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 Two Hatchery and Genetic Management Plans for Early Winter Steelhead in the Snohomish River basin under Limit 6 of the Endangered Species Act Section 4(d) Rule

NMFS Consultation Number: WCR-2015-3441

Action Agencies: National Marine Fisheries Service

Affected Species and Determinations:

ESA-Listed Species	Status	Is the Action Likely to Adversely Affect Species or Critical Habitat?	Is the Action Likely To Jeopardize the Species?	Is the Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	No
Puget Sound Chinook salmon (*O. tshawytscha*)	Threatened	Yes	No	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: for Robert Turner

William W. Stelle, Jr.
Regional Administrator

Date: 4/15/2016

Expires: As per the ESA 4(d) Rule, limit 6, take authorization is open-ended in duration

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1 INTRODUCTION

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

The Proposed Action is the National Marine Fisheries Service's (NMFS) determination under limit 6 of the Endangered Species Act (ESA) 4(d) rule for ESA-listed Puget Sound steelhead and ESA-listed Puget Sound Chinook salmon (50 CFR § 223.203(b)(6)) concerning two hatchery programs in the Snohomish River basin submitted for review by the Washington Department of Fish and Wildlife (WDFW) and Tulalip Tribes as *U.S.* v. *Washington* (1974) fish resource co-managers. NMFS is the only Action Agency for this consultation, because the proposed action is the issuance by NMFS of ESA section 4(d) authorizations for the two state-funded early-winter steelhead (EWS) hatchery programs affecting listed steelhead and salmon. There is no other federal nexus for this consultation. The programs themselves are operated by WDFW and funded predominately through Washington State general funds, and also through recreational fisheries license sale revenue.

The WDFW proposes to operate two hatchery programs that release steelhead into the Skykomish, Wallace, and Snoqualmie rivers under limit 6 of the ESA 4(d) rule as joint state-tribal plans (Table 1)[1]. The "early winter" (previously "Chambers Creek lineage") steelhead (hereafter, EWS) that would be propagated through the two hatchery programs are not part of the Puget Sound steelhead Distinct Population Segment (DPS) (72 FR 26722, May 11, 2007). As described in section 1.8 of the Hatchery and Genetics Management Plans (HGMPs; WDFW 2014a; WDFW 2014b), both hatchery programs would be operated as isolated[2] harvest augmentation programs. Adult steelhead produced by the programs are not intended to spawn naturally and are not intended to establish, supplement, or support any steelhead populations occurring in the natural environment.

Table 1. Early winter steelhead (EWS) (isolated) HGMPs submitted to NMFS for evaluation of ESA-listed salmon and steelhead effects pursuant to ESA 4(d) rule, Limit 6.

Hatchery and Genetics Management Plan	Program Operator	Watershed/MPG *
Wallace/Reiter Early Winter Steelhead Hatchery Program (WDFW 2014a)	WDFW	Skykomish-Wallace/North Cascades
Tokul Creek Winter Steelhead Hatchery Program (WDFW 2014b)	WDFW	Snoqualmie-Tokul/North Cascades

* "MPGs" are "Major Population Groupings" for the Puget Sound Steelhead DPS delineated by the Puget Sound Steelhead Technical Recovery Team (Myers et al. 2015).

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[1] The co-managers subsequently modified the Wallace/Reiter Early Winter Steelhead plan as an outcome of consultation discussions with NMFS by reducing the annual smolt release number from the level proposed in the 2014 HGMP (Unsworth 2016).

[2] This term is defined in Section 2.4.1. "Isolated" is synonymous with the term "segregated" that is used in the HGMP titles.

1.1 Background

The NMFS prepared the biological opinion (opinion) and incidental take statement portions of this document in accordance with section 7(b) of the ESA of 1973, as amended (16 U.S.C. 1531, et seq.), and implementing regulations at 50 CFR 402. The opinion documents consultation on the actions proposed by NMFS.

The NMFS also completed an Essential Fish Habitat (EFH) consultation. It was prepared in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801, *et seq*.) and implementing regulations at 50 CFR 600.

The opinion, incidental take statement, and EFH conservation recommendations are in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-5444) ("Data Quality Act") and underwent pre-dissemination review. The project files for these consultations are held at the Sustainable Fisheries Division (SFD) of NMFS in Lacey, Washington.

1.2 Consultation History

In March 2003, NMFS received from WDFW the first draft versions of 17 HGMPs describing Puget Sound EWS and Skamania early summer steelhead (hereafter, ESS) hatchery programs, and NMFS responded with comments on August 23, 2003. Just over a year later on September 13, 2004, NMFS received a petition to list Puget Sound steelhead as an endangered or threatened species under the ESA. NMFS completed its review of the petition, and the accompanying scientific information, and on April 5, 2005, announced that the petition presented enough information for the agency to conduct a formal review and determine whether Puget Sound steelhead warranted protection under the ESA (70 FR 17223; April 5, 2005). On August 4, 2005, after NMFS announced that there was sufficient reason to review the status of Puget Sound steelhead for potential listing under the ESA, WDFW submitted 14 HGMPs for isolated hatchery steelhead programs to NMFS for ESA review. Seven months later, NMFS announced that it was issuing a proposed rule that Puget Sound steelhead warranted protection as a threatened species under the ESA (FR 15666; March 29, 2006). On May 11, 2007, NMFS issued a final determination that Puget Sound steelhead would receive protection as an ESA-listed threatened species (72 FR 26722). On September 25, 2008, NMFS issued a final 4(d) rule adopting protective regulations for the listed Puget Sound steelhead DPS (73 FR 55451) and 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 became subject to review for effects on ESA-listed salmon and steelhead.

To meet NEPA requirements associated with NMFS's eventual 4(d) determinations for HGMPs within the Puget Sound region, in July 2014, NMFS released a draft EIS. The draft EIS addressed two joint resource management plans (RMPs) submitted to NMFS by the co-managers that served as the overarching frameworks for all Puget Sound region HGMPs. NMFS subsequently withdrew the draft EIS, following notice by the co-managers clarifying their intent to submit revised HGMPs bundled by individual Puget Sound watersheds. This co-manager notice and NMFS's withdrawal of the draft EIS effectively terminated the approach of bundling more than one hundred hatchery programs across Puget Sound into a single analysis. Instead, ESA and NEPA analyses are being conducted for groups of HGMPs, generally at the watershed scale, as they are updated by the co-managers and submitted for

NMFS review and consideration. Due to changes in hatchery programs since the co-managers submitted their RMPs in 2004, and public comments received on the draft EIS, NMFS will replace the draft EIS with environmental reviews of Puget Sound hatchery programs that respond to the updated HGMP received from the co-managers, generally on a watershed-level scale. Under a watershed-scale approach, NMFS can analyze and disclose the effects of hatchery programs that are unique to each watershed and still disclose the cumulative effects of hatchery programs on the human environment. Information in the terminated EIS, along with public comments will be considered by NMFS in subsequent NEPA reviews of watershed-specific hatchery plans. For the proposed EWS hatchery actions evaluated in this opinion, NMFS completed NEPA scoping and concluded that the potential resource effects of the actions rose to a level of significance that necessitated completion of an EIS.

In March and April 2014, WDFW submitted updated versions of six EWS HGMPs, reduced from the original 17 HGMPs to reflect program consolidations or terminations and substantial changes and improvements. After reviewing the six revised plans, NMFS met with WDFW on May 9, 2014 to discuss effects of the HGMPs and required ESA and NEPA evaluation processes. NMFS followed up that meeting with a May 16, 2014 letter describing our general and specific concerns, and additional information needs pertaining to the updated plans. In response, on July 28, 2014, the co-managers provided new updated versions of five EWS HGMPs (Scott 2014a). The sixth plan submitted in April 2014 - the program proposed for Marblemount Hatchery - was retracted by WDFW. On November 21, 2014, an additional HGMP for the Soos Creek Hatchery EWS program was retracted. The April, 2014 HGMP describing proposed EWS hatchery actions in the Snohomish River watershed was revised and resubmitted on November 25, 2014 as two separate HGMPs – one describing EWS releases in the Skykomish River basin from Reiter Ponds and Wallace River Hatchery and the other describing EWS production in the Snoqualmie River basin from Tokul Creek Hatchery (Scott 2014b). On March 18, 2015, WDFW requested that NMFS review and consider the EWS hatchery programs described in Table 1 (Scott 2015) as their first priority and defer review of the HGMPs for Wallace/Reiter EWS and Tokul Creek EWS hatchery programs until later in 2015 (Scott 2015). However, following consideration of public comments on the EA for the programs described in Table 1, NMFS decided to prepare an EIS covering all five programs (Dungeness, Nooksack, Stillaguamish, Skykomish, and Snoqualmie). As a result, NMFS is reviewing all five programs simultaneously, but is preparing separate biological opinions and decision documents for the first three programs and the second two.

NMFS reviewed the information provided in the HGMPs for the Wallace/Reiter and Tokul Creek EWS hatchery programs, and determined that they included information sufficient[3] for the agency to complete its determination of whether the HGMPs addressed criteria specified in the ESA (4)d Rule Limit 6 for the Puget Sound Chinook Salmon ESU and in the 4(d) Rule for the Puget Sound Steelhead DPS [73 FR 55451 (September 25, 2008)] (Jones 2014a). 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 HGMPs.

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[3] "Sufficient" means that an HGMP meets the criteria listed at 50 CFR 223.203(b)(5)(i), which include (1) the purpose of the hatchery program is described in meaningful and measureable terms, (2) available scientific and commercial information and data are included, (3) the Proposed Action, including any research, monitoring, and evaluation, is clearly described both spatially and temporally, (4) application materials provide an analysis of effects on ESA-listed species, and (5) preliminary review suggests that the program has addressed criteria for issuance of ESA authorization such that public review of the application materials would be meaningful. However, it does not prejudge the outcome of NMFS' review to determine whether the program meets the standard for an exemption from the ESA's §9 prohibitions.

NMFS will consider the other Puget Sound HGMPs submitted by the co-managers since the time of Puget Sound Steelhead DPS listing for ESA and NEPA compliance separately from the proposed action reviewed in this opinion. NMFS's reviews will lead to determinations of whether the plans address criteria defined in the ESA (4)d Rule Limit 6 for the Puget Sound Chinook salmon ESU, the Hood Canal summer chum salmon ESU (where applicable) [see 65 FR 42422 (July 10, 2000), as amended 70 FR 37160 (June 28, 2005)], and in the 4(d) Rule for the Puget Sound Steelhead DPS [73 FR 55451 (September 25, 2008)], such that they are exempted from the take prohibition in Section 9.

The effects of take associated with implementation of Puget Sound region hatchery salmon and steelhead production on the Hood Canal Summer Chum salmon ESU were previously evaluated and authorized by NMFS through a separate ESA section 7 consultation process (NMFS 2002a). An Environmental Assessment and FONSI were completed as part of the 2002 NMFS summer chum salmon consultation (NMFS 2002b). Effects on this ESA-listed species associated with the two proposed EWS HGMPs will therefore not be discussed further in this biological opinion.

This biological opinion evaluates information provided in the Wallace/Reiter and Tokul Creek Hatchery EWS HGMPs (WDFW 2014a; 2014b). The evaluation of the HGMPs is also based on relevant scientific information available to NMFS, including analyses provided in the plans, and independent analyses by NMFS of the effects of the proposed hatchery actions.

1.3 Proposed Action

"Action" means all activities, of any kind, authorized, funded, or carried out, in whole or in part, by Federal agencies. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. NMFS has not identified any interrelated and interdependent actions for this analysis.

The Proposed Action is the National Marine Fisheries Service's (NMFS) determination under limit 6 of the ESA 4(d) rule for listed Puget Sound Chinook salmon and listed Puget Sound steelhead (50 CFR § 223.203(b)(6)) concerning two hatchery programs in the Snohomish/Skykomish and Snoqualmie river basins submitted for review by the Washington Department of Fish and Wildlife (WDFW), with the Tulalip Tribes as the *U.S.* v. *Washington* (1974) fish resource co-managers.

NMFS describes a hatchery program as the production of a group of fish for a distinct purpose, and that may have independent spawning, rearing, marking and release strategies (NMFS 2008c). The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg et al. 2004). In this specific case, NMFS was requested to review two HGMPs for EWS hatchery programs in Puget Sound (WDFW 2014a; 2014b) and determined them sufficient for formal consultation under the ESA (Jones 2014a). The two hatchery programs propose to release non-ESA listed EWS into the Skykomish and Snoqualmie river basins respectively. Both hatchery programs are currently operating, however, smolts from the Snoqualmie programs were released into landlocked lakes in 2014 and 2015 under the terms of a settlement agreement in Wild Fish Conservancy v. Anderson, (2:14-cv-00465-JLR, W.D. Wash).

As stated in the HGMPs, the primary purpose or reason for the hatchery programs is to help mitigate for reductions in fisheries caused by adverse impacts to natural-origin steelhead and their habitat resulting from past and on-going human developmental activities in the Snohomish River basin, and from climate change. The goal for the programs is to produce EWS for recreational and tribal fisheries (WDFW 2014a; 2014b). Both of the programs would implement steelhead population monitoring activities in freshwater areas that are important for verifying the performance of the hatchery programs and effect of the programs on ESA-listed natural-origin populations. The fishing seasons and regulations developed specifically to harvest these fish have previously been reviewed under the ESA and NMFS's authorization for 'take' from fisheries in the Snohomish River basin is part of a separate consultation (NMFS 2015a). The co-managers propose fishery management plans for Puget Sound and associated freshwater on either an annual or multi-year basis, and NMFS generally consults on these plans and addressed the take effects of the EWS recreational and commercial fisheries (and other salmon-directed fisheries in the action area) are addressed through a ESA section 7 consultation for the duration of the relevant plan. Most recently, NMFS issued a biological opinion for a 2015 Puget Sound harvest plan assembled by the co-managers (NMFS 2015a; PSTT and WDFW 2015). Harvest plans have remained relatively similar over the past several years and are expected to continue to do so.

1.3.1 Describing the Proposed Action

- Broodstock collection at WDFW's Wallace River, Reiter Ponds, and Tokul Creek hatchery facilities through operation of off-channel traps and weirs from mid-November to January 31. All trapping sites will remain open until at least mid-April to remove hatchery-origin fish returning to traps after January 31;
- Holding, identification, and spawning of adult fish at Wallace River, Reiter Ponds, and Tokul Creek hatchery facilities;
- Egg incubation at Wallace River and Tokul Creek hatchery facilities and fish rearing at Wallace River, Reiter Ponds, and Tokul Creek hatchery facilities;
- Release of up to: 27,600, 140,000, and 74,000 juvenile EWS from Wallace River Hatchery, Reiter Ponds, and Tokul Creek Hatchery, respectively;
- Monitoring and evaluation activities to assess the performance of the programs in meeting harvest objectives and in limiting adverse effects on ESA-listed fish.

1.3.1.1 Proposed hatchery broodstock collection

- Broodstock origin and number:
    - Wallace River Hatchery and Reiter Ponds: Hatchery broodstock are more than moderately diverged from the natural population and are not included in the Puget Sound Steelhead DPS. Up to 150 pairs or 340,000 green (unfertilized) eggs will be collected from hatchery-origin adults (distinguished by an adipose fin-clip) returning to Wallace River and Reiter Ponds. If the number of adults returning to Wallace River and Reiter Ponds hatchery facilities will not meet broodstock needs, eggs collected at Tokul Creek Hatchery may be transferred and used to meet egg take goals.
    - Tokul Creek Hatchery: Hatchery broodstock are more than moderately diverged from the natural population and are not included in the Puget Sound Steelhead DPS. Up to 50 pairs or 110,000 green eggs would be collected from hatchery-origin adults (distinguished by an

adipose fin-clip). If the number of adults returning to Tokul Creek Hatchery will not meet broodstock needs, eggs collected at Wallace River Hatchery and Reiter Ponds may be transferred and used to meet egg take goals.

- Proportion of natural-origin fish in the broodstock (pNOB): None, no natural-origin fish will be used by either of the hatchery programs.

- Broodstock selection: Protocols common to both programs: Hatchery-origin steelhead would be selected based on return timing. Only early-returning fish would be used for spawning. To minimize the temporal spawn timing overlap with natural-origin steelhead, no steelhead would be spawned after January 31.

- Method and location for collecting broodstock:
    - Wallace River Hatchery and Reiter Ponds: Broodstock will be collected from hatchery-origin adults (distinguished by an adipose fin-clip) captured at the Wallace River Hatchery and Reiter Ponds traps (WDFW 2014a, and following). If the number of adults returning to Wallace River and Reiter Ponds hatchery facilities will not meet broodstock needs, eggs collected at Tokul Creek Hatchery may be transferred and used to meet egg take goals.
    - Tokul Creek Hatchery: Broodstock will be collected from hatchery-origin adults (distinguished by an adipose fin-clip) returning to the hatchery trap (WDFW 2014b, and following). If the number of adults returning to Tokul Creek Hatchery will not meet broodstock needs, eggs collected at Wallace River Hatchery and Reiter Ponds may be transferred and used to meet egg take goals.

- Duration of collection:
    - Wallace River Hatchery and Reiter Ponds: Broodstock will be collected from mid-November through January 31 (WDFW 2014a, and following). The trap would remain open through mid-April to capture and prevent EWS from escaping to spawn naturally. Any marked hatchery-origin steelhead volunteering to the trap after January 31 would be removed from the system.
    - Tokul Creek Hatchery: Broodstock would be collected from the third week in November through January 31 (WDFW 2014b, and following). The trap would remain open through mid-April to capture and prevent EWS from escaping to spawn naturally. Any marked hatchery-origin steelhead volunteering to the trap after January 31 would be removed from the system.

- Encounters, sorting and handling, with ESA listed fish, adults and juveniles: Any natural-origin steelhead or bull trout encountered at the hatchery traps would be immediately returned back to the stream or river.

1.3.1.2 Proposed mating protocols

- All steelhead produced by the hatchery programs are not part of the listed Puget Sound Steelhead DPS, and mating protocols applied are therefore not of concern regarding effects on listed fish or the adequacy of the programs in maintaining hatchery population genetic diversity.

1.3.1.3 Proposed protocols for each release group

- Life stage: For Wallace River and Reiter Ponds hatchery programs, steelhead yearlings at 6 fish per pound (fpp) and 198 mm fork length (fl) (WDFW 2014a). For the Tokul Creek hatchery program, steelhead yearlings at 5 fpp and 210 mm fl (WDFW 2014b).

- Acclimation (Y/N): Yes, length of acclimation would vary by program.
  - Wallace River Hatchery: Juveniles are reared on a mix of Wallace River and May Creek water from August through January, and on Wallace River water from January through release in May (WDFW 2014a).
  - Reiter Ponds: Juveniles would be transferred as parr at 25 fpp from the Wallace River Hatchery to Reiter Ponds where they would be reared on a mix of surface water from Austin and Hogarty creeks from October through their release in May (WDFW 2014a).
  - Tokul Creek Hatchery: Juveniles would be reared using Tokul Creek water (WDFW 2014b).

- Volitional release (Y/N):
  - Wallace River Hatchery: Yes. Screens will be removed no earlier than April 15. Screens will remain open for up to three weeks (unless all fish out-migrate). Fish that do not volitionally out-migrate will be placed into landlocked lakes.
  - Reiter Ponds and Tokul Creek hatchery programs: Yes. Screens will be removed no earlier than April 15. Screens will remain open for up to one month (unless all fish out-migrate). Fish that do not volitionally out-migrate will be placed into landlocked lakes.

- External mark(s): All programs: All juveniles released would be marked with an adipose fin clip for easy external identification.
- Internal marks/tags: All programs: No juveniles would be marked with internal marks or tags.
- Maximum number released: Maximum annual smolt release numbers would be: Wallace River Hatchery: 27,600, Reiter Ponds: 140,000, Tokul Creek Hatchery: 74,000.

- Release location(s):
  - Wallace River Hatchery: River Mile (RM) 4.0 on Wallace River, tributary to the Skykomish River at RM 35.7 (continues as the Snohomish River at RM 20.5).
  - Reiter Ponds: fish would be released into the Skykomish River mainstem at RM 46.0 (continues as the Snohomish River at RM 20.5).
  - Tokul Creek Hatchery: RM 0.5 on Tokul Creek, tributary to the Snoqualmie River at RM 39.6, the Snoqualmie River enters the mainstem Snohomish River at RM 20.5.

1.3.1.4 Proposed research, monitoring, and evaluation

- Adult sampling, purpose, methodology, location, and the number of ESA-listed fish handled: The two HGMPs include monitoring and evaluation (M&E) actions designed to verify the performance of the hatchery programs in meeting their fisheries harvest augmentation and listed fish risk minimization objectives. Specific M&E actions for the two HGMPs affecting steelhead are described in section 1.10 and section 11.0 of each HGMP. Although monitoring the harvest benefits of the programs to fisheries from production of returning adult hatchery-origin fish is an important objective (e.g., smolt to adult survival rate and fishery contribution level monitoring), all of the EWS hatchery programs include extensive monitoring, evaluation, and adaptive management measures, designed to monitor and reduce incidental effects on natural-origin fish populations. An adult steelhead monitoring program (spawning ground surveys) will be conducted annually to document abundance and spatial structure of steelhead, both natural-origin and hatchery-origin, escaping to natural spawning areas and the hatcheries in the action area basins (WDFW 2014a; 2014b). In addition, within the Snoqualmie River system adult genetic samples will be collected annually and analyzed to estimate the number of natural-origin hybrid and hatchery-ancestry fish (Anderson et al. 2014, and following). Within the Pilchuck River system, adult genetic sampling will be conducted every three years.

- Juvenile sampling, purpose, methodology, location, and the number of ESA-listed fish handled: Specific M&E actions for the two HGMPs affecting juvenile salmonids are described in section 1.10 and section 11.0 of each HGMP (WDFW 2014a; 2014b). Although the results of these juvenile fish M&E actions will be used to guide implementation of the proposed steelhead hatchery programs, the effects of juvenile salmonid sampling occurring outside of the hatchery locations have been previously authorized through separate ESA consultation processes (NMFS 2009, NMFS 2015b). The co-managers will continue to monitor interactions between juvenile hatchery- and natural-origin salmonids in freshwater and marine areas within the region to evaluate and manage the programs. Continued juvenile out-migrant trapping by the Tulalip Tribes is also planned, using rotary screw traps in the Skykomish and Snoqualmie rivers, to provide important information on the co-occurrence, out-migration timing, relative abundances, and relative sizes of hatchery-origin fish, ESA-listed natural-origin Chinook salmon and steelhead, and non-ESA-listed natural-origin coho, chum, and pink salmon. Smolt traps positioned downstream from single or multiple natural steelhead populations will obtain a mixed sample at trapping sites (Anderson et al. 2014, and following). In cases where there are multiple natural populations of steelhead (e.g., Skykomish River trap site), monitoring for introgressive hybridization at the population scale will rely upon genetic stock identification; however, current genetic tools may not permit assignments at this resolution. In these cases, ongoing efforts to improve the Puget Sound genetic baseline by adding more single nucleotide polymorphism samples to the database will improve upon genetic stock identification; if this effort is ineffective, then monitoring for introgressive hybridization will be conducted at the watershed scale rather than at the population scale. WDFW has developed a ten-year monitoring plan to sample up to 100 unmarked steelhead annually from the Skykomish and Snoqualmie smolt traps. Results from the juvenile out-migrant trapping programs described in the HGMPs (Section 11) will be reported as required in the separate NMFS authorizations for the programs (NMFS 2009; NMFS 2015b).

