Lake Shannon. The Baker coho program was founded from native Skagit watershed fish. Release goals have been and remain 65,000 yearlings into the Baker River below the dams, and 160,000 fry into Lake Shannon, which typically rear in the lake until they are yearlings and outmigrate with the assistance of the FSC.

Baker River Sockeye Salmon

The ongoing Baker River sockeye salmon program, started in 1957, is an integrated program that fulfills several purposes, including conservation, mitigation, and harvest (PSE and WDFW 2018b). Effects from past and present activities associated with this program are included here as part of the environmental baseline. The program is currently being reviewed by NMFS as part of a separate consultation for ESA 4(d) Limit 6 determination, which is expected to be completed in the near future. The historical natural sockeye salmon population was substantially impacted by the construction and operation of the two Baker River dams. These facilities inundated historical lakeshore, tributary, and Baker River spawning habitat, and until recently, had limited upstream and downstream passage. The hatchery program provides suitable semi-natural spawning/incubation opportunity via human-made spawning beaches and traditional culture methods, with the current aim to provide an average adult return of 100,000 harvestable adults. Hatchery juveniles are released into and rear in the two reservoirs and volitionally outmigrate as smolts. Sockeye smolt outmigration has increased from < 10,000 fish in the late 1980's to around 700,000 to 1 million in recent years. The substantial majority of these are hatchery-origin fish. Though natural production is not known, naturally-produced fish are believed to make up less than 6% of the total sockeye smolt outmigration based on redd surveys (Overman 2019).

Skagit River Hatchery Winter Steelhead

This program operated in different forms from the 1960s through 2014 when it was terminated. It was a segregated program with broodstock originating from Chambers Creek. From inception to the mid-1990s, the program annually transported juvenile fish from South Tacoma Hatchery. From the mid-1990s until the program terminated in 2014, the program was maintained by adult hatchery-origin fish returning to Marblemount Hatchery, Barnaby Slough, and the Baker River Upstream Fish Trap. The program release goal was 535,000 smolts released in various locations throughout the Skagit River watershed. The goal of the program was to provide 10,000 adult fish for harvest in terminal Skagit River fisheries.

2.4.6. Harvest

In the past, fisheries in Puget Sound and fisheries in the ocean that catch Puget Sound-origin fish were generally not managed in a manner appropriate for the conservation of naturally-spawning Chinook salmon and steelhead trout populations (NMFS 2022a). Fisheries exploitation rates were in most cases too high, especially in light of the declining pre-harvest productivity of natural-origin populations. In response, over the past several decades, the fisheries co-managers implemented strategies to develop harvest objectives that are more consistent with the underlying productivity of the natural populations, resulting in substantially reduced harvest impacts on most populations relative to pre-listing impacts. Selective gear types and time and area closures are some of the management tools used to reduce catches of diminished populations, and to reduce incidental capture of natural-origin Puget Sound Chinook salmon and steelhead trout in fisheries targeting other species or populations. Other management measures (e.g., size limits, bag limits, mark-selective fisheries, and required use of barbless hooks in recreational fisheries) are also used to achieve these objectives while providing harvest opportunities on more abundant populations and species. As a result, exploitation rates for most natural-origin Puget Sound Chinook salmon and steelhead trout populations have, in most cases, been reduced substantially compared to years prior to listing. The effect of these overall reductions in harvest has been to improve the baseline condition and help to alleviate the effect of harvest as a factor limiting population recovery. Nonetheless, harvest remains an important factor impacting abundance of Puget Sound Chinook salmon abundance, but not Puget Sound steelhead trout (NMFS 2019c; Ford 2022).

Since 2010, Puget Sound fisheries have been managed by the state and tribal co-managers according to the jointly-developed 2010–2014 Puget Sound Chinook Harvest RMP[12], and as amended annually since that time (NMFS 2022a, and references therein). This RMP and its annual amendments describe conservation and allocation objectives and Chinook salmon exploitation rates that guide implementation of the fisheries. The RMP was adopted as the harvest component of the Puget Sound Salmon Recovery Plan for the Puget Sound Chinook Salmon ESU (NMFS 2011b). NMFS regularly completes ESA consultations evaluating effects of the proposed Puget Sound fisheries to listed Puget Sound Chinook salmon and steelhead trout (e.g., NMFS 2022a).

Salmonid fisheries, impacts to Puget Sound Chinook salmon

For fisheries management purposes, Skagit River Chinook salmon are categorized as belonging to either the Skagit Spring Management Unit (MU) or Skagit Summer/Fall MU. The Spring MU represents the three spring Chinook populations in the watershed, whereas the Summer/Fall MU represents the three summer and fall Chinook populations. Total exploitation rates averaged 25% and 44% for the Spring and Summer/Fall MUs, respectively, for the 2009–2018 period, which is the most recent period for which data is available (NMFS 2022a). These rates meet the co-manager objectives of 38% and 50% for the Spring and Summer/Fall MUs, respectively, though the Summer/Fall MU objective was exceeded in one year (61% in 2011) (NMFS 2021; 2022a). Exploitation rates do not appear to have changed much since the time of listing: mean pre-listing exploitation rates (represented by 1992–1998 data) were estimated to be 22% and 45% for the Spring and Summer/Fall MUs, respectively.

A large portion of the total harvest of Skagit Chinook salmon occurs outside of the Action Area in Alaskan and Canadian fisheries: 57% and 59% of the total exploitation occurs in these fisheries for the Skagit Spring and Summer/Fall MUs, respectively (NMFS 2022a). These fisheries are managed under the terms of the Pacific Salmon Treaty (PST) and Canadian domestic law. Ocean salmon fisheries in contiguous U.S. federal waters are managed by NMFS and the Pacific Fishery Management Council (PFMC), under the Magnuson-Stevens Act (MSA) and under the terms of the PST. For salmon fisheries in federal waters off the southeast coast of Alaska (SEAK), the North Pacific Fisheries Management Council (NPFMC) has delegated its management authority to the State of Alaska. These fisheries are also managed under the terms of the PST. The effects of the northern fisheries (Canada and SEAK) on Puget Sound Chinook salmon were assessed in previous NMFS Biological Opinions (NMFS 2004a; 2008e; 2019b). As with Puget Sound fisheries, in recent years these ocean fisheries have been reduced through agreements under the PST in the case of the northern fisheries, and in order to address impacts to ESA-listed and other populations in the case of the PFMC fisheries.

Salmonid fisheries, impacts to Puget Sound steelhead

NMFS observed that previous harvest management practices likely contributed to the historical decline of Puget Sound steelhead, but concluded in the Federal Register Notice for the listing determination (72 FR 26732, May 11, 2007) that the elimination of the direct harvest of natural-

[12] Though titled "Chinook Harvest RMP," the RMP describes management objectives for all Puget Sound fisheries, not just Chinook

origin steelhead in the mid-1990s had largely addressed this threat. From the late 1970s to early 1990s, harvest rates on natural-origin steelhead averaged between 10% and 40%, with some populations in central and south Puget Sound exceeding 60%. Harvest rates on natural-origin steelhead have declined since the 1970s and 1980s and are now stable and generally less than 2%, which is all incidental take except for the Skagit River (see below) (Ford 2022). The recent NWFSC biological viability assessment update (Ford 2022) concluded that continued limits on harvest will facilitate population rebuilding during "good" (high escapement) years and buffer against demographic risks under "bad" (low escapement) years.

For Skagit River steelhead, NMFS estimated that from 1985 to 2001 harvest rates averaged 13.7% (range: 1.6–24.6%), based on available reconstructed Skagit River steelhead runs (NMFS 2018b). Harvest rates declined to mean 4.3% (range: 0.8–10.0%) prior to listing in 2007 (2001-02 to 2006-07 seasons), during which time there were no steelhead-directed fisheries. Harvest rates continued to decline after listing, averaging 2.9% (range: 1.1–5.9%) during the 2007-08 to 2016-17 seasons (NMFS 2022a).

In 2016, the Skagit River fisheries co-managers proposed a five-year joint tribal and state resource management plan (RMP) for implementing and managing fisheries targeting Skagit River natural-origin steelhead, including tribal harvest and recreational catch-and-release fisheries. In 2018, NMFS completed an ESA Biological Opinion (NMFS 2018b) and associated 4(d) determination on the proposed RMP. The RMP proposed, and NMFS evaluated, an annual total allowable impact (i.e., mortality) to Skagit River steelhead from all terminal steelhead- and non-steelhead-directed fisheries combined. This annual allowable impact is determined using a sliding scale system based on the terminal run size forecast for Skagit River steelhead (Table 8). Since the RMP was implemented, steelhead-directed fisheries have occurred during three seasons (2017-18, 2018-19, and 2020-21). During these seasons, impact to Skagit River steelhead has been within that proposed in the RMP and evaluated by NMFS, ranging from 2% to 7% (Table 9).

Table 8. Annual Skagit River steelhead allowable impact levels[a] managed for under the 2016 Skagit River RMP and consulted on by NMFS (NMFS 2018b).

Preseason Forecast for Natural-Origin Skagit Steelhead Terminal Abundance	Allowable Impact (Mortality) Rate
≤ 4,000	4%
4,001–6,000	10%
6,001–8,000	20%
≥ 8,001	25%

[a] Impact levels include all mortalities from fisheries targeting steelhead (tribal harvest and recreational catch-and-release) and mortalities associated with incidental capture in non-steelhead fisheries.

Table 9. Recent allowable and actual fisheries impact (mortality) to natural-origin Skagit River steelhead. Source: NMFS (2022a).

	Steelhead management period			
	2017-2018	2018-2019	2019-2020	2020-2021
Pre-season steelhead forecast	5,247	6,567	3,963	4,297
Steelhead-directed fishery?	yes	yes	no	yes
Allowable impact based on pre-season forecast, % (no. fish)	< 10% (525)	< 20% (1,313)	< 4% (158)	< 10% (430)
Estimated mortalities from fisheries	116	326	72	209
Post-season run estimate	6,199	4,636	3,092	3,578
Actual impact (mortality) rate	1.87%	7.03%	2.33%	5.84%

Halibut fisheries

Commercial and recreational halibut fisheries occur in the Strait of Juan de Fuca and San Juan Island areas of Puget Sound. In a recent biological opinion, NMFS concluded that salmon are not likely to be caught incidentally in the commercial or tribal halibut fisheries when using halibut gear ((NMFS 2018c). The total estimated non-retention mortality of Chinook salmon in Puget Sound recreational halibut fisheries is extremely low, averaging just under two Chinook salmon per year. Of these, the estimated catch of listed fish (hatchery and wild) is between one and two Puget Sound Chinook per year. Given the very low level of impacts and the fact that the fishery occurs in mixed stock areas, different populations within the ESUs are likely affected each year. No steelhead have been observed in the fishery.

Puget Sound bottomfish and shrimp trawl fisheries

Recreational fishers targeting bottom fish and the shrimp trawl fishery in Puget Sound can incidentally catch listed Puget Sound Chinook, including those originating from the Skagit River basin. In 2012 NMFS issued an incidental take permit to the WDFW for listed species caught in these two fisheries, including Puget Sound Chinook salmon (NMFS 2012b). The permit was in effect for 5 years and authorized the total incidental take (capture) of up to 92 Puget Sound Chinook salmon annually. Some of these fish would be released, and some released fish expected to survive. Thus, of the 92 captured fish, NMFS authorized lethal take of up to 50 Chinook salmon annually. As of 2018 this permit has not been renewed. WDFW has applied for a permit allowing incidental take of 137 Chinook annually in the coming years. No steelhead have been observed in the fishery.

Coastal groundfish fishery

Puget Sound Chinook, including those originating from the Skagit River basin, are incidentally caught in small numbers in the U.S. West coast groundfish fishery. NMFS reviewed this bycatch and determined that the numbers of Puget Sound Chinook that are caught constitute a very small portion (<1.0%) of the total abundance of the populations, even under the most impactful scenario. NMFS determined that due to the small numbers of Puget Sound Chinook caught, inclusive of hatchery-produced with no take prohibition and the lack of indication of any disproportionate impacts to specific populations, that the coastal groundfish fisheries were not likely to jeopardized Puget Sound Chinook. In most years, no steelhead were observed in the fishery, and NMFS concluded that effects to the Puget Sound DPS were negligible (NMFS 2017).

2.5. Effects on ESA Protected Species and on Designated Critical Habitat

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action (see 50 CFR 402.02). A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.17). In our analysis, which describes the effects of the proposed action, we considered the factors set forth in 50 CFR 402.17(a) and (b). The methodology and best scientific information NMFS follows for analyzing hatchery effects is summarized in subection 2.5.1 and application of the methodology and analysis of the Proposed Action is in Section 2.5.2.

2.5.1. Factors That Are Considered When Analyzing Hatchery Effects

NMFS has substantial experience with hatchery programs and has developed and published a series of guidance documents for designing and evaluating hatchery programs following best available science (Hard et al. 1992; McElhany et al. 2000; NMFS 2004b; 2005c; Jones 2006; NMFS 2008b; 2012a). For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the population scale (McElhany et al. 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes; abundance, productivity, spatial structure, and diversity and then relates effects of the Proposed Action at the population scale to the MPG level and ultimately to the survival and recovery of an entire ESU or DPS.

"Because of the potential for circumventing the high rates of early mortality typically experienced in the wild, artificial propagation may be useful in the recovery of listed salmon species. However, artificial propagation entails risks as well as opportunities for salmon conservation" (Hard et al. 1992). A Proposed Action is analyzed for effects, positive and negative, on the attributes that define population viability: abundance, productivity, spatial structure, and diversity. The effects of a hatchery program on the status of an ESU or steelhead DPS and designated critical habitat "will depend on which of the four key attributes are currently limiting the ESU, and how the hatchery fish within the ESU affect each of the attributes" (70 FR 37215, June 28, 2005). The presence of hatchery fish within the ESU can positively affect the overall status of the ESU by increasing the number of natural spawners, by serving as a source population for repopulating unoccupied habitat and increasing spatial distribution, and by conserving genetic resources. "Conversely, a hatchery program managed without adequate consideration can affect a listing determination by reducing adaptive genetic diversity of the ESU, and by reducing the reproductive fitness and productivity of the ESU."

NMFS' analysis of the Proposed Action is in terms of effects it would be expected to have 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 of hatchery operation on each listed species, which in turn allows the combination of all such effects with other effects accruing to the species to determine the likelihood of posing jeopardy.

Information that NMFS needs to analyze the effects of a hatchery program on ESA-listed species must be included in an HGMP. Draft HGMPs are reviewed by NMFS for their sufficiency before formal review and analysis of the Proposed Action can begin. Analysis of an HGMP or Proposed Action for its effects on ESA-listed species and on designated Critical Habitat depends on six factors. These factors are:

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

NMFS' analysis assigns an effect category for each factor (negative, negligible, or positive/beneficial) on 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; (3) the target viability for the affected natural population(s) and; (4) the Environmental Baseline, including the factors currently limiting population viability. For more information on how NMFS evaluates each factor, please see Appendix A: Factors Considered When Analyzing Hatchery Effects.

2.5.2. Effects of the Proposed Action on ESA Protected Species

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

The proposed hatchery chum programs do not remove ESA-listed fish from natural populations and use them for broodstock. Thus, there are no effects to listed salmonids from this factor.

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

2.5.2.2.1. Genetic effects

The proposed hatchery chum programs do not have any genetic effects on listed Chinook salmon and steelhead populations because these species do not interbreed.

2.5.2.2.2. Ecological effects

Marine-derived nutrients and ecological services

Historically, adult returns of naturally-spawning anadromous Pacific salmon delivered large quantities of nutrients to freshwater ecosystems across Washington, Oregon, and California, including Puget Sound (Gresh et al. 2000). However, widespread declines in salmon abundance have substantially diminished this subsidy of marine-derived nutrients to freshwater ecosystems (NRC 1996; Gresh et al. 2000). In Puget Sound, recent biomass and nutrient imports from adult salmon returns were estimated to be 12–25% of their historical values. Spawning salmon often provide a substantial and important nutrient subsidy to freshwater ecosystems (e.g., Cederholm et al. 1999; Gende et al. 2002; Schindler et al. 2003; Janetski et al. 2009; Wipfli and Baxter 2010; Walsh et al. 2020) that can increase growth and survival of fish (e.g., Bilby et al. 1998; Wipfli et al. 2003; Moore et al. 2008; Copeland and Meyer 2011; Bentley et al. 2012; Rinella et al. 2012; Nelson and Reynolds 2015) as well as benefit the aquatic ecosystem and watershed as a whole, which in turn benefits the productivity of listed salmonid populations. Adult salmon spawners provide additional ecological services, including streambed disturbance, nutrient release and retention, and release of aquatic invertebrates and salmon eggs from the substrate (e.g., Collins et al. 2015, and references therein). These services may function synergistically with the import of marine-derived nutrients to boost aquatic ecosystem productivity. As a result, abundances of resident and freshwater-rearing anadromous salmonids have increased with increasing spawner abundances in some systems (e.g., Nelson and Reynolds 2014; Swain and Reynolds 2015; Benjamin et al. 2020). Conversely, low spawner numbers may deprive the river system of nutrients and suppress the productivity of fish populations and the aquatic ecosystem (Scheuerell et al. 2005; Copeland and Meyer 2011). Together, these findings raise concerns about negative consequences to freshwater ecosystem generally, and natural salmonid productivity in particular, resulting from low or depressed adult spawner abundances.

Returning hatchery-origin adult chum salmon produced by the Proposed Action are expected to provide marine-derived nutrients and ecological services to the action area. NMFS estimates that mean 13,032 hatchery-origin chum salmon may return to the watershed annually as adults at the Proposed Action's full production levels (NMFS 2022, in. prep.). This would contribute 114,923 pounds (52,128 kg) of biomass and associated nutrients (e.g., phosphorous, nitrogen, and carbon) annually to that part of the action area containing listed salmon and steelhead (i.e., Skagit River below Gorge Dam exclusive of the Baker River system above the Upstream Fish Trap), assuming mean 2011–2015 species-specific adult weights from Losee et al. (2019). This would represent an additional 8% of biomass relative to recent (2010–2019) co-manager escapement estimates and associated contributions from all naturally-spawning Pacific salmon and steelhead in that part of the action area where listed salmon and steelhead are found. These contributions from hatchery-origin chum salmon will partially compensate for the loss associated with the recent decline in natural Skagit River chum salmon abundance (see Appendix B: Skagit River watershed chum salmon). For simplicity, we did not account for chum salmon broodstock collection. However, two of the programs (Skagit River Fall Chum Salmon, Chum Salmon RSI) propose to return hatchery-spawned carcasses to the river banks, though not all biomass from these fish will be returned due to hatchery egg take and retention of potentially-diseased holding mortalities. We did not consider imports from other anadromous salmonids such as cutthroat or bull trout, though contributions from these species are likely relatively low. We also assumed that contributions from stray Baker-origin coho and sockeye salmon were negligible.

Salmon have been noted to transfer contaminants into ecosystems via their carcasses (Ewald et al. 1998; O'Toole et al. 2006). Persistent organic chemicals such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs) are transferred through the food chain and are retained within the tissues of salmon. Analyses show that as the fish burn fat on their spawning migration, they do not metabolize these pollutants (Ewald et al. 1998). These contaminants, acquired during the salmons' ocean migration, concentrate in their tissues and roe. They are ultimately passed (i.e., bio-transferred) on to the freshwater ecosystem to which the salmon return and are introduced into the food chain. The abundance of hatchery-origin chum salmon expected in the watershed at full production levels is relatively small compared to natural-origin salmonids, and the total of the two (natural- and hatchery-origin) is within the range of recent natural adult returns. Thus, risks from contaminant contribution from hatchery-origin fish is minor and not expected to have measureable effects to listed salmon or steelhead trout.

Spawning site competition and redd superimposition

Hatchery-origin chum salmon do not present spawning site competition or redd superimposition risks to steelhead trout. Skagit River chum salmon spawning—which may start as early as mid-October, but primarily occurs during November and December—avoids both the steelhead trout spawning (mid-February through mid-July) period and the subsequent egg incubation and pre-emergent fry periods that end by mid-October (see Table 19 in Appendix C: PCD Risk Model Assessment for Competition and Predation in Freshwater Rearing Areas).

Hatchery-origin chum salmon present a low risk of spawning site competition and redd superimposition to Chinook salmon. Most Chinook salmon spawning is complete prior to the start of chum salmon spawning. Skagit basin spring and summer Chinook are done spawning by September and October, respectively. Skagit fall Chinook salmon spawn from mid-September through mid-November, partially overlapping the chum salmon spawning period which is typically November and December, though sometimes starts as early as October. The two species generally utilize different spawning habitats. Chinook salmon typically spawn in faster and deeper water (Beechie et al. 2008) with larger substrates (Kondolf and Wolman 1993) than chum salmon. Chinook salmon also tend to bury their eggs deeper than chum salmon, though the ranges of observed egg burial depths between the two species partially overlap (DeVries 1997). In the Skagit River basin, observations by WDFW biologists indicate that Chinook and chum salmon exhibit very different spawning habitat selection, primarily in terms of water velocity, but also channel type (Fowler 2022). Chinook salmon typically spawn in the main channels of the Skagit River and its larger tributaries, whereas chum salmon primarily spawn in slower-moving areas such as side channels, sloughs, and margins of the main channel. Where the two species co-occur in time and space, Chinook salmon typically spawn in the deepest part of the channel (the thalweg), whereas chum salmon typically spawn in shallower and slower parts of the channel outside the thalweg. Thus, while there is the potential for spawning site competition and redd superimposition to occur, evidence suggests that it would be rare and unlikely to diminish Chinook salmon spawning and reproductive success to any detectable level.

NMFS estimates that 13,621 and 12,443 hatchery-origin chum salmon adults will return to the watershed during even and odd years, respectively, under the Proposed Action's full production levels (NMFS 2022, in. prep.). Since 2006, the number of natural spawners in the watershed has averaged 32,501 and 12,784 fish during even and odd years, respectively (Appendix B: Skagit River watershed chum salmon). Accounting for broodstock collection at the maximum proposed levels (5,500 fish for all programs combined), the resultant number of natural spawners is thus estimated to be 40,622 and 19,727 fish during even and odd years, respectively (e.g., for even years, 13,621 HO returns plus 32,501 NO returns minus 5,500 taken for broodstock yields 40,622 adults to spawn naturally in the watershed). In comparison, prior to the Skagit chum decline that started with BY 2007 (Appendix B: Skagit River watershed chum salmon), the number of spawners averaged 106,128 and 31,838 fish during even and odd years, respectively. Long-term (10-year) means fluctuated between 93,407 and 112,940 fish for even years, and between 23,639 and 33,817 fish for odd years. Short-term (4-year) means fluctuated between 72,663 and 132,719 fish for even years, and between 19,911 and 46,022 fish for odd years. Thus, at recent natural abundance levels, the Proposed Action is expected to result in total spawner levels that are within recent historical natural limits (BY 1968–2006) even with the addition of hatchery fish. For these reasons, we expect risk of spawning site competition and redd superimposition to Chinook salmon to remain low while the abundance of natural spawners (natural- and hatchery-origin combined) in the watershed remains within historical levels.

2.5.2.2.3. Disease

Adults returning to hatchery facilities can bear infectious pathogens, potentially transmitting them to ESA-listed species and amplifying them in the natural environment. Hatchery monitoring and control protocols are designed to minimize pathogen transmission and amplification. For example, adults held and used for broodstock are routinely screened for pathogens considered "regulated" by the co-manager's disease control policy. Few pathogens have been detected in adult broodstock in recent years (Table 10), and those that have been detected are endemic to the Skagit River watershed. Chum salmon adults held for broodstock are not given prophylactic treatments. There is no evidence to suggest that returning hatchery-origin fish to the Skagit River watershed, including those held for broodstock, present pathogen risks beyond baseline levels (i.e., that present naturally from natural-origin fish). Based on these factors, we conclude that the risk of disease transmission and amplification from returning hatchery-origin adults to the watershed, including those held for broodstock, is low.

Table 10. Pathogen information for adult fish held and/or used broodstock, 2016–2021.[a]

Program	Pathogens detected in adults held/used for broodstock	Disease outbreaks in adults held/used for broodstock
Upper Skagit Chum Salmon	*Flavobacterium psychrophilum* (2016); *Aeromonas salmonicida* (2018); No program in 2020 or 2021	none
Chum Salmon RSI[b]	*Flavobacterium psychrophilum* (2019)	none
Skagit River Fall Chum Salmon	none	none

[a] Sources: Email communications from co-managers.
[b] Pathogen screening data represent adults collected in 2017 and 2019–2021. No broodstock were collected in 2016. No pathogen screening data are available for 2018.

2.5.2.2.4. Adult collection

Broodstock collection is likely to result in the capture and handling of both natural- and hatchery-origin Chinook salmon and steelhead trout via the Marblemount Hatchery adult trap and in-river collection efforts (Table 11). However, broodstock collection is not anticipated to capture or kill a large number of natural-origin Chinook salmon or steelhead trout relative to the sizes of the Skagit populations. For Chinook salmon, in-river broodstock collection is most likely to affect the Lower Skagit Fall Chinook population. Spring Chinook salmon in the Skagit River watershed are typically done spawning before chum broodstock collection is proposed to begin in mid-October. Summer Chinook salmon are mostly done spawning by mid-October, though some late-arriving fish could be affected. For steelhead trout, in-river broodstock collection is most likely to affect the Skagit River and Sauk River populations due to the proposed times and places of broodstock collection. Collection practices and protocols are expected to minimize risk of injury and delayed mortality.

Table 11. Historical[a] and anticipated numbers of ESA-listed salmon and steelhead captured annually during in-river broodstock collection efforts and at adult collection facilities during the chum broodstock collection period (November–December) included in the Proposed Action. NO = natural-origin; HO = hatchery-origin.

Broodstock collection facility or location	Hatchery program collecting fish at facility/location	Chinook salmon		Steelhead trout, natural-origin[b]	
		Historical annual mean captures (range) / maximum mortalities	Maximum anticipated annual captures / mortalities[c,d]	Historical annual mean captures (range) / maximum mortalities	Maximum anticipated annual captures / mortalities
Skagit River, RM 8–57	Upper Skagit Chum Salmon	0	5 / 1	0	20 / 4
Sauk River, RM 12–18	Chum Salmon RSI	0	5 / 1	0	10 / 2
Marblemount Hatchery Fish Trap	Skagit River Fall Chum Salmon[e]	NO: 0	NO: 5 / 1	0	3 / 1
		HO: 0	HO: 100 / 20		
Skagit River, > RM 69	Skagit River Fall Chum Salmon	3 / 0	10 / 5	1 / 0	50 / 10

[a] Historical data encompasses: 2006–2021 for the Marblemount Hatchery trap and the Upper Skagit Chum Salmon program (except the Upper Skagit program was not operated in 2015, 2020, or 2021); 2014–2021 for the Chum Salmon RSI program; and, 2020 for the Skagit River Fall Chum Salmon program in-river collection (incidental capture of ESA-listed species was not recorded in 2021).
[b] There have been no hatchery steelhead trout releases in the Skagit River basin since 2014. Therefore, no incidental capture of hatchery-origin steelhead trout is anticipated.
[c] Figures represent combined total of natural- and hatchery-origin fish unless otherwise indicated. For captures and mortalities shown as mixed-origin (hatchery and natural combined), we assumed that 100% were natural-origin for purposes of evaluating the effects of the proposed action on listed Chinook salmon populations.
[d] ESA Section 9 take prohibitions do not apply to hatchery-origin fish with a clipped adipose fin.
[e] The hatchery trap will operate to collect chum salmon broodstock during November and December. Therefore, numbers shown represent historical and anticipated captures during this time period only.

Effects of operating the Marblemount Hatchery adult trap include the potential for delayed migration and mortality. Although the pond is checked daily for fish presence, fish are removed from the pond only once per week. Therefore, if captured, listed fish species may be retained in the pond until the subsequent removal, up to one week maximum. The pond is large (2,000 square feet), relatively deep (4–5 feet), fed with continuously-flowing surface water, and protected from predators by cyclone fencing around its perimeter. These conditions help minimize stress, injury, and mortality from prolonged captivity. Prolonged captivity in the adult trap delays upstream migration of spawners, and may result in affected fish either not spawning or spawning in suboptimum locations or less favorable habitats. Very few fish are anticipated to be affected (Table 11).

All listed natural-origin fish, if inadvertently intercepted and not targeted for broodstock, will be released as soon as possible to the Cascade River upstream from Clark Creek where no weir is present and fish migration is not affected. Hatchery protocols minimize handling and transport time and fish stress. Fish are handled in a way (bare hands) that minimizes handling time (both in and out of water), strain, scale loss, and mucous loss. In the transport vessel (tote), holding time is short (up to 5 minutes) and fish density is low (up to 5 fish per 250-gallon tote). Fish are released into a slow-moving area of the river near the shoreline where they can acclimate and re-orient. Staff that handle fish are trained and knowledgeable on safe fish handling procedures. Risks to ESA-listed Chinook salmon or steelhead trout at the scale of the population resulting from Marblemount Hatchery trap operations during the time of chum broodstock collection (November–December) is minimal given the interception history and the trap location, configuration, and operational protocols in place.

2.5.2.3. Factor 3: Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas, the estuary and ocean

2.5.2.3.1. Competition and predation in rearing areas and the freshwater migratory corridor

Natural-origin juvenile fish in freshwater rearing areas may be exposed to competition and predation from hatchery-released fish. Numerous factors may influence the degree of competition and predation, including but not limited to the degree of spatial and temporal overlap between hatchery- and natural-origin fish, relative sizes of hatchery- and natural-origin fish, and amount of available rearing space and forage resources, among other factors. See Appendix A for a more detailed overview of the factors that influence freshwater competition and predation by hatchery-origin fish, and how these factors are considered in NMFS hatchery consultations.

The term “predation” in our analysis below refers to direct predation. We acknowledge the theoretical plausibility of indirect predation. However, there currently is insufficient evidence to conclude that releases of hatchery fish associated with the Proposed Action are reasonably certain to result in indirect predation to ESA-listed Chinook salmon or steelhead trout.

Predation and adverse effects resulting from competition can rarely if ever be observed and directly calculated. In addition, available research and information is insufficient to precisely determine the degree of predation and adverse competitive interactions that can be expected in a particular watershed from specific hatchery programs. However, the science is developed enough to allow for an evaluation of the relative risk to natural-origin fish populations from these effects.

We utilized complementary qualitative and quantitative methods in our assessment. Qualitatively, we considered the factors detailed in Appendix A in the context of the Proposed Action’s hatchery fish releases and ESA-listed Chinook salmon and steelhead trout in the Skagit River watershed. To supplement this analysis, we used the PCD Risk model (version 3.2) developed by Pearsons and Busack (2012) to quantify potential effects from competition and predation to natural-origin Chinook salmon and steelhead trout. Similar to the use of models for biological systems elsewhere, this model has important limitations including but not limited to its lack of empirical validation and lack of accounting for all variables that influence competition and predation. For these reasons, we implemented the model to aid in assessing relative risk of adverse effects, not for estimating actual expected mortality to ESA-listed fish. Data, parameter inputs, and results of the PCD Rick model are detailed in Appendix C: PCD Risk Model Assessment for Competition and Predation in Freshwater Rearing Areas. The qualitative assessment relied on the same Skagit-specific information described for the PCD Risk model pertaining to HO and NO fish periodicity, spatial and temporal overlap, body size, and approximate abundance.

Hatchery-origin chum salmon do not present a predation risk to either ESA-listed species because of their small size relative to Chinook salmon and steelhead trout present in freshwater rearing areas and migratory corridors at the time of chum release. The mean sizes of hatchery chum salmon released by each of the three programs are 46–50 mm FL. In comparison, natural-origin Chinook salmon fry are mean 41 mm FL, Chinook salmon subyearling parr are mean 57 mm FL, and steelhead trout age 1 parr—the smallest steelhead age class present—are mean 91 mm FL (see Appendix C: PCD Risk Model Assessment for Competition and Predation in Freshwater Rearing Areas for description of how these sizes were determined). Furthermore, juvenile salmonids the size of chum fry are not piscivorous (Keeley and Grant 2001).

Qualitatively, competition risk from hatchery chum is low for both Chinook salmon and steelhead trout. A large proportion of Chinook salmon and steelhead trout spawning and rearing occurs in areas outside of hatchery chum migratory corridors. Hatchery chum salmon are released before steelhead trout fry start emerging from spawning gravels, and after most Chinook salmon fry have emerged and grown to parr size. Chinook parr are expected to be larger, on average, than released hatchery chum. Juvenile steelhead trout are expected to be about twice as large or larger than released hatchery chum. There is likely only partial overlap in rearing microhabitat between chum and the two listed species. In addition, juvenile Chinook salmon and steelhead trout are generally expected to be more aggressive than juvenile chum salmon. Hatchery origin chum salmon are expected to outmigrate to marine waters relatively quickly—within 11–17 days of release depending on the program—minimizing freshwater residence.

PCD Risk model results corroborated the qualitative determination. Model inputs were chosen to yield conservatively high estimates of mortality. Thus, we interpret model outputs as representing a potential maximum mortality level. Results from the model indicated potential annual mortality of up to 2,140 Chinook salmon fry and 780 parr, which we estimated to represent 15 adult equivalents. For steelhead trout, the model indicated annual mortality of up to 27 parr, which we estimated to represent 1 adult equivalent. Even in the unlikely event of experiencing the maximum potential mortality, these figures are very low relative to the sizes of the natural populations involved.

The six Skagit River basin Chinook populations are likely to experience different levels of effects from competition given that each population's spawning habitats are differentially distributed across the basin relative to hatchery chum migratory corridors. Hatchery fish migratory corridors overlap most extensively with the Lower Skagit Fall Chinook population's spawning and rearing area. Therefore, this population is likely to experience proportionally greater ecological impacts from hatchery fish. Conversely, spawning occurs outside of hatchery fish migratory corridors for three populations (Cascade Spring, Suiattle Spring, Upper Sauk Spring). It is likely that some number of juveniles from these populations disperse downriver and rear in hatchery fish migratory corridors, thus potentially being exposed to ecological effects from hatchery fish. However, the extent to which such dispersion occurs is unknown. Nonetheless, it is likely that a substantial proportion of juveniles from each of these populations rear in areas outside of hatchery fish migratory corridors (i.e., in spawning areas and areas between spawning grounds and hatchery fish migratory corridors), and thus are not exposed to ecological effects from hatchery fish.

2.5.2.3.2. Competition and predation in the estuary and ocean

Ecological interactions between hatchery- and natural-origin salmonids in the ocean (i.e., marine waters outside of the Salish Sea) are not well understood (e.g., Beamish 2018). There currently is no evidence suggesting that hatchery fish from the proposed programs may influence listed salmon and steelhead in the ocean such that those listed entities would be affected at the scale of the population, MPG, or ESU/DPS. While there is evidence that hatchery production of pink and chum salmon in Alaska, Japan, and Russia, can affect natural-origin salmon survival and productivity in the Northeast Pacific Ocean (Ruggerone et al. 2010; Ruggerone et al. 2012), the degree of impact is not yet understood or predictable. Further, the extent to which these findings may apply to Chinook salmon or steelhead trout are unknown. The number of hatchery fish released as part of the proposed action is a small fraction of hatchery- and natural-origin salmonids that utilize the Pacific Ocean. Effects from these relatively small releases of hatchery fish to listed salmon and steelhead in the Pacific Ocean would be correspondingly small and indistinguishable from effects from other natural- and hatchery-origin fish. The remainder of this section will focus on interactions in the estuary and Puget Sound.

Effects to steelhead trout

Juvenile steelhead trout do not typically utilize estuary habitat for rearing, with some exceptions in a few specific locations (Myers 2018; Quinn 2018). Evidence from the Salish Sea (Fresh 2006; Melnychuk et al. 2007; Moore et al. 2010; Goetz et al. 2015; Moore and Berejikian 2017) suggests that juvenile steelhead trout in these areas move rapidly through estuaries, likely owing to their large size at outmigration. In addition to moving rapidly through their natal estuaries, juvenile steelhead trout also move rapidly through Puget Sound and the Strait of Juan de Fuca. Moore et al. (2015) observed that steelhead from four Puget Sound river systems, exclusive of Hood Canal, took around 3–13 days to move from river mouth into the Strait of Juan de Fuca, and a total of about 6–12 days to move from river mouth to the Pacific Ocean. Skagit River natural- and hatchery-origin fish were among the fastest, taking on average 2.9 days to move from the river mouth to the Strait of Juan de Fuca, and 7.2 days to move from the river mouth to the ocean. Because of their rapid movement through estuarine and Puget Sound habitats, there is minimal opportunity for detrimental interactions from hatchery-origin fish associated with the Proposed Action.

Puget Sound steelhead trout populations, including the Skagit River populations, experience extremely high mortality during their short residence in Puget Sound (Moore et al. 2010; Moore et al. 2015), much more so than during their time in the Pacific Ocean (Kendall et al. 2017; Sobocinski et al. 2020). There is strong evidence that predation—particularly though not exclusively by harbor seals—is the most dominant cause of mortality in Puget Sound waters (PSSMSW 2018, and references therein; Sobocinski et al. 2020; Pearsall et al. 2021). Though recent reviews and investigations do not rule out ecological interactions from hatchery salmonids as one potential source of reduced fitness and mortality, they do indicate that any such causes are likely minor. The Synthesis Committee of the Salish Sea Marine Survival Project[13] (SCSSMSP) recently concluded that competition (intra- and inter-specific) and foraging opportunities are likely not a factor or not very important for steelhead survival in Puget Sound (Pearsall et al. 2021). Disease is also believed to have a minimal impact. Juvenile steelhead in Puget Sound are too large to be preyed upon by hatchery-origin fish from the Proposed Action.

Sobocinski et al. (2020) evaluated effects from Chinook salmon hatchery practices and a variety of other potential drivers of Puget Sound steelhead marine survival over a recent 30-year time series. The authors found a positive correlation between steelhead marine survival and hatchery Chinook abundance in Puget Sound, suggesting that ecological interactions from hatchery Chinook were at the very least not detrimental, and potentially beneficial to steelhead trout. Steelhead survival increased with more protracted releases of hatchery fish, though this factor was confounded with release year. That is, hatchery releases across Puget Sound were condensed into a narrower time window during the latter part of the time series analyzed. Thus, there is uncertainty as to whether the difference in survival was due to release timing duration (condensed or protracted) or some other unanalyzed factor that influenced survival differently during the earlier and later parts of the time series analyzed. Moore et al. (2015) speculated that large releases of hatchery steelhead and coho into Puget Sound during a short annual time period may have contributed to elevated steelhead mortality during their early May study period by attracting large numbers of predators. In general, such indirect predation effects are largely speculative and require further research, particularly as they pertain to specific hatchery programs and listed salmon and steelhead populations. The extent to which Skagit hatchery-origin fish may attract predators and increase predation on natural-origin steelhead is unknown. These findings highlight the need for further research into hatchery release strategies and their effects on early marine survival of salmonids.

[13] The Salish Sea Marine Survival Project, launched in 2013, describes itself as follows (Pearsall et al. 2021): "[The Salish Sea Marine Survival Project is] a US-Canada research collaboration to identify the primary factors affecting the survival of juvenile Chinook, Coho, and steelhead in the Salish Sea marine environment. From 2014–2018, this international collaborative of over 60 federal, state, tribal, nonprofit, academic, and private entities implemented a coordinated research effort that encompassed all major hypothesized impacts on Chinook, Coho, and steelhead as they entered and transited the Salish Sea. Ultimately, several hundred scientists collaborated to implement over 90 studies…[The Synthesis Report (i.e., Pearsall et al. 2021)] synthesizes the work to date and provides [the Synthesis Committee's] perspectives regarding the primary factors affecting survival and the next steps in research and management."

Effects to Chinook salmon

Hatchery-origin chum salmon from the Proposed Action may present competition risk to natural-origin Chinook salmon rearing in the Skagit River estuary. After emigrating from freshwater, both juvenile Chinook and chum salmon rear for extended periods in estuary and nearshore shallow-water habitats before moving to offshore (neritic; > 30 m bottom depth) areas of Puget Sound (Simenstad et al. 1982; Fresh 2006). In the Skagit River, chum and Chinook salmon fry freshwater outmigration timing to the estuary overlaps: chum fry enter the estuary mostly from mid-March through mid-May, and Chinook fry enter mostly from February through April, based on WDFW RM 17 outmigrant trap data. Small Chinook salmon subyearling (i.e., "parr") outmigrants also start entering in April. Juvenile Skagit River Chinook salmon utilize estuary habitat until they are about 70–75 mm FL, at which point they move offshore (Healey 1980; Davis et al. 2020; Greene et al. 2021). In the Skagit estuary, juvenile Chinook salmon may be found from about February through July, with peak occurrence from March through May (Beamer et al. 2005; Greene et al. 2021). Observed residence times of chum salmon in estuaries range from 4 to 32 days, with a period of about 24 days being the most common (Johnson et al. 1997). In estuarine areas, chum and Chinook salmon may utilize the same habitats and prey species (Duffy et al. 2005; Kennedy et al. 2018), though diets and extent of diet overlap may vary regionally across Puget Sound (e.g., Duffy 2003; Davis et al. 2020).

Skagit estuary habitat capacity is likely limiting for natural-origin Skagit Chinook salmon (Beamer et al. 2005; Greene et al. 2016; Greene et al. 2021). Theoretically, Chinook and chum salmon may compete for similar prey items, and/or large numbers of hatchery-origin chum salmon may deplete forage resources to the detriment of Chinook salmon. Skagit River chum salmon have experienced a nearly 70% decline in abundance since 2007 (Appendix B: Skagit River watershed chum salmon). Prior to this decline, hatchery-origin chum salmon comprised less than 3% of all chum fry entering the estuary (Table 12). Under the Proposed Action, hatchery-origin chum salmon would likely make-up a greater proportion of chum fry entering the estuary. However, the combined abundance of natural- and hatchery-origin chum would not exceed 75–79% of pre-decline means using conservatively high estimates of freshwater survival (Table 12). Skagit River natural-origin Chinook salmon survival and abundance has not exhibited any clear and consistent increase since 2007, during which time chum salmon abundance has remained low (Ford 2022). Though not definitive, this is one indicator that chum salmon abundances within historical levels likely do not exert a measureable influence on Chinook salmon fitness and survival. While abundances of chum salmon (natural- and hatchery-origin combined) entering the estuary remain within historical levels, we do not anticipate that risk to Chinook salmon in the estuary will increase.

For Chinook salmon, the time spent rearing in Puget Sound is one of the most critical periods impacting their fitness and survival (Greene et al. 2005; Sobocinski et al. 2020; Pearsall et al. 2021). However, assessment of the effects of hatchery fish on natural-origin Chinook salmon in Puget Sound is problematic because relevant scientific knowledge is incomplete, albeit rapidly evolving (Pearsall et al. 2021). Based on a comprehensive review of the science to date, the SCSSMSP noted that the following factors appear to be most influential to Chinook mortality in

Table 12. Estimated historical and projected abundance of chum salmon fry entering the Skagit River estuary annually from the Skagit River. HO = hatchery origin; NO = natural origin.

Description		Chum abundance in estuary, millions		
		Odd BYs	Even BYs	All years[a]
Historical chum abundance (prior to BY 2006 decline)	NO (pre-decline mean)[b]	6.78	12.23	10.18
	HO (BY 1996–2006 mean)[c]	0.19	0.26	0.24
	All chum (NO+HO, BY 1996–2006 mean)[d]	6.97	12.49	10.42
Projected chum abundance (with proposed action)	NO (post-decline mean, BY 2007–2020)[e]	0.62	5.14	3.03
	HO (all Skagit basin hatchery programs)[f]	4.74	4.74	4.74
	All chum (NO+HO)	5.36	9.88	7.77
Difference in chum abundance (projected minus historical)		-1.61	-2.61	-2.65
Projected chum abundance as a percentage of historical abundance		77%	79%	75%

[a] To avoid bias from the even-odd year chum cycle, groupings based on historical data that combined even and odd years were restricted so that the same number of even and odd years were represented. This meant having to exclude one year from some data sets. When this was necessary, the earliest year of data was excluded. Therefore, BY 1996 and BY 2008 data were excluded.
[b] Figures are based on outmigrant trap data (footnote d), accounting for hatchery releases (footnote c) and assuming 100% survival from RM 17 to estuary entrance.
[c] Hatchery releases were assumed to survive at 78% from release to estuary (Salo 1991). Hatchery release data provided by SSIT, USIT, and WDFW.
[d] Figures are based on WDFW estimates of outmigrant abundance at the RM 17 smolt trap, assuming 100% survival from trap to the estuary.
[e] Figures in the table are based on WDFW outmigrant abundance estimates from the RM 17 smolt trap, adjusted to account for hatchery releases (all unmarked) which were assumed to survive at 78% (Salo 1991) from release to trap. We assumed 100% survival from trap to the estuary. There was no outmigrant estimate available for BY 2019. Hatchery production data provided by SSIT, USIT, and WDFW.
[f] Projected hatchery-origin abundance includes 10% production overage and 78% survival (Salo 1991) from release to estuary.

Puget Sound: predator abundance (particularly seals), contaminants, water quality, prey availability, and growth during the early marine "critical period" (Pearsall et al. 2021).