1.3.1.5 Proposed operation, maintenance, and construction of hatchery facilities

- Water source(s) and quantity for hatchery facilities: Three hatchery facilities are currently used by the proposed two EWS hatchery programs. Two of the facilities use surface water exclusively (Wallace River Hatchery and Reiter Ponds) and one facility (Tokul Creek Hatchery) use a combination of groundwater and surface water.
  - Wallace River Hatchery Program: The Wallace River Hatchery facility uses surface water exclusively, withdrawn through water intakes on the Wallace River and May Creek, an adjacent tributary. Wallace River Hatchery may withdraw up to 40 cfs of surface water from

the Wallace River and up to 14 cfs from May Creek. Surface water withdrawal rights are formalized through Washington State water right permits S1-00108C (16 cfs) and S1-00109C (24 cfs) for the Wallace River and permits S1-05617 (10 cfs) and S1-23172C (4 cfs) for May Creek. Current pumping capacity from the Wallace River and May Creek are 26.7 cfs and 1.8 cfs, respectively. Monitoring and measurement of water usage are reported in monthly National Pollutant Discharge Elimination System (NPDES) reports to the Washington State Department of Ecology (WDOE).

- Reiter Ponds Hatchery Program: The Reiter Ponds facility uses surface water diverted from Austin and Hogarty creeks. The Reiter Ponds program can divert up to 10 cfs from Austin and Hogarty creeks. Surface water withdrawal rights are formalized through Washington State water right permits S1-00667C (10 cfs) and S1-00313C (10 cfs) for Austin and Hogarty creeks, respectively. Monitoring and measurement of water usage are reported in monthly NPDES reports to WDOE.

- Tokul Creek Hatchery Program: The Tokul Creek Hatchery facility uses mainly surface water with a backup source of groundwater pumped from a single well. Surface water is withdrawn from an unnamed spring and Tokul Creek. Water rights are formalized through Washington State trust water right permits #S1-08944C (unnamed spring; 6 cfs), S1-03416C (Tokul Creek; 3 cfs), and S1-21399C (Tokul Creek; 9 cfs). Up to 0.9 cfs of well water is available for emergency use. Monitoring and measurement of water usage are reported in monthly NPDES reports to WDOE.

- Water diversions meet NMFS screen criteria (Y/N):
  - Wallace River Hatchery: No. WDFW has notified NMFS of its plans to modify screening at Wallace River Hatchery to comply with NMFS screening requirements to protect natural-origin fish from entrainment and impingement that may lead to injury and mortality (WDFW 2014a). Although the hatchery water intake screens on the Wallace River and in May Creek are in compliance with state and federal guidelines (NMFS 1995, 1996), they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). Intake screens on both tributaries are scheduled by WDFW for rebuild in the 2019 -2020 funding biennium to bring the screens into compliance with those criteria.

  - Reiter Ponds Facility: No. The two water intake structures that supply water to the Reiter Ponds facility are in compliance with state and federal guidelines (NMFS 1995, 1996), however, they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). A natural barrier to anadromous fish passage exists just upstream of the water intake structure on Austin Creek limiting the effects to ESA-listed anadromous fish (i.e., there are few fish produced upstream of the screens). The Hogarty Creek intake structure is not likely a risk factor as there are no known ESA-listed fish present in this small tributary. Based on low or no ESA listed fish use upstream of the screens, there are no plans to improve intake structures.

  - Tokul Creek Hatchery: No. Screening for the surface water intake structure that supplies water to the Tokul Creek Hatchery is in compliance with state and federal guidelines (NMFS 1995, 1996), however, the structure does not meet the latest NMFS Anadromous Salmonid

Passage Facility Design Criteria (NMFS 2011c). The State of Washington has allocated $3.7 million to renovate the Tokul Creek intake to meet the latest screening and fish passage criteria, and to restore a fish ladder in the dam to allow unimpeded fish passage. NMFS has authorized in-water activities associated with WDFW's proposed replacement of the screens, and renovation of the intake structure and ladder, through a separate consultation (NMFS 2016a). NMFS concluded that effects of these in-water construction activities are not likely to jeopardize ESA-listed species or adversely affect their critical habitat. With this authorization, WDFW will replace the Tokul Creek screens so that they are in compliance with NMFS (2011c) criteria by fall, 2016.

- Permanent or temporary barriers to juvenile or adult fish passage (Y/N):
  - Wallace River Hatchery: Yes. The hatchery weir on May Creek, operated seasonally from June through mid-March, to collect broodstock, would be a temporary barrier to upstream and downstream fish passage.

  - Reiter Ponds: No. The intake screens at the Reiter Ponds facility are in compliance with state and federal guidelines (NMFS 1995; 1996), but do not meet the latest anadromous salmonid passage facility design criteria (NMFS 2011c). Because few, if any, ESA-listed fish use the area upstream of the screens, there are no plans to improve intake structures.

  - Tokul Creek Hatchery: Yes. The intake screens and water intake dam at the Tokul Creek Hatchery do not meet the current anadromous salmonid passage facility design criteria (NMFS 2011c). Upstream anadromous fish access in Tokul Creek is currently limited to the lowest 0.3 miles below the water intake structure and dam. The area of Tokul Creek upstream of the hatchery water intake structure and dam represents about 0.55 miles or 2 acres of potential habitat for Chinook salmon (NMFS 2016a). The State of Washington has allocated $3.7 million to renovate the Tokul Creek intake to meet current screening and fish passage criteria, and to renovate the fish ladder to allow unimpeded fish passage. NMFS has authorized in-water activities associated with replacement of the screens, and renovation of the intake structure and ladder, through a separate consultation (NMFS 2016a). NMFS concluded that effects of these inwater construction activities are not likely to adversely affect ESA-listed species. With this authorization, WDFW will renovate the ladder for the Tokul Creek water intake dam to provided unimpeded passage to migrating fish, incompliance with NMFS (2011c) criteria by fall, 2016.

- Instream structures (Y/N):
  - Wallace River Hatchery: Yes. A hatchery weir is operated seasonally from June through mid-March in May Creek to collect steelhead broodstock.

  - Reiter Ponds: Yes. The spring-fed creek on which Reiter Ponds is located is not used by natural-origin salmon or steelhead and hatchery instream structures would therefore have no effect on ESA-listed fish.

  - Tokul Creek Hatchery: Yes. The water intake structure and dam used to supply water for the hatchery is located in Tokul Creek. A weir and trap are also operated seasonally in Tokul Creek to collect steelhead broodstock.

- Streambank armoring or alterations (Y/N): No. There is no streambank armoring or alterations included as part of the proposed actions considered in this opinion.

- Pollutant discharge and location(s):
  - All hatchery facilities used by the Snohomish River basin EWS hatchery programs are operated in compliance with NPDES permits issued by WDOE. As authorized under NPDES Permit # WAG 13-3006 all hatchery effluent at Wallace River Hatchery is passed through a pollution abatement pond to settle out any uneaten food and fish waste before being discharged into receiving waters (WDFW 2014a). The Reiter Ponds facility operates under NPDES Permit # WAG 13-3005. The Tokul Creek Hatchery operates under NPDES Permit # WAG 13-3004.

1.3.2 Interrelated and Interdependent Actions

“Interrelated actions” are those that are part of a larger action and depend on the larger action for their justification. “Interdependent actions” are those that have no independent utility apart from the action under consideration. In determining whether there are interrelated and interdependent actions that should be considered in this consultation, NMFS has considered whether fisheries impacting steelhead produced by the Snohomish/Skykomish River Winter Steelhead and Tokul Creek Winter Steelhead hatchery programs are interrelated or interdependent actions that are subject to analysis in this opinion.

Recreational fisheries and tribal commercial and ceremonial and subsistence fisheries for steelhead produced by the proposed hatchery programs incidentally take ESA-listed salmon and steelhead. These fisheries are managed by WDFW and the Tulalip Tribes, and occur within the Snohomish River basin. Outside of this area, there are no directed fisheries for EWS, and those salmon-directed fisheries would occur regardless of whether the proposed action continues and are therefore not interrelated or interdependent with the proposed action. Therefore, only those fisheries for EWS in the Snohomish River basin are interrelated and interdependent actions. The 2015-16 fisheries were evaluated and authorized through a separate NMFS ESA consultation (NMFS 2015a). They were determined not likely to jeopardize the continued existence of the Puget Sound Steelhead DPS, the Puget Sound Chinook Salmon ESU, or the Hood Canal summer chum salmon ESU or adversely modify designated critical habitat for these listed species (NMFS 2015a). A new fishery management plan for 2016-17 is currently under development and is expected to be submitted for Section 7 consultation in April 2016. Past effects of these fisheries are described in the environmental baseline section; future effects are described in the discussion of effects of the action.

Construction of fish passage facilities and repair of an existing dam at Tokul Creek may also be considered interrelated and interdependent with the operation of the EWS program at that facility. The proposed construction has been analyzed in a separate biological opinion issued concurrently with this opinion. The effects of that construction are discussed as part of the effects analysis in this opinion.

1.4 Action Area

The "action area" means all areas to be affected directly or indirectly by the Proposed Action, in which the effects of the action can be meaningfully detected measured, and evaluated (50 CFR 402.02). The action area resulting from this analysis includes the places within or immediately adjacent to the Snohomish River basin where EWS originating from the proposed hatchery programs would migrate, potentially stray, and spawn naturally (Figure 1).

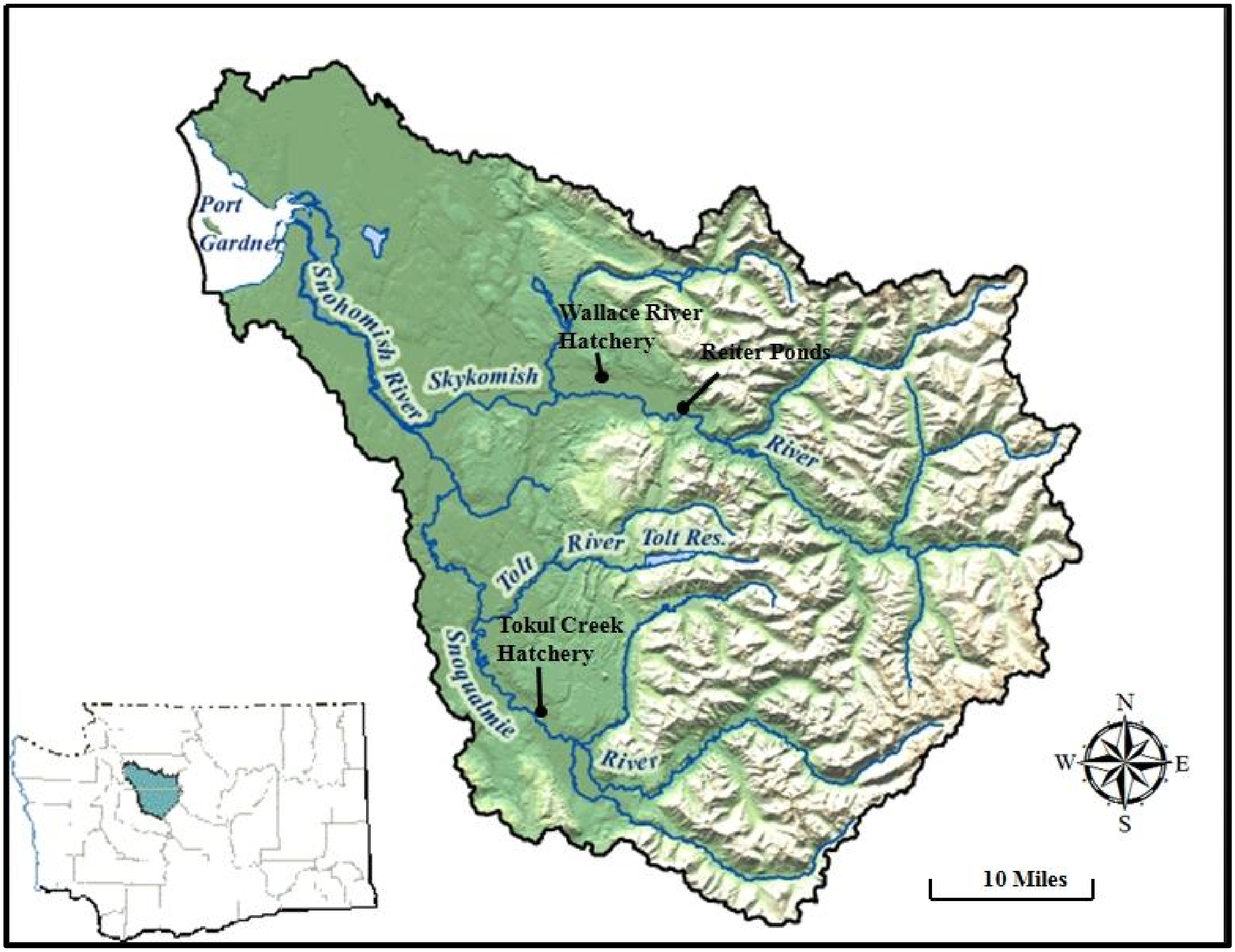

Figure 1. Action area for the proposed continued operation of Snohomish River basin EWS hatcheries. The map includes locations of all WDFW EWS hatchery facilities in the basin. Source: Modified from WDFW Score data, accessed July 17, 2015- https://fortress.wa.gov/dfw/score/score/maps/map_details.jsp?geocode=wria&geoarea=WRIA07_Snohomish.

The following facilities would be used by the proposed hatchery programs:

- Wallace River Hatchery (RM 4.0 on the Wallace River [at its confluence with May Creek], entering the Skykomish River at RM 35.7).
- Reiter Ponds facility (RM 46 on Skykomish River)

- Tokul Creek Hatchery (RM 0.5 on Tokul Creek, tributary to the Snoqualmie River at RM 39.6, the Snoqualmie River enters the mainstem Snohomish River at RM 20.5)

In addition, monitoring and evaluation activities would be implemented at the hatcheries and in their immediate vicinities, in the Wallace River, in the Skykomish River and its other tributaries, in the Snoqualmie River and its tributaries, and in the Snohomish River, extending from the mouths of each watershed upstream to the limits of anadromous fish access.

NMFS considered whether the marine areas of Puget Sound outside of the estuarine environment in immediate proximity to the Snohomish River and the ocean should be included in the action area. The potential concern is a relationship between hatchery production and density dependent interactions affecting steelhead growth and survival. NMFS however has determined that, based on best available science, it is not possible to establish any meaningful causal connection between hatchery production on the scale anticipated in the Proposed Action and any such effects.

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. Section 7(a)(2) of the ESA requires Federal agencies to consult with the USFWS, NMFS, or both, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Section 7(b)(3) requires that at the conclusion of consultation, the Service provide an opinion stating how the agencies' actions will affect listed species and their critical habitat. If incidental take is expected, section 7(b)(4) requires the consulting agency to provide an ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures to minimize such impacts.

2.1 Approach to the Analysis

Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. The jeopardy analysis considers both survival and recovery of the species. The adverse modification analysis considers the impacts on the conservation value of designated critical habitat.

"To jeopardize the continued existence of a listed species" means to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the species in the wild by reducing the reproduction, numbers, or distribution of that species or reduce the value of designated or proposed critical habitat (50 CFR 402.02).

This biological opinion relies on the definition of "destruction or adverse modification", which is "a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214, February 11, 2016). We will use the following approach to determine whether the Proposed Action is likely to jeopardize a listed species, or destroy or adversely modify critical habitat:

- First, the current status of listed species and designated critical habitat, relative to the conditions needed for recovery, are described in Section 2.2.
- Next, the environmental baseline in the action area is described in Section 2.3.
- In Section 2.4, we consider how the Proposed Action would affect the species' abundance, productivity, spatial structure, and diversity and the Proposed Action's effects on critical habitat features.
- Section 2.5 describes the cumulative effects in the action area, as defined in our implementing regulations at 50 CFR 402.02
- In Section 2.6, the status of the species and critical habitat (Section 2.2), the environmental baseline (Section 2.3), the effects of the Proposed Action (Section 2.4), and cumulative effects (Section 2.5) are integrated and synthesized to assess the effects of the Proposed Action on the survival and recovery of the species in the wild and on the conservation value of designated or proposed critical habitat.
- Our conclusions regarding jeopardy and the destruction or adverse modification of critical habitat are presented in Section 2.7.
- If our conclusion in Section 2.7 is that the Proposed Action is likely to jeopardize the continued existence of a listed species, or destroy or adversely modify designated critical habitat, we must identify a "Reasonable and Prudent Alternative (RPA) to the action in Section 2.8.

ESA-listed anadromous salmonid species in the action area (see Section 1.4) are described in Table 2. The ESA-listed threatened Coastal-Puget Sound bull trout (*Salvelinus confluentus*) DPS is administered by the USFWS. In a February 24, 2016 letter, NMFS requested informal consultation with USFWS regarding effects on listed species under USFWS regulatory purview (Jones 2016). On March 29, 2016, USFWS responded with its concurrence that NMFS's proposed determination under ESA 4(d) rule, limit 6 for the two proposed hatchery steelhead programs was not likely to adversely affect bull trout or other USFWS listed species, and that formal consultation regarding the NMFS action was not required (USFWS 2016). Research and monitoring specifically directed at bull trout in the action area are considered separate actions, which would be the subject of separate section 7 consultations. These actions will not be considered as part of the proposed steelhead hatchery-related actions considered in this opinion.

In addition, NMFS has further determined that the proposed action would have no effect on other ESA-listed species under NMFS regulatory purview, including Pacific eulachon, southern resident killer whales, or rockfish. This determination is based on the likely absence of any adverse effects on any of these species, considering the very small proportion of the total numbers of fish present in the Salish Sea and Pacific Ocean areas where these ESA-listed species occur that would be represented by hatchery-origin program steelhead produced by the two proposed programs (see Subsection 2.4.2.4). Based on these no effect determinations, these species will not be addressed further in this opinion.

2.2 Range-wide Status of the Species and Critical Habitat

This opinion examines the status of each species and designated critical habitat that would be 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 2. Status of the species is the level of risk that the listed species face based on parameters considered in documents such as recovery plans, status reviews, and ESA listing determinations. The species status section helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the status and conservation value of critical habitat in the action area and discusses the current function of the essential physical and biological features that help to form that conservation value.

Table 2. 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.

Species	Listing Status	Critical Habitat	Protective Regulation
Chinook salmon (*Oncorhynchus tshawytscha*)			
Puget Sound	Threatened, March 24, 1999; 64 FR 14508	Sept 2, 2005; 70 FR 52630	June 28, 2005; 70 FR 37160
Steelhead (*Oncorhynchus mykiss*)			
Puget Sound	Threatened, May 11, 2007; 72 FR 26722	February 24, 2016; 81 FR 9252	September 25, 2008; 73 FR 55451

"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 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 ESA if it represents an evolutionarily significant unit (ESU) of the biological species. The group 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. Puget Sound steelhead constitute a DPS of the taxonomic species *O. mykiss*, and as such is considered a "species" under the ESA. Puget Sound Chinook salmon constitute an ESU (salmon DPS) of the taxonomic species *Oncorhynchus tshawytscha*, and as such is considered a "species" under the ESA.

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 Steelhead DPS

2.2.1.1 Life History and Status

Oncorhynchus mykiss has an anadromous form, commonly referred to as steelhead, of which Puget Sound steelhead are a DPS. Steelhead 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. They depend on freshwater areas for spawning and rearing, and marine environments for growth and maturation. 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 often referred to as kelts. Averaging across all West Coast steelhead populations, eight percent 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 steelhead enter freshwater at an early stage of maturation beginning in the late spring, migrate to headwater areas and hold until spawning in the winter and following spring. Winter steelhead typically enter freshwater at an advanced stage of maturation later in the year and spawn in the winter and spring (Busby et al. 1996; Hard et al. 2007).

Puget Sound steelhead are dominated by the winter life history type and typically migrate as smolts to sea at age two, with smaller numbers of fish emigrating to the ocean at one to three years of age. Seaward emigration commonly 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 rather than migrating nearer to the coast as do salmon. During fall and winter, juveniles move southward and eastward (Hartt and Dell 1986). Adults from extant populations of winter steelhead return from December to May, and peak spawning occurs in 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 run 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 Proposed Action evaluates hatchery programs that are likely to adversely affect both summer-and winter-run natural populations in the Snohomish River basin. The Puget Sound steelhead DPS was listed as threatened on May 11, 2007 (72 FR 26722; Table 2).

Recovery planning for Puget Sound steelhead has produced a great deal of information. As part of the recovery planning process, NMFS convened the Puget Sound Steelhead Technical Recovery Team (PSSTRT) to identify historical populations and develop viability criteria for the recovery plan. The final technical team report describing historical population structure was released in March 2015 (Myers et al. 2015). NMFS also released the final PSSTRT report describing viability criteria for Puget Sound steelhead in May 2015 (Hard et al. 2015).

No new estimates of productivity, spatial structure and diversity for Puget Sound steelhead have been made available since the 2007 review, when the BRT concluded that low and declining abundance and low and declining productivity were substantial risk factors for the DPS/species (Hard et al. 2007). Loss of diversity and spatial structure were judged to be "moderate" risk factors due to reduced complexity and diminishing connectivity among populations, influences of non-native hatchery programs and the low numbers of summer steelhead populations in the Puget Sound DPS (Hard et al. 2007). The 2011 status review (Ford et al. 2011) determined that the DPS should remain in threatened status. The PSSTRT recently concluded that the DPS was at very low viability, as were all three of its MPGs, and many of the "Demographically Independent Populations" (DIPs) (Hard et al. 2015; Table 3). In spring 2016, the Northwest Fishery Science Center completed an updated five-year review of the status of the DPS. This status review update concludes that biological risks faced by the DPS have not substantively changed since listing in 2007, and the viability status of the DPS and component MPGs continued to be very poor (NWFSC 2015).

The PSSTRT has also completed a set of population viability analyses (PVAs) for the natural populations and the major population groups (MPGs) within the DPS. The roles of individual populations in recovery of the DPS have not yet been defined. However, as part of the PSSTRT's analysis, they developed interim abundance-based guidelines for various potential recovery scenarios stating that in order for the DPS to achieve full recovery, steelhead natural populations in the DPS need to be robust enough to withstand natural environmental variation and even some catastrophic events, and should be resilient enough to support harvest and habitat loss due to human population growth (Hard et al. 2015).

Spatial Structure and Diversity. The Puget Sound steelhead DPS includes all naturally spawned anadromous winter-run and summer-run steelhead populations in streams 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 2). Also included as part of the ESA-listed DPS are six hatchery-origin stocks derived from local natural steelhead populations and produced for conservation purposes, including fish from the Green River Natural Program; White River Winter Steelhead Supplementation Program; Hood Canal Steelhead Supplementation Off-station Projects in the Dewatto, Skokomish, and Duckabush Rivers; and the Lower Elwha Fish Hatchery Wild Steelhead Recovery Program (FR 79 20802, April 14, 2014). Non-anadromous ''resident'' *O. mykiss* occur within the range of Puget Sound steelhead but are not part of the DPS due to marked differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007). Puget Sound steelhead populations are aggregated into three extant MPGs containing a total of 32 DIPs based on genetic, environmental, and life history characteristics (Myers et al. 2015) (Table 3). DIPs can include summer steelhead only, winter steelhead only, or a combination of summer and winter run timing (i.e., summer/winter).

Abundance and Productivity. The 2007 BRT considered the major risk factors facing Puget Sound steelhead to be: widespread declines in abundance and productivity for most natural steelhead populations in the DPS, including those in the Skagit and Snohomish rivers (previously considered to be strongholds); the low abundance of several summer-run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca (Hard et al. 2007).

The 2015 status review (NWFSC 2015) concluded that the most recent data available indicate some minor increases in spawner abundance and/or improving productivity over the last two to three years for Puget Sound steelhead; however, most of these improvements are viewed as small and abundance and productivity throughout the DPS remain at levels of concern. The recent increases in abundance observed in a few populations are encouraging, however they are generally within the range of variability observed in the past several years and overall trends in abundance of natural-origin spawners remain predominately negative (NWFSC 2015). Changes in hatchery production for both summer-run and winter-run hatchery steelhead, in particular reductions in the number of EWS and ESS hatchery programs and number of hatchery fish released, as well as reduced harvest have reduced adverse effects on natural populations in recent years. In general, the biological status of the Puget Sound Steelhead DPS has not substantively changed since the listing in 2007, or since the 2011 status review (NWFSC 2015).

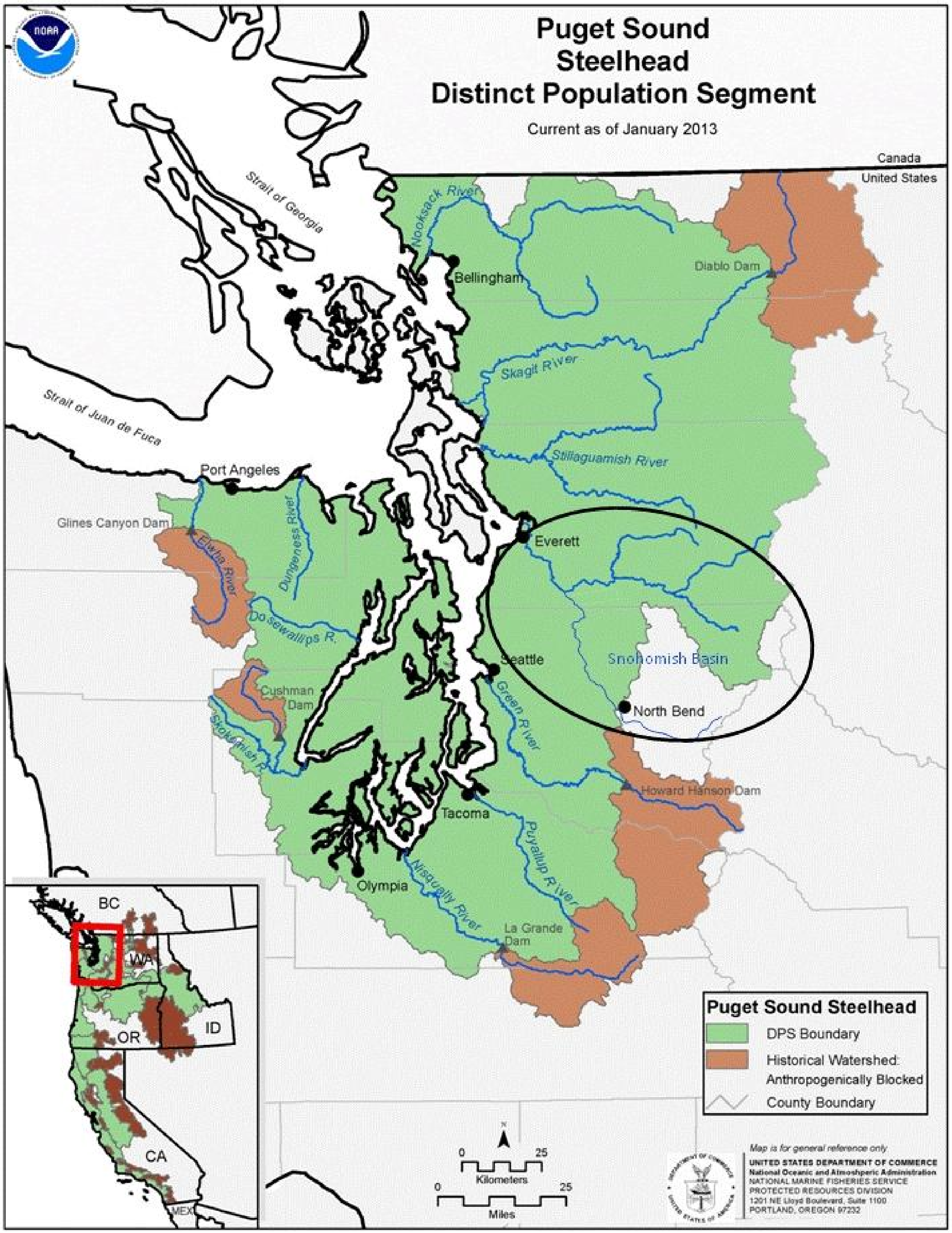

Figure 2. Location of the Snohomish River steelhead populations in the Puget Sound Steelhead DPS (generalized location indicated by black oval).

Table 3. Puget Sound steelhead populations and extinction risks (Hard et al. 2015).

Geographic Region (MPGs)	**Population (Run Time)**	**Extinction Risk (probability of decline to an established quasi-extinction threshold (QET) for each population)**	**Quasi-extinction threshold (number of fish)**
Northern Cascades	Drayton Harbor Tributaries (winter)	Unable to calculate	
	SF Nooksack River (summer)	Unable to calculate	
	Nooksack River (winter)	Unable to calculate	
	Samish River/Bellingham Bay (winter)	Low—about 30% within 100 years	31
	Skagit River (summer/winter)	Low—about 10% within 100 years.	157
	Baker River (summer/winter)	Unable to calculate	
	Sauk River (summer/winter)	Unable to calculate	
	Snohomish/Skykomish River (winter)	Low—about 40% within 100 years	73
	Stillaguamish River (winter)	High—about 90% within 25 years	67
	Deer Creek (summer)	Unable to calculate	
	Canyon Creek (summer)	Unable to calculate	
	Tolt River (summer)	High—about 80% within 100 years	25
	NF Skykomish River (summer)	Unable to calculate	
	Snoqualmie (winter)	High---about 70% within 100 years	58
	Nookachamps (winter)	Unable to calculate	--
	Pilchuck (winter)	Low---about 40% within 100 years	34
Central and Southern Cascades	North L. Washington/L. Sammamish (winter)	Unable to calculate	
	Cedar River (summer/winter)	High---about 90% within the next few years	36
	Green River (winter)	Moderately High—about 50% within 100 years	69
	Nisqually River (winter)	High—about 90% within 25 years	55
	Puyallup/Carbon River (winter)	High—about 90% within 25-30 years	
	White River (winter)	Low—about 40% within 100 years	64
	South Sound Tributaries (winter)	Unable to calculate percentage	--
	East Kitsap (winter)	Unable to calculate	
Hood Canal and Strait of Juan de Fuca	Elwha River (summer[4]/winter)	High— about 90% currently	41
	Dungeness River (summer/winter)	High—about 90% within 20 years	30
	South Hood Canal (winter)	High---about 90% within 20 years	30
	West Hood Canal (winter)	Low—about 20% within 100 years	32
	East Hood Canal (winter)	Low—about 40% within 100 years	27
	Skokomish River (winter)	High—about 70% within 100 years	50
	Sequim/Discovery Bay Independent Tributaries (winter)	High—about 90% within 100 years (Snow Creek)	25 (Snow Creek)
	Strait of Juan de Fuca Independent Tributaries (winter)	High—about 90% within 60 years (Morse & McDonald creeks)	26 (Morse & McDonald Ck)

Limiting factors. In its status review and listing documents for the Puget Sound Steelhead DPS (e.g., Ford et al. 2011; 76 FR 1392; 71 FR 15666), NMFS noted that the factors for decline for the DPS also persist as limiting factors:

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[4] Native summer-run in the Elwha River basin may no longer be present. Further work is needed to distinguish whether existing feral summer-run steelhead are derived from introduced Skamania Hatchery (Columbia River) summer run.

- In addition to being a factor that contributed to the present decline of Puget Sound steelhead natural populations, the principal factor limiting the viability of the Puget Sound steelhead DPS is the continued destruction and modification of steelhead habitat.
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years.
- Threats to diversity from non-local hatchery steelhead stocks, EWS and ESS.
- Declining diversity in the DPS, including the uncertain but weak status of summer-run fish in the DPS.
- A reduction in spatial structure for steelhead in the DPS. Large numbers of barriers, such as impassable culverts, together with declines in natural abundance, greatly reduce opportunities for adfluvial movement and migration between steelhead groups within watersheds.
- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris.
- Increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows in the lower reaches of many rivers and their tributaries in Puget Sound where urban development has occurred, have resulted in gravel scour, bank erosion, and sediment deposition.
- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, have increased the likelihood of gravel scour and dislocation of rearing juveniles.

Northern Cascades MPG: The Northern Cascades MPG has 16 DIPs including eight summer or summer/winter, and eight winter DIPs (Figure 2; Table 4). Differences in bedrock erodability throughout the Northern Cascades MPG create cascades and falls that may serve as isolating mechanisms for summer-and winter-run populations. This geology is likely responsible for the relatively large number of summer-run populations (Myers et al. 2015) since returning summer steelhead tend to migrate to headwater areas in the spring and early-summer when flows are higher. Eight of the 10 DIPs in the DPS with extant summer run-timing or summer components are in this MPG. The Northern Cascade MPG accounts for 75 percent of the steelhead abundance in the DPS (NWFSC 2015). Although information on the DIPs within the Northern Cascades MPG is extremely limited, abundance varies greatly among the populations (Table 4) with the Skagit and Snohomish natural populations comprising the majority of steelhead in the MPG. Through the most recent five year species status review, abundance trends from 1999 through 2014 for three DIPs within the MPG were evaluated (NWFSC 2015). Two of the DIPs had negative long-term trends and one had a positive long-term trend (Samish). Between the two most recent five-year periods (2004-2009 and 2010-2014), the geometric mean of estimated abundance for eight DIPs evaluated increased by an average of 3% in the North Cascades MPG (NWFSC 2015). Risk assessment by the PSSTRT indicated three populations are at high risk of extinction and four are at low risk (Table 3) with the Snohomish populations equally divided. However, more natural populations are at lower risk in this MPG than in the other MPGs in the DPS. In summary, the North Cascades MPG is a stronghold of the DPS in terms of life history diversity, abundance, and relatively lower extinction risk.

Table 4. Naturally spawning steelhead abundances and trends for DIPs within the North Cascades MPG for which information is available. Populations within the action area are bolded. Note WR=winter-run, SUR=summer run, and SWR=summer/winter run population.

Population (Run Timing)	2005-2009 Geometric Mean Escapement (Spawners)[1]	2010-2014 Geometric Mean Escapement (Spawners)[1]	Percent Change[1]
Nooksack R WR	**NA**	**1,834**	**NA**
Pilchuck R WR	597	614	3%
Samish R WR	534	846	58%
Skagit R SWR[2]	4,767	5,123	7%
Snohomish/Skykomish WR	3,084[3]	930	-70%
Snoqualmie R. WR	1,249	680	-46%
Stillaguamish R. WR[4]	327	392	20%
Tolt River SUR	73	105	44%

1 Source: NWFSC 2015

2 Skagit data includes four DIPs: Skagit, Nookachamps, Baker, and Sauk.

3 Does not include return years 2007-2009, which were among the lowest abundance for Snohomish Basin populations.

4 Only includes the estimated number of naturally spawning steelhead in the North Fork Stillaguamish River index segments.

Snohomish Basin Natural Populations

The Snohomish Basin includes five steelhead DIPs: Snohomish/Skykomish winter-run; Pilchuck winter-run; Snoqualmie winter-run; Tolt summer-run; and North Fork Skykomish summer-run (Myers et al. 2015). The DPS viability criteria developed by NMFS (Hard et al. 2015), require that at least 40 percent of the steelhead populations within each MPG achieve viability (restored to a low extinction risk), as well as at least 40 percent of each major life history type (e.g., summer-run and winter-run) historically present within each MPG achieve viability.

Winter-run steelhead in the Snohomish River basin enter freshwater as adults between mid-October and May (Myers et al. 2015). Spawning occurs from mid-March through mid-June with peak spawning in April. Most winter-run steelhead return to spawn as four year-olds (57%), and five year-fish (42%)(PSSTRT 2013a citing WDFW 1994b). Juvenile out-migrant trapping data indicate that natural-origin Snohomish River basin steelhead juveniles emigrate seaward in April and May as smolts predominantly as two-year old fish (84%)(PSSTRT 2013a citing WDFW 1994b). Three year old smolts are a lesser seaward emigration component, 15% of the total smolt migration.

Adult summer steelhead return to the watershed between late-May and mid-October ((PSSTRT 2013a), and predominately as four year olds. Myers et al. (2015) (this and following) reported that summer-run steelhead in the Tolt River spawn from January through May, with two peak spawning periods; one in February and the other in mid-April. Non-native stock ESS produced by WDFW's Reiter Ponds program spawn from late -December through April. The spawn timing of ESS hatchery stock is believed to overlap with naturally spawning native summer-run steelhead in the region, but the overlap may be diminished because of current broodstock collection procedures that have retained the earliest returning fish for spawning. However, recent genetic analyses conducted by WDFW indicate that introgression by ESS is substantial in at least two putative steelhead natural populations in the watershed (K. Warheit, WDFW, pers. comm., February 2014). Summer-run steelhead are thought to exhibit the same predominantly 2-year smolt emigration life history strategy as natural-origin winter-run steelhead.

Historically, the Snohomish River basin was one of the primary producers of steelhead in Puget Sound ((PSSTRT 2013a). Abundance estimates are lacking for the pre-developmental period, but steelhead harvest levels in basin fisheries in the late 1800s and early 1900s indicate that the numbers of steelhead were quite high. Harvests recorded for Snohomish County during these years were indicative of runs over 100,000 fish (PSSTRT 2013a). Escapement surveys by the Washington Department of Fish and Game in 1929 found large aggregations of steelhead in the Pilchuck, Sultan, Skykomish, and Tolt rivers, and medium aggregations in the North Fork and South Fork Skykomish, Wallace, Snoqualmie, and Raging rivers (Myers et al. 2015, citing WDFG 1932). Intrinsic potential (IP) production estimates indicate that the Snohomish River basin could support a total winter-run steelhead abundance for the three DIPs of approximately 43,322 fish (assumes a 10% SAS; (PSSTRT 2013a). Myers et al. (2015) estimated IP-based adult productivity capacity ranges from 21,389 to 42,779 adults for the Snohomish/Skykomish winter-run steelhead DIP; 5,193 to 10,386 adults for the Pilchuck River DIP; and 16,740 to 33,479 adults for the Snoqualmie River DIP. There are no estimates of annual steelhead smolt production for the basin. However, by comparison, the recent year (2000-2015) combined geometric mean escapement for the three winter-run populations in the Snohomish River basin is 3,066 fish (Marshall 2013), or 7.1% of the combined low- IP production capacity for the basin (Figure 3). Winter-run steelhead escapements have declined significantly since the mid-1990s (Ford et al. 2011; PSSTRT 2013b; Scott and Gill 2008b). The TRT-derived interim DIP abundance goals for viable populations for the three winter-run populations are 10,695 for the Snohomish/Skykomish River population, 2,597 for the Pilchuck River winter-run population, and 8,370 for the Snoqualmie River winter-run (Hard et al. 2015). The co-managers' upper management threshold for winter-run steelhead, reflecting the estimated escapement level that would optimally utilize available spawning and rearing habitat based on recent productivity and habitat conditions is 6,500 fish (or 15% of the combined low- IP production capacity for the basin).

The 5-year geometric mean abundance for the Snohomish/Skykomish population was 3,084 natural-spawners from 2005 through 2009 and only 930 from 2010 through 2014; indicating an overall decline of -70% (from Table 59 *in* NWFSC 2015). Hard et al. (2015) estimated that the probability that the population would decline to a QET of 73 steelhead was low (about 40% within 100 years; see Table 3) based on a mean population growth rate of -0.005 (λ=0.995). The 5-year geometric mean abundance for the Pilchuck population was 597 natural-origin spawners from 2005 through 2009 and 614 from 2010 through 2014; indicating an overall increase of +3% (from Table 59 *in* NWFSC 2015). Hard et al. (2015) estimated that the probability that the population would decline to a QET of 34 steelhead was low (about 40% within 100 years) based on a mean population growth rate of -0.006 (λ=0.994). The 5-year geometric mean abundance for the Snoqualmie population was 1,249 natural-spawners from 2005 through 2009 and only 680 from 2010 through 2014; indicating an overall decline of -46% (from Table 59 *in* NWFSC 2015). Hard et al. (2015) estimated that the probability that the population would decline to a QET of 73 steelhead was high (nearly 70% within 100 years) based on a mean population growth rate of -0.027 (λ=0.973).

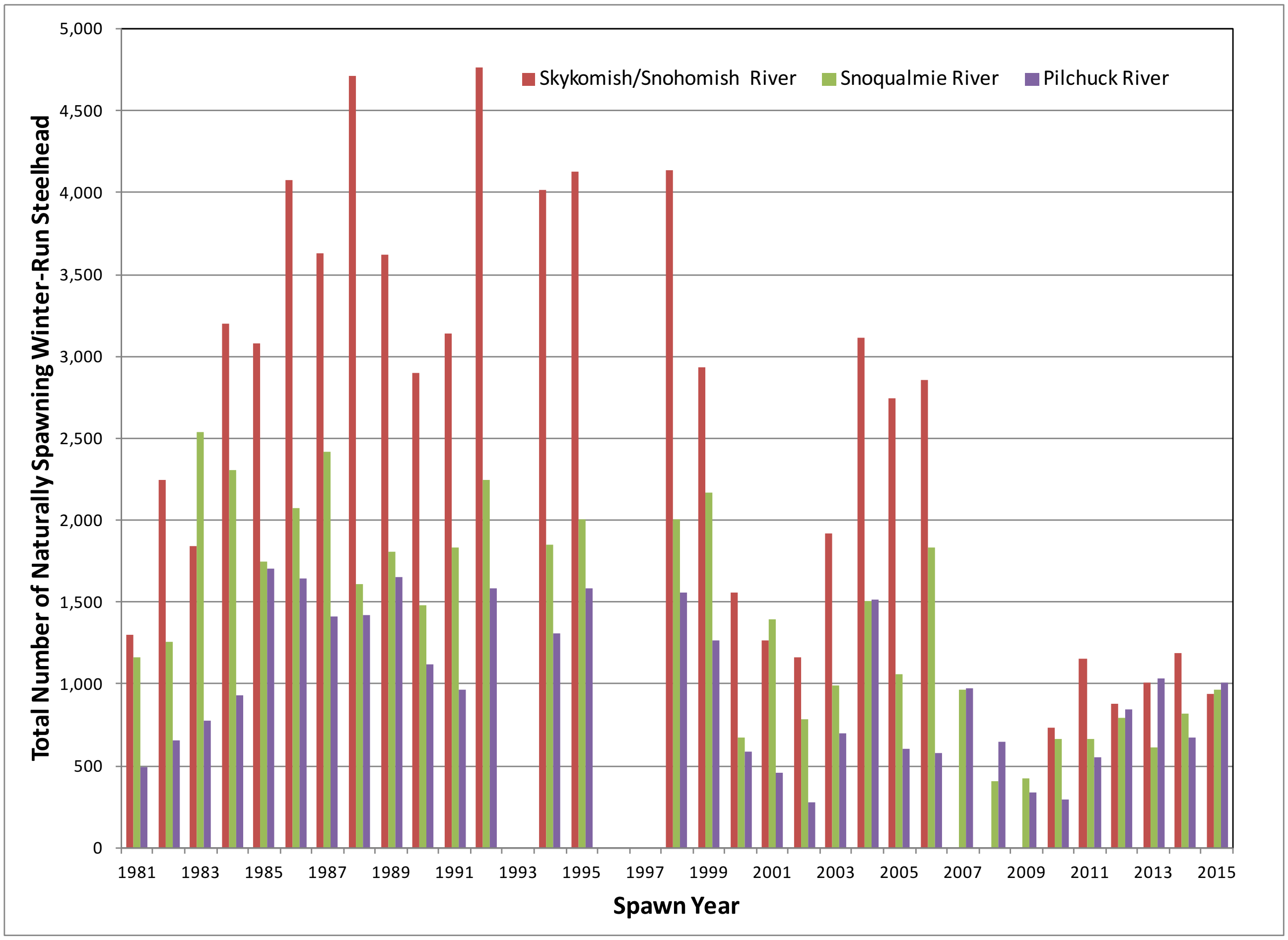

Figure 3. Total estimated number of naturally spawning winter-run steelhead for the Skykomish, Snoqualmie, and Pilchuck rivers for return years 1981-2015: Source: WDFW Score Database.

The combined intrinsic potential for the two summer-run steelhead DIPs in the basin is 984 fish (assumes a 10% SAS; Myers et al. 2015). The IP capacity ranges for each summer-run steelhead DIP are 321 to 641 adults in the Tolt River DIP and 663 to 1,325 adults in the North Fork Skykomish River (Myers et al. 2015). For Tolt River summer-run steelhead (the only summer-run population in the basin for which redd count data are available), escapements have declined since the late 1990s. The recent year (2000-2015) average Tolt River summer-run steelhead escapement is 105 fish (Marshall 2013; WDFW Score Database). The TRT viable abundance goals for the two summer populations are 250 natural-origin fish for the Tolt River population and 331 for the North Fork Skykomish River natural population (Hard et al. 2015). The 5-year geometric mean abundance for the Tolt population was 73 natural-origin spawners from 2005 through 2009 and 105 from 2010 through 2014; indicating an overall increase of +44% (from Table 59 *in* NWFSC 2015). Hard et al. (2015) estimated that the probability that the population would decline to a QET of 25 steelhead was high (about 80% within 100 years; see Table 3) based on a mean population growth rate of -0.013 (λ=0.987).