With regards to effects from hatchery fish, competitive interactions that negatively affect natural Chinook salmon in the marine environment (e.g., depleting prey resources and negatively impacting growth) are of particular concern. The SCSSMPS concluded that: 1) there is some evidence that intra- and inter-specific competition during some time periods and in some places of the Salish Sea impacts Chinook salmon marine survival; 2) study results are mixed; and, 3) if competition does occur, it is most likely dictated by factors other than Chinook abundance that deplete or limit prey availability or habitat (e.g., dynamic environmental variables, ecosystem productivity, and food web interactions involving natural-origin species such as pink salmon, herring, and crab) (Pearsall et al. 2021). Therefore, hatchery releases could exacerbate density-dependent effects during years of low ocean productivity. While abundances of Skagit River chum salmon (natural- and hatchery-origin combined) entering marine waters remain within historical levels, we anticipate that risk to Chinook salmon in Puget Sound from the Proposed Action will be low.

2.5.2.3.3. Naturally-produced progeny competition

Naturally spawning hatchery-origin salmon and steelhead may be less efficient at reproduction than their natural-origin counterparts (Christie et al. 2014). However, the progeny of such hatchery-origin spawners may comprise a sizable proportion of the juvenile fish population where hatchery-origin fish spawn naturally. This is an acceptable outcome for the conservation-oriented chum salmon programs in the Skagit basin because these programs are intended to increase the abundance of naturally-spawned chum salmon in the watershed. We do not have any data that suggests that offspring of naturally spawning hatchery-origin adults behave differently from the offspring of natural-origin parents. Therefore, the only potential effects of this added natural production are similar minor competitive interactions as those described in subsections 2.5.2.3.1 and 2.5.2.3.2 for hatchery-origin fish. As discussed in subsection 2.5.2.2.2, NMFS expects the Proposed Action to result in total spawner numbers (natural- and hatchery-origin combined) in the watershed to remain within historical levels, which consisted almost exclusively of natural-origin fish. Thus, the total number of progeny is also expected to remain within historical levels. Risk to Chinook salmon and steelhead trout is therefore deemed low.

2.5.2.3.4. Disease

The hatchery programs included in the proposed action implement policies and practices for preventing, monitoring, and controlling pathogens in the hatchery environment. When implemented, these protocols help contain pathogen outbreaks at hatchery facilities, minimize release of infected fish from hatcheries, and reduce the risk of fish pathogen transfer and amplification to natural origin fish (e.g., Naish et al. 2008; also see Appendix A). Frequent inspections and fish health monitoring allow for rapid detection and treatment of pathogens and disease. Treatments for nearly all commonly encountered pathogens are usually effective within hours to weeks, minimizing the length of time pathogens may be shed and amplified in the hatchery. As a result, relatively few pathogens have been detected (Table 13) and no pathogen outbreaks have occurred in recent years. High egg-to-smolt survival rates reported in the HGMPs provide further evidence that pathogen management protocols are effective. The risk of any pathogen amplification effects is further reduced because the sizes of the primary receiving waterbodies (i.e., Cascade, Sauk, and Skagit Rivers) are relatively large and would rapidly dilute the concentrations of any infectious agents in the hatchery effluent. There is no evidence to suggest that the hatchery programs meaningfully elevate pathogen risks within the Skagit River watershed beyond baseline levels (i.e., that present naturally from natural-origin fish). Based on these factors, we conclude that the risk of disease amplification and transmission is low.

Table 13. Pathogen and related disease detections in juvenile fish rearing at hatchery facilities that are included in the proposed action, release years 2016–2021.[a,b]

Program	Pathogens or diseases detected (release year)
Upper Skagit Chum	EGD (2017); none (2018–2020); no program was operated in 2016 or 2021
Chum RSI	EGD (2018); NGD (2018); no program was operated in 2016 or 2017; there were no fish health inspections in 2019 because of catastrophic loss of rearing fry due to storm damage; there were no fish health inspections in 2020 due to COVID-19
Skagit River Fall Chum	none

[a] Sources: Email communications from co-managers.
[b] BCWD = bacterial cold water disease; BGD = bacterial gill disease; BKD = bacterial kidney disease; EGD = environmental gill disease; NGD = nutritional gill disease; no program = hatchery program did not operate and no juveniles were present at the hatchery facility.

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

RM&E in the Skagit River Basin for adults may include foot and boat spawning ground surveys that count spawning fish and may include sampling carcasses for scales, otoliths, tissues for DNA analysis, and other similar types of carcass biosampling. The same level and types of biological sampling would occur for some species escaping to the hatcheries and collected as broodstock. Surveyor presence is temporary and infrequent, on the order of minutes within a given stream reach, occurring once or twice per week. The effects of these activities on ESA-listed adult salmon and steelhead are confined to avoidance behavior and temporary displacement from preferred areas until surveyors move through a stream reach. Fish frightened by disturbance, turbulence, and/or noise are likely to seek temporary refuge in deeper water, or behind/under rocks or vegetation. In extreme cases, some individuals may leave a particular pool or habitat type. These avoidance behaviors are expected to be in the range of normal predator and disturbance behaviors. Therefore, we do not anticipate RM&E actions to result in a decrease in the likelihood of survival and recovery of the listed species.

Juvenile outmigrant trapping in the Skagit River at RM 17 is conducted annually, and is covered under a separate ESA 4(d) authorization renewed annually by NMFS[14]. Data collected through operation of the outmigrant trap allows assessment of emigrating natural- and hatchery-origin fish abundance and timing. Other data collected at the trap used to assess hatchery effects may include fish size, origin (based on mark and tag presence/absence), and other biological data (e.g., tissues sampled for genetic analyses).

[14] Recent NMFS permit numbers are as follow (year of permit coverage in parentheses): 22521 (2019), 21773 (2018), 20801 (2017), 19946 (2016), 19139 (2015), 18435 (2014), 17467 (2013), 16732 (2012), 15836 (2011), 14874 (2010).

2.5.2.5. Factor 5: Operation and maintenance of hatchery facilities

2.5.2.5.1. Marblemount Hatchery infrastructure in Clark Creek

The Marblemount Hatchery was constructed in-line with Clark Creek. As Clark Creek enters the hatchery grounds, a portion is diverted to raceways via a surface water intake. The remainder of Clark Creek flows into and through the hatchery by one of the following three pathways: 1) the adult trap and holding pond; 2) the steelhead channel; and, 3) the asphalt lined rearing channels and release/bypass channel (Figure 3). These intakes and pathways are not screened for fish because they lie above weirs that prohibit upstream movement of juvenile and adult fish into these areas.

Occasional high flow events may allow periodic upstream fish movement into the release/bypass channel above the weir. The frequency, intensity, and duration of such events is not known with certainty, and neither is the extent to which Chinook salmon and steelhead trout move above the weir during such events. WDFW staff have indicated that such events may occur on the order of about once per year. Any juvenile or adult fish that move upstream of the weir during these events may become stranded above the weir. These fish may be vulnerable to delayed or prohibited migration, starvation, or predation, particularly if the area they are stranded in lacks cover and suitable habitat conditions. At the population scale, risks from stranding or entrainment are likely low because relatively few fish are likely affected. The full extent of the risk is not known because the frequency, intensity, and duration of occurrence of weir-compromising high flow events is not known with certainty, and the abundance of affected juvenile and adult Chinook salmon and steelhead trout is not known with certainty.

Natural-origin fish are not intended to move upstream of the Clark Creek weirs. Above the hatchery, Clark Creek and its tributaries are small, spring-fed floodplain streams. There are no reliable surveys of accessible stream length above the hatchery. However, USGS Hydroline data suggest that approximately 1.9 miles of the Clark Creek network lie above the Marblemount Hatchery weirs, and approximately 1.1 miles of an unnamed floodplain stream network lie above the bypass/release channel weir. Neither Chinook salmon nor steelhead trout would likely spawn in either of these networks, though juveniles of both species would likely find off-channel refuge and rearing habitat here. Although fish are prohibited from accessing this habitat, there is similar habitat elsewhere in the Cascade River subwatershed and the Skagit River basin. Thus, its loss of use is relatively minor at the scale of the affected Chinook salmon and steelhead trout populations. However, Zimmerman et al. (2015) concluded that rearing habitat is likely a limiting factor to freshwater Chinook salmon production. Thus, prohibiting the use of Clark Creek may represent a minor incremental decrease in freshwater Chinook salmon production.

The raceway discharge pipe, which is located near the entrance to the adult trap, is perched approximately 2 feet above the water surface. The pipe is grated except on days when fish are released from the hatchery raceways when the grating is lifted to allow hatchery fish to exit. The grating has rounded corners and no sharp edges to minimize potential for fish injury. Water exiting the pipe is not diffused. This creates a false attraction and injury potential to any adults attempting to jump and follow this flow pathway. The number of adults affected during the time of year the chum program is operating (November–April) is likely very low. Few if any adult Chinook salmon are expected in this area of the watershed at this time of year because spring and summer Chinook salmon are done spawning by November, and fall Chinook salmon spawn lower in the Skagit River watershed. No natural-origin adult Chinook salmon or steelhead trout have been captured in the Marblemount adult trap during the time period that the chum program is operating. This lack of captures is evidence that few if any natural-origin Chinook salmon and steelhead trout are present in this area during this time of year. Further, any fish that may be present would likely be more attracted to the higher discharge volume flowing through the nearby adult trap fish ladder. Thus, we anticipate that no more than the numbers of Chinook salmon and steelhead shown in Table 11 anticipated to be captured in the Marblemount Hatchery adult trap may also be exposed to effects from the discharge pipe.

2.5.2.5.2. Surface water intake screening (other than Clark Creek)

Hatchery facilities that withdraw surface water risk entraining fish into water intakes and/or impinging fish on intake infrastructure such as screening. Intake structures and screening that are designed and operated in accordance with current NMFS screening criteria (NMFS 2022b) substantially minimize this risk. Structures that meet previous NMFS criteria (NMFS 1995; 1996; 2011a) may also reduce risk. Screening in Clark Creek for the Marblemount Hatchery was addressed in the preceding subsection. The remainder of the hatchery facilities and surface water intakes, including Marblemount Hatchery's Jordan Creek and Cascade River, are addressed in this subsection.

The following Skagit hatchery facilities present low or no risk to Chinook salmon or steelhead trout for the reasons indicated:

- *Countyline Pond, Powerline Channel*. There are no water intakes at these facilities. Both facilities are off the main river channel and are groundwater-fed.

- *Jordan Creek intake (Marblemount Hatchery)*. The Jordan Creek intake screening and passage structure was upgraded in 2018 to meet NMFS standards in place at the time (i.e., NMFS 2011a) (Simmons 2019). Current screening criteria (NMFS 2022b) are very similar to those used in the design. It is therefore likely that the intake is highly protective of listed fish.

- *Sauk-Suiattle RSI.* Screening at this facility complies with NMFS (2011a) criteria. Chinook and steelhead have not been observed or documented in currently or historically accessible reaches of Hatchery Creek, as indicated in the HGMP (Sauk-Suiattle Indian Tribe 2018) and by WDFW[15]. There is currently a barrier to anadromous fish passage (i.e., culvert) downstream from the intake. If the fish passage barrier is remedied and anadromous fish access is restored, the SSIT have proposed to upgrade the intake to meet NMFS criteria in place at the time (Kirby 2022a).

[15] WDFW source: SalmonScape, http://apps.wdfw.wa.gov/salmonscape/map.html. Accessed May 12, 2021.

The following Skagit hatchery facilities present an elevated risk to Chinook salmon and steelhead trout for the reasons indicated:

- *Cascade River intake (Marblemount Hatchery)*. The Cascade River intake screening does not meet current (NMFS 2022b) or previous (NMFS 1995; 1996; 2011a) criteria due to the following: there are gaps in civil works, there is an inadequate active cleaning system, there are excessive and non-uniform approach velocities, and there is likely not enough screening area at some flow levels (Meyer 2020a; Simmons and Rogala 2020). Any fry-sized fish (< 60 mm) coming down the hatchery-side shoreline are likely to encounter the intake. There is an eddy in front of the screen which compounds the risk: any fish that get caught in the eddy may have to make multiple passes in front of the screen face before they either become impinged or are swept downstream. The high approach velocity could impinge fry-sized fish, and the gaps between the screen panels and the supporting structure could allow fry in. The full extent of risk depends on the number of fry that are in this area and encounter the intake. Both Chinook salmon and steelhead trout spawn upriver from the intake. Mitigating the risk is the relatively small percentage of the total river flow pulled into the intake (Figure 20). Any fish swimming out in the main current or along the opposite shoreline would likely be swept past the screen with no interaction. The WDFW has requested funding from the Washington State Legislature to bring the intake screening up to NMFS standards (Coutu 2021). Pre-design, design, and permitting funding will be requested for the 2023-2025 biennium, and construction funding requested for the 2025-2027 and 2027-2029 biennia.

- *Upper Skagit (Red Creek) Hatchery*. Screening at this facility has clear openings of 3.18 mm, nearly twice as large as the 1.75 mm indicated in both current (NMFS 2022b) and previous (NMFS 1995; 1996; 2011a) criteria (Meyer 2019). This presents an elevated risk of entrainment and/or impingement to fry. Other aspects of the screening—including an appropriate cleaning and maintenance plan—meet current criteria (Meyer 2019; McClure 2020; Meyer 2020b). Though the screening presents an elevated risk of entrainment and/or impingement to fry in the area, the current risk to listed species is low. To our knowledge, listed species have not been observed in Red Creek in recent history, likely owing to degraded habitat and passage conditions throughout the creek. Listed Chinook salmon and steelhead trout are known to occupy nearby Hansen Creek, and recent and ongoing habitat restoration and passage improvements throughout the Hansen Creek subwatershed increase the likelihood that some individuals may enter Red Creek. However, a natural barrier to fish passage (log dam) is present in Red Creek approximately 0.5 miles downstream from the hatchery discharge. USIT fish survey data indicate that this barrier currently prohibits upstream fish movement (McClure 2022).

2.5.2.5.3. Water withdrawal

Hatchery water use is typically non-consumptive, though the relative quantity of water withdrawn and relative locations of withdrawal and discharge points may present risks to migration, spawning, and rearing habitat to listed fish. Facilities that withdraw a small proportion of total stream discharge, and/or that discharge near the point(s) of withdrawal, minimize risks. At the Marblemount Hatchery, other hatchery programs (Chinook, coho) are operating and using water during the same time the chum salmon program is operating. The quantity of water used specifically by any one program, including the chum program, is not known. Further, the Marblemount Hatchery lacks instrumentation on the various surface water intakes for measuring flow. Thus, the quantity of water being withdrawn from any particular source at any one time is not known. For these reasons, we evaluated effects of water withdrawals at the Marblemount Hatchery at the full water right during the time the chum salmon program is operating (November–April).

The following Skagit hatchery facilities present low or no risk to Chinook salmon and steelhead trout for the reasons indicated:

- *Countyline Pond, Powerline Channel*. There are no water withdrawals associated with these facilities. Both facilities are off the main river channel and are naturally groundwater-fed.

- *Clark Creek withdrawal (Marblemount Hatchery)*. Water withdrawals affect approximately 300 ft of Clark Creek between the mouth of the bypass/release channel and the lower steelhead channel and adult trap weir (Figure 3). Some or all water may be returned in the vicinity of the lower steelhead channel and adult trap weir, and the remainder is returned via the bypass/release channel. This section is not a migratory corridor for listed fish. There are likely to be few if any Chinook salmon or steelhead trout spawning or rearing in lower Clark Creek due to its small size.

- *Sauk-Suiattle RSI*. This facility uses up to 0.1 cfs of surface water withdrawn from Hatchery Creek, affecting approximately 150 ft of the creek. Limited, opportunistically-collected flow readings indicate that Hatchery Creek runs at approximately 5.5–19 cfs during the time of year that the RSIs operate. Water use at the facility is thus a small proportion (less than 2 %) of stream discharge. In addition, Chinook and steelhead have not been observed or documented in currently or historically accessible reaches of Hatchery Creek, as indicated in the HGMP (Sauk-Suiattle Indian Tribe 2018) and by WDFW[16].

- *Cascade River withdrawal (Marblemount Hatchery)*. The hatchery water right for the Cascade River is 30 cfs, though the hatchery typically uses less (Simmons and Rogala 2020). USGS gage 12182500 (Cascade River at Marblemount)[17] is located immediately upstream (within 100 feet) from the hatchery intake and has operated since 2006. The gage data shows that the maximum water right of 30 cfs typically represents a relatively small proportion of river flow throughout the year, rarely exceeding 10% (Figure 20). River flow is naturally high during the time of year (April–July) when most listed species would be moving through (steelhead trout and Chinook salmon) or spawning in (steelhead trout only) the affected 1,650-foot reach (Fowler 2021). Hatchery water

[16] WDFW source: SalmonScape, http://apps.wdfw.wa.gov/salmonscape/map.html. Accessed May 12, 2021.
[17] USGS gage data source: https://waterdata.usgs.gov/nwis/uv?site_no=12182500. Accessed April 20, 2021.

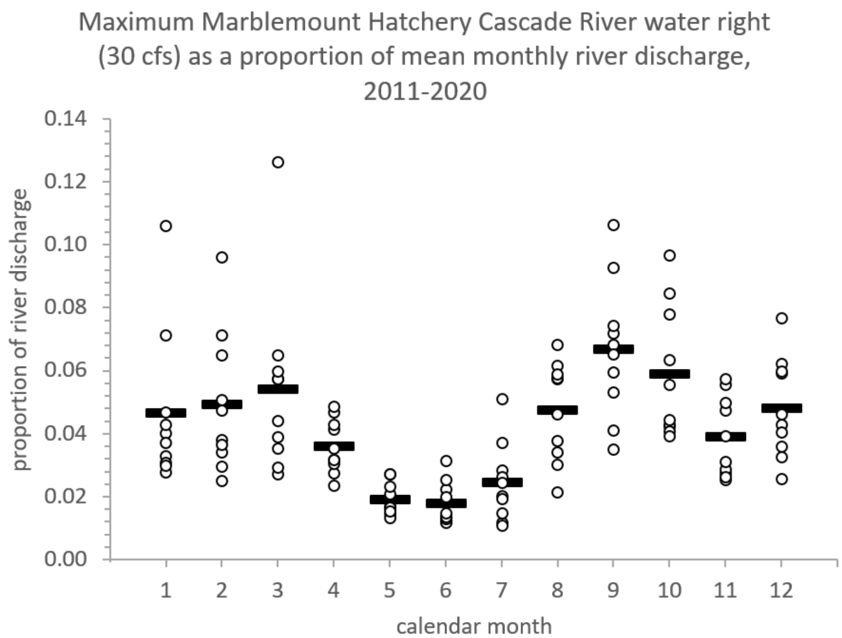

Figure 19. Marblemount Hatchery Cascade River water right (30 cfs) as a proportion of mean monthly river discharge, 2011–2020. Open circles represent individual years; bold horizontal lines represent the ten-year mean for each month. Source data from USGS gage 12185500 (https://waterdata.usgs.gov/nwis/uv?site_no=12182500).

withdrawal is thus expected to have less of an impact during this time. There are currently no data or formal surveys describing the relationship between river discharge and passage or spawning conditions in the partially dewatered reach. Visual observations by WDFW staff indicate that neither fish passage nor spawning appear affected (Fowler 2021). The hatchery water withdrawal may have some small effect on rearing habitat in the affected reach, though this is expected to be negligible given the small proportion of river flow that may be withdrawn and the relatively short length of the affected reach. Fish passage through or habitat conditions in this reach were not identified as concerns for salmon and steelhead in the Skagit River watershed (Smith 2003).

The following Skagit hatchery facilities present an elevated risk to Chinook salmon and steelhead trout for the reasons indicated:

- *Jordan Creek withdrawal (Marblemount Hatchery)*. The hatchery water right for Jordan Creek is 15 cfs. Typical water use may be less, though accurate estimates of hatchery withdrawal volume are not available because the intake is not equipped with flow measurement instrumentation (Simmons and Rogala 2020). Therefore, our evaluation is based on withdrawal of the maximum water right (15 cfs). Jordan Creek discharge is not currently gaged, and there are no quantitative assessments of water withdrawal impacts to passage and habitat conditions in the affected 1,310-foot reach. Limited historical USGS gage data from 1944–1947[18] provides some basis for assessment, though these decades-old data must be used with caution as they may not accurately reflect current streamflow patterns and volumes. Based on these historical data, maximum water withdrawal under the existing water right may take, on average, up to 35% of the stream flow during steelhead trout spawner migration periods (Table 14). These historical data also indicate that withdrawal at the maximum water right would occasionally take 50% or more of streamflow for periods of up to 17 days or more.

Steelhead trout are likely to spawn and/or rear in lower portions of Jordan Creek, including in areas below the intake and up to 3.5 miles above the intake, based on WDFW data[19]. Steelhead trout that attempt to migrate through the partially dewatered reach could be subject to significant disruption of their normal behaviors caused by reduced flows that will impede movement. If water levels drop too low, more extreme effects are likely to occur, including the following: 1) direct mortality from attempting to migrate through very shallow water; 2) injury and delayed mortality from scraping against substrates; 3) predation caused by delay or injury; and, 4) injury and mortality to eggs and juveniles associated with delayed or displaced spawning. There are currently no data describing the relationship between river discharge and passage conditions in the partially dewatered reach. However, we conclude that passage conditions will be

Table 14. Marblemount Hatchery water withdrawal from Jordan Creek at maximum water right (15 cfs) relative to historical (1944–1947[a]) Jordan Creek discharge[b].

Month	Years with recorded data	Average median monthly flow (cfs)	% of Jordan Creek flow withdrawn at maximum water right (15 cfs)
Nov	1944–1946	52	29%
Dec	1944–1946	51	29%
Jan	1945–1947	50	30%
Feb	1945–1947	43	35%
Mar	1945–1947	43	35%
Apr	1945–1947	67	23%

[a] 1944–1947 is the entire period of record of available Jordan Creek quantitative discharge data for the months the chum program is operating.
[b] Source: USGS, https://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=12183500. Accessed July 11, 2019.

[18] USGS station 12183500, Jordan Creek at Marblemount, WA, https://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=12183500.
[19] SalmonScape, http://apps.wdfw.wa.gov/salmonscape/map.html#

degraded because maximum hatchery water withdrawal represents a significant proportion of stream flow during the steelhead trout migration and spawning period. The number of steelhead trout likely to be affected annually is expected to be a relatively small proportion of the population based on the size of the affected area and the amount of accessible habitat in Jordan Creek relative to that used by the population across the Skagit River basin.