Human developmental activities in the Snohomish River basin have adversely affected steelhead population spatial structure. Scott and Gill (2008b) reported that the distribution of winter-run steelhead in the basin has been reduced up to 23% (432 miles) from the pre-development distribution of 433 to 562 miles of riverine habitat. Similarly, the distribution of summer-run steelhead had been reduced from an historic distribution of 431 to 570 miles to a current distribution of 431 miles (up to a 24% reduction).

Data are not available to evaluate changes in the diversity of steelhead in the Snohomish River basin. However, it is likely that the degradation and loss of habitat in the watershed and past harvest practices that disproportionately affected the earliest returning fish have reduced the diversity of the species relative to historical levels. Genetic diversity of the winter-run natural populations has likely been adversely affected by releases of non-native EWS from basin hatcheries, in watershed areas where spawn timings for natural and hatchery-origin fish have over-lapped. Hatchery introduction of ESS into the South Fork Skykomish River, coincident with the initiation of a trap-and-haul operation at Sunset Falls in the mid-1950s, has likely reduced the diversity of the summer-run race the watershed. This introduced population, and continued releases of ESS through the WDFW Reiter ponds program, pose a risk of genetic introgression to the native summer-run stocks.

2.2.1.2 Status of Critical Habitat for Puget Sound Steelhead

Critical habitat has been designated for Puget Sound steelhead (81 FR 9252, February 24, 2016). 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, Lake Washington, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha. The designation does not include specific areas in the nearshore zone in Puget Sound. Steelhead move rapidly out of freshwater and into offshore marine areas, unlike other salmonid species including Puget Sound Chinook and Hood Canal summer chum. It also does not include offshore marine areas. There are 18 subbasins (HUC4 basins) containing 66 occupied 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 nine watersheds within the Snohomish system (Skykomish River Forks, Skykomish River/Wallace River, Sultan River, Skykomish River/Woods Creek, Tye and Beckler Rivers, Pilchuck River, Snohomish River, Lower Snoqualmie River, and Middle Fork Snoqualmie River), seven received high and two received medium conservation value ratings.

NMFS determines the range-wide status of critical habitat by examining the condition of its physical and biological features (also called “primary constituent elements,” or PCEs, in some designations) that were 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). In the proposed rule for Puget Sound steelhead (78 FR 2726, January 14, 2013), PCEs for the Snohomish populations included:

(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 steelhead in the Dungeness, Nooksack, and Stillaguamish river basins within the action area. Critical habitat includes the stream channels within the basins, 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 (CHART) identified management activities that may affect the PCEs within the action area (NMFS 2013b). These activities included agriculture, grazing, irrigation impoundments and withdrawals, channel modifications/diking, dams, forestry, urbanization, sand/gravel mining, wetland loss/removal, and road building/maintenance (81 FR 9252, February 24, 2016).
The Puget Sound CHART found that habitat utilization by steelhead in a number of Puget Sound areas has been substantially affected by large dams and other manmade barriers in a number of drainages (this and following from NMFS 2013b). Affected areas include the Nooksack, Skagit, White, Nisqually, Skokomish, and Elwha river basins. In addition to limiting habitat accessibility, dams have affected steelhead habitat quality through changes in river hydrology, altered temperature profile, reduced downstream gravel recruitment, and the reduced recruitment of large woody debris. In addition, many upper tributaries in the Puget Sound region have been affected by poor forestry practices, while many of the lower reaches of rivers and their tributaries have been altered by agriculture and urban development. Urbanization has caused direct loss of riparian vegetation and soils, significantly altered hydrologic and erosional rates and processes (e.g., by creating impermeable surfaces such as roads, buildings, parking lots, sidewalks etc.), and polluted waterways with storm-water and point-source discharges. The loss of wetland and riparian habitat has dramatically changed the hydrology of many streams all to the detriment of steelhead habitat, with increases in flood frequency and peak flow during storm events and decreases in groundwater driven summer flows. River braiding and sinuosity have been reduced through the construction of dikes, hardening of banks with riprap, and channelization of the mainstem rivers. These actions have led to constriction of river flows, particularly during high flow events, increasing the likelihood of gravel scour and the dislocation of rearing juvenile steelhead. The loss of side-channel habitats has also reduced important areas for spawning, juvenile rearing, and overwintering habitats.

Estuarine areas have been dredged and filled, resulting in the loss of important juvenile steelhead rearing areas.

In addition to being a factor that contributed to the present decline of Puget Sound steelhead natural populations, the continued destruction and modification of steelhead habitat is the principal factor limiting the viability of the Puget Sound steelhead DPS into the foreseeable future (NMFS 2013b). Because of their limited distribution in upper tributaries, summer-run steelhead may be at higher risk than winter-run steelhead from habitat degradation in larger, more complex watersheds.

2.2.2 Puget Sound Chinook Salmon ESU

2.2.2.1 Life History and Status

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 compared to stream type Chinook salmon that spend 2 to 3 years and exhibit extensive offshore ocean migrations. They also enter freshwater later, upon returning to spawn, than the stream type, 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 fresh water for no more than 3 months compared to spring Chinook salmon that spawn and rear high in the watershed and 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 species, in this case, the Puget Sound Chinook salmon ESU is at high risk and is threatened with extinction (Ford 2011; Table 2). NMFS issued its five-year species status review on August 15, 2011 (76 FR 50448), and concluded that Puget Sound Chinook salmon should remain listed as threatened under the ESA.

NMFS adopted a recovery plan for Puget Sound Chinook salmon on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan prepared by the Shared Strategy for Puget Sound and NMFS’ Final Supplement to the Shared Strategy Plan. The Recovery Plan 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 Puget Sound Technical Recovery Team (PSTRT)(Ruckelshaus et al. 2002). The PSTRT’s Biological Recovery Criteria will be met when the following conditions are achieved:

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

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

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

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

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

Spatial Structure and Diversity. The PSTRT 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 4) (Table 5).

Based on genetic and historical evidence reported in the literature, the PSTRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct[5] (Ruckelshaus et al. 2006). The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, including the Straits of Juan de Fuca from the Elwha River (inclusive) 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.

As of 2015, there are 22 artificial propagation programs (described in individual HGMPs) producing Chinook salmon that are included as part of the listed ESU: Kendall Creek Hatchery, Skookum Creek Hatchery, Marblemount Hatchery (two HGMPs - spring and summer-run), Harvey Creek Hatchery, Brenner Creek Hatchery, Whitehorse Springs Hatchery, Wallace River Hatchery, Tulalip Hatchery, Issaquah Hatchery, Soos Creek Hatchery (includes Icy Creek and Palmer Ponds programs), White River Hatchery, White Acclimation Ponds, Hupp Springs Hatchery, Voights Creek Hatchery, Clarks Creek (Diru Creek) Hatchery, Clear Creek Hatchery, Kalama Creek Hatchery, George Adams Hatchery, Hamma Hamma Hatchery, Dungeness River/Hurd Creek Hatchery, and Elwha Channel Hatchery (64 FR 14308, March 24, 1999; 70 FR 37160, June 28, 2005; 71 FR 20802, April 14, 2014).

Indices of spatial distribution and diversity have not been developed at the natural population level, though diversity at the ESU level is declining. Abundance is becoming more concentrated in fewer natural populations and regions within the ESU. Abundance has increased particularly within the Whidbey Basin Region (NWFSC 2015). During the last 5-year period (2010-2014) natural-origin escapement in the Strait of Georgia, Strait of Juan de Fuca, Hood Canal, Whidbey Basin, and Central-South Sound BGR's made up 1%, 1%, 2%, 70%, and 26% of the natural-origin escapement, respectively (from Table 56 *in* NWFSC 2015). There is a declining trend in the proportion of natural-origin spawners across the ESU during the entire time period from 1990 through 2014 (NWFSC 2015).

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[5] It was not possible, in most cases, to determine whether these Chinook salmon spawning groups historically represented independent populations or were distinct spawning aggregations within larger populations.

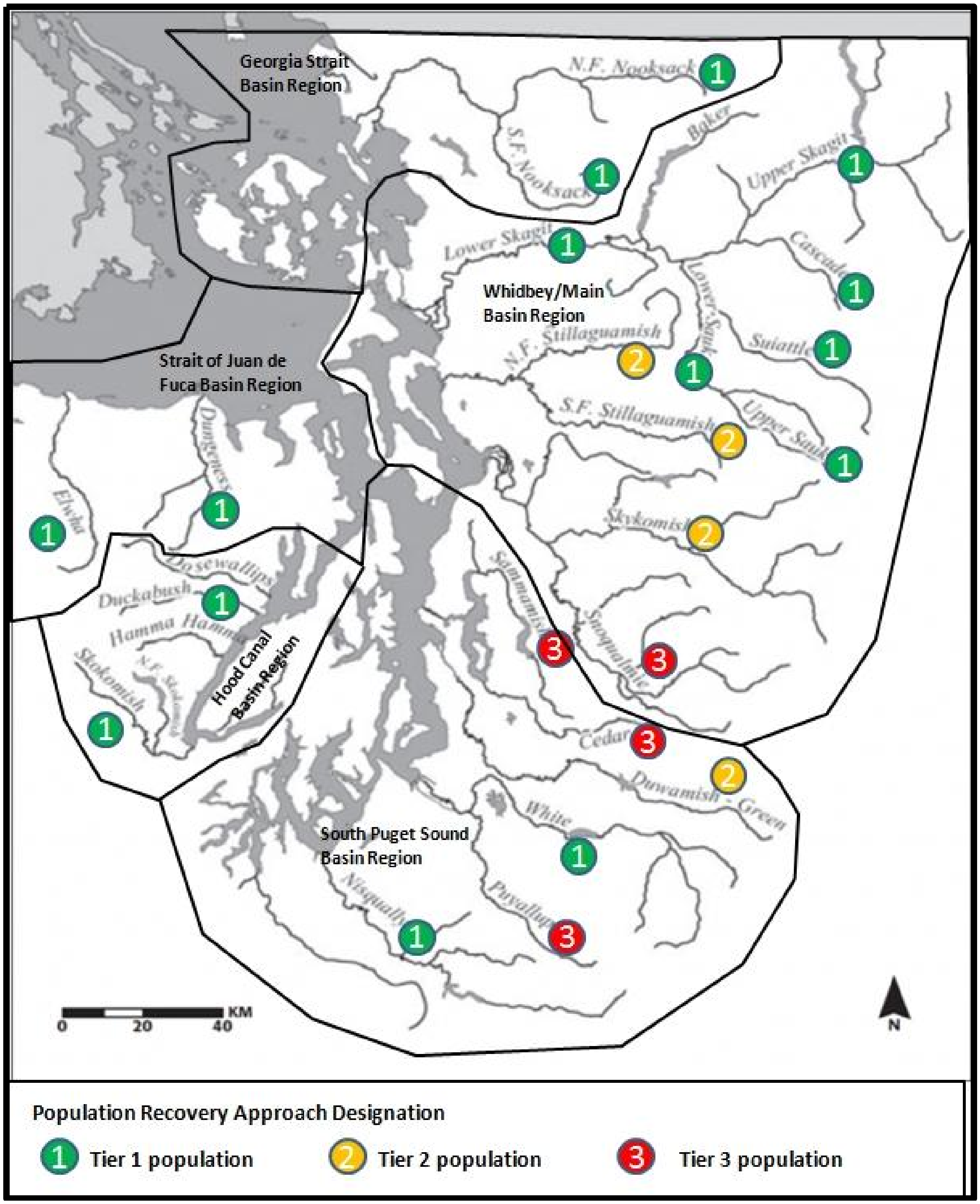

Figure 4. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU (SSPS 2005) and their assigned Population Recovery Approach tier status (NMFS 2010). Note: Dosewallips, Duckabush and Hamma Hamma River Chinook salmon are aggregated as the “Mid Hood Canal” population.

Table 5. Extant Puget Sound Chinook salmon populations by biogeographical region (NMFS 2006b).

Biogeographical Region	Population (Watershed)
Strait of Georgia	**North Fork Nooksack River**
	South Fork Nooksack River
Strait of Juan de Fuca	**Elwha River**
	Dungeness River
Hood Canal	**Skokomish River**
	Mid Hood Canal River
Whidbey Basin	Skykomish River (late)
	Snoqualmie River (late)
	North Fork Stillaguamish River (early)
	South Fork Stillaguamish River (moderately early)
	Upper Skagit River (moderately early)
	Lower Skagit River (late)
	Upper Sauk River (early)
	Lower Sauk River (moderately early)
	Suiattle River (very early)
	Upper Cascade River (moderately early)
Central/South Puget Sound Basin	Cedar River (late)
	Sammamish River (late)
	Green/Duwamish River (late)
	Puyallup River (late)
	White River (early)
	Nisqually River (late)

NOTE: NMFS has determined that the bolded natural populations in particular are essential to recovery of the Puget Sound ESU (NMFS 2006b). In addition, at least one other natural population of each race within the Whidbey Basin (one each of the early, moderately early and late spawn timing) and Central/South Puget Sound Basin (one late spawn-timing) regions would need to be viable for recovery of the ESU.

NMFS further classified Puget Sound Chinook salmon natural populations into three tiers based on its Population Recovery Approach (PRA) using a variety of life history, production and habitat indicators and the Puget Sound Recovery Plan biological delisting criteria (NMFS 2010; NMFS 2011)(Figure 4). NMFS appreciates and 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 natural populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 natural populations play a secondary role in recovery of the ESU, and Tier 3 natural populations play a tertiary role. When NMFS analyzes proposed actions, it evaluates impacts at the individual natural population scale for their effects on the viability of the ESU. Impacts to Tier 1 natural populations would be more likely to affect the viability of the ESU as a whole than similar impacts to Tier 2 or 3 natural populations, because of the primary importance of Tier 1 natural populations to overall ESU viability. Skykomish Chinook salmon are classified through the approach as a Tier 2 natural populaiton; Snoqualmie Chinook salmon are a Tier 3 natural population (NMFS 2010).

Abundance and Productivity. Table 6 and Table 7 summarize available scientific information on current abundance and productivity and their trends for the Puget Sound Chinook salmon natural populations including NMFS' critical and rebuilding thresholds[6] and recovery plan targets for abundance and productivity. The information is summarized using updated estimates based on methodologies in the recent status review of West Coast salmon ESUs (Ford et al. 2011) and recent escapement and fisheries data provided by tribal and state co-managers (data summarized in NMFS 2015a).

Most Puget Sound Chinook salmon natural populations are well below escapement levels identified as required for recovery to low extinction risk (Table 6). All populations are consistently below productivity goals identified in the recovery plan (Table 6). Although trends vary for individual populations across the ESU, most populations have declined in total natural origin recruit (NOR) abundance (prior to harvest) since the last status review. However, most populations exhibit a stable or increasing growth rate in natural-origin escapement (after harvest) (Table 7). No clear patterns in trends in escapement or abundance are evident among the five major regions of Puget Sound. No trend was notable for total ESU escapements. Trends in growth rate of natural-origin escapement are generally higher than growth rates for natural-origin abundance indicating some stabilizing influence on escapement from past reductions in fishing-related mortality (Table 7). Survival and recovery of the Puget Sound Chinook Salmon ESU will depend, over the long term, on necessary actions in all H sectors. Many of the habitat and hatchery actions identified in the Puget Sound Chinook salmon recovery plan are likely to take years or decades to be implemented and to produce significant improvements in natural population attributes (NWFSC 2015).

For the purpose of assessing population status, NMFS has derived critical and rebuilding escapement thresholds for some of the Puget Sound Chinook salmon natural populations based on an assessment of current habitat and environmental conditions (NMFS 2000; NMFS 2004; NMFS 2011). The 2015 status review concluded that total abundance in the ESU over the entire time series shows that individual populations have varied from increasing or decreasing abundance; generally, many populations increased in abundance during the years 2000 through 2008 and then declined in the last five years (NWFSC 2015). Abundance across the ESU has generally decreased since the last status review, with only 5 populations showing an increase in the 5-year geometric mean natural-origin abundance since the 2010 status review (NWFSC 2015). The remaining 17 populations showed a decline in their 5-year geometric mean natural-origin abundance as compared to the previous 5-year period. The 5-year geometric mean abundance for the entire ESU was 27,716 natural-origin adults from 2005 through 2009 and only 19,258 from 2010 through 2014; indicating an overall decline of -31% (from Table 56 *in* NWFSC 2015). Geometric mean (1999-2014) natural-origin escapements for 5 of the 22 populations are above their NMFS-derived rebuilding thresholds (Table 6). Geometric mean (1999-2014) escapements for ten of the 22 populations are between their critical and rebuilding thresholds. Geometric mean (1999-2014) natural-origin escapements are below their critical thresholds for seven populations (Table 6). The most recent

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[6] The NMFS-derived thresholds are based on population-specific information focused on natural-origin spawners or generic guidance from the scientific literature using methods which are applied consistently across populations in the ESU. A more detailed description of the process NMFS used in deriving these population-specific rebuilding and critical thresholds is presented in Appendix C: Technical Methods - Derivation of Chinook Management Objectives and Fishery Impact Modeling Methods, Final Environmental Impact Statement, Puget Sound Chinook Harvest Resource Management Plan NMFS. 2004. Puget Sound Chinook Harvest Resource Management Plan Final Environmental Impact Statement. NMFS Northwest Region with Assistance from the Puget Sound Treaty Tribes and Washington Department of Fish and Wildlife..

geometric mean (2010-2014) natural-origin escapements indicate that 8 populations are currently below their critical thresholds.

Table 6. Estimates of escapement and productivity for Puget Sound Chinook salmon. Natural origin escapement information is provided where available. For several populations, data on hatchery contribution to natural spawning are limited or unavailable. Source: NMFS 2015a.

Region	Population	1999 to 2014 Geometric mean Escapement (Spawners)		NMFS Escapement Thresholds		Recovery Planning Abundance Target in Spawners (productivity)[2]	Average % hatchery fish in escapement 1999-2013 (min-max)[5]
		Natural[1]	Natural-Origin (productivity[2])	Critical[3]	Rebuilding[4]		
Georgia Basin	Nooksack MU	1,937	268	*400*	500		
	NF Nooksack	1,638	211 (0.3)	*200*[6]	-	3,800 (3.4)	85 (63-94)
	SF Nooksack	399	53 (1.7)	*200*[6]	-	2,000 (3.6)	84 (62-96)
Whidbey/ Main Basin	Skagit Summer/Fall MU						
	Upper Skagit River	7,976	7,748[8] (1.8)	967	7,454	5,380 (3.8)	3 (1-8)
	Lower Sauk River	543	552[8] (1.8)	*200*[6]	681	1,400 (3.0)	1 (0-10)
	Lower Skagit River	1,993	1,932[8] (1.4)	251	2,182	3,900 (3.0)	4 (2-8)
	Skagit Spring MU						
	Upper Sauk River	522	502[8] (1.6)	130	330	750 (3.0)	1 (0-5)
	Suiattle River	327	319[8] (1.2)	170	400	160 (3.2)	2 (0-5)
	Upper Cascade River	290	291[8] (1.1)	170	*1,250*[6]	290 (3.0)	8 (0-25)
	Stillaguamish MU						
	NF Stillaguamish R.	952	582 (0.9)	300	552	4,000 (3.4)	35 (8-62)
	SF Stillaguamish R.	110	**104** (0.7)	*200*[6]	300	3,600 (3.3)	NA
	Snohomish MU						
	Skykomish River	3,367	2,052[8] (0.9)	1,650	3,500	8,700 (3.4)	30 (8-36)
	Snoqualmie River	1,583	1,142[8] (1.5)	400	*1,250*[6]	5,500 (3.6)	19 (3-62)
Central/ South Sound	Cedar River	842	802[8] (1.9)	*200*[6]	*1,250*[6]	2,000 (3.1)	20 (10-36)
	Sammamish River	1,172	128[8] (0.5)	*200*[6]	*1,250*[6]	1,000 (3.0)	86 (66-95)
	Duwamish-Green R.	3,562	1,179[8] (1.1)	835	5,523	-	57 (33-75)
	White River[9]	1,753	1,268[8] (0.6)	*200*[6]	1,100[7]	-	39 (15-49)
	Puyallup River [10]	1,570	655[8] (0.8)	*200*[6]	522[7]	5,300 (2.3)	53 (18-77)
	Nisqually River	1,687	522[8] (1.0)	*200*[6]	1,200[7]	3,400 (3.0)	72 (53-85)
Hood Canal	Skokomish River	1,305	345 (0.8)	452	1,160	-	66 (7-95)
	Mid-Hood Canal R.[11]	175		*200*[6]	*1,250*[6]	1,300 (3.0)	66
Strait of Juan de Fuca	Dungeness River	354	114[8] (0.6)	*200*[6]	925[7]	1,200 (3.0)	67 (39-96)
	Elwha River[12]	1,919	117[8] (NA)	*200*[6]	*1,250*[6]	6,900 (4.6)	94 (92-95)

[1] Includes naturally spawning hatchery fish. Nooksack spring Chinook 2014 escapements not available.

[2] Source productivity is Abundance and Productivity Tables from NWFSC database; measured as the mean of observed recruits/observed spawners. Sammamish productivity estimate has not been revised to include Issaquah Creek. Source for Recovery Planning productivity target is the final supplement to the Puget Sound Salmon Recovery Plan (NMFS 2006); measured as recruits/spawner associated with the number of spawners at Maximum Sustained Yield under recovered conditions.

[3] Critical natural-origin escapement thresholds under current habitat and environmental conditions (McElhaney et al. 2000; NMFS 2000).

[4] Rebuilding natural-origin escapement thresholds under current habitat and environmental conditions (McElhaney et al. 2000; NMFS 2000).

[5] Estimates of the fraction of hatchery fish in natural spawning escapements are from the Abundance and Productivity Tables and co-manager postseason reports on the Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2013, WDFW and PSTIT 2005, 2006, 2007, 2008, 2009, 2010, 2011a, 2012) and the 2010-2014 Puget Sound Chinook Harvest Management Plan (PSIT and WDFW 2010a). North Fork and South Fork Nooksack estimates are through 2011 and 2010, respectively. Skagit estimates are through 2011.

[6] Based on generic VSP guidance (McElhaney et al. 2000; NMFS 2000).

[7] Based on alternative habitat assessment.

[8] Estimates of natural-origin escapement for Nooksack, Skagit springs, Skagit falls and Skokomish available only for 1999-2013; Snohomish for 1999-2001 and 2005-2014; Lake Washington for 2003-2014; White River 2005-2014; Puyallup for 2002-2014; Nisqually for 2005-2014; Dungeness for 2001-2014; Elwha for 2010-2014.

[9] Captive broodstock program for early run Chinook salmon ended in 2000; estimates of natural spawning escapement include an unknown fraction of naturally spawning hatchery-origin fish from late- and early run hatchery programs in the White and Puyallup River basins.

[10] South Prairie index area provides a more accurate trend in the escapement for the Puyallup River because it is the only area in the Puyallup River for which spawners or redds can be consistently counted (PSIT and WDFW 2010a).

[11] The Puget Sound TRT considers Chinook salmon spawning in the Dosewallips, Duckabush, and Hamma Hamma rivers to be subpopulations of the same historically independent population; annual counts in those three streams are variable due to inconsistent visibility during spawning ground surveys. Data on the contribution of hatchery fish is very limited, and is primarily based on returns to the Hamma Hamma River.

[12] Estimates of natural escapement do not include volitional returns to the hatchery or those fish gaffed or seined from spawning grounds for broodstock collection.

Table 7. Trends in abundance and productivity for Puget Sound Chinook salmon populations. Long-term, reliable data series for natural-origin contributions to escapement are limited in many areas. Green, yellow and red highlights indicate increasing, stable, and declining trends (Source: NMFS 2015a)

Region	**Population**	**Natural Escapement and Trend[1] (1990-2013)**		**Growth Rate[2] (1990-2011)**	
				Return (Recruits)	**Escapement (Spawners)**
Georgia Basin	NF Nooksack (early)	1.14	increasing	1.03	1.02
	SF Nooksack (early)	1.05	increasing	1.02	1.01
Whidbey/Main Basin	Upper Skagit River (moderately early)	1.02	stable	0.97	1.00
	Lower Sauk River (moderately early)	1.00	stable	0.94	0.96
	Lower Skagit River (late)	1.01	stable	0.96	0.99
	Upper Sauk River (early)	1.04	increasing	0.96	1.00
	Suiattle River (very early)	0.99	stable	0.94	0.98
	Upper Cascade River (moderately early)	1.03	increasing	0.98	1.03
	NF Stillaguamish R. (early)	1.01	stable	0.96	1.00
	SF Stillaguamish R[3] (moderately early)	0.96	**declining**	0.90	0.94
	Skykomish River (late)	1.00	stable	0.92	1.02
	Snoqualmie River (late)	1.02	stable	0.93	1.00
Central/South Sound	Cedar River (late)	1.05	increasing	1.01	1.05
	Sammamish River[4] (late)	1.05	stable	0.97	1.01
	Duwamish-Green R. (late)	0.95	**declining**	0.88	0.93
	White River[5] (early)	1.12	increasing	1.06	1.10
	Puyallup River (late)	0.97	**declining**	0.88	0.95
	Nisqually River[3] (late)	1.07	increasing	0.96	0.99
Hood Canal	Skokomish River (late)	1.02	stable	0.88	0.98
	Mid-Hood Canal Rivers (late)	1.04	stable	0.86	0.99
Strait of Juan de Fuca	Dungeness River (early)	1.06	increasing	1.04	1.06
	Elwha River[3] (late)	1.01	stable	0.92	0.97

[1] Escapement Trend is calculated based on all spawners (i.e., including both natural-origin spawners and hatchery-origin fish spawning naturally) to assess the total number of spawners passed through the fishery to the spawning ground. Directions of trends defined by statistical tests.

[2] Growth rate (λ) is calculated based on natural-origin production assuming the reproductive success of naturally spawning hatchery fish is equivalent to that of natural-origin fish (for populations where information on the fraction of hatchery fish in natural spawning abundance is available). Source: Abundance and Productivity Tables-Puget Sound TRT).

[3] Estimate of the fraction of hatchery fish in time series is not available for use in λ calculation, so trend represents that in hatchery-origin + natural-origin spawners.

[4] Growth rate estimates for Sammamish have not been revised to include escapement in Issaquah Creek.

[5] Natural spawning escapement includes an unknown fraction of naturally spawning hatchery-origin fish from late- and early run hatchery programs in the Puyallup River basin.

Limiting factors. Limiting factors described in SSPS (2007) and NMFS (2011a) 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 Chinook salmon natural populations.
- Salmon harvest management: Total fishery exploitation rates have decreased 14 to 63 percent from rates in the 1980s, but weak natural-origin Chinook salmon populations in Puget Sound still require enhanced protective measures to reduce overharvest.

The severity and relative contribution of these factors varies by natural population. One theory for the declines in fish populations in Puget Sound during 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 2.3).

Whidbey Basin BGR: The Whidbey Basin BGR contains 10 natural populations including the two Snohomish populations. The Suiattle and at least one other population within the Whidbey Basin (one each of the early, moderately early and late spawn-timing) would need to be viable for recovery of the ESU. Evidence suggests that the Puget Sound Chinook Salmon ESU has lost 15 spawning aggregations that were either demographically independent historical populations or major components of the life history diversity of the remaining 22 extant independent historical natural populations (Ruckelshaus et al. 2006). Nine of the 15 putatively extinct spawning aggregations were thought to be early type Chinook salmon. The majority of extant populations with early run-timing are in this BGR and it currently accounts for about 47 and just under 70 percent of the all-natural spawners and natural-origin Chinook salmon escapement in the ESU, respectively (Table 56 *in* NWFSC 2015). Abundance varies greatly among the populations (Table 6) with the Skagit populations comprising the majority (76%) of Chinook salmon in the BGR (NWFSC 2015). Based on estimates of most recent 5-year (2010-2014) geometric mean abundances, two populations in the BGR are above their rebuilding thresholds (representing early and moderately early life histories) and the South Fork Stillaguamish is in critical status (WDFW Score Database; NWFSC 2015). As described above, only 5 populations showed an increase in abundance in the 5-year geometric mean natural-origin abundance since the 2010 status review (NWFSC 2015), and 3 of these 5 are within the Whidbey Basin BGR. Long-term (1990-2013) escapement trends are increasing or stable for all but the South Fork Stillaguamish population (Table 7). Long-term growth rates for pre-harvest abundance (return) are declining for all populations within the BGR except for the Skykomish River (NMFS 2015a). Growth rates for escapement are stable or increasing for all populations within the BGR except for the Suiattle and South Fork Stillaguamish populations. In summary, the Whidbey Basin BGR is a stronghold of the ESU in terms of life history diversity, spatial structure, and abundance.

Snohomish River Basin Chinook - The two Snohomish River basin Chinook salmon natural populations – Skykomish and Snoqualmie –are grouped with eight other natural populations in the Whidbey Basin BGR for recovery planning purposes (NMFS 2006b; SSPS 2005). Both Snohomish River basin populations are ocean-type Chinook salmon with juveniles emigrating seaward in March through June. A significant proportion of adult Chinook salmon in each population, averaging 24% and 22% for the Skykomish and Snoqualmie populations respectively from 1996-2011(Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2014), are comprised of a yearling fresh water life history type ("stream type"). Adults return primarily as four-year-old fish although both populations exhibit a relatively strong age-5 component. For the period 2005 through 2013, age-5 Chinook salmon made up 20- and 17-percent of the natural-origin spawners in the Skykomish and Snoqualmie populations, respectively (Rawson and Crewson 2014).

Adult summer Chinook salmon return to the Skykomish River watershed beginning in May and extending through July (PSIT and WDFW 2010). The Skykomish natural population has a late-summer/early-fall spawn timing with Chinook salmon spawning in the Snohomish River mainstem, the mainstem of the Skykomish, Pilchuck, Wallace, and Sultan rivers; Woods, Elwell, Olney, Proctor, and Bridal Veil creeks; and the North and South Forks of the Skykomish River (WDFW spawning ground database). The Snoqualmie Chinook salmon population is considered a fall-run stock, migrating into the Snohomish River basin from August through October. Spawning occurs later than in the Skykomish (PSIT and WDFW 2010), generally in the fall months (mid/late-September through early-November) (WDFW spawning ground database). Snoqualmie Chinook salmon spawn in the Snoqualmie River and its larger tributaries, including the Tolt and Raging rivers, and Tokul Creek (PSIT and WDFW 2010).

Abundance of Snohomish River basin Chinook salmon is a fraction of historical levels (SSPS 2005) (Figure 5 and Figure 6). The most recent estimates of escapement, hatchery contribution, and productivity for the Snohomish Basin populations are summarized in Table 8 and Table 9. Naturally-produced Chinook salmon comprise a majority of the natural spawners, averaging 74.5 percent for the basin in recent years (2006-2014; see Table 8). The average hatchery-origin fraction of the naturally spawning Skykomish Chinook salmon population in the last nine recent years (2006-2014; 27.8%) has decreased by nearly half from the level 15 years ago (1997-2001 avg. = 49.9%). The hatchery-origin fraction of the naturally spawning Snoqualmie Chinook salmon population has largely remained consistent over the last 17 years. A moderate increase was observed in recent years (20.4 percent from 2005-2014) relative to the 1997-2001 average of 15.6 percent (Tulalip 2012; Tulalip Tribes, unpublished data 2016). This increase can be attributed to lower numbers of natural-origin spawners in recent years; as the actual number of hatchery-origin spawners declined by 5.9 percent for the period 2005-2014 relative to the 1997-2001 period. Productivity trends for the Skykomish and Snoqualmie populations, as measured by recruit per spawner and spawner to spawner rates are stable or increasing (Table 9).

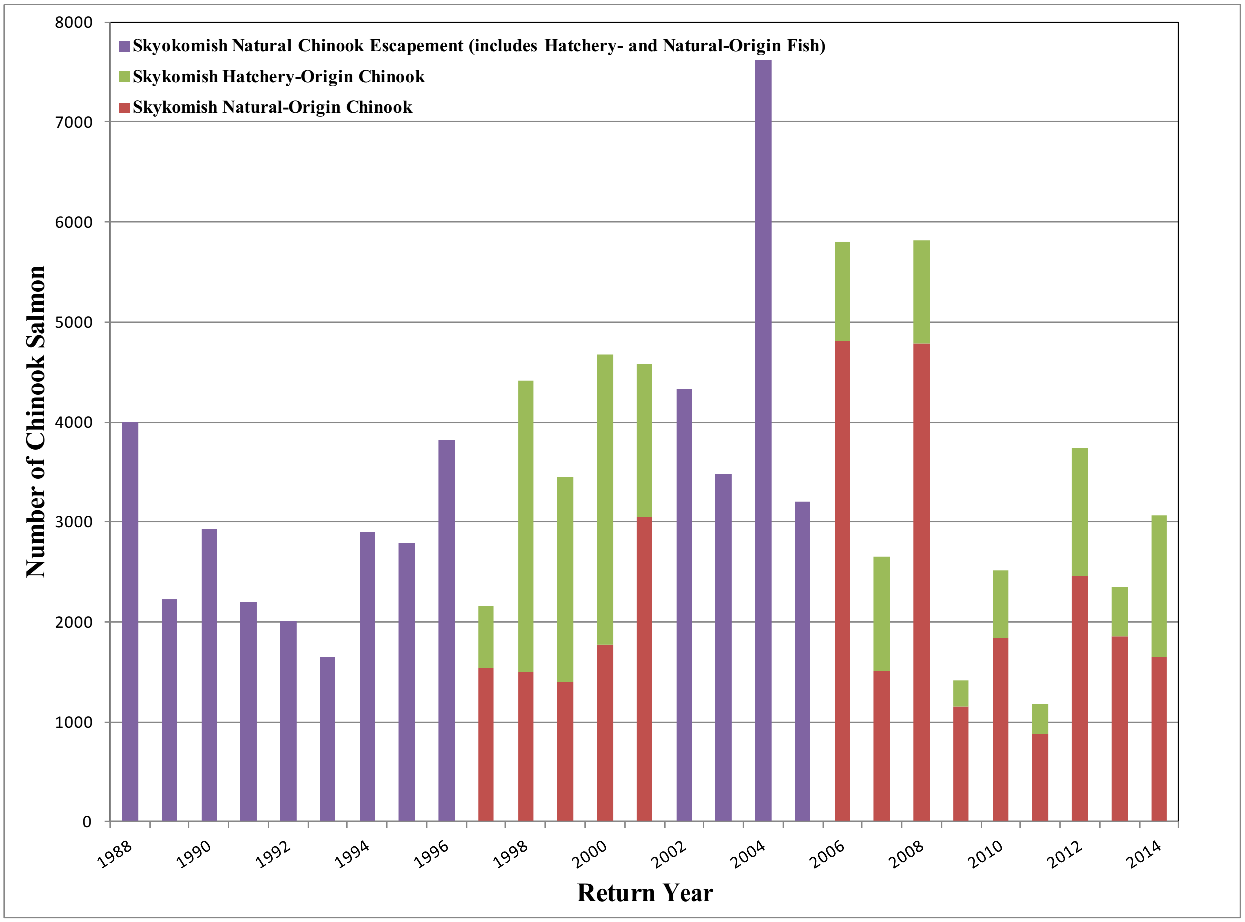

Figure 5. Estimated annual natural Chinook salmon escapement abundances in the Skykomish River for 1988 through 2014. Natural- and hatchery-origin breakouts are included for years where data are available. Source Tulalip 2012; Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2016.

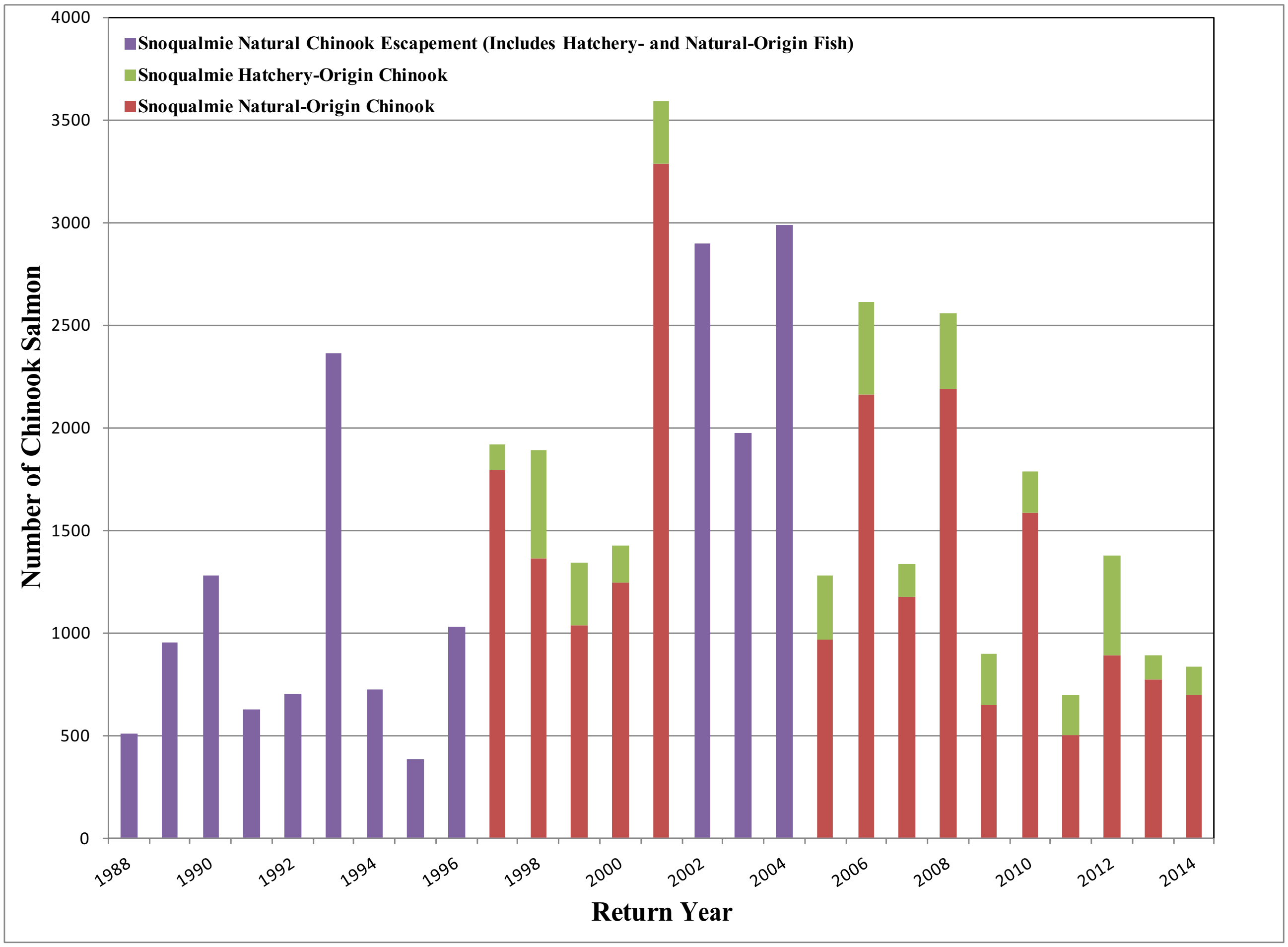

Figure 6. Estimated annual natural Chinook salmon escapement abundances in the Snoqualmie River for 1988 through 2014. Natural- and hatchery-origin breakouts are included for years where data are available. Source Tulalip 2012; Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2016.

Table 8. Summary of Skykomish and Snoqualmie populations natural escapement, natural-origin escapement, and percent of natural escapement composed of hatchery-origin spawners (pHOS) for return years 1997-2014 (where estimates are available). Source Tulalip 2012; Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data, 2016.

Return Year	Skykomish Natural Escapement	Skykomish Natural-Origin Escapement	Skykomish Percent Hatchery-Origin	Snoqualmie Natural Escapement	Snoqualmie Natural-Origin Escapement	Snoqualmie Percent Hatchery-Origin
1997	2,161	1,540	28.7%	1,917	1,796	6.3%
1998	4,415	1,495	66.1%	1,891	1,361	28.0%
1999	3,446	1,401	59.3%	1,345	1,040	22.7%
2000	4,668	1,775	62.0%	1,427	1,248	12.5%
2001	4,577	3,054	33.3%	3,589	3,284	8.5%
2002	4,327	NA	NA	2,896	NA	NA
2003	3,472	NA	NA	1,975	NA	NA
2004	7,614	NA	NA	2,988	NA	NA
2005	3,201	NA	NA	1,279	968	24.3%
2006	5,573	4,642	16.7%	2,615	2,161	17.4%
2007	2,648	1,510	43.0%	1,334	1,174	12.0%
2008	5,813	4,780	17.8%	2,560	2,190	14.5%
2009	1,414	1,146	19.0%	895	649	27.5%
2010	2,511	1,836	26.9%	1,788	1,585	11.3%
2011	1,176	876	25.5%	702	479	31.8%
2012	3,738	2,462	34.1%	1,379	898	34.9%
2013	2,355	1,860	21.0%	889	770	13.4%
2014	3,063	1,654	46.0%	839	698	16.8%
1997-2001 Skykomish pHOS			49.9%			
2006-2014 Skykomish pHOS			27.8%			
			1997-2001 Snoqualmie pHOS			15.6%
			2005-2014 Snoqualmie pHOS			20.4%
1997-2001 Basin Wide pHOS			38.9%			
2006-2013 Basin Wide pHOS			25.5%			

Table 9. Recent productivity estimates for Skykomish and Snoqualmie river Chinook salmon natural populations (source: Rawson and Crewson 2014).

Brood Year (BY)	Skykomish Population Recruits per Natural Spawner (based on observed annual average age distribution)	Skykomish Population Recruits per Natural Spawner (based on observed annual age distribution)	Snoqualmie Population Recruits per Natural Spawner (based on observed annual average age distribution)	Snoqualmie Population Recruits per Natural Spawner (based on observed annual age distribution)
1995	0.79	0.54	3.09	2.09
1996	0.67	0.63	2.02	2.06
1997	1.71	2.33	1.59	2.24
Missing Data				
2000	1.76	2.09	2.49	2.80
2001	1.39	0.83	0.67	0.42
2002	1.57	1.38	1.04	1.27
2003	1.29	0.70	1.16	0.66
2004	0.81	1.11	0.93	1.17
2005	0.79	0.94	1.11	1.32
2006	0.41	0.28	0.61	0.53
1995-1997 Average	**1.05**	**1.17**	**2.23**	**2.13**
2000-2006 Average	**1.15**	**1.05**	**1.14**	**1.17**

The spatial structure for the Skykomish and Snoqualmie river Chinook salmon natural populations has been reduced by habitat loss and degradation. Bank protection and diking of the river and major tributaries have disconnected river channels from their floodplains leading to loss of accessible river areas and habitat complexity for rearing and migrating Chinook salmon (Snohomish Basin Salmonid Recovery Technical Committee [SBSRTC] 1999). Lack of adequate in-channel large woody debris, relative to historic conditions, has decreased the amount of rearing and refuge areas available for juvenile Chinook salmon (SBSRTC 1999). Chinook salmon habitat has been further reduced by loss of wetlands through draining and land conversion for human use (SBSRTC 1999). Road construction, commercial and residential construction, and bank hardening for flood control have also impaired Chinook salmon habitat use and access and population spatial structure. Artificial barriers at locations throughout the Basin, including dams, tide gates, water diversions, culverts, and pumping stations, prevent juvenile Chinook salmon from reaching rearing habitat to the further detriment of population spatial structure (SBSRF 2005). Since the 1950s, the spawning distribution of the Skykomish Chinook salmon population appears to have shifted upstream. Since that time, a much larger proportion of fish spawn higher in the drainage, between Sultan and the North and South Forks of the Skykomish River, than in previous decades (SBSRTC 1999).

Life history diversity of the Snohomish River basin Chinook salmon populations has been reduced by anthropogenic activities over the last century (Haring 2002, citing J. Houghton and M. Chamblin), and is further threatened by on-going developmental actions in the watershed. Lost and degraded estuarine habitat has impaired the fry migrant components of the Skykomish and Snoqualmie populations, which need a properly functioning, braided lower river and brackish water environment to grow to a viable smolt size. Fry migrants represent a particularly important component of the life history diversity for both populations.

The Chinook salmon populations in the Snohomish River basin have been particularly affected by habitat loss in the estuary. The quantity and quality of salmon rearing habitat available to the two populations in the estuary is a small fraction of pre-development conditions (Snohomish County 2013). Historically, the Snohomish River estuary included a rich complex of tidal channels and productive marshes. Under current conditions, only one-sixth of the historic tidal marsh area downstream of the head of Ebey Slough remains intact and accessible to salmonids (Snohomish County 2013). The current lack of critical estuarine tidal marsh habitat is considered a limiting factor for Chinook salmon recovery (SBSRP 2005). These conditions compromise prospects for restoration of natural-origin Chinook salmon population viability, because ocean-type Chinook salmon stocks are extremely dependent on a properly functioning estuary due to their predominantly fry migrant life history.