- *Upper Skagit (Red Creek) Hatchery*. The hatchery operates November–May, withdrawing surface water from Red Creek during this time. The hatchery does not operate or withdraw surface water during the rest of the year (June–October). Typical and maximum surface water withdrawals from Red Creek are 0.05–0.06 cfs during January–March, and 0.25–0.56 cfs during the other months of operation, affecting 700 feet of the stream (Shannahan 2019). Red Creek is not gauged, but limited flow measurements by USIT indicate that flows during the months of hatchery operations are typically 1.53–2.81 cfs based on monthly averages. Based on these data, hatchery water use represents < 4% of steam flow during January–March, 10–23% during November, December, and April, and 29–37% during May. These percentages will be greater during periodic times of lower flow. Passage conditions and rearing habitat are more likely to be negatively affected when the hatchery diverts greater proportions of stream flow from the affected reach, though available data is insufficient for us to assess the full extent of these effects. As mentioned above, a natural barrier (log dam) currently prohibits upstream movement of anadromous fish into the affected reach (McClure 2022), making it unlikely that listed fish species will be exposed to any effects of hatchery water withdrawal in the near future.

2.5.2.5.4. Effluent discharge

Hatchery operations require the use and discharge of surface and/or well water into streams adjacent to the operating facilities. Hatchery water discharge may affect several water quality parameters in the aquatic system. Hatchery facility waste products may include uneaten food, fish waste products (i.e., fecal matter, mucus excretions, proteins, soluble metabolites such as ammonia), chemotherapeutic agents (e.g., Formalin), cleaning agents (e.g., chlorine), drugs and antibiotics, nutrients (e.g., various forms of nitrogen and phosphorus), bacterial, viral, or parasitic microorganisms, and algae[20]. Some of these waste products are in the form of suspended solids and settleable solids, while others are dissolved in the water. Water temperature may increase and dissolved oxygen decrease as water flows through hatchery raceways and holding ponds. Maintenance activities, such as vacuuming and removal of accumulated sediment on the bottoms of hatchery ponds and raceways, may temporarily elevate the concentration of some contaminants in the hatchery water system.

The direct discharge of hatchery facility effluent is regulated by the Environmental Protection Agency (EPA) under the Clean Water Act through NPDES permits. For discharges from

[20] Risk of pathogens from effluent discharge is addressed in section 2.5.2.3.4.

hatcheries not located on federal or tribal lands within Washington, the EPA has delegated its regulatory oversight to the State. Washington Department of Ecology is responsible for issuing and enforcing NPDES permits that ensure water quality standards for surface and marine waters remain consistent with public health and enjoyment, and the propagation and protection of fish, shellfish, and wildlife (WAC 173-201A).

All hatchery facilities included in this consultation are operated in compliance with NPDES permits issued by Washington Department of Ecology, or do not require a NPDES permit. NPDES permits are not required for hatchery facilities that release less than 20,000 pounds of fish per year or that feed less than 5,000 pounds of fish food during any calendar month. Additionally, Native American tribes may adopt their own water quality standards for permits on tribal lands (i.e., tribal wastewater plans).

Under its NPDES permit, the Marblemount Hatchery operates a pollution abatement pond to remove suspended solids and settleable solids from effluent prior to discharge. The following water quality parameters, selected by EPA and WDOE as important for determining hatchery-related water quality effects, are monitored:

- Total Suspended Solids, measured 1 to 2 times per month on composite effluent, maximum effluent and influent samples.
- Settleable Solids, measured 1 to 2 times per week through effluent and influent sampling.
- In-hatchery Water Temperature, daily maximum and minimum readings.

The Marblemount Hatchery has an established record of no exceedances for at least the past 10 years.

The other hatchery facilities considered in this consultation are proposed to operate below production and feed thresholds which would require NPDES permits. The Upper Skagit Hatchery and Sauk-Suiattle RSI facilities operate for only part of the year, operate during months of seasonally high flow volumes, and produce relatively small quantities of fish. Effluent effects are therefore expected to be correspondingly small. Off-station release sites (e.g., County Line Ponds) are not used for rearing (i.e., the fish are not fed or medicated while there), and have fish present for only a few days per year. Any effluent effects associated with these sites are thus minor.

Most, if not all, chemicals used at hatcheries are used periodically (not constantly) and in relatively low volumes. This is particularly true for chemotherapeutic agents (e.g., formaldehyde, sodium chloride, iodine, potassium permanganate, hydrogen peroxide, antibiotics), which must be used at levels that will not appreciably affect the fitness or survival of juvenile salmonids rearing at the hatchery. In addition, many of these agents break down quickly in the water and/or are not likely to bioaccumulate in the environment. For example, formaldehyde readily biodegrades within 30 to 40 hours in stagnant waters. Similarly, potassium permanganate would be reduced to compounds of low toxicity within minutes. Aquatic organisms are also capable of transforming formaldehyde through various metabolic pathways into non-toxic substances, preventing bioaccumulation in organisms (EPA 2015). Although potentially more harmful, cleaning agents may be used periodically, but are diluted prior to being discharged.

Hatchery effluent is anticipated to be rapidly diluted near the point of discharge to the receiving waterbody. The likelihood of injury to listed salmonids from exposure to effluent is related to the frequency of occurrence, length of time they are exposed (e.g., how long they remain in the immediate vicinity of the effluent discharge points), and concentration of substances within the effluent water. Due to the periodic nature of chemical and chemotherapeutic use, and the low concentrations that are commonly achieved at or very near the point of discharge, we do not expect any deleterious effects to Chinook salmon or steelhead trout.

Compliance with NPDES requirements is not an assurance that effects on ESA-listed salmonids will not occur. However, the hatchery facilities use water specifically for the purpose of incubating and rearing juvenile salmon. Survival of eggs and juveniles in hatcheries are typically much higher than those in the natural environment. Egg and juvenile survival of the programs included in this consultation are indicative of generally good water quality. Chemicals are used periodically and diluted prior to discharge. Effluent discharge volumes are relatively small compared to the volumes of the receiving waters. Therefore, pollutants in the effluent are expected to be rapidly diluted near the point of discharge. In addition, any increase in temperature or decrease in dissolved oxygen that may have occurred in the hatchery would quickly return to background levels. For these reasons, effluent from the facilities included in this consultation are believed to present minimal risk to ESA-listed salmonids.

2.5.2.5.5. Other operations and maintenance

Maintenance of hatchery equipment and infrastructure (e.g., weirs, fish ladders, holding ponds, raceways) occurs intermittently and for short time periods. Such maintenance may generate disturbance from noise (equipment operation) and resuspension of fine sediments localized near the operation. Adult and larger juvenile salmonids are highly mobile and able to detect and avoid areas of disturbance. Salmonids in these age classes can easily move around or pass through sediment plumes. Individuals that may pass through a sediment plume will be exposed to elevated levels of turbidity for brief periods (less than 1 hour), and are not expected to be measurably affected. Noise from heavy equipment is not expected to reach levels that would be harmful. Therefore, direct effects associated with short-term exposure to elevated levels of turbidity and/or noise from maintenance activities are not expected to be significant.

Herbicides (primarily glyphosate-based chemicals) are used at many hatchery facilities to maintain landscaping and lawns. Herbicides are used in accordance with the manufacturer's label guidelines, and are applied during dry weather conditions (i.e., not raining or expected to rain) to prevent runoff into surface waters. Roundup is used around buildings and landscaped areas, and is not applied within 300 feet of water. Rodeo is used for applications closer to water. A backpack sprayer is used for all applications. Because herbicide use is relatively low and conservation measures are implemented to prevent chemicals from entering the water, effects to salmonids associated with the use of herbicides is considered insignificant.

Other maintenance activities (e.g., building and grounds maintenance, painting, minor building repairs, lighting and fence repair, weeding and mowing) do not occur near water and are not expected to have any adverse effects to fish. Maintenance activities that may affect water quality of effluent (e.g., vacuuming and removal of accumulated sediment on the bottoms of hatchery ponds and raceways) are discussed above in the Effluent Discharge subsection.

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

There are no fisheries that exist because of the Proposed Action. Fisheries in the action area are subject to consultation on an annual or multi-year basis, depending on the duration of the Puget Sound fishery management plan submitted by the co-managers. As described in Section 2.4, Environmental Baseline, the effects of all fisheries on ESA-listed species are expected to continue at similar levels to those described in the Environmental Baseline. (NMFS et al. 2020) found that the fisheries will not appreciably reduce the likelihood of survival and recovery for the listed species.

2.5.3. Effects of the Proposed Action on Designated Critical Habitat

In the vicinity of the Marblemount Hatchery, the following areas are designated Critical Habitat:

- For Chinook salmon and steelhead trout, the Skagit and Cascade Rivers.
- For steelhead trout only, the lower approximately 4 miles of Jordan Creek, starting from its mouth.
- For steelhead trout only, the lower approximately 1,800 ft of Clark Creek[21], extending from its mouth upstream through the hatchery grounds.

In the vicinity of the Upper Skagit Hatchery, the following areas are designated Critical Habitat:

- For Chinook salmon and steelhead trout, Hansen Creek, which is approximately 1.6 miles downstream from the hatchery.
- For steelhead trout only, lower Red Creek, from its mouth at Hansen Creek to approximately 300 ft downstream from the hatchery's effluent discharge (the nearest part of the hatchery).

In the vicinity of the Sauk-Suiattle RSI, the Sauk River, which is approximately 300–400 ft downstream from the hatchery's effluent discharge (the nearest part of the hatchery), is designated Critical Habitat for Chinook salmon and steelhead trout.

[21] The "Clark Creek" mentioned here is "Unnamed [stream] (48.522841, -121.416253)" specified in the NMFS Puget Sound Steelhead Critical Habitat designation. The "Clark Creek (48.519616, -121.404247)" identified in the NMFS Puget Sound Steelhead Critical Habitat designation is not the same Clark Creek that runs through the hatchery, but is rather located about 0.5 miles to the east of the hatchery and is called "Shoemaker Creek" in this consultation. See subsection 1.3.1.1 for explanation of these discrepancies.

Effects to PCEs are as follows:

PCE 1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.

Water quantity in Critical Habitat is not affected by the Upper Skagit Hatchery or the Sauk-Suiattle RSI facilities. Surface water diversions to the Marblemount Hatchery are expected to result in changes to water quantity, especially during annual low flow periods. Water use is non-consumptive, and water is returned relatively short distances from the withdrawal points. Therefore, any effects to water quantity are limited in area and duration. However, we anticipate that due to these diversions, the effects to water quantity will be measureable between the points of diversion to the point of return. Therefore, the effects to this PCE are expected to be adverse.

This PCE is substantially degraded in the portion of Clark Creek that runs through the Marblemount Hatchery grounds. However, this is a very small proportion of Critical Habitat in the Skagit River watershed. Further, due to the nature of Clark Creek (small spring-fed floodplain stream), steelhead would be unlikely to spawn here regardless of the hatchery impacts.

All facilities discharge hatchery effluent into or near Critical Habitat. An insignificant decrease in water quality may result from the discharge of hatchery effluent. The areas affected by discharges are relatively small and will not measurably impair water quality in the receiving water body. Chemicals and other hatchery-related pollutants in the effluent, slightly reduced dissolved oxygen levels, and minor increases in temperature will not alter water quality downstream of the facilities to a degree that would inhibit or measurably affect reproduction, growth or survival of Chinook salmon or steelhead trout downstream of any of the facilities. In addition, the discharge volumes are relatively small compared to the volumes of the receiving waterbodies in critical habitat. Compliance with applicable NPDES permits will help ensure that water quality in downstream Critical Habitat areas is not degraded or adversely affecting this PCE. In-water broodstock collection efforts may result in minor, localized, and temporary disturbances to water quality in Critical Habitat.

None of the facilities or hatchery activities included in the Proposed Action are expected to have more than insignificant effects to spawning substrate quantity or quality. Any work in or near surface waters that are included in Critical Habitat will be done in compliance with a WDFW Hydraulic Project Approval permit that specifies allowable in-water work windows and Best Management Practices. Any affects to spawning substrates would be minor, temporary, and limited in area. In-water broodstock collection efforts may result in minor, localized, and temporary disturbances to Critical Habitat substrates.

PCE 2. Freshwater rearing sites with: (i) Water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) Water quality and forage supporting juvenile development; and (iii) Natural cover such as shade, *submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.*

Effects to water quality and quantity related to this PCE are the same as those described for PCE 1. At the Marblemount hatchery, weirs on Clark Creek and water intake infrastructure and affiliated structures and bank armoring on the Cascade River, Jordan Creek, and Clark Creek diminish habitat complexity. However, their effects are relatively small and localized, and are not expected to affect the functioning of this PCE at the scale of the watershed or spatial extent of the populations. There may be minor effects to cover as a result of needing to keep hatchery infrastructure such as surface water intakes clear of debris such as large wood, rocks, and aquatic vegetation. However, these areas are very small relative to available Critical Habitat throughout the watershed. Floodplain connectivity and access to side channels is substantially impaired and essentially non-functioning in the portion of Clark Creek that runs through the Marblemount Hatchery grounds. However, this is a small proportion of Critical Habitat in the Skagit River watershed.

PCE 3. Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

Effects to water quality and quantity related to this PCE are the same as those described for PCE 1. Effects to cover related to this PCE are the same as those described for PCE 2. Marblemount Hatchery surface water usage is non-consumptive. However, water withdrawal affects Critical Habitat in a 1,650-foot reach of the Cascade River and a 1,310-foot-reach of Jordan Creek (distance between points of withdrawal and discharge). Juvenile and adult mobility and survival is unlikely to be more than insignificantly affected by the volume of the Cascade River water withdrawal because it is a relatively small proportion of river volume. However, in Jordan Creek, during lower-flow periods, the hatchery water withdrawal may degrade passage conditions through the partially dewatered reach. Steelhead trout mobility may be temporarily impaired and made more strenuous due to the challenges of navigating riffles that are shallower than they otherwise would be without the water withdrawals. We expect these effects to be temporary (only occurring during lower-flow periods), and that passage will not be precluded. For these reasons, the effects to this PCE are considered adverse in Jordan Creek.

PCE 4. Estuarine areas free of obstruction and excessive predation with: (i) Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and (iii) Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

None of the hatchery facilities or activities are in or near estuarine areas. Released hatchery fish that enter the estuary may directly and indirectly compete with Chinook salmon and steelhead trout for forage resources. However, we expect that juvenile chum salmon abundance within historical levels will not impair this PCEs ability to function. Therefore, effects to this PCE are considered insignificant.

PCE 5. Nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

Effects to this PCE are the same as those described for PCE 4.

PCE 6. Offshore marine areas with water-quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Any effects of hatchery fish in marine waters outside of Puget Sound are undetectable. Effects to this PCE are therefore considered insignificant.

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 and 402.17(a)). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. For the purpose of this analysis, the Action Area is described in Section 2.3. Future Federal actions, including the ongoing operation of the hydropower system, other hatchery programs, fisheries, and land management activities will be reviewed through separate section 7 consultation processes.

The Federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (SSDC 2007) describes, in detail, the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to listed Puget Sound Chinook salmon in the Snohomish River watershed. Similarly, a recovery plan for Puget Sound steelhead was recently issued (NMFS 2019c), and many of the actions implemented for Chinook salmon recovery will also benefit steelhead. Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy initiatives, and land use and other types of permits. Government and private actions may include changes in land and water uses, including ownership and intensity, which could affect listed species or their habitat. Government actions are subject to political, legislative and fiscal uncertainties.

Non-Federal actions are likely to continue affecting listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species (e.g., SSDC 2007). The cumulative effects of non-Federal actions in the action area are difficult to analyze because of the political variation in the Action Area, and the uncertainties associated with funding and implementation of government and private actions. However, we expect the activities identified in the baseline to continue at similar magnitudes and intensities as in the recent past.

On-going State, tribal, and local government salmon restoration and recovery actions implemented through plans such as the recovery plans (SSDC 2007; NMFS 2019c) would likely continue to help lessen the effects of non-Federal land and water use activities on the status of listed fish species. The temporal pace of reducing these effects would be similar to the pace observed in recent years. Habitat protection and restoration actions implemented thus far have focused on preservation of existing habitat and habitat-forming processes; protection of nearshore environments, including estuaries, marine shorelines, and Puget Sound; instream flow protection and enhancement; and reduction of forest practice and farming impacts on salmon habitat. Because the projects often involve multiple parties using Federal, state, and utility funds, it can be difficult to distinguish between projects with a Federal nexus and those that can be properly described as Cumulative Effects.

With these improvements, however, based on the trends discussed above, there is also the potential for adverse cumulative effects associated with some non-Federal actions to increase, such as those associated with urban expansion and development (Judge 2011). To help protect environmental resources from potential future urbanization and development effects, Federal, state, and tribal laws, regulations, and policies are designed to conserve air, water, and land resources. A few examples include the Federal Navigable Waters regulations of the Clean Water Act, and in Washington state, various habitat conservation plans (HCPs) have been implemented, such as the Washington Department of Natural Resources Forest Practices HCP (WDNR 2005).

Some continuing non-Federal activities are reasonably certain to contribute to climate effects within the Action Area. However, it is difficult if not impossible to distinguish between the Action Area's future environmental conditions caused by global climate change that are properly part of the environmental baseline and those from cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the Environmental Baseline (Section 2.4).

2.7. Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, NMFS adds the effects of the Proposed Action (Section 2.5.2) to the Environmental Baseline (Section 2.4) and to Cumulative Effects (Section 2.6) to formulate the agency's opinion as to whether the Proposed Action is likely to: (1) result in appreciable reductions in the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species (Section 2.2).

In assessing the overall risk of the proposed action on each species, NMFS considers the risks of each factor discussed in Section 2.5.2, above, in combination, considering their potential additive effects with each other and with other actions in the area (environmental baseline and cumulative effects). This combination serves to translate the threats posed by each factor of the proposed action into a determination as to whether the proposed action as a whole would appreciably reduce the likelihood of survival and recovery of the listed species.

2.7.1. Puget Sound Chinook Salmon ESU

Best available information indicates that the Puget Sound Chinook Salmon ESU remains threatened (Ford 2022). In the Skagit River watershed, spawner abundance of all six Chinook salmon populations are above critical thresholds, and five populations are at or above rebuilding thresholds (see subsection 2.2.1). Productivity is stable or increasing for five of the six populations. However, one population—the Cascade spring population—appears to be in a long-term decline, with recent abundances just above the critical threshold and generally negative productivity since the early 2000's. Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound Chinook Salmon. Although all may have contributed to the listing, all factors have also seen improvements in the way they are managed/operated. As we continue to contend with a changing climate, management of these factors may also alleviate some of the potential adverse effects (e.g., hatcheries serving as a genetic reserve for natural populations).

The ongoing effects of the Proposed Action on the ESU are ecological in nature, with small, localized effects from facility infrastructure and operation, RM&E, and other hatchery activities (i.e., in-river broodstock collection). Ecological effects on the Puget Sound Chinook salmon ESU associated with hatchery program releases are likely to be small because hatchery chum salmon releases, and adult returns from these releases, combined with natural Skagit River basin chum salmon production, are expected to remain within historical natural abundance levels prior to BY 2006. Any resulting decrease in Chinook salmon adult abundance is likely to be very small and at a level that is likely to have little to no effect on the ESU. The ESU is composed of 16 other populations in addition to those in the Skagit River watershed, and 8 of these are above critical thresholds, many of which are approaching or exceeding rebuilding thresholds.

Operation of the Marblemount Hatchery adult trap and in-river broodstock collection requires ongoing annual handling of individuals, though the number captured and handling mortality are expected to be low. The Marblemount Hatchery adult trap is expected to affect primarily if not exclusively individuals from one population, the Cascade River spring Chinook population. Individuals from primarily the fall Chinook, but also the summer Chinook, populations are expected to be affected by in-river broodstock collections. Broodstock collection is an essential component of the action. The effects of broodstock collection (i.e., incidental capture, handling, and mortality) are expected to be small, and primarily limited to two populations, one of which (Lower Skagit fall) is relatively abundant. Effects of broodstock collection are therefore unlikely to cause a decline in abundance, reproduction, survival, or distribution of Puget Sound Chinook salmon at the scale of the ESU.

Marblemount Hatchery infrastructure and operations are expected to adversely affect Chinook salmon in the following ways:

1. surface water intake screening on the Cascade River does not meet current NMFS criteria for preventing fish entrainment and/or injury;
2. juvenile and adult fish that move above the bypass/release channel weir during high-water events may become stranded above the weir making them vulnerable to delayed or prohibited migration, starvation, or predation;
3. hatchery infrastructure blocks access to approximately 3 miles of floodplain stream refuge and rearing habitat in Clark Creek;
4. water coming out of perched raceway discharge pipe is not diffused, creating false attraction and injury potential to adult fish; and,
5. Jordan Creek water withdrawals may not be conducive to safe upstream and downstream fish movement through the partially dewatered reach.

These are expected to affect only two populations—the Upper Skagit summer and Cascade spring Chinook populations—by virtue of the hatchery's location relative to where these populations and the other Skagit populations spawn. Clark Creek and Jordan Creek are small tributaries with degraded habitats that few natural Chinook salmon would typically use relative to the sizes of the affected populations. There is relatively abundant accessible habitat elsewhere in the Cascade and Skagit Rivers. The affected populations have met or exceeded rebuilding and recovery thresholds in the past despite hatchery effects, which have existed at similar or greater levels in the past. Thus, effects from the Marblemount Hatchery infrastructure and operations are expected to have a relatively minor effect at the scale of the affected populations, and little to no effect at the scale of the ESU.

The Upper Skagit Hatchery infrastructure and operations are expected to cause adverse effects to Chinook salmon from the following: the water intake screening does not meet current NMFS screening criteria for preventing fish entrainment and/or injury; and, water withdrawals may not be conducive to safe upstream and downstream fish movement through the partially dewatered reach. Red Creek is a small stream that relatively few Chinook salmon are likely to use. Further, effects to Chinook salmon will not be incurred unless and until upstream anadromous passage below the hatchery is restored. Thus, effects from the hatchery infrastructure and operations are expected to have a minor affect at the scale of the affected populations, and little to no affect at the scale of the ESU.

Added to the Species' Status, 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. The recovery plan for this ESU describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed Chinook salmon. Such actions include improving habitat conditions, and hatchery and harvest practices to protect natural-origin Chinook salmon, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure and diversity.

Drawing from the above discussion, we conclude that the effects of the Proposed Action, considered with Cumulative Effects, and in the context of the degraded and changing baseline conditions, will not affect reproduction, abundance, or distribution of the Chinook salmon populations within the Skagit River watershed. Therefore, the action also will not affect reproduction, abundance, or distribution, or the survival and recovery potential of Puget Sound Chinook salmon at the scale of the ESU.

2.7.2. Puget Sound Steelhead DPS

Best available information indicates that the Puget Sound Steelhead trout DPS remains threatened (Ford 2022). In the Skagit River watershed, steelhead trout spawner abundance of monitored populations is not meeting recovery targets, but is sufficiently high that risk of extirpation is low, and long-term productivity is positive (see subsection 2.2.3). Two populations—the Skagit River and the Sauk River populations—make up the substantial majority of spawners. Spawner escapement has been relatively stable since the early 1990's, though some fluctuations have occurred. Our environmental baseline considers the effects of dams, habitat condition, fisheries, and hatcheries on Puget Sound Steelhead trout. Although all may have contributed to the listing, all factors have also seen improvements in the way they are managed/operated. As we continue to contend with a changing climate, management of these factors may also alleviate some of the potential adverse effects (e.g., hatcheries serving as a genetic reserve for natural populations).

The ongoing effects of the Proposed Action on the DPS are ecological in nature, with small, localized effects from facility infrastructure and operation, RM&E, and other hatchery activities (i.e., in-river broodstock collection). Ecological effects on the Puget Sound steelhead trout DPS associated with hatchery program releases are likely to be small because hatchery chum salmon releases, and adult returns from these releases, combined with natural Skagit River basin chum salmon production, are expected to remain within historical natural abundance levels prior to BY 2006. Any resulting decrease in steelhead trout adult abundance is likely to be very small and at a level that is likely to have little to no effect on the DPS.

Operation of the Marblemount Hatchery adult trap and in-river broodstock collection requires ongoing annual handling of individuals, though the number captured and handling mortality are expected to be low. The Marblemount Hatchery adult trap is expected to affect primarily if not exclusively individuals from one population, the Skagit River population. Individuals from the Skagit River and Sauk River populations are expected to be affected by in-river broodstock collections. Broodstock collection is an essential component of the action. The effects of broodstock collection (i.e., incidental capture, handling, and mortality) are expected to be small most years, and primarily limited to two populations, which are both relatively abundant. Effects of broodstock collection are therefore unlikely to cause a decline in abundance, reproduction, survival, or distribution of Puget Sound steelhead trout at the scale of the DPS.

Marblemount Hatchery infrastructure and operations are expected to adversely affect steelhead trout in the following ways:

1. surface water intake screening on the Cascade River does not meet current NMFS criteria for preventing fish entrainment and/or injury;
2. juvenile and adult fish that move above the bypass/release channel weir during high-water events may become stranded above the weir making them vulnerable to delayed or prohibited migration, starvation, or predation;
3. hatchery infrastructure blocks access to several miles of floodplain stream refuge and rearing habitat in Clark Creek;
4. water coming out of the perched raceway discharge pipe is not diffused, creating false attraction and injury potential to adult fish; and,
5. Jordan Creek water withdrawals may not be conducive to safe upstream and downstream fish movement through the partially dewatered reach.

These are expected to affect primarily or exclusively the Skagit River population by virtue of the hatchery's location relative to where this population and the other Skagit River basin populations spawn. Clark Creek and Jordan Creek are small tributaries with degraded habitats that few steelhead trout would typically use relative to the size of the affected population. There is relatively abundant accessible habitat elsewhere in the Cascade and Skagit Rivers. The affected population has maintained abundance levels despite ongoing hatchery effects, which have existed at similar or greater levels in the past. Thus, effects from the Marblemount Hatchery infrastructure and operations are expected to have a relatively minor effect at the scale of the affected populations, and little to no effect at the scale of the DPS.

The Upper Skagit Hatchery infrastructure and operations are expected to cause adverse effects to steelhead trout from the following: the water intake screening does not meet current NMFS screening criteria for preventing fish entrainment and/or injury; and, water withdrawals may not be conducive to safe upstream and downstream fish movement through the partially dewatered reach. Red Creek is a small stream that relatively few steelhead trout are likely to use. Further, effects to steelhead trout will not be incurred unless and until upstream anadromous passage below the hatchery is restored. Thus, effects from the hatchery infrastructure and operations are expected to have a minor affect at the scale of the affected populations, and little to no affect at the scale of the DPS.

Added to the Species' Status, 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. The recovery plan for this DPS describes the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed steelhead trout. Such actions include improving habitat conditions, and hatchery and harvest practices to protect natural-origin steelhead trout, and NMFS expects this trend to continue, potentially leading to increases in abundance, productivity, spatial structure and diversity.

Drawing from the above discussion, we conclude that the effects of the Proposed Action, considered with Cumulative Effects, and in the context of the degraded and changing baseline conditions, will not affect reproduction, abundance, or distribution of the steelhead trout populations within the Skagit River watershed. Therefore, the action also will not affect reproduction, abundance, or distribution, or the survival and recovery potential of Puget Sound steelhead trout at the scale of the DPS.

2.7.3. Designated Critical Habitat for Puget Sound Chinook Salmon and Puget Sound Steelhead

Critical Habitat for ESA-listed Puget Sound Chinook salmon and Puget Sound steelhead trout is described in subsections 2.2.2 and 2.2.4, respectively, of this Opinion. In reviewing the Proposed Action and evaluating its effects, NMFS has determined that the Proposed Action will, at small spatial scales, incrementally degrade designated Critical Habitat for both species, but will not preclude its functioning or intended conservation role.

The status of habitat conditions and the PCEs of designated Critical Habitat in the Action Area vary throughout the watershed. Most upper watershed areas are in fair to good condition. In contrast, PCEs in lower watershed areas are more impaired, severely so in some areas. The degradation of PCEs in the watershed is primarily caused by historical land and river management practices (channelization, levee and dike construction, large wood removal, riparian and upland deforestation, and historical timber extraction activities in the upper watershed), urbanization, dam construction and operation, and road crossings. Impairment is expected to become worse due to persistence of these alterations, population growth, and climate change.

None of the hatchery structures or activities are a primary cause of the most significant impairments to Critical Habitat in the watershed. However, the Proposed Action does, to varying degrees, exacerbate the degraded conditions. Marblemount Hatchery water withdrawal reduces the quantity of water in short reaches of Critical Habitat where Chinook salmon (Cascade River) and steelhead trout (Cascade River, Jordan Creek) may spawn. Water withdrawal from Jordan Creek may affect safe passage into and out from approximately 4 miles of steelhead trout Critical Habitat in Jordan Creek. The affected areas are relatively short reaches at the scale of the population and watershed. Therefore, at the scale of the population and the watershed, the effects are minor and not expected to affect the overall functioning of the PCEs.

PCEs 1, 2, and 3 currently do not and will not function in Clark Creek while the current two weirs on Clark Creek remain in place as-is (effectively complete barriers to passage). However, Critical Habitat in Clark Creek makes up a very small proportion of rearing and foraging habitat within the Skagit River watershed. Other accessible foraging habitat of equal or greater quality is located nearby and throughout the watershed. Steelhead would be unlikely to spawn in Clark Creek due to the stream's small size. Therefore, at the scale of the population and the watershed, the effects are minor and not expected to affect the overall functioning of the PCEs. The Clark Creek weirs and water intake infrastructure and affiliated structures and bank armoring on the Cascade River, Jordan Creek, and Clark Creek diminish habitat complexity (PCE 2). However, their effects are relatively small and localized, and are not expected to affect the functioning of this PCE at the scale of the watershed or core area. All other effects to critical habitat from hatchery facilities and operations are considered insignificant.

Historical habitat degradation and persistent effects of urbanization are the dominant and primary factors contributing to degraded habitat conditions and PCEs throughout the watershed. Further degradation is likely due to the persistence of these factors, population growth, and climate change. The effects of the Proposed Action exacerbate these, but represent only incremental declines at small spatial scales, and do not preclude Chinook salmon or steelhead trout from migrating, spawning, and rearing within the Action Area. Within the Action Area, the Proposed Action will not preclude Critical Habitat from establishing and maintaining functioning PCEs. The Proposed Action will not impair or prohibit Critical Habitat within the Action Area from serving the intended conservation role for either of the species at the scale of the population, watershed, or listed entity.

2.8. Conclusion

After reviewing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed actions, including effects of the Proposed Actions that are likely to persist following expiration of the proposed actions, and cumulative effects, it is NMFS' biological opinion that the proposed actions are not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU and the Puget Sound Steelhead DPS or to destroy or adversely modify designated critical habitat.

2.9. Incidental Take Statement (ITS)

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 interim 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.

2.9.1. Amount or Extent of Take

The proposed action will result in both direct and indirect take of ESA-listed species. Direct take will be exempted from ESA take prohibitions via the proposed NMFS 4(d) Limit 6 determination. Incidental take is reasonably certain to occur as described below for the factors indicated.

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**

Spawning ground competition and redd superimposition

NMFS has determined that a small level of spawning ground competition and redd superimposition between hatchery-origin chum salmon and ESA-listed Chinook salmon may occur as a result of the Proposed Action. It is not possible to quantify the associated take because it is not possible to meaningfully measure the number of interactions between hatchery-origin chum salmon and Chinook salmon on the spawning grounds. Therefore, NMFS will rely on chum salmon spawner escapement estimates as a surrogate take indicator, utilizing the combined total of hatchery- and natural-origin chum salmon spawners spawning naturally. This is a reliable surrogate take indicator because we expect that the number of spawning ground competition and redd superimposition interactions is in part a function of chum spawner abundance, such that greater numbers of chum salmon spawners would yield greater numbers of interactions. At recent natural abundance levels (BY 2007–2020), the Proposed Action is expected to result in total spawner abundances (NO and HO combined) that are less than or equivalent to recent historical abundances (BY 1968–2006) which were comprised entirely or almost entirely of natural-origin fish. Existing, on-going co-manager spawner escapement surveys will be utilized for monitoring this take. The incidental take that was evaluated was based on historical chum salmon spawner abundances (BY 1968–2006) prior to the chum salmon decline that began with BY 2007. Thus, our surrogate for establishing limits on the take of listed Chinook salmon is as follows, starting with the first brood year after this Biological Opinion is issued:

- For even years, 4-year mean chum spawner abundance not exceeding 132,719 fish, and 10-year means not exceeding 112,940 fish.
- For odd years, 4-year mean chum spawner abundance not exceeding 46,022 fish, and 10-year means not exceeding 33,817 fish.

If the running average spawner abundance at any year prior to the fourth year (for 4-year means) or tenth year (for 10-year means) after this Biological Opinion is issued is so high that exceedance of any of these metrics is a reasonable expectation, NMFS will consider the take limit to have been exceeded at that time.

Broodstock collection

Incidental capture and handling of ESA-listed Chinook salmon and steelhead trout is expected to occur at the Marblemount Hatchery adult trap and during in-river broodstock collection for all three chum programs. The maximum amount of annual incidental take of ESA-listed Chinook salmon and steelhead trout expected to occur is shown in Table 11 in the columns entitled “Maximum anticipated annual captures/mortalities” for each species.

Factor 3: Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas

Predation, competition, and pathogen transmission, collectively referred to as ecological interactions, as a result of the Proposed Action are expected to result in take of natural-origin Chinook salmon and steelhead trout. This type of take is difficult to quantify because it cannot be observed, and, therefore, cannot be directly or reliably measured. However, as described in subsection 2.5.2.3, ecological interactions are the direct result of hatchery releases, and more of these events will occur as more fish are released from the hatchery. Therefore, NMFS will rely on two surrogates as take indicators: one will apply to take in freshwater habitats, and a second will apply to take in estuarine habitats. These are described below.

For take in freshwater habitats, the take surrogate will be the total number of fish released from the hatchery programs, both annually and on a running 5-year mean basis. This is a reliable surrogate take indicator because we expect that the number of ecological interactions is in part a function of juvenile hatchery chum abundance, such that greater numbers of juvenile hatchery chum salmon would yield greater numbers of interactions. As ecological interactions are the direct result of hatchery releases, anticipated ecological effects can be and were evaluated using a qualitative tool and the PCDRisk model. NMFS expects some annual variability in release numbers due to the level of unpredictability inherent in hatchery operations. Therefore, we expect that annual releases will not exceed the release goals described in the Proposed Action in Table 3 in the column entitled “Number and life stage” by more than 10% in any year. Further, starting with the first year of release after this Biological Opinion is issued, we expect the running 5-year average production of each program to remain less than 105% of the release goals described in the Proposed Action in Table 3 in the column entitled “Number and life stage.” At any time during the first 5 years after this Biological Opinion is issued, if the running average of fish released is so high that exceedance of this take surrogate by year 5 is a reasonable expectation, NMFS will consider the take limit to have been exceeded at that time.

For estuarine habitats, the take surrogate will be the combined total outmigration abundance of hatchery- and natural-origin juvenile chum salmon estimated at the RM 17 trap. This is a reliable surrogate take indicator because we expect that the number of ecological interactions is in part a function of juvenile chum abundance, such that greater numbers of juvenile chum salmon would yield greater numbers of interactions. At recent natural juvenile abundance levels (BY 2007–2020), the Proposed Action is expected to result in total juvenile outmigrant abundances (NO and HO combined) that are less than or equivalent to recent historical abundances (BY 1996–2006) which were comprised entirely or almost entirely of natural-origin fish and were not detrimental to Chinook salmon. Existing, on-going co-manager trapping and outmigration estimates will be utilized for monitoring this take. The incidental take that was evaluated was based on historical outmigration abundances (BY 1996–2006) prior to the chum salmon decline that began with BY 2007. Thus, our surrogate for establishing limits on take is as follows, starting with the first brood year after this Biological Opinion is issued:

- For even brood years, 4-year mean juvenile chum salmon outmigration abundance not exceeding 16.221 million fish, and long-term (≥ 10 year) means not exceeding 12.495 fish.
- For odd years, 4-year mean juvenile chum salmon outmigration abundance not exceeding 8.029 million fish, and long-term (≥ 10 year) means not exceeding 6.970 million fish.

If the running average juvenile chum salmon outmigration abundance at any year prior to the fourth year (for 4-year means) or tenth year (for long-term means) after this Biological Opinion is issued is so high that exceedance of any of these metrics is a reasonable expectation, NMFS will consider the take limit to have been exceeded at that time.

Factor 5: Operation and maintenance of hatchery facilities

Hatchery infrastructure and operations are expected to result in take of natural-origin Chinook salmon and/or steelhead trout listed below. It is not possible to quantify the associated take because it is not possible to meaningfully measure the number of interactions and the number of fish affected. Therefore, NMFS will rely on the amount of habitat affected, as indicated for each individual take pathway, as a surrogate take indicator.

- The Cascade River (Marblemount Hatchery) surface water intake may entrain and/or impinge juvenile Chinook salmon and steelhead trout, causing injury or death. The surface area of the Cascade River screens is 307 ft^2. Therefore, the surrogate metric for take is the extent of habitat impacted by the intake, which is expected to be no more than 307 ft^2.
- If the anadromous passage barrier downstream from the Upper Skagit Red Creek Hatchery is remedied, the existing surface water intake may entrain and/or impinge juvenile Chinook salmon and steelhead trout, causing injury or death. The surface area of the Cascade River screens is approximately 14 ft^2. Therefore, the surrogate metric for take is the extent of habitat impacted by the intake, which is expected to be no more than 14 ft^2.
- Marblemount Hatchery infrastructure blocks access to approximately 3 miles of floodplain stream refuge and rearing habitat in the Clark Creek stream network, diminishing freshwater Chinook salmon production. Therefore, the surrogate metric for take is the extent of habitat impacted, which is approximately 3 miles of floodplain stream refuge and rearing habitat.
- The Jordan Creek (Marblemount Hatchery) water withdrawal may not be conducive to safe fish movement at all times through the 1,310-foot-long partially dewatered reach, resulting in delayed migration and mortality to listed fish. Therefore, the surrogate metric for take is the extent of habitat impacted, which is 1,310 feet of stream length.
- If the anadromous passage barrier downstream from the Upper Skagit Red Creek Hatchery is remedied, the hatchery water withdrawal may not be conducive to safe fish movement at all times through the 700-foot-long partially dewatered reach, resulting in delayed migration and mortality to listed fish. Therefore, the surrogate metric for take is the extent of habitat impacted, which is 700 feet of stream length.

Each of these take surrogates are reliable indicators of the extent of incidental take, as they represent the space in which take can occur, so that if the area remains limited, the extent of take will as well. These surrogates can be reliably monitored because the spatial extent over which take may occur can be surveyed and measured.

In addition to the take listed above, juvenile and adult fish that move above the bypass/release channel weir during high-water events may become stranded above the weir, resulting in delayed or prohibited migration, starvation, or predation. We anticipate the following numbers of ESA-listed natural-origin fish to be affected:

- Up to 100 juvenile Chinook salmon annually
- No more than 1 adult Chinook salmon annually
- Up to 100 juvenile steelhead trout annually
- No more than 1 adult steelhead trout annually

The perched raceway discharge at the Marblemount Hatchery creates a false attraction and injury potential to adult fish. We anticipate that no more than the numbers of Chinook salmon and steelhead trout shown in Table 11 anticipated to be captured in the Marblemount Hatchery adult trap may also be exposed to effects from the discharge pipe.

2.9.2. 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.

2.9.3. Reasonable and Prudent Measures

"Reasonable and prudent measures" are measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

1. Minimize and monitor adverse effects to Chinook salmon and steelhead trout associated with hatchery broodstock collection activities, including incidental capture and handling.

2. Minimize potential for surface water withdrawals on the Cascade River (Marblemount Hatchery) and Red Creek (Upper Skagit Red Creek Hatchery) to entrain or impinge juvenile Chinook salmon or steelhead trout.

3. Minimize and monitor effects of Jordan Creek and Red Creek water withdrawals on safe Chinook salmon and steelhead trout passage through the partially dewatered reaches.

4. Monitor extent to which high water events introduce Chinook salmon and steelhead trout

into areas of Clark Creek above hatchery weirs, and minimize adverse effects.

5. Monitor the quantity and quality of refuge and rearing habitat for juvenile Chinook salmon and steelhead trout above hatchery weirs, and minimize adverse effects of restricting access to refuge and rearing habitat.

6. Minimize adverse effects from the perched raceway discharge pipe.

7. Monitor and report information pertaining to hatchery programs, take, and take surrogates.

2.9.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the Federal action agencies must comply (or must ensure that any applicant complies) with the following terms and conditions. The action agencies and applicants have a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this 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.

Terms and Conditions associated with RPM 1:

1a. All unmarked and untagged Chinook salmon and steelhead trout incidentally captured during in-river broodstock collection shall be released with the minimum handling necessary to liberate the fish from the capture gear and safely return it to the river or transfer it to a mobile net pen. Fish will be released from net pens once broodstock collection is completed in the area on any given day. Gill net sets will be of such duration as to avoid killing Chinook salmon and steelhead trout. Gill nets and seines shall not be left unattended in the river.

1b. WDFW shall ensure that all unmarked and untagged Chinook salmon and steelhead trout that enter the Marblemount Hatchery adult trap are released back to the river as soon as practicable.

1c. All unmarked and untagged Chinook salmon and steelhead trout captured during broodstock collection activities (in nets or at the Marblemount Hatchery trap) shall be reported annually to NMFS. Reports shall include the following (separately for each hatchery program and method of capture): date of capture and location (river and approximate RM), capture method, condition of the fish at release (including any obvious injuries or descaling, and whether these were the result of incidental capture and handling associated with broodstock collection), and whether the fish was released alive or died.

Terms and Conditions associated with RPM 2:

2a. Within 10 years of issuance of this Biological Opinion, the WDFW shall modify or replace the Cascade River surface water intake to be consistent with updated NMFS criteria. Criteria specified in the most up-to-date NMFS standards at the time of design shall be used. WDFW shall notify NMFS when the surface water intake has been modified to be consistent with NMFS criteria. The 10-year timeline may be extended with NMFS approval.

2b. USIT will annually verify the continued presence of the anadromous barrier (naturally-formed log dam) on Red Creek approximately 100 yards below the Alpine Lane bridge crossing. Observations from this annual verification will be documented in the annual report described in Term and Condition 7a. USIT will notify NMFS within one week of discovering that the blockage has been or will be removed. When or if the barrier is removed, or if visual verification of its presence is not possible, USIT will perform periodic juvenile and adult fish surveys to determine any use by listed Chinook salmon or steelhead trout of Red Creek above the current blockage site. USIT will coordinate with NMFS to determine the type(s), location(s), and frequency of surveys. Survey results will be documented in the annual report described in Term and Condition 7a. USIT will notify NMFS within 48 hours of discovering that listed Chinook salmon or steelhead trout are present in Red Creek above the current blockage site. When or if listed Chinook salmon or steelhead trout are observed in fish surveys above the current blockage site, USIT will coordinate with NMFS to determine need for additional surveys and/or need for upgrading the Red Creek Hatchery intake screening material. If and when USIT must replace the current intake screening for any reason, the new screening material shall meet criteria specified in the most up-to-date NMFS standards at the time of design. USIT shall notify NMFS when the screening material has been replaced and is consistent with NMFS criteria.

Terms and Conditions associated with RPM 3:

3a. Within 1 year of issuance of this Biological Opinion, the WDFW shall install flow measurement instrumentation to accurately measure hatchery surface water withdrawal volumes from Jordan Creek. WDFW shall notify NMFS when the instrumentation is installed and operating. This timeline may be extended with NMFS approval.

3b. The WDFW shall develop and implement a plan, in coordination with and subject to NMFS approval, to monitor and evaluate the effects of hatchery water withdrawals on safe fish passage conditions within the affected 1,310-foot reach of Jordan Creek. The following shall be submitted to NMFS: 1) a draft plan describing monitoring and evaluation methodologies, submitted within 12 months of issuance of this Biological Opinion; 2) a final plan, submitted within 18 months of issuance of this Biological Opinion; and, 3) a report documenting results, findings, and conclusions, submitted within 3 years of issuance of this Biological Opinion. These timelines may be extended with NMFS approval.

3c. The measures described in Term and Condition 2b for annual verification of anadromous blockage, fish surveys, and reporting equally apply to this Term and Condition 3c. When or if listed Chinook salmon or steelhead trout are observed in fish surveys above the current blockage site, USIT will coordinate with NMFS to determine need for additional surveys and/or need for evaluating fish passage conditions in the reach that is partially dewatered during hatchery operation.

Terms and Conditions associated with RPM 4:

4a. Within 10 years of issuance of this Biological Opinion, WDFW shall develop and implement a plan, in coordination with and subject to NMFS approval, to determine the extent to which the bypass/release channel weir is breached during flood events such that juvenile and adult fish may move into the area upstream from the weir. The plan will include provisions for monitoring and evaluating the extent to which juvenile and adult Chinook salmon and steelhead trout move above the bypass/release channel weir during high flow events, thereby potentially becoming stranded. This Term and Condition will become void if the weir is permanently removed or equipped to allow safe downstream passage of juvenile and adult salmonids.