2.2.2.2 Status of Critical Habitat for Puget Sound Chinook Salmon

Designated critical habitat for the Puget Sound Chinook ESU includes 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, Duwamish, Puyallup, Nisqually, Deschutes, Skokomish, Hood Canal, Kitsap, and Dungeness/Elwha (70 FR 52630, September 2, 2005). The designation also includes some nearshore areas, adjacent to watersheds occupied by the 22 populations and extending from extreme high water out to a depth of 30 meters, because of their importance to rearing and migrating juvenile Chinook salmon and their prey, but does not otherwise include offshore marine areas. There are 61 watersheds 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). 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 2005b).

NMFS determines the range-wide status of critical habitat by examining the condition of its physical and biological features (also called “primary constituent elements,” or PCEs, in some designations) that were 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 Snohomish 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 habitat that supports 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 Snohomish River basin action area. Critical habitat includes the estuarine areas and the stream channels within the proposed stream reaches of the Snohomish sub-basin, 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 management activities that may affect the PCEs in the three subbasins including agriculture, grazing, channel modifications/diking, dams, forestry, urbanization, sand/gravel mining and road building/maintenance (NMFS 2005a).

2.2.3 Climate Change

Climate change has negative implications for designated critical habitats in the Pacific Northwest (Climate Impacts Group 2004; ISAB 2007; Scheuerell and Williams 2005; Zabel et al. 2006). The distribution and productivity of salmonid populations in the region are likely to be affected (Beechie et al. 2006). Average annual 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 while allowing them to undertake migrations through, or to make foraging forays into, areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold water refugia (Mantua et al. 2009).

These changes will not be spatially homogeneous across the entire Pacific Northwest. Low-lying areas are likely to be more affected. Climate change may have long-term effects that include, but are not limited to, depletion of cold water habitat, variation in quality and quantity of tributary rearing habitat, alterations to migration patterns, accelerated embryo development, premature emergence of fry, and increased competition among species (ISAB 2007).

Habitat preservation and restoration actions can help mitigate the adverse impacts of climate change on salmonids. Examples include restoring connections to historical floodplains and freshwater and estuarine habitats to provide fish refugia and areas to store excess floodwaters, protecting and restoring riparian vegetation to ameliorate stream temperature increases, and purchasing or applying easements to lands that provide important cold water or refuge habitat (Battin et al. 2007; ISAB 2007). 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).

2.3 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, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02). The effects of future actions over which the Federal agency has discretionary involvement or control will be analyzed as "effects of the action."

In order to understand what is affecting a species, it is first necessary to understand the biological requirements of the species. Each stage in a species' life history has its own biological requirements (Groot and Margolis 1991; NRC 1996; Spence et al. 1996). Generally speaking, during spawning migrations, adult salmon require clean water with cool temperatures and access to thermal refugia, dissolved oxygen near 100 percent saturation, low turbidity, adequate flows and depths to allow passage over barriers to reach spawning sites, and sufficient holding and resting sites. Anadromous fish select spawning areas based on species-specific requirements of flow, water quality, substrate size, and groundwater upwelling. Embryo survival and fry emergence depend on substrate conditions (*e.g.*, gravel size, porosity, permeability, and oxygen concentrations), substrate stability during high flows, and, for most species, water temperatures of 13ºC or less. Habitat requirements for juvenile rearing include seasonally suitable microhabitats for holding, feeding, and resting. Migration of juveniles to rearing areas, whether the ocean, lakes, or other stream reaches, requires free access to these habitats.

A variety of human activities have affected Puget Sound steelhead and PCEs in the action area. These activities, more recently, include reclamation actions that are having beneficial effects. At 1,856 square miles, the Snohomish River basin is the second largest watershed draining to Puget Sound (SBSRTC 1999). The Snohomish River is formed by the confluence of the Skykomish and Snoqualmie rivers. Numerous tributaries enter the Snohomish River mainstem, with the largest being the Pilchuck River. Over 1,730 tributary rivers and streams have been identified in the basin, totaling approximately 2,718 miles in length (Williams et al. 1975). The Snohomish River basin is the major source of municipal water supply for Everett and southwest Snohomish County, and it contributes to water supplies in Seattle, Bellevue, and King County.

Forest lands or wilderness comprise approximately 75 percent of the Snohomish River basin which contributes to greater hydrologic and riparian function and better sediment conditions than are found in other basins across Puget Sound (SSPS 2005). Approximately 50 percent of the forest lands within the basin are in federal ownership. However, degradation and fragmentation of freshwater habitat, with consequent effects on connectivity, are one of the primary limiting factors and threats affecting salmon and steelhead natural populations in the basin. Another primary limiting factor is the degradation and loss of nearshore, estuary, mainstem river and key tributary salmon and steelhead habitats that have been adversely affected, or are threatened, by a number of activities (SSPS 2005). Approximately 70 percent of the Snohomish River basin nearshore shoreline has experienced significant modification and subsequent population declines in plant and animal species important for various salmon life stages (SBSRF 2005). Riparian conditions, intertidal habitat conditions, and sediment delivery, transport, and storage have been extensively modified along the Snohomish nearshore, most notably due to construction of the Burlington Northern/Santa Fe railroad in the 1890s, construction of bulkheads, riprap, and piers in the industrial waterfront, and dredging of berths and the federal navigation channel (SBSRF 2005). The most significant habitat impacts in the nearshore result from the railroad and from shoreline armoring. The largest threat to habitat facing the estuary is urbanization downstream of Interstate-5. Agricultural uses dominate the floodplain and account for 5 percent of the basin area (SBSRTC 1999). Dikes and water control structures associated with these activities exist throughout the estuary which limits the aquatic habitat accessible by fish and has reduced salmon rearing habitat in the lower mainstem and estuary by over 70 percent (SBSRTC 1999). Some re-establishment of tidal influence has occurred since the late 1980's due to both intentional and natural breaching of dikes at some locations. These actions have improved salmon habitat in the area.

Dikes, bank armoring, roads, railroads, and bridges confine the mainstem Snohomish, Skykomish, and South Fork Skykomish Rivers, disconnect off-channel habitat, reduce edge habitat complexity, and increase peak flows downstream. Riparian forest cover has been substantially degraded within these areas, reducing large woody debris recruitment and further simplifying the habitat. Other habitat problems in the mainstem rivers include excessive erosion of stream banks, culverts that restrict or completely block fish access to streams, and degraded water quality (i.e., high temperature, low dissolved oxygen, high fecal coliform counts, and high levels of toxic metals).

The Skykomish River originates in the Cascade Mountains. The upper Skykomish River mainstem has a steep gradient, transporting sediment quickly through confined channels (SBSRF 2005). As the river gradient decreases downstream of Gold Bar, gravel and cobble settle out, forming multiple channels and excellent spawning riffles and rearing habitat (SBSRF 2005). In the lower reaches, the river banks in many places are armored and this blocks access to side-channel rearing habitat (this and following from

SBSRTC 1999). Forestry comprises 50% of the land base in the mainstem-primary restoration group (SBSRF 2005). Forestry is most dominant in the highest elevation areas, including the Upper North Fork Skykomish and South Fork Skykomish watershed upstream of Sunset Falls (SBSRF 2005). Logging road failures in the upper basins has resulted in channel destabilization and sedimentation which has degraded the quality of salmon and steelhead spawning habitat (SBSRTC 1999). Approximately 30% of the land use in the mainstem-primary restoration group is currently in residential development (SBSRF 2005). Residential land uses are, for the most part, located away from the river shorelines, which are zoned primarily for agricultural production (SBSRF 2005). Pockets of rural residential development occur directly adjacent to mainstem river reaches near several small cities (SBSRF 2005).

Two types of hydroelectric operations are present in the Snohomish River basin: storage facilities and run-of-the-river facilities. The Henry M. Jackson and the South Fork Tolt River hydroelectric projects are both storage facilities. Bedload transport (quantity and quality) and water level drawdowns are both on-going issues with the Jackson facility, which is located on the Sultan River, a tributary to the lower Skykomish River. The remaining projects in the basin are run-of the- river operations with little or no storage, and they are all upstream of natural barriers to anadromous fish migration (SBSRTC 1999).

The Snohomish Basin is one of the fastest growing areas in the Puget Sound region and the human population is projected to increase by 59 percent from 311,224 in 2000 to 528,293 in 2030 (SSPS 2005). Population growth within and adjacent to the Snohomish River basin will result in increased demand for limited water resources. It is estimated that approximately 1.4 million people will be dependent upon water withdrawals from the basin by 2020 resulting in an increased withdrawal of 53 million gallons per day (SBSRTC 1999 citing Pentec 1998). The areas that will experience the greatest population pressures are along the mainstem rivers and lowland tributaries and when these lands are converted to residential and urban areas, forest cover and ecosystem processes are altered or lost.

2.3.1 Fisheries

The EWS produced at these hatchery facilities are subject to indirect harvest in terminal area net fisheries in marine waters and directed harvest in terminal area freshwater net fisheries, and direct and indirect recreational fisheries in marine waters and freshwater. Harvest of Snohomish River basin-origin natural- and hatchery-origin steelhead occurs in mixed stock marine area fisheries in U.S. and Canadian waters. There are currently no fisheries (tribal, commercial, or recreational) that target any natural population of steelhead from the Snohomish River basin. However, the earliest returning natural-origin steelhead are harvested or impacted incidentally in fisheries directed at hatchery-origin steelhead, or in other freshwater directed salmon fisheries.

During the 2001/02 to 2006/07 seasons, an average of 325 steelhead (natural- and hatchery-origin combined) were encountered (i.e., caught) in Puget Sound marine treaty and non-treaty commercial, ceremonial and subsistence and recreational fisheries (i.e., 126 treaty marine; 1 non-treaty commercial; 198 non-treaty recreational) (this and following from NMFS 2015a). An average of 176 steelhead have been encountered in marine treaty and non-treaty commercial, ceremonial and subsistence, and recreational fisheries (i.e., 49 treaty marine; 5 non-treaty commercial; 122 non-treaty recreational) for the most recent time period (2008/2009 to 2013/2014). Since not all fish in marine area fisheries are sampled for marks, this annual estimate includes both encounters (fish that will be caught and released) and incidental mortality of ESA-listed natural-origin steelhead and hatchery origin steelhead. Overall, marine treaty and non-treaty fisheries have demonstrated a decrease in steelhead encounters of 46% from 2008/2009 to 2013/2014 as compared to the previous 2001/2002 to 2006/2007 time period. Retention of steelhead in non-treaty commercial fisheries is prohibited in all marine areas. Washington State prohibits the retention of natural-origin steelhead in all recreational fisheries within the Puget Sound ESU boundaries. In general, Puget Sound Treaty Indian freshwater fisheries primarily target hatchery-origin steelhead during the early winter months when natural-origin steelhead are absent or at low abundance.

Long-term time series data, including escapement and harvest information, are lacking for all natural steelhead populations within the action area. Five Puget Sound watersheds have data sufficient to determine harvest rates (Skagit, Snohomish, Green, Puyallup, and Nisqually watersheds). Analyses of these data indicate the annual terminal harvest rates on ESA-listed natural-origin steelhead under the current Puget Sound fisheries management approach averaged 1.8 percent annually in Puget Sound fisheries during the 2007/2008 to 2013/2014 time period (NMFS 2015a).). Given the similarity of recent freshwater fisheries and the predominance of hatchery fish in the forecast for the 2015-16 fishery season, the projected catch of hatchery-origin and natural-origin Puget Sound steelhead in freshwater treaty and non-treaty fisheries for the five representative populations is 1.8 percent. This impact level is below the level of 4.2 percent estimated for the period when the fish were listed under the ESA (NMFS 2015a). At the time of listing, NMFS determined that the current harvest management strategy, including the termination of fishing directed at natural-origin steelhead in Puget Sound had largely addressed the threat of decline to the listed DPS posed by harvest (72 FR 26722, May 11, 2007).

For Chinook salmon, because of their earlier (summer-fall month) adult migration and spawn timing, Chinook salmon are absent from freshwater areas within the action area where fisheries directed at EWS occur. Harvest impacts on ESA-listed Chinook salmon in EWS directed fisheries are therefore negligible. In summary, and as mentioned in Section 1.3.2, NMFS analyzed the effects of all fisheries on listed Snohomish River basin salmon and steelhead, and concluded that fishing within and outside of the action area is not likely to jeopardize the continued existence of the Puget Sound Steelhead DPS and the Puget Sound Chinook salmon ESU, or adversely modify designated critical habitat for these listed species (NMFS 2015a).

Within the action area, Tulalip tribal commercial and ceremonial and subsistence fisheries for primarily hatchery-origin salmon and steelhead occur seasonally in Everett Bay, Port Susan, Tulalip Bay, and in the lower Snohomish River, contingent on the availability of fish surplus to escapement needs. WDFW-managed non-Indian commercial fisheries in Everett Bay target surplus returning coho, fall chum, and pink salmon. Non-Indian commercial fishing is closed to steelhead in all areas, although there is some incidental harvest mortality in salmon-directed fisheries. Recreational fisheries for salmon and unlisted steelhead managed by WDFW occur in the Snohomish River, Snoqualmie River, and Skykomish River. Between 2000 and 2012, annual tribal and non-Indian fishery harvests of non-listed hatchery-origin EWS in the analysis area averaged 95 and 4,482 fish, respectively (WDFW 2014a).

Annual Tulalip tribal fisheries targeting non-listed hatchery winter steelhead in the action area are conducted for commercial, subsistence, and ceremonial purposes. Commercial tribal harvest of steelhead is restricted to marine areas (Everett Bay and Tulalip Bay). Pursuant to court orders, the tribes have not opened fisheries directed at hatchery-produced summer steelhead, but rather choose to pursue their allocation of summer steelhead in the winter steelhead fishery, which occurs in the fall and winter months. Depending on the river basin (Stillaguamish, Skykomish, Snoqualmie Rivers and several other tributaries), the steelhead recreational fishery is open from June 1 to January 31 (or February 15 for a sport fishery at the mouth of Tokul Creek). Angling regulations require release of any natural-origin (unmarked) steelhead encountered) and are structured to allow harvest of trout, marked steelhead, and/or salmon. The daily retention limit during open fishing periods is two hatchery origin (marked) steelhead over 20 inches, and/or trout over 14 inches per day. The areas and time periods open to the recreational fishery are adjusted and/or closed if in-season information (i.e. monitoring the hatchery escapement) suggests a shortfall in broodstock. There is currently no accounting for the mortality of unmarked wild steelhead caught and released in these recreational fisheries. Estimated catch-and-release mortalities are included in pre-season fishery management plans.

2.3.2 Hatcheries

Another important aspect of the Environmental Baseline is hatchery effects, including past effects from the EWS programs evaluated in this opinion (Section 2.4.2), effects of other salmon and steelhead hatchery programs operating in the action area, and, effects from hatchery fish that stray into the action area from hatchery programs located outside the Snohomish River basin. Past operation of steelhead and salmon hatchery programs in the basin may have affected the viability of steelhead and Chinook salmon natural populations. The factors in analyzing hatchery effects are identified in Section 2.4.1. Through these factors and their effects, the EWS hatchery programs considered in this opinion have likely had some negative effect on the abundance, diversity, spatial structure, and productivity of the natural-origin steelhead populations in the two watersheds where the EWS are released.

Steelhead hatchery programs in Puget Sound were initiated beginning in the early 1900s. In 1935, steelhead returning to Chambers Creek were used to establish a hatchery stock that was subsequently released throughout much of Puget Sound (Crawford 1979), including in the Skykomish and Snoqualmie river basins (1960s; WDFW 2014a; 2014b). During the 1960s, advances in hatchery cultural techniques led to further development of the Chambers Creek (aka “Early Winter”) hatchery-origin stock through broodstock selection and accelerated rearing practices (Crawford 1979). The earliest maturing adult steelhead were selected in order to produce fish that smolted at one year of age, rather than what normally occurs in the wild, at age-2 or older (WDFW 2005a). The Snohomish basin program began collecting hatchery broodstock in the early-1960s (WDFW 2014a; 2014b, and following). From the late-1970s to late-1990s, the Snohomish River basin EWS released at all sites in the basin were propagated from adult returns to Tokul Creek (and Whitehorse Ponds when insufficient broodstock was available). Prior to 1994, eggs collected at Tokul Creek were incubated to the eyed stage on-site and transferred to Lakewood Hatchery for further incubation, rearing, and mass-marking subsequent to dispersal of juvenile EWS for rearing and release in other Puget Sound areas, including the Snohomish Basin. The current goal for the Snohomish River basin EWS program is to manage the two programs separately. Beginning last year (in 2015), broodstock for the Wallace/Reiter EWS program will be maintained primarily through collection of adults returning to Wallace River Hatchery and Reiter Ponds.

No genetic data for Puget Sound steelhead are available that reflect the patterns of genetic diversity among Puget Sound steelhead populations that existed before the EWS programs began. Thus, although NMFS assumes that these patterns have been altered to some degree over the years by returning EWS spawning in the wild with naturally produced winter steelhead, the cumulative impact of the EWS programs on genetic diversity (and fitness) is unknown. The Chambers Creek stock, originating from a south Puget Sound stream, is simply too similar in molecular genetic profile to other Puget Sound steelhead populations to leave a clear gene-flow signal.

Although no data are available on genetic diversity among Puget Sound steelhead from years before hatchery programs began, in the early 2000's WDFW researchers attempted to gain some perspective on diversity changes in Puget Sound steelhead by comparing genetic profiles (based on allozyme[7] data) of a small group of steelhead populations that had been sampled in the 1970's and then again in the 1990's (Phelps et al. 1997) to the genetic profile of Chambers Creek steelhead. Some results from this analysis are presented in Scott and Gill (2008, Table 4.5), including estimates of gene flow over the 20-yr period into the North Fork Stillaguamish that ranged from 3 to 10%. Although these results seem plausible, in general the analysis led to mixed, unsatisfactory results, likely due to the effects of random genetic drift (see Section 2.4.1) and sampling[8]. As can be seen from the summary of the source data (Phelps et al. 1997, Table 4-1) there was no clear tendency of the resampled populations to be genetically closer to EWS in the 1990's than in the 1970's.

Another potential approach to determining cumulative effects of gene flow from hatchery programs is comparison of among-population diversity in groups of populations that have been subjected to hatchery influence with those that have been subjected to less or none. However, in any group of populations, among-population diversity patterns are a reflection of fluctuations in population size and natural gene flow, as well as the age of the populations, and other factors. We know of no existing group of steelhead populations is sufficiently genetically unaffected by hatchery releases and similar to Puget Sound in terms of age and geological history to serve as a reference for pre-hatchery influence genetic diversity.

In the case of summer steelhead, the production and release of hatchery-origin Skamania stock lineage early summer steelhead (ESS) into the Snohomish basin has negatively affected the abundance, diversity, spatial structure, and productivity of the winter and summer steelhead natural populations. ESS returns in Puget Sound, derived approximately 40 years ago from transplanted Columbia River basin Washougal and Klickitat stock, were similarly developed through hatchery release programs in the Stillaguamish, Snohomish, and Green River watersheds. Self-sustaining broodstock returns have been maintained in Stillaguamish River watershed hatcheries for about 30 years (WDFW 2005a). Hatchery smolts from these cultured stocks, released at a size of 5 to 6 fish per pound (198 – 210 mm fl), have been shown to emigrate quickly seaward after release, and survive well to adult return. ESS are thought to spawn somewhat earlier than summer steelhead natural populations in Puget Sound (Myers et al. 2015 citing Campbell et al. 2008), with spawn timing analyses suggesting peak spawning activity for ESS in February, and peak spawning for steelhead from natural-origin populations in mid-April. While the genetic profile of the Chambers Creek EWS stock is too close to the other Puget Sound steelhead

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[7] Allozymes are genetic variants of proteins, usually enzymes. From the 1960's into the early 1990's, allozyme variation was the major source of molecular data available on plant and animal populations. Current molecular methods that focus instead on DNA are capable of detecting more genetic variability with far less data interpretation variation between labs.

[8] Analysis was done by Craig Busack, one of the authors of this opinion.

populations to be able to assess cumulative gene flow effects, more can be said in the case of releases of ESS because of their Columbia Basin origin. This is discussed in greater detail in Section 2.4.2, but WDFW estimates that impacts to two summer steelhead populations in the Snohomish Basin have been so large that they are now considered feral populations of Skamania-stock fish (Warheit 2014a).

The EWS hatchery programs have largely been successful at producing hatchery fish that generally return to freshwater earlier and spawn earlier than the majority of steelhead from natural populations, enabling selective harvest of the hatchery-origin fish (Crawford 1979). Some overlap in river entry timing has been observed, which may lead to incidental harvest of steelhead from natural populations at low levels (e.g., harvest rate of 1.8 percent [Section 2.3.1]) in fisheries targeting EWS (Hard et al. 2007; NMFS 2015a). Overlap in spawn timing between the latest spawning EWS and the earliest returning steelhead from natural populations has been reported in some Puget Sound watersheds (Pess et al. 2010; McMillan 2015a). Based on field observations of estimated redd counts and personal assignments of the origin of fish creating the redds (hatchery and natural), McMillan (2015a) reported that overlap was substantial in five tributaries within the Skagit River watershed. However, a closer look at the report reveals that this conclusion is not supported by the data. Only 6 natural-origin steelhead were observed during the five year period surveyed and only one wild steelhead was observed prior to March. Five hatchery-origin steelhead were observed during the five year period of surveys, and none were observed after March 12. Within the five year period no hatchery-origin steelhead were observed spawning with natural-origin steelhead.

McMillan (2015b) estimated that within five mid-Skagit River basins, 17% of all steelhead redds were constructed prior to March 15 in the 2014/15 spawning season and that 50 to 67 percent of the early redds were constructed by hatchery origin steelhead; this equates to an estimated 8.5 to 5.6 percent of natural-origin steelhead redds being constructed prior to March 15. However, this spawn timing is not likely representative of the entire DIP. Telemetry studies within the Skagit River system indicate that most of the earliest arriving natural-origin steelhead are from the middle Skagit reach (Pflug et al. 2013). WDFW spawning ground survey data indicates that the earliest natural-origin spawners are typically seen in middle Skagit tributaries such as Finney and Grandy Creeks (Brett Barkdull, personal communication *in* Pflug et al. 2013). WDFW spawning ground survey data indicate that redds/mile surveyed are higher from January through February than the first half of March, further suggesting many of the early steelhead redds counted in McMillan (2015a; 2105b) were likely hatchery-origin steelhead. Genetic analysis of unmarked adult steelhead in Finney Creek contained no hybrids and one adult that was the progeny of two hatchery origin steelhead (Warheit 2014a), further suggesting minimal or no hybridization is occurring in Finney Creek.