Terms and Conditions associated with RPM 5:

5a. Within 10 years of issuance of this Biological Opinion, WDFW shall develop and implement a plan, in coordination with and subject to NMFS approval, to determine the quantity and quality of floodplain stream refuge and rearing habitat for steelhead trout and Chinook salmon above hatchery weirs in Clark Creek and its tributaries, including the unnamed stream comprising the bypass/release channel. This Term and Condition will become void if passage is restored into areas currently blocked by hatchery weirs (e.g., if weirs are removed; if that part of Clark Creek that flows through the hatchery is restored to its original channel where no weirs are present; if means for safe upstream and downstream movement are provided at weirs).

5b. Any future major redesigns of the Marblemount Hatchery that include reconfiguring the ponds, channels, and weirs between the Clark Creek surface water intake and the bypass/release channel weir shall allow for safe upstream and downstream movement of juvenile Chinook salmon and steelhead trout throughout Clark Creek and its tributaries. This Term and Condition will become void if WDFW can demonstrate that the quantity and quality of habitat is so low in Clark Creek and its tributaries, including the unnamed stream comprising the bypass/release channel, that few if any steelhead trout and/or Chinook salmon are likely to utilize these areas.

Terms and Conditions associated with RPM 6:

6a. Within 1 year of issuance of this Biological Opinion, the WDFW shall minimize the potential for adult ESA-listed fish injury at the raceway discharge pipe by ensuring that water coming out of the pipe is diffused at all times adult ESA-listed fish may be present implementing the following. This timeline may be extended with NMFS approval. WDFW shall notify NMFS when these have been completed.

Terms and Conditions associated with RPM 7:

7a. The co-managers shall submit annual reports as detailed below. Reports shall be submitted no later than June 15 for all activities and monitoring occurring the previous calendar year. This timeline may be extended with NMFS approval. NMFS and the co-managers will determine reporting format (e.g., required information for all programs may be bundled into one report). Reports shall include the following information:

1. For each program, information pertaining to chum salmon collected for broodstock, including the following: number of fish collected, location(s) of collection, date(s) of collection, and method(s) of collection (e.g., gear type, net mesh size, etc.).
2. For each program, information pertaining to incidental capture and mortality of unmarked and untagged Chinook salmon and steelhead trout during broodstock collection activities, as described in Term and Condition 1c.
3. For each program, information pertaining to release of hatchery juveniles, including the following: number of fish released, release location(s), date(s) of release, fish size at release, and whether the release abundance exceeded the program's goal by more than 10%, as described in Section 2.9.1.
4. For each program, the running 5-year mean hatchery production, and whether the running 5-year mean is below the 105% take threshold described in Section 2.9.1. For the first four years after this Biological Opinion is issued, instead of 5-year means, the running mean reported shall start with the year this Biological Opinion is issued (e.g., report the running 2-year mean for the first two years after this Biological Opinion is issued, the running 3-year mean for the first three years, and so on until 5-year means can annually be reported).
5. Disease occurrence at the hatchery facilities, including during adult broodstock holding, juvenile fish rearing, and time of juvenile release.
6. Any unforeseen effects on listed fish, and program(s) those effects were associated with.
7. For even and odd years separately, the running 4-year and 10-year mean total chum salmon spawner escapement abundance in the Skagit River watershed (i.e., total abundance regardless of origin), and whether these means are

within the take thresholds identified in Section 2.9.1. Running means reported shall start with the year this Biological Opinion is issued.

8. For even and odd years separately, the running 4-year and 10-year mean juvenile chum salmon outmigration abundance (i.e., total abundance regardless of origin), as determined by RM 17 trap catch, and whether these means are within the take thresholds identified in Section 2.9.1. Running means reported shall start with the year this Biological Opinion is issued.
9. WDFW shall report results of monitoring described in Term and Condition 4b, if that Term and Condition is deemed necessary as described, and whether the surveyed fish abundances are within the take thresholds identified in Section 2.9.1.

7b. Notify NMFS within 48 hours after knowledge of exceeding any take threshold for listed Chinook salmon and steelhead trout described in Section 2.9.1, or if activities deviate from the Proposed Action described in Section 1.3.1 (e.g., release of hatchery fish outside of the time periods specified). The applicants shall submit a written report, and/or convene a discussion with NMFS, to discuss why the take threshold was exceeded and/or the Proposed Action deviated from.

7c. All reports and notifications described in these Terms and Conditions are to be submitted electronically to the NMFS, West Coast Region, Sustainable Fisheries Division, Anadromous Production and Inland Fisheries Branch. The current point of contact for document submission and notifications is Mark Celedonia (mark.celedonia@noaa.gov; 360-763-2095).

2.10. Conservation Recommendations

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

1. Ecological interactions between chum salmon and listed Chinook salmon and steelhead trout could be better understood in freshwater, estuarine, nearshore, and offshore habitats in Puget Sound. The co-managers should endeavor to continue to assess beneficial and detrimental interactions between these species in these habitats to better understand how hatchery programs can be managed to aid in the recovery of Puget Sound Chinook salmon and steelhead trout.
2. Long-term effects of hatchery production on fitness of natural chum salmon populations are poorly understood. The co-managers should design and implement a research program to evaluate such effects in the Skagit River watershed to ensure that long-term fitness of the natural population is not unduly affected. Diminished fitness of the natural

population may outweigh benefits of the programs in the long term, to the detriment of the aquatic ecosystem and listed Chinook salmon and steelhead trout.

2.11. Re-initiation of Consultation

This concludes formal consultation for the National Marine Fisheries Service (NMFS) Evaluation of Three Hatchery and Genetic Management Plans for Skagit River Basin Chum Salmon under Limit 6 of the Endangered Species Act Section 4(d) Rule.

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 agency 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."

3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT CONSULTATION

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

This analysis is based, in part, on the EFH assessment provided by the NMFS and descriptions of EFH for Pacific Coast salmon (PFMC 2014b; 2014a) contained in the fishery management plans developed by the Pacific Fishery Management Council and approved by the Secretary of Commerce.

3.1. Essential Fish Habitat Affected by the Project

The Proposed Action is implementation of three hatchery chum salmon programs in the Skagit River basin, as described in detail in Section 1.3. The areas affected by the Proposed Action include the Skagit River and its tributaries, from RM 0.0 to the upstream extent of anadromous fish access, except for areas of the Baker River upstream from the Upstream Fish Trap (RM 0.7). The Action Area of the Proposed Action includes habitat described as EFH for Chinook salmon, coho salmon, and pink salmon. Because EFH has not been described for steelhead trout or chum salmon, the analysis is restricted to the effects of the Proposed Action on EFH for the three salmon species for which EFH has been designated.

Freshwater EFH for Pacific salmon, includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable manmade barriers, and long-standing, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years) (PFMC 2014a). As described by PFMC (2014a), within these areas, freshwater EFH for Pacific salmon consists of four major components: (1) spawning and incubation; (2) juvenile rearing; (3) juvenile migration corridors; and, (4) adult migration corridors and adult holding habitat. Marine EFH for Pacific salmon in Washington, Oregon, and California includes all estuarine, nearshore, and marine waters within the western boundary of the EEZ, 200 miles offshore. Marine EFH consists of three components, (1) estuarine rearing; (2) ocean rearing; and (3) juvenile and adult migration.

The Skagit River and its tributaries accessible to anadromous salmon have been designated EFH for Chinook, coho, and pink salmon. Assessment of the potential adverse effects on these salmon species' EFH from the Proposed Action is based, in part, on these descriptions. The aspects of EFH that might be affected by the Proposed Action include: effects of hatchery infrastructure and operations on adult and juvenile fish migration corridors in the Skagit River watershed; ecological interactions and genetic effects in Chinook, coho, chum, and pink salmon spawning areas in the watershed; and ecological effects in rearing areas for the species in the Skagit River watershed, including its estuary and adjacent nearshore marine areas.

3.2. Adverse Effects on Essential Fish Habitat

The Proposed Action generally does not have substantial effects on the major components of EFH. With some minor, localized exceptions, adult salmon holding and spawning habitat, and juvenile salmon rearing locations, are not expected to be affected by the operation of the hatchery programs. This section also considers effects of the Proposed Action on natural chum salmon in the Skagit River because of the beneficial ecological effects chum salmon may have on forage resources and aquatic ecosystem productivity—and by extension EFH—as described in subsection 2.5.2.2.2 of the Biological Opinion.

Regarding hatchery facility infrastructure and operation effects on Pacific salmon EFH, the NMFS Biological Opinion indicates the following:

- Surface water intakes and/or screening on the Cascade River (Marblemount Hatchery) and Red Creek (Upper Skagit/Red Creek Hatchery) do not meet current or recent NMFS criteria. Other facilities either meet current or recent NMFS criteria (Jordan Creek/Marblemount Hatchery; Hatchery Creek/Sauk-Suiattle RSI), are groundwater-fed with no surface water intakes (Countyline Pond, Powerline Channel), or lie above impassable barriers (hatchery weirs) where anadromous fish are prohibited from accessing (Clark Creek/Marblemount Hatchery).
- Hatchery surface water withdrawal may negatively affect safe fish passage conditions in affected reaches of Jordan Creek (Marblemount Hatchery) and Red Creek (Upper Skagit/Red Creek Hatchery). Surface water withdrawal is unlikely to affect safe fish passage conditions in the Cascade River (Marblemount Hatchery) or Hatchery Creek (Sauk-Suiattle RSI) because water withdrawals are a relatively small proportion of stream flow.
- Off-channel floodplain stream rearing and refuge habitat is currently blocked by impassable Marblemount Hatchery weirs. Other hatchery facilities included in the Proposed Action do not block access to habitat.
- The weir on the Marblemount Hatchery's bypass/release channel regularly becomes breached allowing fish to access areas upstream of the weir where they may become stranded, resulting in delayed or prohibited migration, starvation, or predation.

- Our analysis of facility effects did not reveal any substantial concerns related to effluent discharge (see subsection 2.5.2.5). The proposed hatchery programs minimize effects of effluent discharge through compliance with the NPDES permits, where applicable.
- Proposed pathogen prevention, monitoring, and control programs will adequately minimize risk of disease amplification and transmission from the proposed hatchery programs and their operation.

The NMFS ESA consultation includes conditions for ameliorating substantive negative effects from hatchery facility infrastructure and operation. These include the following:

- Conditions for upgrading intakes and/or screening on the Cascade River (Marblemount Hatchery) and Red Creek (Upper Skagit/Red Creek Hatchery) to meet current NMFS criteria.
- Conditions for evaluating hatchery surface water withdrawal effects to safe fish passage conditions in affected reaches of Jordan Creek (Marblemount Hatchery) and Red Creek (Upper Skagit/Red Creek Hatchery).
- Conditions for evaluating the extent to which the Marblemount Hatchery's bypass/release channel weir becomes breached, and the abundance of ESA-listed fish affected.
- Conditions for evaluating the quantity and quality of off-channel floodplain stream rearing and refuge habitat currently blocked by impassable Marblemount Hatchery weirs, and for providing safe fish movement into and out from these habitats.

Outside of these minor and localized effects associated with facility infrastructure and operation, potential effects on EFH by the Proposed Action are only likely to occur predominately in Skagit River basin waters downstream of hatchery facilities where chum salmon migrate and spawn naturally. These are detailed below.

Implementation of the three Skagit River basin hatchery chum programs is intended to increase abundance of naturally-spawning chum salmon (both natural- and hatchery-origin) and concomitant juvenile production throughout much of their native range in the Skagit River watershed, particularly in under-seeded areas. The intention is to increase chum salmon abundances to levels up to those observed prior to their substantive decline beginning in 2007. The PFMC (PFMC 2014a) recognized concerns regarding the "genetic and ecological interactions of hatchery and wild fish … [which have] been identified as risk factors for wild populations." Thus, despite the positive intention and potential benefits of the hatchery programs, we also consider their potential negative effects to natural Skagit chum salmon given the implications to forage resources and aquatic ecosystem productivity—and by extension EFH—as described in subsection 2.5.2.2.2 of the Biological Opinion.

Chum salmon, because they are released shortly after hatching, may be less prone to negative genetic and domestication effects of hatchery production than species that rear for longer periods of time in hatcheries (e.g., (Berejikian et al. 2009; Small et al. 2009; McConnell et al. 2018). This seems particularly true for integrated hatchery chum programs founded from local endemic stock (Berejikian et al. 2009; Small et al. 2009) such as the proposed Skagit basin programs. Berejikian et al. (2009) observed similar reproductive success between natural-origin and first-through third-generation hatchery chum salmon founded from local stock, though the ancestry of the hatchery- and natural-origin fish used in the study prior to their parental generation was unknown. Small et al. (2009) found little to no negative genetic effects in Hood Canal summer chum salmon during limited-duration local stock supplementation programs, most of which lasted for 12 years. Some negative effects (Ryman-Laikre effects and genetic drift) were identified in one of the subpopulations (Lilliwaup) evaluated. Data presented by the authors, though not conclusive, suggest that this subpopulation experienced the greatest degree of hatchery influence during supplementation relative to the other subpopulations. It was also one of the longer-running supplementation programs. It is plausible that similar negative effects could occur within the Skagit basin chum salmon population as a result of the proposed programs. However, there is insufficient evidence to conclude that such effects, should they occur, would detrimentally affect Skagit basin chum salmon productivity or survival to a degree that EFH would be affected. Therefore, any negative effects to EFH associated with risks of hatchery supplementation to the natural chum salmon population are expected to be insignificant.

In addition to enhancing the overall abundance of Skagit River chum salmon, the hatchery programs may serve as a genetic reserve for the extant populations in the basin as buffers against catastrophic losses of the naturally spawning components, and as an important rebuilding tool for the integrated recovery of Skagit River chum salmon. In addition, adult salmon produced through the hatchery programs that escape to natural spawning areas may benefit spatial structure of the populations by augmenting natural spawning abundances in under-seeded and under-utilized areas. These potential benefits would help offset risks to Skagit River basin chum salmon diversity and productivity that may result from natural spawning by hatchery-origin fish at high proportions of total abundances. For these reasons, adverse effects on salmon EFH resulting from genetic effects would be inconsequential.

The Biological Opinion describes in considerable detail the impacts, both positive and negative, the proposed hatchery programs are likely to have on natural Chinook salmon populations due to ecological interactions (subsection 2.5.2). The proposed programs are likely to yield positive effects by increasing abundance of natural chum spawners, thereby increasing delivery of ecosystem services and marine derived nutrients to the watershed, ultimately increasing aquatic ecosystem productivity for the benefit of many if not all salmonid species. In regards to negative effects from ecological interactions, the Biological Opinion concluded that negative effects from the proposed hatchery programs are likely to be minor as long as the combined abundance of hatchery- and natural-origin chum salmon in the watershed remains within historical levels prior to the 2007 chum salmon decline. This applied to both spawner abundance and juvenile outmigration abundance. Chinook salmon and steelhead trout populations have not appeared to be affected by chum salmon abundances. Limited spatial and temporal overlap in spawning, habitat and resource partitioning, and very short juvenile chum salmon freshwater residence times are the primary factors limiting any negative effects of chum salmon to Chinook salmon and steelhead trout. The same rationale and factors apply to chum salmon effects to the other Skagit River salmon and trout populations. The NMFS Biological Opinion includes conditions for monitoring hatchery chum salmon production, and Skagit River chum salmon spawner abundance and juvenile production to ensure that these levels will remain within historical limits during hatchery program operation. Negative effects to salmon EFH from the proposed chum salmon programs from ecological interactions are therefore considered inconsequential.

3.3. Essential Fish Habitat Conservation Recommendations

For each of the potential adverse effects by the Proposed Action on EFH for Chinook, coho, and pink salmon, NMFS believes that the Proposed Action, as described in the HGMPs, and the Biological Opinion's Reasonable and Prudent Measures, Terms and Conditions, and Conservation Recommendations include the best approaches to avoid or minimize those adverse effects in most areas. Thus, NMFS has no conservation recommendations specifically for Chinook, coho, or pink salmon EFH. However, the Biological Opinion's Reasonable and Prudent Measures, Terms and Conditions, and Conservation Recommendations are likely to address potential EFH effects.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the federal agency 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 measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

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

3.5. Supplemental Consultation

The NMFS and Skagit River co-managers (SITC, SSIT, USIT, WDFW) must reinitiate EFH consultation if the Proposed Action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920(l)).

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The 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 WDFW (co-manager; operator), the Upper Skagit Indian Tribe (co-manager; operator); the Sauk-Suiattle Indian Tribe (co-manager; operator), the Swinomish Indian Tribal Community (co-manager), NMFS (regulatory agency), USFWS (regulatory agency; funder), and BIA (funder). Other interested users could include the scientific community, resource managers, and stakeholders. Individual copies of this opinion were provided to the WDFW, the Upper Skagit Indian Tribe; the Sauk-Suiattle Indian Tribe, the Swinomish Indian Tribal Community, NMFS, USFWS, and BIA. The document will be available within two weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adheres 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 described in the references section. The analyses in this Biological Opinion/EFH consultation contain more background on information sources and quality.

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

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

5. APPENDIX A: EFFECTS OF HATCHERY PROGRAMS ON SALMON AND STEELHEAD POPULATIONS: REFERENCE DOCUMENT FOR NMFS ESA HATCHERY CONSULTATIONS (REVISED FEBRUARY 2022)[1]

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.

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

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

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.

5.1. 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

5.2. 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.

5.2.1. Genetic effects

5.2.1.1.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 2011c). 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 rare[2] 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 21):

- 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).

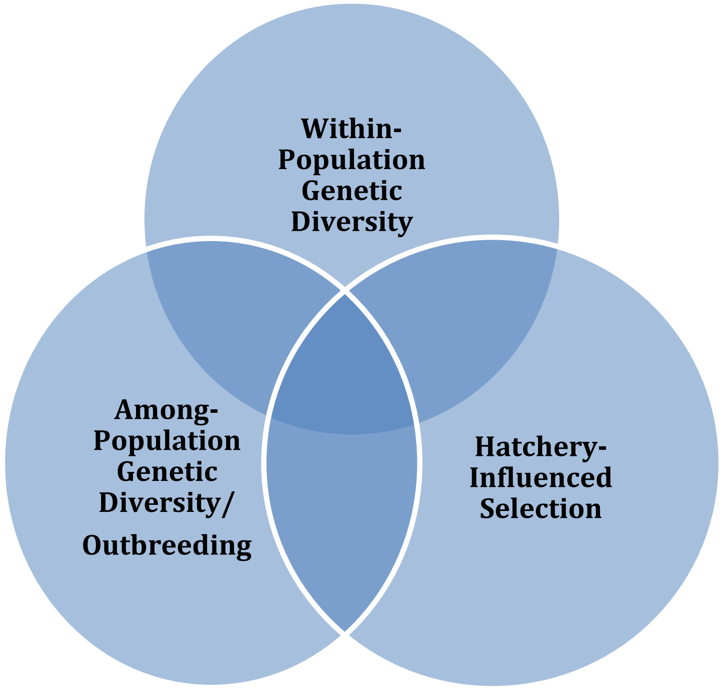

Figure 20. Major categories of hatchery program genetic effects analyzed by NMFS

5.2.1.1.1. Key Terms

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

- **Hatchery-origin (HO)**- refers to fish that have been reared and released by a hatchery program, regardless of the origin (i.e., from a hatchery or from spawning in nature) of their parents. A series of acronyms has been developed for subclasses of HO fish:

    - **Hatchery-origin recruits (HOR)** – HO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature, used for hatchery broodstock, or surplused.

    - **Hatchery-origin spawners (HOS)**- hatchery-origin fish spawning in nature. A very important derivative term, used both in genetic and ecological risk, is **pHOS,** the proportion of fish on the spawning grounds of a population consisting of HO fish. pHOS is the expected maximum genetic contribution of HO spawners to the naturally spawning population.

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

- **Natural-origin (NO)**- refers to fish that have resulted from spawning in nature, regardless of the origin of their parents. A series of acronyms parallel to those for HO fish has been developed for subclasses of NO fish:

    - **Natural-origin recruits (NOR)** – NO fish returning to freshwater as adults or jacks. Usage varies, but typically the term refers to post-harvest fish that will either spawn in nature or used for hatchery broodstock.

    - **Natural-origin spawners (NOS)**- natural-origin fish spawning in nature.

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

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

- **Integrated hatchery programs**- programs that intentionally incorporate natural-origin fish into the broodstock at some level (i.e., pNOB > 0)

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

5.2.1.2.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.

5.2.1.2.1. 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].

This definition can be baffling, so an example is useful. A commonly used effective-size equation is $Ne = 4 * N_m * N_f/(N_m + N_f)$, where N_m and N_f are the number of male and female parents, respectively. Suppose a steelhead hatchery operation spawns 5 males with 29 females. According to the equation, although 34 fish were spawned, the skewed sex ratio made this equivalent to spawning 17 fish (half male and half female) in terms of conserving genetic diversity because half of the genetic material in the offspring came from only 5 fish.

Various guidelines have been proposed for what levels of N_e should be for conservation of genetic diversity. A long-standing guideline is the 50/500 rule (Franklin 1980; Lande and Barrowclough 1987): 50 for a few generations is sufficient to avoid inbreeding depression, and 500 is adequate to conserve diversity over the longer term. One recent review (Jamieson and Allendorf 2012) concluded the rule still provided valuable guidance; another (Frankham et al. 2014) concluded that larger values are more appropriate, basically suggesting a 100/1000 rule. See Frankham et al. (2010) for a more thorough discussion of these guidelines.

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

In salmon and steelhead management, effective size concerns are typically dealt with using the term effective number of breeders (N_b) in a single spawning season, with per-generation N_e equal 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).

[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.

- 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 Ne.

5.2.1.2.2. 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 5.2.1.4.

5.2.1.3. 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 5.2.1.4.

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 (ICBTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstock.

In addition, unusual high rates of straying into other populations within or beyond the population's MPG, salmon ESU, or a steelhead DPS, can have a homogenizing effect, decreasing intra-population genetic variability (e.g., Vasemagi et al. 2005), and increasing risk to population diversity, one of the four attributes measured to determine population viability (McElhany et al. 2000). The practice of backfilling — using eggs collected at one hatchery to compensate for egg shortages at another—has historically a key source of intentional large-scale "straying". Although it now is generally considered an unwise practice, it still is common.

There is a growing appreciation of the extent to which among-population diversity contributes to a "portfolio" effect (Schindler et al. 2010), and lack of among-population genetic diversity is considered a contributing factor to the depressed status of California Chinook salmon populations (Carlson et al. 2011; Satterthwaite 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 5.2.1.4, pHOS[4] 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).

[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.

5.2.1.4. Hatchery-influenced selection effects

Hatchery-influenced selection (often called domestication[5]), the third major area of genetic effects of hatchery programs that NMFS analyses, occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with HO fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program.