There also have to be reservations with the analysis in McMillan (2015a) based on the large numbers of coho salmon in the surveys from January through early-March. In the surveys, coho salmon outnumbered steelhead 28:1, but McMillan (2015a) only estimated 4.7 coho redds per steelhead redd. The over five-fold difference between the ratios of estimated coho salmon to steelhead redds at least suggests the possibility of an error or errors in assigning each species to the number of observed redds. During the years surveyed, the majority (63%) of estimated steelhead redds observed prior to mid-March occurred during a three-year period when steelhead redds outnumbered coho redds 1.2-to-1, but only coho salmon were observed in the streams. This finding further suggests McMillan (2015a) erred in the assignment of redds to species.

Regarding estimates of EWS and natural-origin steelhead spawn timing overlap in the Skagit River watershed reported by McMillan (2015a), the spawning ground data provided to NMFS (Tynan 2015), collected in the same locations and during the same time periods, is substantially different(WDFW 2015b). These data indicate that observations by (McMillan 2015) of redd counts are overestimates of the number of steelhead redds actually constructed. McMillan (2015a) reported over three times as many redds as WDFW data for the same times and in the same survey reaches.

Other data suggest that the degree to which EWS and natural-origin steelhead overlap in Puget Sound spawning areas is very low, and that redd count and species assignment data suggesting otherwise are of questionable validity (WDFW 2015a). Steelhead spawning ground survey data reported in Scott and Gill (2008) indicate that approximately 11-percent of the natural-origin steelhead in Snow Creek (an independent tributary to Discovery Bay) spawn prior to March 15. Hoffman (2014) determined that this corresponds to a natural-origin overlap with EWS equal to approximately 7-percent. Recently collected spawning ground survey data from the Nooksack River indicate that approximately 5 percent of the steelhead redds were observed prior to March 15 (WDFW, unpublished spawning ground survey data). Comprehensive spawning ground surveys conducted in 2015 in the Dungeness River basin indicate that approximately 4 percent of all steelhead redds were observed prior to March 15 (Jamestown Tribe, unpublished spawning ground survey data). In 2009, extensive early surveys were conducted in the mainstem Pilchuck River (a tributary to the Snohomish River) and only three redds (2.5% of all redds observed) were observed prior to April 10th (WDFW, unpublished spawning ground surveys). All three redds were observed on February 12 suggesting these redds were likely constructed by hatchery-origin steelhead. Hoffman (2014) used river-specific redd data to model steelhead temporal spawning distributions, and estimated that 1.96, 1.88, and 2.1 percent of all redds were constructed prior to March 15 in the Skykomish, Pilchuck, and Snoqualmie rivers, respectively.

Substantial changes in EWS production strategies have been implemented since the inception of programs in Puget Sound to reduce negative effects on co-occurring natural populations. Beginning in 1991, all juvenile fish released from EWS programs were marked with an adipose fin clip to allow for effective identification and differentiation from natural-origin steelhead in migration, spawning, and harvest areas. As indicated in the HGMPs under review (WDFW 2014a; 2014b), further Puget Sound-wide measures were implemented beginning in the early 2000s specifically to reduce negative effects to natural-origin winter-run steelhead. These measures included a greater than 50% reduction in the number of EWS smolts released each year from the programs covered by the HGMPs to reduce the number of interactions between juvenile and adult EWS steelhead and natural-origin steelhead in natural habitat. Since 2004, annual EWS smolt release numbers from Snohomish River basin hatcheries have been reduced by 47%, from 457,000 fish to approximately 242,000 fish.

Another measure implemented in the Snohomish Basin programs to reduce negative effects was a greater than 65% reduction in EWS smolt release locations. For example, annual off station transfers and releases of smolts from the Snohomish River basin hatcheries into the Pilchuck River, Raging River, Sultan River, N.F. Skykomish River, Barr Creek, Howard Creek, Silver Creek, and Index Creek, have been terminated. To reduce the risk of EWS adult straying into natural steelhead spawning areas, cross-basin smolt transfers (e.g., from Reiter Ponds to Canyon Creek), off-station smolt releases (e.g., Reiter Ponds into Pilchuck River), and recycling of adult EWS captured at the hatcheries into natural migration areas have been eliminated. EWS fry releases into anadromous waters have also been eliminated to reduce the risk of extended ecological interactions in freshwater resulting from hatchery fish rearing to smolt size in natural steelhead production areas. To reduce the duration of hatchery and natural-origin steelhead interactions, and negative ecological effects, all Puget Sound EWS hatchery programs (except Dungeness River Hatchery) apply volitional smolt release practices so that EWS smolts emigrate quickly downstream, without residualizing. Smolts that do not migrate after a three to six week period are collected and planted into non-anadromous waters. To reduce the overlap in spawn timing between EWS and natural-origin steelhead, EWS hatchery broodstock are collected no later than January 31st each year. To reduce the number of hatchery steelhead that escape to spawn naturally, hatchery broodstock collection weirs are maintained open from January 31st through mid-April to capture and cull any EWS returning later than January 31st. Finally, to monitor the genetic effects resulting from EWS straying into natural-spawning areas, tissue samples are collected from naturally spawning steelhead and their progeny for DNA analyses.

Under the current baseline in the action area, hatcheries remain a very important feature of salmon and steelhead conservation and management. On average, 104 hatchery programs release between 140 and 150 million juvenile salmon and steelhead into Puget Sound freshwater and marine areas each year. This total includes approximately 46 million Chinook salmon; 14-15 million coho salmon; 44-45 million fall chum salmon; 4-5 million pink salmon; 35 million sockeye salmon; and 2 million steelhead (NMFS 2014). In Puget Sound, run size and escapement monitoring indicate that for recent years, hatchery-origin fish make up 76% of all Chinook salmon returns, 47% of all coho salmon returns, 29% of all fall chum salmon returns, 30% of all sockeye salmon returns, and 2% of all pink salmon returns (NMFS 2014). Hatchery-origin steelhead make up an average of 46% of all steelhead returns (Subsection 2.4.2.4).

In addition to the two EWS hatchery programs considered in this opinion, WDFW and the Tulalip Tribes operate six other hatchery salmon programs in the action area (Table 10). Three programs are operated by WDFW and three are operated by the Tulalip Tribes. The primary purpose or reason for the hatchery programs is to mitigate for losses to tribal and non-tribal fisheries resulting from past and on-going human developmental activities in the Snohomish River basin, and from climate change. The goals for the programs are to provide Chinook, coho and chum salmon for harvest to support regional fisheries, provide values associated with Treaty-reserved fishing rights recognized by the Federal courts, and help to meet Pacific Salmon Treaty harvest sharing agreements with Canada (Tulalip 2012; WDFW 2013).

The effects of the programs described in Table 10 on ESA-listed Chinook salmon and steelhead are likely to include migration delay or blockage, and water quantity and quality effects on freshwater migration and rearing areas from operation of facilities used to rear hatchery fish; competition and predation and fish disease pathogen transfer occurring when juvenile hatchery fish are released into the natural environment and when adult hatchery-origin fish return to spawn, and for the programs producing Chinook salmon and steelhead, genetic diversity effects (within and among population diversity loss; hatchery-influenced selection) resulting from broodstock selection, mating and rearing practices applied while the fish are under propagation, and interbreeding between hatchery-origin and natural-origin fish in natural spawning areas. The purposes of the hatchery programs, their broodstock sources, their locations, and how they are operated to reduce negative effects to listed Chinook salmon and steelhead are therefore of critical importance regarding listed fish effects. Harvest-directed programs that rear fish in freshwater locations where no delineated Chinook salmon or steelhead populations are present (e.g., Tulalip and Battle creeks), with releases nearly into saltwater, are expected to have unsubstantial or negligible effects.

Table 10. Salmon hatchery programs operating in the action area, with species produced, program purpose, proposed annual juvenile fish release numbers, life stages, timings, and locations (data from WDFW and Tulalip Tribes HGMPs).

Program	Purpose	Release Number (millions)	Life Stage	Release Timing	Release Location
Tulalip Summer Chinook Salmon	Harvest	2.4	Subyearling	May	Tulalip Creek
Tulalip Bay Hatchery Coho Salmon	Harvest	2.0	Yearling	May - June	Tulalip Creek
Tulalip Bay Hatchery Chum Salmon	Harvest	12.0	Fed fry	April to mid-May	Battle Creek
Wallace River Hatchery Summer Chinook Salmon	Harvest	0.5	Yearling	April	Wallace River
	Harvest	1.0	Subyearling	June	Wallace River
Wallace River Hatchery Coho Salmon	Harvest	0.15	Yearling	May	Wallace River
Everett Bay Net-Pen Coho Salmon	Harvest	0.02	Yearling	June	Everett Bay

Tribal and state co-managers and NMFS have worked on the HGMPs for the six Snohomish River basin hatchery salmon programs described in Table 10 and the co-managers have requested that NMFS consider the HGMPs for approval under limit 6 of the 4(d) rule. NMFS has determined that they are sufficient for consideration under the ESA 4(d) rule and has initiated that review process. NMFS anticipates that a Pending Evaluation and Proposed Determination and a draft NEPA analysis will be published for public review in 2016. In the meantime, NMFS' Draft EIS (DEIS) for Puget Sound hatcheries analyzes and discloses Snohomish River watershed salmon hatchery effects on ESA-listed Chinook salmon and steelhead (NMFS 2014). Evaluations of the risks and benefits of the six Snohomish River basin salmon programs identified in Table 10 are included in the Draft EIS.

From the DEIS, the Tulalip Bay Chum Salmon and Everett Bay Net Pen Coho Salmon hatchery programs do not have a negative effect on ESA-listed fish. The hatchery programs produce non-listed species that do not interbreed with Chinook salmon or steelhead, so there are no genetic risks. Because of their small size at release, and due to differences in migration behavior and diet preferences, fall chum salmon fry produced by the Tulalip program pose negligible ecological risks to listed fish species. The fall chum salmon program operates on a stream where no listed species are present, so facility operation effects are not a risk factor. Delayed release coho salmon produced by the Everett Bay Net Pen program are released directly into seawater, and have no freshwater ecological effects on ESA-listed fish species. Because of the marine water location of the net pen program, coho salmon production through the program poses no effects of facility operation on listed fish. The Tulalip Bay Hatchery Coho Salmon program releases yearlings into a stream lacking ESA-listed fish and directly into seawater, so there are no effects on listed fish in freshwater associated with competition or predation.

The Wallace River Coho Salmon hatchery program could have predation effects on any co-occurring juvenile steelhead and Chinook salmon in the Wallace River, Skykomish River and Snohomish River after the yearling smolts are released from the hatchery. Coho salmon yearlings released from both hatchery programs could also prey on ESA-listed juvenile Chinook salmon as they enter seawater. The Wallace River Hatchery and Tulalip Hatchery summer Chinook salmon hatchery programs operate for integrated harvest, and both produce hatchery-origin fish that are ESA-listed (they are not diverged from the local Chinook salmon population) could benefit the viability status of the Skykomish River Chinook salmon natural population. Hatchery-related risks from the summer Chinook salmon programs are genetic diversity reduction effects on Snohomish River basin natural Chinook salmon populations; resource competition effects on co-occurring natural-origin juvenile Chinook salmon and steelhead in freshwater and estuary areas after the hatchery-origin Chinook salmon are released; and predation effects on natural-origin juvenile Chinook salmon in basin freshwater migration areas after the hatchery-origin Chinook salmon are released.

The Reiter Ponds ESS are likely to prey on natural-origin juvenile Chinook salmon and steelhead in the Snohomish River watershed during the short time they are in the river following release from the hatchery. Facility operation effects on ESA-listed fish species are not a concern because of the hatchery location on a small creek where no natural-origin ESA-listed-salmon and steelhead are known to exist (Austin and Hogarty creeks). The program may have genetic diversity reduction effects on natural-origin steelhead due to straying by returning adult hatchery-origin steelhead into natural spawning areas. Overlap in spawn timing between returning adult hatchery-origin non-native ESS originating from the Reiter Ponds program and natural-origin steelhead in the Snohomish River watershed creates the potential for gene flow into naturally producing steelhead populations, which may adversely affect their genetic integrity. Augmenting effects analysis in the Draft Hatchery EIS (NMFS 2014), Warheit (2014a) found that isolated EWS and ESS hatchery programs have negatively affected the genetic structure of associated natural steelhead populations to varying degrees. A higher level of gene flow (measured as "Proportion Effective Hatchery Contribution" or "*PEHC*") from hatchery-origin ESS was found in the N.F. Skykomish and Tolt rivers compared to all other collections in the Puget Sound. Analysis of the N.F. Skykomish River summer run sample indicated an average ESS *PEHC* of 95%, with a ninety percent confidence interval of 94% to 96% (Warheit 2014a, Table 8). Analysis of the S.F. Tolt River summer run sample indicated an average ESS *PEHC* of 69%, with a ninety percent confidence interval of 59% to 80% (Warheit 2014a, Table 8). Analysis of the Snoqualmie, Skykomish, and Pilchuck river winter-run steelhead samples indicated an average ESS *PEHC* (from past practices) of 3-, 5-, and 3-percent, respectively (Section 2.4.2.3). As a measure to reduce gene flow from the Reiter Ponds ESS program, beginning in 2016, WDFW is reducing annual ESS smolt release levels by 40%, from a recent five-year average of 193,000 fish to 116,000 fish (Unsworth 2016), thereby substantially reducing the number of returning adult ESS that could stray into natural summer steelhead spawning areas. The *PEHC* estimated for this hatchery program into the winter-run steelhead natural populations in the Snoqualmie, Skykomish, and Pilchuck rivers is now estimated to decline to 0-, 2-, and 0-percent, respectively (Unsworth 2016).

The effects of salmon and steelhead hatchery programs outside of the action area on natural Chinook salmon and steelhead populations in the Snohomish River watershed are unknown but, for most hatchery-related factors, are likely unsubstantial for the following reasons. The closest programs are in the Stillaguamish River watershed. Because of the geographic distance separating the two watersheds, and considering life history strategies for salmon during their freshwater phase that sequester rearing and migrating fish to their natal streams, juvenile fish from the Stillaguamish watershed are unlikely to interact with salmon and steelhead in the action area, and substantial ecological effects are unlikely. The degree to which hatchery-origin salmon and steelhead adults originating from outside the action area stray into the Snohomish River watershed has not been quantified, but it is unlikely that straying occurs at levels that are different from stray rates exhibited by their natural-origin Puget Sound salmon and steelhead cohorts. Measures have been implemented at Puget Sound region hatcheries to reduce the likelihood for straying into other watersheds, including use of native-origin or localized broodstocks that will have a high return fidelity to their natal watersheds, and rearing and acclimation of juvenile fish prior to release in their watersheds of origin. Among-population diversity reduction effects from out-of-basin hatchery steelhead and salmon straying into action area watersheds would be negligible if assumptions of low levels of straying that are no greater than levels exhibited by the species naturally persist.

2.3.3 Other Restoration and Recovery Activities

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established by Congress to help protect and recover salmon and steelhead populations and their habitats (NMFS 2007). The states of Washington, Oregon, California, Idaho, and Alaska, and the Puget Sound, Pacific Coastal and Columbia River tribes, receive PCSRF appropriations from NMFS each year. The fund supplements existing state, tribal and local programs to foster development of Federal-state-tribal-local partnerships in salmon and steelhead recovery. The PCSRF has made substantial progress in achieving program goals, as indicated in annual Reports to Congress, workshops, and independent reviews.

The federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (Ruckelshaus et al. 2005), Volume II of the plan (SSPS 2005), and the Snohomish River Basin Salmon Conservation Plan (SBSRF 2005) describe, in detail, on-going and proposed state, tribal, and local government restoration and recovery activities for listed Chinook salmon in the Snohomish River basin. Snohomish River basin habitat restoration activities are also guided by the State of Our Watersheds report, that examines key indicators of habitat quality and quantity within the Tulalip Tribes' usual and accustomed fishing area (accessible at: http://maps.nwifc.org:8080/sow2012/). Many of the projects currently being implemented in the Snohomish River basin are funded through the PCSRF. Although a recovery plan for Puget Sound steelhead, including summer- and winter-run populations in the Snohomish River basin, has yet to be complete, many of the actions implemented for Chinook salmon recovery will also benefit steelhead. Tribal, state, and local government fish restoration actions include legislation, administrative rules, policy initiatives, and land use and other types of permits. Government and private actions may also include changes in land and water uses, including ownership and intensity that would benefit listed species.

Habitat protection and restoration actions implemented thus far in the Snohomish River basin have focused on the preservation of existing habitat and habitat-forming processes; protection of nearshore environments, including estuaries and marine shorelines; instream flow protection and enhancement; and reduction of forest practice and farming impacts to salmon habitat. Specific actions to recover listed salmon and steelhead have included: implementation of land use regulations to protect existing habitat and habitat-forming processes through updating and adopting Federal, state, and local land use protection programs, as well as more effectively combining regulatory, voluntary, and incentive-based protection programs; implementation of nearshore and shoreline habitat protection measures such as purchase and protection of estuary areas important for salmon productivity; protection and restoration of habitat functions in lower river areas, including deltas, side-channels, and floodplains important as rearing and migratory habitat; implementation of protective instream flow programs to reserve sufficient water for salmon production; and implementation of protective actions on agricultural lands.

Recent examples of habitat restoration and salmon recovery projects funded through the PCSRF and state sources that are expected to benefit listed Snohomish River steelhead population viability include:

- Purchase and preservation of high quality floodplain, off-channel and riparian habitat between river mile four and five on the Tolt River, a tributary to the Snoqualmie River. One 6.33-acre parcel purchased borders 1,200 feet of a side channel to the Tolt River and the other 0.7 acre parcel purchased borders 160 feet of the Tolt River.

- Restoration of a 2.8 mile reach on the Lower Skykomish River to improve instream and floodplain habitat through placement of floodplain flood fencing interplanted with trees, modular log jam structures, habitat boulder-ballasted logs with rootwads, edge complexity wood structures, bio-engineered fabric, and plantings that will work with natural channel processes to promote habitat and water quality improvements, and to help safeguard the productivity of adjoining floodplain areas.

- Enhancement of degraded riparian and wetland areas adjacent to streams and shorelines in the Tulalip Bay area through riparian and wetland riparian planting projects, replacement of an undersized 4-foot diameter culvert, removal of approximately 4,900-sq ft. of non-native plant species from the stream bank and replacement with 4,900-sq ft. of native vegetation, supplementation of an additional 9,000 square feet of riparian area with native tree planting, placement of in-stream LWD, and channel realignment and habitat feature installation.

- Project design to remove a barrier to fish passage and improve the habitat in a back channel to the Snohomish River, resulting in re-connection of nearly 10 acres of back-channel habitat, 2.4 miles downstream of the confluence of the Skykomish and Snoqualmie Rivers.

- Re-establishment of 50 foot wide riparian buffers along 1 mile of the Pilchuck River through invasive vegetation control, planting native trees, exclusion of livestock, and installation of beaver fencing around trees to promote survival of native vegetation.

Over the last several years, NMFS has completed several section 7 consultations on large-scale habitat projects affecting listed species in the action area. Among these are the Washington State Forest Practices Habitat Conservation Plan (NMFS 2006a), and consultations on Washington State Water Quality Standards (NMFS 2008a) and the National Flood Plain Insurance Program (NMFS 2008b). These documents considered the effects of the proposed actions that would occur up to the next 50 years on the ESA listed salmon and steelhead species in the action area, and more comprehensively, in the Puget Sound basin. The environmental baselines in these documents consider the effects from timber, agriculture and irrigation practices, urbanization, hatcheries and tributary habitat, estuary, and large scale environmental variation. These biological opinions and HCPs, in addition to the watershed specific information in the recovery plans for the Snohomish River basin mentioned above, provide a current and comprehensive overview of baseline habitat conditions in Puget Sound. The portions of those documents that deal with effects in the action area (described in Section 2.4) are hereby incorporated by reference.

2.4 Effects on ESA Protected Species and on Designated Critical Habitat

This section describes the effects of the Proposed Action, independent of the environmental baseline and cumulative effects. The "effects of the action" means the direct and indirect effects of the action on the species and on designated critical habitat, together with the effects of other activities that are interrelated or interdependent, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the Proposed Action and are later in time, but still are reasonably certain to occur. Effects of the Proposed Action that are later in time (i.e., after expiration of the Proposed Action) are included in the analysis in this opinion. In Section 2.6, the Proposed Action, the status of ESA-protected species and designated critical habitat under the Environmental Baseline, and the cumulative effects of activities within the action area that are reasonably certain to occur are analyzed comprehensively to determine whether the Proposed Action is likely to appreciably reduce the likelihood of survival and recovery of ESA protected species.

2.4.1 Factors That Are Considered When Analyzing Hatchery Effects

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 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.

This section describes the methodology NMFS follows to analyze hatchery effects. The methodology is based on the best available scientific information. Analysis of the Proposed Action itself is described in Section 2.4.2 of the opinion.

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

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 on the general type of effect of that aspect of hatchery operation in the context of the specific application in the Snohomish River basin. This allows the clear quantification (wherever possible) of the various factors of hatchery operation to be applied to each applicable life-stage of the listed species, at the population level (in Section 2.4.2), which, in turn, allows the combination of all such effects with other effects accruing to the species to determine the likelihood of posing jeopardy to the species as a whole (Section 2.6).

The effects, positive and negative, for two categories of hatchery programs are summarized in Table 11. Generally speaking, effects range from beneficial to negative for programs that use local fish[9] for hatchery broodstock and from negligible to negative when a program does not use local fish for broodstock[10]. Only integrated propagation programs can benefit population viability. Integrated hatchery programs use local fish for broodstock (natural-origin and hatchery-origin fish included in an ESU or DPS), follow "best management practices", and are designed around natural evolutionary processes that promote population viability (NMFS 2004b). When hatchery programs use fish originating from a different population, MPG, or from a different ESU or DPS, including programs like the Proposed Action, NMFS is particularly interested in how effective the program will be at isolating hatchery fish and avoiding co- occurrence and effects that potentially disadvantage fish from natural populations. The range in effects are refined and narrowed after available scientific information and the circumstances and conditions that are unique to individual hatchery programs are accounted for.

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.

NMFS analyzes seven hatchery-related factors for their effects on ESA-listed species. The seven factors are:

(1) broodstock origin and collection,
(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds,
(3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas,
(4) hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, estuary, and ocean,
(5) research, monitoring, and evaluation (RM&E) that is called for by the hatchery program,
(6) the operation, maintenance, and construction of hatchery facilities, and
(7) fisheries that occur because of the hatchery program.

2.4.1.1 Broodstock collection

Broodstock collection is arguably the single most important aspect of a hatchery program and is therefore a particularly important factor in the effects analysis. The first consideration in analyzing and assigning effects for broodstock collection is the origin and number of fish collected. The analysis

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[9] The term "local fish" is defined to mean fish that are no more than moderately divergent from the associated local natural population. See 70 FR 37204, June 28, 2005.

[10] Exceptions include restoring extirpated populations and gene banks.

Table 11. Range in effects on natural population viability parameters from two categories of hatchery programs. The range in effects are refined and narrowed after the circumstances and conditions that are unique to individual hatchery programs are accounted for.