Hatchery-influenced selection can range from relaxation of selection that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to intentional selection for desired characteristics (Waples 1999), but in this section, for the most 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

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

currently largely focused on gene flow between NO and HO fish[6]. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

5.2.1.4.1. 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

[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.

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.

5.2.1.4.2. 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.

[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).

The HSRG developed gene-flow guidelines based on mathematical models developed by Ford (2002) and by Lynch and O'Hely (2001). Guidelines for segregated programs are based on pHOS, but guidelines for integrated programs also include PNI, which is a function of pHOS and pNOB. PNI is, in theory, a reflection of the relative strength of selection in the hatchery and natural environments; a PNI value greater than 0.5 indicates dominance of natural selective forces.

The HSRG guidelines (HSRG 2009b) vary according to type of program and conservation importance of the population. The HSRG used conservation importance classifications that were developed by the Willamette/Lower Columbia Technical Recovery Team (McElhany et al. 2003).[8] (Table 15). 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 15. HSRG gene flow guidelines (HSRG 2009b).

	Program classification	
Population conservation importance	**Integrated**	**Segregated**
Primary	**PNI $\geq$ 0.67 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 0.05**
Contributing	**PNI $\geq$ 0.50 and pHOS $\leq$ 0.30**	**pHOS $\leq$ 0.10**
Stabilizing	**Existing conditions**	**Existing conditions**

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

[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%.

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 5.2.1.4.3).

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

5.2.1.4.2.1.PNI and segregated hatchery programs

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

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

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

$$PNI \approx \frac{h^2 + (1.0 - h^2 + \omega^2) * pNOB}{h^2 + (1.0 - h^2 + \omega^2) * (pNOB + pHOS)},$$

where h^2 is heritability and ω^2 is the strength of selection in standard deviation units, squared. Ford (2002) used a range of values for the latter two variables. Substituting those values that created the strongest selection scenarios in his simulations (h^2 of 0.5 and ω^2 of 10), which is appropriate for risk assessment, results in:

$$PNI \approx \frac{0.5 + 10.5 * pNOB}{0.5 + 10.5 * (pNOB + pHOS)}$$

HSRG (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.

5.2.1.4.2.2.The effective pHOS concept

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

$$pHOS_{eff} = (RRS * HOS_{census}) / (NOS + RRS * HOS_{census}),$$

where RRS is the reproductive success of HO fish relative to that of NO fish. They then recommend using this value in place of $pHOS_{census}$ in PNI calculations.

We feel that adjustment of census pHOS by RRS for this purpose should be done not nearly as freely as the HSRG document would suggest because the Ford (2002) model, which is the foundation of the HSRG gene-flow guidelines, implicitly includes a genetic component of RRS. In that model, hatchery fish are expected to have RRS < 1 (compared to natural fish) due to selection in the hatchery. A component of reduced RRS of hatchery fish is therefore already incorporated in the model and by extension the calculation of PNI. Therefore, reducing pHOS values by multiplying by RRS will result in underestimating the relevant pHOS and therefore overestimating PNI. Such adjustments would be particularly inappropriate for hatchery programs with low pNOB, as these programs may well have a substantial reduction in RRS due to genetic factors already incorporated in the model.

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

However, even in a situation like the Wenatchee spring Chinook salmon, it is unclear how much of an adjustment would be appropriate.

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

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

5.2.1.4.2.3. 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 16). 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 16. HSRG gene flow guidelines/standards for conservation and harvest programs, based on recovery phase of impacted population (Table 2 from HSRG 2015).

Natural Population		Hatchery Broodstock Management	
Designation	**Status**	**Segregated**	**Integrated**
Primary	Fully Restored	pHOS<5%	PNI>0.67
	Local Adaptation	pHOS<5%	PNI>0.67
	Re-colonization	pHOS<5%	Not Specified
	Preservation	pHOS<5%	Not Specified
Contributing	Fully Restored	pHOS<10%	PNI>0.50
	Local Adaptation	pHOS<10%	PNI>0.50
	Re-colonization	pHOS<10%	Not Specified
	Preservation	pHOS<10%	Not Specified
Stabilizing	Fully Restored	Current Condition	Current Condition
	Local Adaptation	Current Condition	Current Condition
	Re-colonization	Current Condition	Current Condition
	Preservation	Current Condition	Current Condition

We have two concerns regarding the phases of recovery approach. First, although the phase structure is intuitively appealing, no scientific evidence was presented the HSRG for existence of the phases. Second, while we agree that conservation of populations at perilously low abundance may require prioritization of demographic over genetic concerns, we are concerned that high pHOS/low PNI regimes imposed on small recovering populations may prevent them from advancing to higher recovery phases[10]. A WDFW scientific panel reviewing HSRG principles and guidelines reached the same conclusion (Anderson et al. 2020). In response, the HSRG in issued revised guidance for the preservation and recolonization phases (HSRG 2020):

1. *Preservation – No specific pHOS or PNI recommendations, but hatchery managers are encouraged to use as many NOR brood as possible. In some cases (e.g., very low R/S values at low spawner abundances or low intrinsic productivity), it may be preferable to use all available NORs in the hatchery brood and allow only extra hatchery-origin recruits (HORs) to spawn naturally.*

2. *Recolonization – No specific pHOS or PNI recommendations, but managers are encouraged to continue to use some NOR in broodstock (perhaps 10%-30% of NORs), while allowing the majority of NORs to spawn naturally.*

[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).

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

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

A good example is a system of genetically linked hatchery programs, an integrated program in which in which returnees from a (typically smaller) integrated hatchery program are used as broodstock for a larger segregated program, and both programs contribute to pHOS (Figure 22). It seems logical that this would result in less impact to the natural population than if the segregated program used only its own returnees as broodstock, but because the two-population implementation of the Ford model did not apply, there was no way to calculate PNI for this system.

Extending Ford's recursion equations (equations 5 and 6) to three populations allowed us to calculate PNI for a system of this type. We successfully applied this approach to link two spring Chinook salmon hatchery programs: Winthrop NFH (segregated) and Methow FH (integrated). By using some level of Methow returnees as broodstock for the Winthrop program, PNI for the natural population could be increased significantly[11] (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.

[11] Such programs can lower the effective size of the system, but the model of Tufto (Section 5.2.1.3) can easily be applied to estimate this impact.

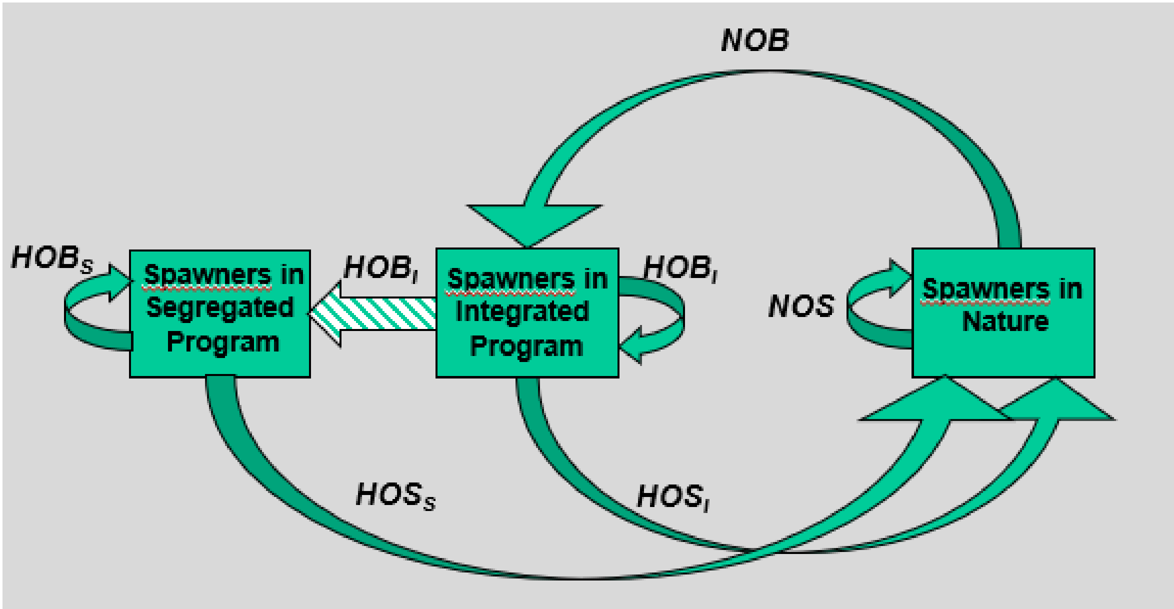

Figure 21. Example of genetically linked hatchery programs. The natural population is influenced by hatchery-origin spawners from an integrated (HOS_I) and a segregated program (HOS_S). The integrated program uses a mix of natural-origin (NOB) and its own returnees (HOB_I) as broodstock, but the segregated 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.

5.2.1.4.4. California HSRG

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

- Felt that truly isolated programs in which no HO returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept of segregated programs. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5 percent.

- Rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as "the amount of spawning by NO fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between HO and NO fish, and societal values, such as angling opportunity."

- Recommended that program-specific plans be developed with corresponding population-specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors.

However, they did state that PNI should exceed 50 percent in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5 percent, even approaching 100 percent at times.

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

5.2.2. Ecological effects

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

To the extent that hatcheries contribute added fish to the ecosystem, there can be positive effects. For example, when anadromous salmonids return to spawn, hatchery-origin and natural-origin alike, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production (Kline et al. 1990; Piorkowski 1995; Larkin 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).

5.2.3. 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.

5.3. 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.

5.3.1. 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 (SIWG 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 (1954b) rarely observed aggression in sockeye salmon fry, and observed considerably less aggression in sockeye than coho salmon smolts. Taylor (1990b) 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 1991a). Taylor (1991a) 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 (1991a) 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.

5.3.2. 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

[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.

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 (SIWG 1984). Due to their location in the stream, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is greatest immediately upon emergence from the gravel and then decreases as they move into shallow, shoreline areas (USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are as large as 1/2 their length (Hargreaves 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

5.3.3. 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 Zones[13] (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

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

addition, current hatchery operations often rear hatchery fish on a timeline that mimics their natural life history, which limits the presence of fish susceptible to pathogen infection and prevents hatchery fish from becoming a pathogen reservoir when no natural fish hosts are present.

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

Treating the hatchery effluent reduces pathogen amplification, but does not reduce disease outbreaks within the hatchery caused by pathogens present in the incoming water supply. Another challenge with treating hatchery effluent is the lack of reliable, standardized guidelines for testing or a consistent practice of controlling pathogens in effluent (LaPatra 2003). However, hatchery facilities located near marine waters likely limit freshwater pathogen amplification downstream of the hatchery without human intervention because the pathogens are killed before transmission to fish when the effluent mixes with saltwater.

Noninfectious diseases are typically caused by environmental factors (e.g., low dissolved oxygen). Hatchery facilities routinely use a variety of chemicals for treatment and sanitation purposes. Chlorine levels in the hatchery effluent, specifically, are monitored with a National Pollutant Discharge Elimination System (NPDES) permit administered by the Environmental Protection Agency. Other chemicals are discharged in accordance with manufacturer instructions. The NPDES permit also requires regular monitoring of settleable and unsettleable solids, temperature, and dissolved oxygen in the hatchery effluent to ensure compliance with environmental standards and to prevent fish mortality.

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

5.3.4. 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.

5.3.5. 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.

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

NMFS also analyzes proposed research, monitoring, and evaluation (RM&E) for its effects on listed species and on designated critical habitat. Negative effects from RM&E are weighed against the value of new information, particularly information that tests key assumptions and that reduces uncertainty. RM&E actions that can cause harmful changes in behavior and reduced survival include, but are not limited to:

- 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)

NMFS also considers the overall effectiveness of the RM&E program. There are five factors that we take into account when it assesses 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 it makes 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.

5.4.1. Observing/Harassing

For some activities, 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.

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.

5.4.2. Capturing/handling

Any physical handling or psychological disturbance is known to be stressful to fish (Sharpe et al. 1998). Primary contributing factors to stress and death from handling are excessive doses of anesthetic, differences in water temperatures (between the river and holding vessel), dissolved oxygen conditions, the amount of time fish are held out of the water, and physical trauma. Stress increases rapidly if the water temperature exceeds 18ºC or dissolved oxygen is below saturation. Fish transferred to holding tanks can experience trauma if care is not taken in the transfer process, and fish can experience stress and injury from overcrowding in traps if the traps are not emptied regularly. Decreased survival can result from high stress levels, and may also increase the potential for vulnerability to subsequent challenges (Sharpe et al. 1998).

NMFS has developed general guidelines to reduce impacts when collecting listed adult and juvenile salmonids (NMFS 2000a; 2008a) that have been incorporated as terms and conditions into section 7 opinions and section 10 permits for research and enhancement. Additional monitoring principles for supplementation programs have been developed by Galbreath et al. (2008).

5.4.3. 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 codes[15] 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

[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).

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 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.

5.4.4. 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.

5.5. 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.

5.6. 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 2005b). In any event, fisheries must be carefully evaluated and monitored based on the take, including catch and release effects, of ESA-listed species.

6. Appendix B: Skagit River watershed chum salmon

Mid-2000's decline in abundance

The Skagit chum salmon population has experienced a substantial and ongoing decline in abundance beginning with brood year (BY) 2007 (Figure 23; Table 17). We determined the extent of this decline using the following data sets:

- WDFW spawner escapement data for BY 1968–2020, which includes the entire time period that data has been collected. The BY 2020 escapement estimate provided by WDFW was preliminary and subject to change as of June 9, 2022. No BY 2021 estimate was available at the time of this writing.
- WDFW juvenile outmigrant abundance estimates for BY 1996–2018, 2020, based on RM 17 trap catch. This includes the entire time period that data has been collected. Due to trap operational issues, no estimate was available for BY 2019.
- Hatchery release numbers provided by the co-managers for all years that hatchery fish were released, except for BY 1990–1991, 1993–1996 releases from Red Creek Hatchery, which were unavailable.
- Hatchery broodstock collection numbers provided by the co-managers for all years that broodstock were collected, except for BY 1990–2000 collections for Red Creek Hatchery, which were unavailable.

We calculated adult returns to the watershed by adding the annual broodstock collections to the annual spawner escapement for years when one or more hatchery programs were collecting broodstock. We estimated broodstock collection numbers for years when this was unavailable (BY 1990–2000). Values for BY 1992 and 1997–2000 were estimated based on the number of juveniles released from that brood year, and mean BY 2001–2019 Red Creek Hatchery production rates (number of juveniles produced per adult). For years lacking juvenile release numbers (BY 1990–1991, 1993–1996), the mean number of adults estimated to have been collected in BY 1992, 1997–2000 were used. These data and estimates indicate that the proportion of adult returns taken for broodstock has been very low, ≤ 2.8% annually (Figure 24).

Plots of annual adult return and juvenile outmigrant data, and 4-year means of each for even and odd years separately, show that both adult returns and juvenile outmigration abundance entered a period of ongoing depression beginning with BY 2006 (Figure 24). The declines have been substantial: 69% and 60% for even and odd brood year adult returns, respectively; and 57% and 90% for even and odd brood year juvenile outmigration abundances, respectively (Figure 23). These declines are all statistically significant ($\alpha = 0.05$), except for even brood year juvenile outmigrant abundance.

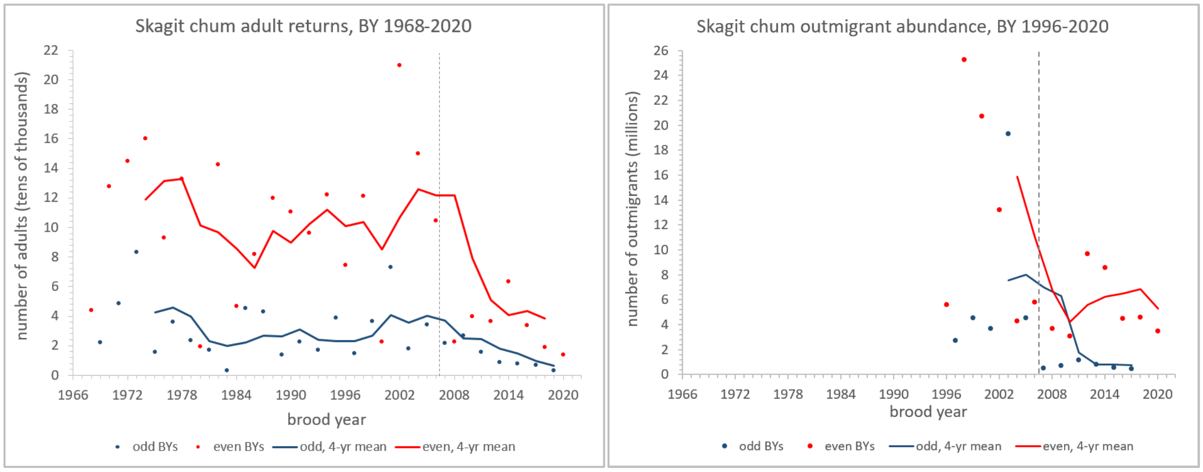

Figure 22. Abundance of Skagit River chum salmon adult returns (left panel) and juvenile outmigrants (right panel) over time. The BY 2020 adult return estimate is preliminary and subject to change. The vertical dashed line divides the pre- and post-decline periods.

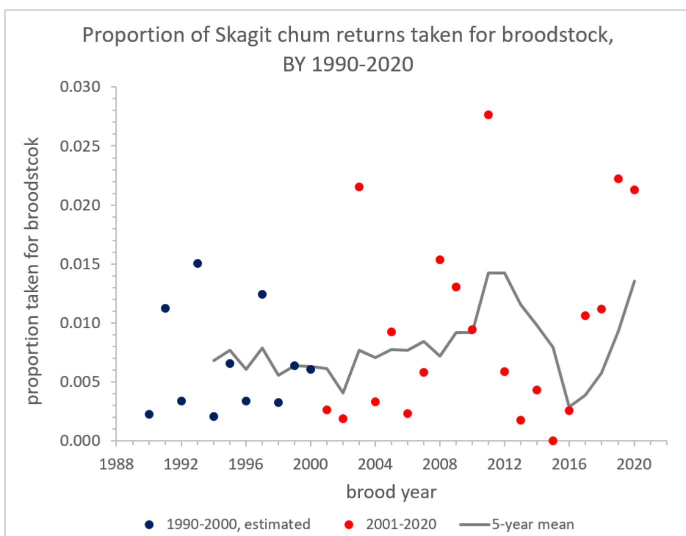

Figure 23. Proportion of returning Skagit adult chum salmon collected for broodstock for all programs combined, BY 1990–2020. Broodstock collection numbers were estimated for BY 1990–2000 (see text for additional information).

Table 17. Summary of historical abundances and recent decline in Skagit River chum salmon adult returns (BY 1968–2020[a]) and juvenile outmigrants (BY 1996–2018, 2020[b]). Adult return figures include spawner escapements and fish collected for broodstock. Results of nonparametric Mann-Whitney *U* test (2-tail) are shown (p value), indicating level of statistical significance between pre-decline (≤ BY 2006) and post-decline (BY > 2006) abundances. Values in bold are significant at the α = 0.05 level. All years shown are brood years.

	≤ BY 2006	> BY 2006	difference	Percent decline	p value
Even brood years					
Adult returns	106,267 n = 20 (1968–2006)	32,759 n = 7 (2008–2020)	-73,507	-69%	**$p < 0.01$**
Outmigrant abundance	12.49 mil n = 6 (1996–2006)	5.39 mil n = 7 (2008–2020)	-7.11 mil	-57%	$0.05 < p \leq 0.10$
Odd brood years					
Adult returns	31,947 n = 19 (1969–2005)	12,936 n = 7 (1969–2005)	-19,011	-60%	**$0.01 < p < 0.02$**
Outmigrant abundance	6.97 mil n = 5 (1997–2005)	0.72 mil n = 6 (2007–2017)	-6.25 mil	-90%	**$p \leq 0.01$**
Combined (odd and even BYs)[c]					
Adult returns	70,744 n = 38 (1969–2006)	22,848 n = 14 (2007–2020)	-47,896	-68%	**$p < 0.01$**
Outmigrant abundance	10.42 mil n = 10 (1997–2006)	3.20 mil n = 12 (2007, 2009–2018, 2020)	-7.22 mil	-69%	**$0.01 < p < 0.02$**

[a] The adult return estimate for 2020 is preliminary and subject to change.
[b] No outmigrant estimate was available for BY 2019.
[c] To avoid bias from the even-odd year chum cycle, each data set that combined even and odd years was limited to having the same number of even and odd years represented within it. This meant having to exclude one year from some data sets. When this was necessary, the earliest year of data was excluded. For example, outmigrant data was available for 11 years up to and including BY 2006, over-representing even BYs in the data set. Therefore, the BY 1996 data point was excluded.

Juvenile production as a function of spawner abundance

We evaluated the extent to which Skagit River chum salmon juvenile outmigration abundance is dependent on the abundance of spawners that produced them. To do this, we utilized WDFW outmigrant estimates based on RM 17 trap catch for trap years 1997–2019, 2021 (brood years 1996–2018, 2020), and WDFW chum salmon spawner abundance estimates for brood years 1996–2018, 2020. Unmarked hatchery chum salmon were released during this time and were indistinguishable from naturally-produced fish. However, hatchery release abundances were typically a relatively small proportion of the total chum salmon outmigration (median 6%, mean 9%, range: 0–45%) (Figure 25). Though mortality from release to the trap is unknown, chum fry mortality during freshwater outmigration is typically high (Groot and Margolis 1991). We therefore assumed that any bias introduced by not accounting for hatchery-released fish would be minor.

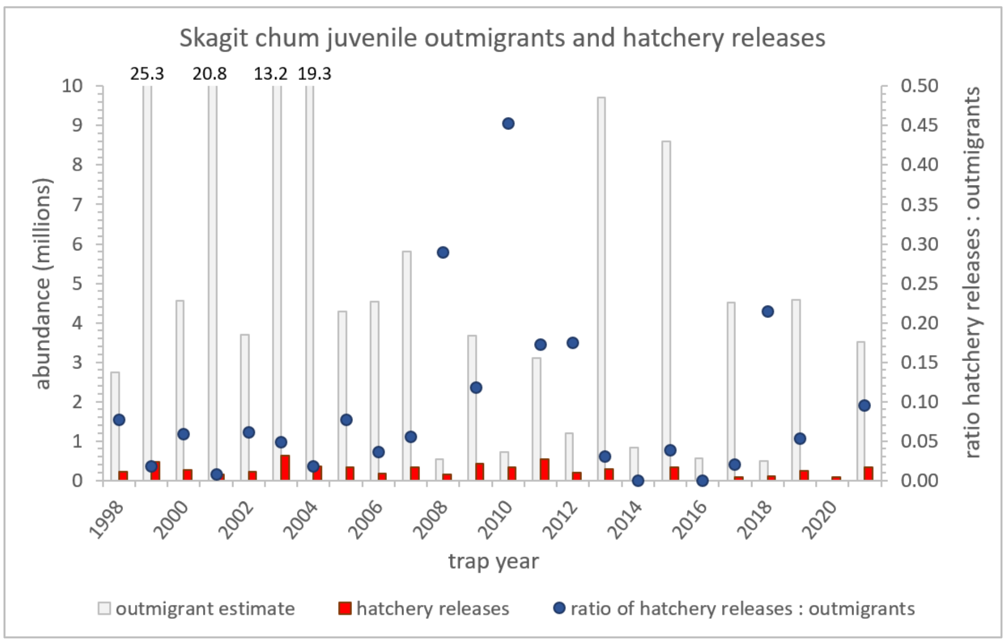

Figure 24. Juvenile hatchery chum salmon release abundances, total Skagit River juvenile chum salmon outmigrant abundance (estimated by WDFW from RM 17 trap catch), and ratio of the former to the latter, 1998–2021. The proportion of outmigrants represented by hatchery fish cannot be estimated, but is likely considerably less than the ratios shown because chum fry are generally known to suffer high levels of mortality during freshwater outmigration (Groot and Margolis 1991). Outmigrant estimate for trap year 2020 was unavailable.

The Spearman's rank correlation coefficient for the trap catch and spawner abundance data set was 0.6113, indicating a moderate correlation between outmigrant abundance and the spawners that produced them. This relationship was statistically significant ($p = 0.0015$). Despite this, the best-fit equation was a power function with relatively low explanatory power ($r^2 = 0.3614$) (Figure 26), indicating that factors other than spawner abundance contribute more substantially to outmigrant abundance.

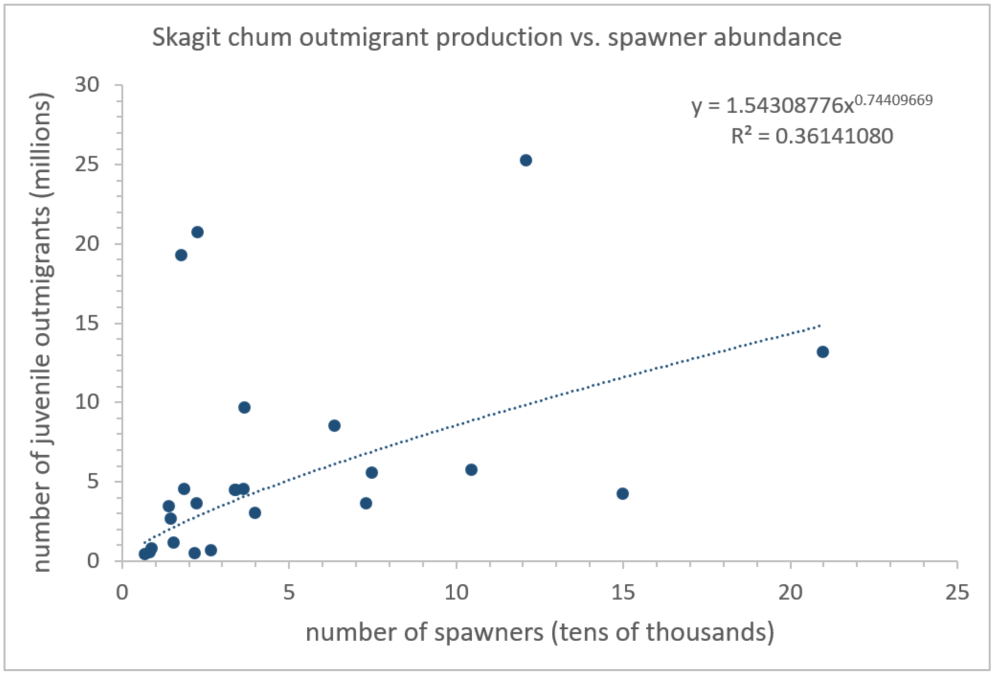

Figure 25. Regression of Skagit River chum salmon juvenile outmigration abundance (year Y) against chum salmon spawner abundance (year Y-1) for brood years 1996–2018, 2020. Spawner and outmigrant abundance data provided by WDFW.

Historical spawner escapement trends

Despite some fluctuations, spawner abundances during even and odd years were relatively stable during the period of record (BY 1968–2006) (Figure B-5). The slight positive and negative slopes in abundance evident for even and odd years, respectively, were not statistically significant (even years: Spearman correlation coefficient = 0.029, $p = 0.905$, $n = 20$; odd years: Spearman correlation coefficient = -0.082, $p = 0.737$, $n = 19$). Linear regressions further showed that time explained very little of the variation (Figure 27). For even years, average spawner abundance was 106,128 fish, with 4-year means not exceeding 132,718 fish. For odd years, average spawner abundance was 31,838 fish, with 4-year means not exceeding 46,022 fish.

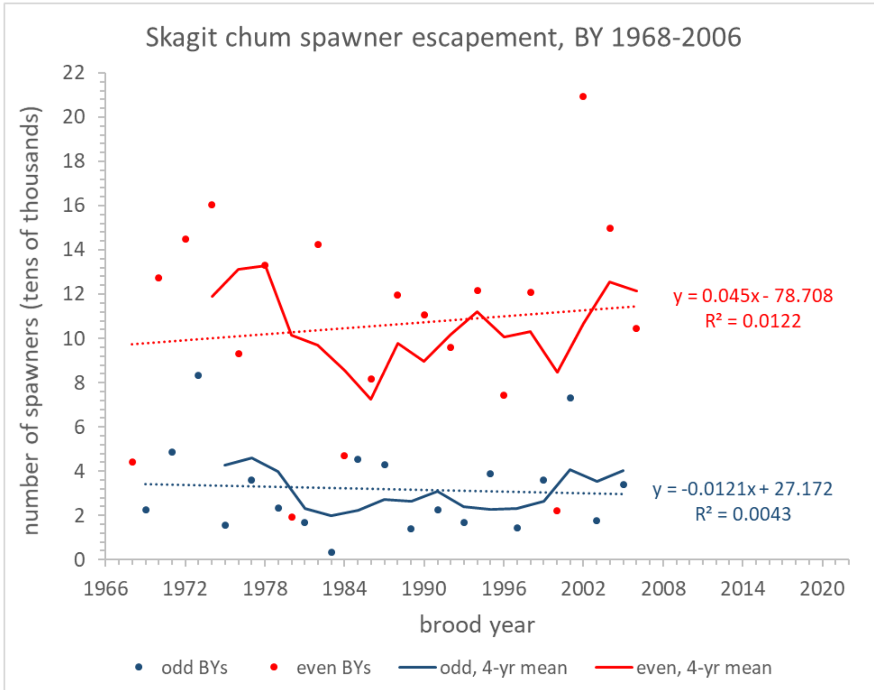

Figure 26. Historical pre-decline abundance trends in Skagit River chum salmon spawner escapement. Fish collected for broodstock are excluded. Linear regression results are shown for even years (red dashed line and text) and odd years (blue dashed line and text).

7. APPENDIX C: PCD RISK MODEL ASSESSMENT FOR COMPETITION AND PREDATION IN FRESHWATER REARING AREAS

The PCD Risk model (version 3.2) developed by Pearsons and Busack (2012) was used to quantify potential risk to natural-origin Chinook salmon and steelhead trout from competition and direct predation in freshwater habitat resulting from the release of hatchery-origin chum salmon. Although model logic is still largely as described in Pearsons and Busack (2012), the PCD Risk model has undergone considerable modification since then to increase supportability and reliability. See NMFS (2019a) for a description of model modifications.

Model input parameters

Values for several model input parameters must be assumed, as described in NMFS (2019a). The values used for the present evaluation (Table 18) are consistent with those used in other NMFS consultations that have implemented the PCD Risk model. For the population overlap parameter, we assumed 100% overlap between hatchery fish and natural-origin Chinook salmon. This would overestimate hatchery-natural interaction potential because there are many areas, especially tributaries, used by natural-origin fish where hatchery-origin juveniles would not be expected to occur. For natural-origin steelhead trout, we assumed 100% overlap for smolts and 50% overlap for fry and parr. The lower value for fry and parr was used because most steelhead spawning and juvenile rearing occurs in tributaries outside of hatchery fish migratory corridors (Beamer et al. 2010; Barkdull 2020a).

In assigning dominance mode, we considered species-specific dominance traits of chum and Chinook salmon and steelhead trout. Specifically, species and life history variants that outmigrate very early from stream habitats, such as chum salmon, are much less aggressive than those that spend longer periods of time rearing in lotic habitats, such as coho and Chinook salmon and steelhead trout (Hoar 1951; 1954a; Taylor and Larkin 1986; Taylor 1990a; 1991b; Hutchison and Iwata 1997; Hasegawa et al. 2014), although intraspecific aggression is generally more intense than interspecific aggression regardless of species (e.g., Hartman 1965; Tatara and Berejikian 2012). We also considered that smaller individuals of a dominant species are generally competitively superior to larger individuals of the subordinate species to a point (e.g., Nakano 1995; Hasegawa et al. 2004; Blann and Healey 2006; Thornton et al. 2017). For example, in one evaluation, Blann and Healey (2006) observed coho to be 85% dominant over Atlantic salmon even though Atlantic salmon had a 10–30% length advantage. Based on this body of literature, we used the user-defined dominance mode 6 for hatchery-origin chum salmon with the following percent dominance of hatchery-origin fish (corresponding percent difference in size of hatchery fish relative to natural-origin fish shown in parentheses): 0 (<-25), 5 (-25 to -15), 10 (-15 to -5), 25 (>-5).

Table 18. Values used in the PCD Risk model for selected parameters. Values for parameters not shown are provided in Table 20 and Table 21. NO = natural origin.

Parameter	Value
Habitat complexity	0.1
Population overlap	1.0, NO Chinook salmon (all life history stages); steelhead trout smolts 0.5, NO steelhead trout fry and parr
Habitat segregation	0.6
Maximum encounters per day	3
Predator:prey length ratio for predation	0.25[a]
Probability dominance results in body weight loss	0.05
Percentage of body weight loss that results in death	50

[a] Sources: Keeley and Grant (2001); Daly et al. (2009)

Size and abundance of natural-origin fish exposed to hatchery fish

Similar to NMFS (2019a), we used Skagit-specific data to derive abundances of natural-origin fish exposed to hatchery-origin fish interactions in the model. Our general approach in deriving these abundances was as follows:

1. Total basin-wide production of juvenile natural-origin fish, including emergent fry, freshwater rearing parr (age-specific), and smolts (age-specific) was estimated.
2. Conservatively-high, knowledge-based assumptions about spatial overlap between natural-origin and hatchery-origin fish (i.e., population overlap in Table 18) were applied to the estimates derived in step 1. This represented the maximum potential abundance of natural-origin fish in the model space prior to accounting for temporal overlap (step 3).
3. Results from step 2 were adjusted to account for temporal overlap. That is, the abundance of each life history stage present during a hatchery program's release depends on the time of release relative to fry emergence timing (Chinook and steelhead), smolt outmigration timing (Chinook and steelhead), and parr outmigration timing from tributaries (steelhead only) (Table 19). These adjustments were made using empirical Skagit-specific data, as described below. The resultant numbers of natural-origin fish by life history stage, including fish size, exposed to hatchery fish are shown in Table 20.

Skagit River data—including WDFW spawner survey data (Barkdull 2019), outmigrant trap data (Kinsel 2019a; 2019b; 2019c), and other supplemental data sources (as indicated below)—provided the primary basis for estimating the number of natural-origin Chinook salmon and steelhead trout exposed to hatchery-origin fish interactions in freshwater for modelling purposes. For natural-origin Chinook salmon, modeled subyearling abundance was determined using redd-based stock escapement estimates for each of the six Skagit Chinook populations determined by WDFW for brood years 2007–2016. We assumed 2.5 spawners per redd, a 1:1 male-to-female ratio, and applied population-specific fecundity values (Zimmerman et al. 2015) to estimate mean annual Chinook egg deposition. A literature-based 44.6% egg-to-fry survival rate (Quinn 2018) was then applied to estimate mean annual emergent fry production. To be conservative, zero mortality from non-hatchery sources was assumed from fry emergence through the end of July.

For yearling natural-origin Chinook salmon, basin-wide abundance was determined using outmigrant trap-based outmigration estimates (2008–2017 trap data). We used the mean annual yearling outmigration estimate and applied a multiplier of 2 (equivalent to 50% mortality) to account for non-hatchery sources of mortality during this time. The applied 50% mortality rate is comparable to typical salmonid mortality during the entirety of their first winter in freshwater (Quinn 2018), and is therefore conservatively high for the spring outmigration period. The resultant figure is thus a conservatively high estimate of basin-wide yearling abundance at the time of outmigration.

In the Skagit River basin, natural-origin Chinook fry, parr[37], and/or yearlings may be exposed to hatchery-origin fish depending on when hatchery-origin fish are released (Table 19). The ratio of natural-origin fry to parr varies during the season as: 1) earlier-emerging fry grow to parr-size while other fry are still emerging or have yet to emerge; and, 2) both fry and subyearling outmigrants exit the system, doing so at different periodicities. Outmigrant trap data was used to estimate fry-to-parr ratios and outmigration timing (2014–2018 trap data) as well as total number of outmigrants of each life history variant (i.e., fry, subyearling, and yearling outmigrants) (2008–2017 trap data). Monthly fry catch at the trap was used to approximate emergence timing and to estimate fry-to-parr ratios for each month that both fry and parr are present in freshwater. Thus, for example, trap data showed that mean 78% of fry outmigrants leave the system prior to April. Therefore, in evaluating April hatchery releases, we assumed that 78% of all emergent Chinook fry produced in the basin emerged prior to April and were parr-size during April. Outmigrants were accounted for by using the outmigrant trap data to estimate the proportion and abundance of each life history variant leaving freshwater each month from January through July (e.g., proportion of all fry outmigrants that leave in January, proportion that leave in February, etc.). Thus, for example, to evaluate April hatchery releases, the estimated proportion of natural-origin fry, subyearling, and yearling outmigrants that leave the system prior to April were excluded from hatchery effects.

[37] We defined natural-origin Chinook fry as fish < 48 mm FL, and parr as subyearlings ≥ 48 mm FL.

Table 19. Generalized annual periodicity table for Skagit River hatchery releases and natural-origin Chinook salmon and steelhead trout. Horizontal bars are shaded to show peak outmigration timings (dark shade), with progressively lighter shades representing smaller proportions of outmigrants.

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
NATURAL-ORIGIN STEELHEAD TROUT[a]												
spawning												
fry emergence												
parr (≥ age 1) outmigration from tributaries												
parr present in mainstem Skagit and tributaries												
smolt outmigration from tributaries												
smolt outmigration from mainstem												
NATURAL-ORIGIN CHINOOK SALMON[b]												
fry emergence												
fry outmigration												
subyearling parr presence												
subyearling smolt outmigration												
yearling smolt outmigration												
HATCHERY RELEASES[c]												
Chum RSI release												
USIT (Red Creek) chum												
Skagit (Marblemount) chum												

[a] Natural-origin steelhead trout data sources: Kinsel et al. (2013); Kinsel et al. (2014); Kinsel et al. (2015a); Kinsel et al. (2015b); Kinsel et al. (2016); Barkdull (2020b).
[b] Natural-origin Chinook salmon data sources: Kinsel (2019b; 2019c).
[c] Hatchery release data sources: HGMPs.

Table 20. Estimated mean size[a] and abundance[b] of listed natural-origin Chinook salmon and steelhead trout encountered by juvenile hatchery chum salmon after release. Estimated fish size (mm FL) and coefficient of variation for each age and life history class are shown in parentheses in the header row, unless otherwise specified in the body of the table.

		Steelhead Trout								Chinook Salmon		
			Parr			Smolts						
Hatchery fish	Time period	Fry (41, 0.10)	Age 1 (91, 0.14)	Age 2 (115, 0.14)	Age 3 (138, 0.18)	Age 1 (155, 0.09)	Age 2 (166, 0.11)	Age 3 (180, 0.11)	Age 4 (192, 0.13)	Fry (41, 0.05)	Subyearling parr	Age 1 (100, 0.11)
Chum (all programs)	April–May	0	304,200	75,800	4,400	5,900	152,600	67,000	4,400	2.78 mil	9.61 million (57, 0.12)	34,180

[a] Natural-origin fish size was determined using size data from the WDFW RM 17 trap for Chinook salmon (Kinsel 2019a) and steelhead trout smolts (Barkdull 2018). For steelhead parr, data from Kinsel et al. (2015b), Kinsel et al. (2016), and Thompson and Beauchamp (2016) were used to estimate age-specific sizes.
[b] See text for methods describing derivation of abundance estimates.

Similar approaches and data sets as those used for Chinook salmon were used for natural-origin steelhead trout. Basin-wide emergent fry production was estimated using redd-based stock escapement estimates for brood years 2009–2018. We assumed two spawners per redd, a 1:1 male-to-female ratio, and generalized steelhead fecundity (4,923 eggs per female) and egg-to-fry survival (29.3%) values reported by Quinn (2018).

Total basin-wide smolt production for each smolt age class (ages 1, 2, 3, and 4) was calculated for years with available data. Age class distributions were available only for outmigration years 2012–2014 (Kinsel et al. 2015a) and 2015–2017 (Barkdull 2018). Using these data, we estimated abundance of smolts within each age class for outmigration years 2008–2014 (the only years with available basin-wide smolt production estimates) (Kinsel et al. 2015a) as follows:

- For outmigration years 2012–2014, each year's smolt abundance estimate was partitioned according to the corresponding year's age class distribution from Kinsel et al. (2015a).
- For outmigration years 2008–2011, each year's smolt abundance estimate was partitioned according to the 2012–2017 6-year mean age class distribution.

Next, the number of age-specific smolts per spawner was calculated using the redd-based stock escapement estimates noted above for brood years 2004–2013. The resultant mean number of age-specific smolts per spawner was then applied to the 2009–2018 10-year mean spawner abundance to yield an estimated annual smolt abundance for each smolt age class to use for the model. We applied a generalized 50% annual mortality rate Quinn (2018) to yield basin-wide estimates for freshwater-rearing parr in each age class (ages 1, 2, and 3).

Modeled hatchery-origin fish

Model parameters and related release information for hatchery-origin fish are shown in Table 21. These were based on information presented in the HGMPs.

Table 21. Hatchery fish abundance and parameter values used in the PCD Risk model. CV = coefficient of variation. Data for release number, release size (mm) and CV, release timing, and release location are from HGMPs.

Program	Release number[a]	Release size (mm)	Release size CV	Release timing	Release temp.[b] (°C)	Release location (River and river mile)	Piscivory rate[c]	Survival[d] (percent)	Travel rate[e] (miles/day)	Travel time to mouth (days)
Upper Skagit Chum	495,000	46	0.22	April–May	8.3	Skagit RM 57	0	78	5.4	11
Chum RSI	137,500	50	0.20	April–May	8.3	Sauk RM 14.5	0	78	5.4	16
Skagit Fall Chum	5.45 mil	47	0.21	April–May	8.3	Skagit RM 90	0	78	5.4	17

[a] Our analysis includes an extra 10% added to the proposed production targets to account for variability in release numbers.

[b] Mean daily surface water temperature data from the following USGS gage sites were used to estimate temperature during release and outmigration of hatchery fish: USGS 12200500 SKAGIT RIVER NEAR MOUNT VERNON, WA (1975–2018); USGS 12181000 SKAGIT RIVER AT MARBLEMOUNT, WA (1987–2018); USGS 12178000 SKAGIT RIVER AT NEWHALEM, WA (2002–2018); USGS 12189500 SAUK RIVER NEAR SAUK, WA (2018); USGS 12187500 SAUK RIVER AT DARRINGTON, WA (2017–2018).

[c] Chum fry are too small to be piscivorous.

[d] We applied a generalized 22% mortality, which was the lowest chum fry mortality rate of several empirical studies reviewed by Groot and Margolis (1991).

[e] No Skagit-specific data was available, so we used values for Green River chum salmon indicated in NMFS (2019a).

Results

PCD Risk model output is summarized in Table 22. For steelhead trout, model results for all ages of parr were combined into total parr mortality. Juvenile mortality was converted to Adult Equivalents as described in Table 22.

Table 22. PCD Risk model results of mortality to natural-origin Chinook salmon and steelhead trout caused by competition from hatchery-origin chum salmon released as part of the Proposed Action. Mortality to juvenile life history stages and corresponding adult equivalents (AE) are shown.

Hatchery program	Chinook salmon				Steelhead trout			
	juvenile mortalities			AEs[a]	juvenile mortalities			AEs[b]
	fry	parr (age 0)	age 1		fry	parr (ages 1–3)	smolts	
chum (all programs)	2,140	780	0	15	-	27	0	1

[a] Adult equivalents for Chinook salmon were calculated as follow:

- Yearlings (age 1): Data was insufficient to estimate survival. Therefore, the SAR estimated for steelhead smolts (note b) was used as a surrogate.
- Subyearling parr (March–July): 1.6% survival-to-adult was estimated by dividing mean number of adult spawners (return years 2009–2018) by mean number of smolts (excluding fry outmigrants) (outmigration years 2006–2015).
- Subyearling parr (September–October): Data was insufficient to estimate survival. Therefore, we used 3.1%, which was the mean of the values used for spring parr and yearling outmigrants.
- Fry: Fry-to-smolt survival was calculated by first subtracting the mean number of fry outmigrants (2008–2018) from the mean annual basin-wide emergent fry production described in the text. Mean parr and smolt outmigrant abundance (2008–2018) was then divided by this number of fry to yield a fry-to-smolt survival of 6.2%. The 1.6% parr outmigrant-to-adult survival rate was then applied.

[b] Adult equivalents for steelhead trout were calculated as follow:

- Smolts, all age classes: A smolt-to-adult survival (SAR) of 4.6% was applied to all smolt age classes. This was determined by dividing the mean number of adult spawners (return years 2010–2016) by the mean number of smolts produced (outmigration years 2008–2014).
- Parr, each age class: Age-specific parr-to-smolt survival rates (age 1, 37%; age 2, 47%; age 3, 50%) were calculated by dividing the number of parr in a given age class (e.g., age 1) by the total number of smolts in subsequent age classes (e.g., ages 2, 3, and 4). The SAR determined for smolts was then applied.
- Fry: 4.9% fry-to-smolt survival was calculated by dividing the annual emergent fry abundance by the annual estimated smolt outmigration (all ages combined). The SAR determined for smolts was then applied.

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