Natural population viability parameter	Hatchery broodstock originate from the local population and are included in the ESU or DPS	Hatchery broodstock originate from a non-local population or from fish that are not included in the same ESU or DPS
Productivity	**Positive to negative effect.** Hatcheries are unlikely to benefit productivity except in cases where the natural population's small size is, in itself, a predominant factor limiting population growth (i.e., productivity).	**Negligible to negative effect.** Effects dependent on differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish the greater the threat), the duration and strength of selection in the hatchery, and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect).
Diversity	**Positive to negative effect.** Hatcheries can temporarily support natural populations that might otherwise be extirpated or suffer severe bottlenecks and they also have the potential to increase the effective size of small natural populations. Broodstock collection that homogenizes population structure is a threat to population diversity.	**Negligible to negative effect.** Effects dependent on the differences between hatchery fish and the local natural population (i.e., the more distant the origin of the hatchery fish the greater the threat) and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect).
Abundance	**Positive to negative effect.** Hatcheries can increase genetic resources to support recovery of an ESU or DPS in the wild. Using natural fish for broodstock can reduce abundance.	**Negligible to negative effect.** Effects dependent on the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect), and specific handling, RM&E, and facility operation, maintenance and construction actions.
Spatial Structure	**Positive to negative effect.** Hatcheries can accelerate re-colonization and increase population spatial structure, but only in conjunction with remediation of the factor(s) that limited spatial structure in the first place.	**Negligible to negative effect.** Effects dependent on facility operation, maintenance, and construction actions and the level of isolation achieved by the hatchery program (i.e., the greater the isolation the closer to a negligible effect).

considers whether broodstock are of local origin and the consequences of using ESA-listed fish (natural or hatchery-origin). It considers the maximum number of fish proposed for collection, the proportion of the donor population tapped for broodstock, and whether the program "backfills" with fish from outside the local or immediate area. "Mining" a natural population to supply hatchery broodstock can reduce population abundance and spatial structure.

The analysis also considers the effects from encounters with ESA-listed fish that are incidental to the conduct of broodstock collection. Here, NMFS analyzes the effects on ESA-listed fish when they encounter weirs, volunteer into fish ladders, or are subject to sorting and handling in the course of broodstock collection. Some programs collect their broodstock from fish volunteering into the hatchery itself, typically into a ladder and holding ponds, while others sort through the run at large, usually at a weir, ladder, or sampling facility. Generally speaking, the more a hatchery program accesses the run at large for hatchery broodstock – that is, the more fish that are handled or delayed during migration – the greater the negative effect to 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.

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

NMFS also analyzes the effects of hatchery returns and the progeny of naturally spawning hatchery fish on the spawning grounds. There are two aspects to this part of the analysis: genetic effects and ecological effects. NMFS generally views genetic effects as detrimental because at this time, based on the weight of available scientific information, we believe that artificial breeding and rearing is likely to result in some degree of genetic change and fitness reduction in hatchery fish and in the progeny of naturally spawning hatchery fish relative to desired levels of diversity and productivity for natural populations. Hatchery fish thus pose a threat to natural population rebuilding and recovery when they interbreed with fish from natural populations. However, NMFS recognizes that there are benefits as well, and that the risks just mentioned may be outweighed under circumstances where demographic or short-term extinction risk to the population is greater than risks to population diversity and productivity. Conservation hatchery programs may accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford 2011). Furthermore, NMFS also recognizes there is considerable uncertainty regarding genetic risk. The extent and duration of genetic change and fitness loss and the short and long-term implications and consequences for different species, for species with multiple life-history types, and for species subjected to different hatchery practices and protocols remains unclear and should be the subject of further scientific investigation. As a result, NMFS believes that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that harmonize conservation with the implementation of treaty Indian fishing rights and other applicable laws and policies (NMFS 2011).

Hatchery fish can have a variety of genetic effects on natural population productivity and diversity when they interbreed with natural-origin fish. Although there is biological interdependence between them, NMFS considers three major areas of genetic effects of hatchery programs: within-population diversity, outbreeding effects, and hatchery-induced selection. As we have stated above, in most cases, the effects are viewed as risks, but in small populations, these effects can sometimes be beneficial, reducing extinction risk.

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, a random loss of diversity due to population size. The rate of loss is determined by the population's effective population size (N_e). Effective population size, census size adjusted for variation in sex ratio and reproductive success, determines the level of genetic diversity that can be maintained by a population, and the rate at which diversity is lost. Effective size can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, the effective size should be in the hundreds (e.g., Lande and Barrowclough 1987), and diversity loss can be severe if N_e drops to a few dozen. Effective size is typically a per-generation measure. Diversity issues in anadromous salmonids are usually discussed in terms of the single-year version of $N_{e,}$ the effective number of breeders (N_b).

Hatchery programs, simply by virtue of creating more fish, can increase N_e. In very small populations, this 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, such as the programs preserving and restoring Snake River sockeye salmon, South Fork Nooksack Chinook salmon, and Elwha River Chinook salmon, are important genetic reserves. However, hatchery programs can also directly depress N_e through two principal methods. One is by the simple removal of fish from the population so that they can be used in the hatchery. 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). N_e can also be 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 semen is especially problematic because when semen of several males is mixed and applied to eggs, a large portion of the eggs may be fertilized by a single male (Gharett and Shirley 1985; Withler 1988). Factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_e (Fiumera et al. 2004; Busack and Knudsen 2007). An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman et al. 1995; Ryman and Laikre 1991), which N_e is reduced through the return to the spawning grounds of large numbers of hatchery fish from very few parents.

Inbreeding depression, another N_e-related phenomenon, is caused by the mating of closely related individuals (e.g., siblings, half-siblings, or cousins). The smaller the population, the more likely spawners will be related. Related individuals are likely to contain similar genetic material, and the resulting offspring may then have reduced survival because they are less variable genetically or have double doses of deleterious mutations. The lowered fitness of fish due to inbreeding depression accentuates the genetic risk problem, helping to push a small population toward extinction.

Outbreeding effects are caused by gene flow from other populations. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1993; Quinn 1997). Natural straying serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources. Hatchery programs can result in straying outside natural patterns for two reasons. First, hatchery fish may exhibit reduced homing fidelity relative to natural-origin fish (Goodman 2005; Grant 1997; Jonsson et al. 2003; Quinn 1997), resulting in unnatural levels of gene flow into recipient populations, either in terms of sources or rates. Second, even if hatchery fish home at the same level of fidelity as natural-origin fish, their higher abundance can cause unnatural straying levels into recipient populations. One goal for hatchery programs should be to ensure that hatchery practices do not lead to higher rates of genetic exchange with fish from natural populations than would occur naturally (Ryman 1991). Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997).

Gene flow from other populations can have two effects. It can increase genetic diversity (e.g., Aylon et al. 2006) which can be a benefit in small populations, but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population's level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICTRT 2007), and the greater potential for outbreeding depression (Figure 7). For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstocks. Additionally, unusual rates of straying into other populations within or beyond the population's MPG or ESU or a steelhead DPS can have an 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. Reduction of within-population and among-population diversity can reduce adaptive potential.

The proportion of hatchery fish among natural spawners, or "pHOS", is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze hatchery affects. Adult salmon may wander on their return migration, entering and then leaving tributary streams before finally 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). Caution must also be applied in assuming that strays contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Blankenship et al. 2007; Saisa et al. 2003). The causative factors for poorer breeding success of strays are likely similar to those identified as responsible for reduced productivity of hatchery-origin fish in general, e.g., differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Leider et al. 1990; McLean et al. 2004; Reisenbichler and McIntyre 1977; Williamson et al. 2010).

Hatchery-influenced selection (often called domestication) occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with hatchery-origin fish. 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).

Genetic change and fitness reduction resulting from hatchery-influenced selection depends on: (1) the difference in selection pressures; (2) the exposure or amount of time the fish spends in the hatchery environment; and, (3) the duration of hatchery program operation (i.e., the number of generations that fish are propagated by the program). On an individual level, exposure time in large part equates to fish culture, both the environment experienced by the fish in the hatchery and natural selection pressures, independent of the hatchery environment. On a population basis, exposure is determined by the proportion of natural-origin fish in the hatchery broodstock and the proportion of natural spawners consisting of hatchery-origin fish (Ford 2002; Lynch and O'Hely 2001), and then by the number of years the exposure takes place. In assessing risk or determining impact, all three levels must be considered. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

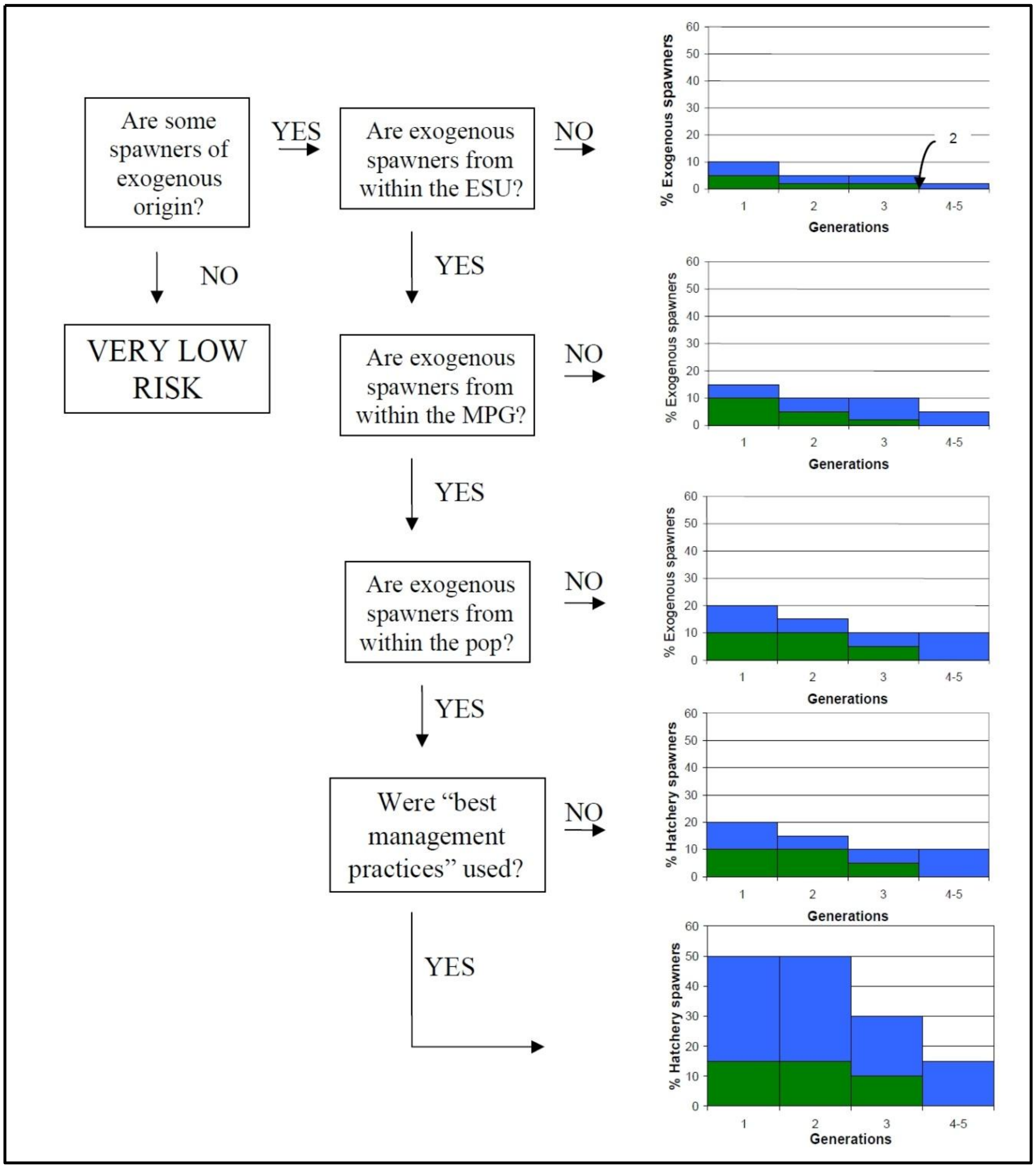

Figure 7. ICTRT (2007) risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Green (darkest) areas indicate low risk combinations of duration and proportion of spawners, blue (intermediate areas indicate moderate risk areas and white areas and areas outside the graphed range indicate high risk. Exogenous fish are considered to be all fish hatchery origin, and non-normative strays of natural origin.

Most of the empirical evidence of fitness depression due to hatchery-influenced selection comes from studies of species that are reared in the hatchery environment for an extended period – one to two years – prior to release (Berejikian and Ford 2004). Exposure time in the hatchery for the majority of fall and summer Chinook salmon (95% of juvenile Chinook salmon in Puget Sound are released as subyearlings), and all chum salmon (released as fed fry) is much shorter, just a few months. One especially well publicized steelhead study (Araki et al. 2007; Araki et al. 2008), showed dramatic fitness declines in the progeny of naturally spawning Hood River hatchery steelhead. Researchers and managers alike have wondered if these results could be considered a potential outcome applicable to all salmonid species, life-history types, and hatchery rearing strategies.

Besides the Hood River steelhead work, a number of studies are available on the relative reproductive success (RRS) of hatchery-origin and natural-origin fish (e.g.,Berntson et al. 2011; Ford et al. 2012; Hess et al. 2012; Theriault et al. 2011). All have shown that generally hatchery-origin fish have lower reproductive success, though the differences have not always been statistically significant and in some years in some studies, the opposite is true. Lowered reproductive success of hatchery-origin fish in these studies is typically considered evidence of hatchery-influenced selection. Although RRS may be a result of hatchery-influenced selection, studies must be carried out for multiple generations to unambiguously detect a genetic effect. To date only the Hood River steelhead (Araki et al. 2007; Christie et al. 2011) and Wenatchee spring Chinook salmon (Ford et al. 2012) RRS studies have reported multiple-generation effects.

Critical information for analysis of hatchery-induced selection includes the number, location and timing of naturally spawning hatchery fish, the estimated level of gene flow between hatchery-origin and natural-origin fish, the origin of the hatchery stock (the more distant the origin compared to the affected natural population, the greater the threat), the level and intensity of hatchery selection and the number of years the operation has been run in this way. Efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between natural-origin and hatchery-origin fish[11]. The ICTRT developed guidelines based on the proportion of spawners in the wild consisting of hatchery-origin fish (pHOS) (Figure 7).

More recently, the Hatchery Scientific Review Group (HSRG) developed gene flow criteria/guidelines based on mathematical models developed by Ford (2002) and by Lynch and O'Hely (2001). Guidelines for isolated programs are based on pHOS, but guidelines for integrated programs are also based on a metric called proportionate natural influence (PNI), which is a function of pHOS and the proportion of natural-origin fish in the broodstock (pNOB)[12]. 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 vary according to type of program and conservation importance of the population. For a population of high conservation importance their guidelines are a pHOS of no greater than 5% for isolated programs or a pHOS no greater than 30% and PNI of at least 67% for integrated programs (HSRG 2009b). Higher levels of hatchery influence are acceptable, however, when a population is at high risk or very high risk of extinction due to low abundance and the hatchery program is being used to conserve the population and reduce extinction risk, in the short-term.

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[11] Gene flow between natural-origin and hatchery-origin fish is often, and quite reasonably, interpreted as meaning actual matings between natural-origin and hatchery-origin 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, hatchery-origin spawners in the wild will either spawn with other hatchery-origin fish or with natural-origin fish. Natural-origin spawners in the wild will either spawn with other natural-origin fish or with hatchery-origin fish. But all these matings, to the extent they are successful, will generate the next generation of natural-origin fish. In other words, all will contribute to the natural-origin gene pool.

[12] PNI is computed as pNOB/(pNOB+pHOS). This statistic is really an approximation of the true proportionate natural influence (HSRG 2009b). However, operationally the distinction is unimportant.

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. The HSRG recently produced an update report (HSRG 2014) in which they stated that the guidelines for isolated programs may not provide as much protection from fitness loss as the corresponding guidelines for integrated programs.

Another HSRG team recently reviewed California hatchery programs and developed guidelines that differed considerably from those developed by the earlier group (California HSRG 2012). The California HSRG felt that truly isolated programs in which no hatchery-origin returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of the concept. However, if programs were to be managed as isolated, they recommend a pHOS of less than 5%. They 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 natural-origin 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 hatchery- and natural-origin fish, and societal values, such as angling opportunity". They 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% in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5%, even approaching 100% at times. They also recommended for conservation programs that pNOB approach 100%, but pNOB levels should not be so high they pose demographic risk to the natural population.

Discussions involving pHOS can be problematic due to variation in its definition. Most commonly, the term pHOS refers to the proportion of the total natural spawning population consisting of hatchery fish, and the term has been used in this way in all NMFS documents. However, the HSRG has defined pHOS inconsistently in its Columbia Basin system report, equating it with "the proportion of the natural spawning population that is made up of hatchery fish" in the Conclusion, Principles and Recommendations section (HSRG 2009b), but with "the proportion of *effective* hatchery origin spawners" in their gene flow criteria. In addition, in their Analytical Methods and Information Sources section (HSRG 2009b, appendix C) they introduce a new term, *effective pHOS*. Despite these inconsistencies, their overall usage of pHOS indicates an intent to use pHOS as a surrogate measure of gene flow potential. This is demonstrated very well in the fitness effects appendix (HSRG 2009b, appendix A1), in which pHOS is substituted for a gene flow variable in the equations used to develop the criteria. This confusion was cleared up in the 2014 update document (HSRG 2014), where it is clearly stated that the metric of interest is effective pHOS.

In the 2014 report, the HSRG explicitly addressed the differences between *census* pHOS and *effective* pHOS (HSRG 2014). In the document, the HSRG defined PNI as

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

where $\mathrm{pHOS}_{\mathrm{eff}}$ is the effective proportion of hatchery fish in the naturally spawning population (HSRG 2014). The HSRG recognized that hatchery fish spawning naturally may on average produce fewer adult progeny than natural-origin spawners, as described above. To account for this difference the HSRG defined *effective* pHOS as

$$\text{pHOS}_{\text{eff}} = \text{RRS} * \text{pHOS}_{\text{census}}$$

where $\text{pHOS}_{\text{census}}$ is the proportion of the naturally spawning population that is composed of hatchery-origin adults (HSRG 2014).

NMFS feels that adjustment of census pHOS by RRS should be done very cautiously, not nearly as freely as the HSRG document would suggest. The basic reason is quite simple: the Ford (2002) model, 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, however, particularly if there is strong evidence of a non-genetic component to RRS. An example of a case in which an adjustment by RRS might be justified is that of Wenatchee spring Chinook salmon (Williamson et al. 2010) where, the spatial distribution of natural-origin and hatchery-origin spawners differs, and the hatchery-origin fish tend to spawn in poorer habitat. However, even in a situation like this 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 natural-origin 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 also important 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 information in the underlying models rather than make ad hoc adjustments to a statistic that was only intended to be 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 gene flow data reflecting natural spawning effects of hatchery-origin fish are available, or an adjustment for RRS has strong justification, NMFS feels that census pHOS is the appropriate metric to use for genetic risk evaluation.

Additional perspective on pHOS that is independent of HSRG modeling is provided by a simple analysis of the expected proportions of mating types. Figure 8 shows the expected proportion of mating types in a mixed population of natural-origin (N) and hatchery-origin (H) fish as a function of the census pHOS, assuming that N and H adults mate randomly[13]. For example, the vertical line on the diagram marks the situation at a census pHOS level of 10%. At this level, expectations are that 81% of the matings will be NxN, 18% will be NxH, and 1% will be HxH. This diagram can also be interpreted as probability of parentage of naturally produced progeny, assuming random mating and equal reproductive success of all

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[13] These computations are purely theoretical, based on a simple mathematical binomial expansion ($(a+b)^2=a^2 + 2ab + b^2$).

mating types. Under this interpretation, progeny produced by a parental group with a pHOS level of 10% will have an 81% chance of having two natural-origin parents, etc.

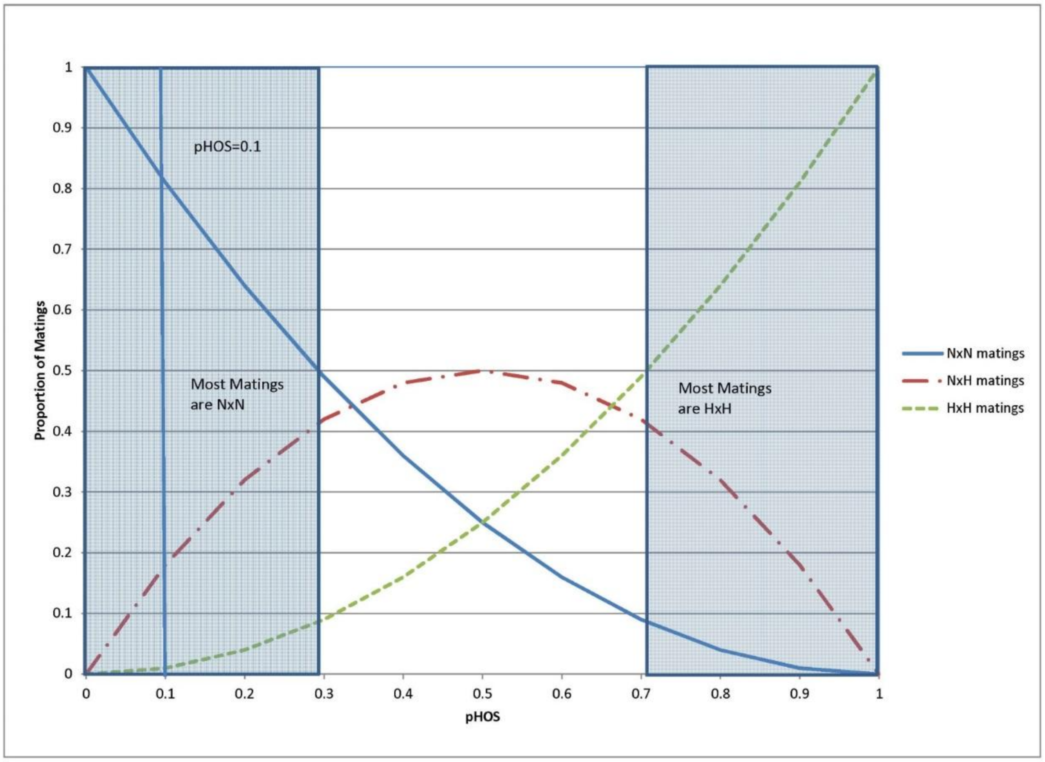

Figure 8. Relative proportions of types of matings as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS) (NxN – natural-origin x natural-origin; NxH – natural-origin x hatchery; HXH – hatchery x hatchery).

Random mating assumes that the natural-origin and hatchery-origin spawners overlap completely spatially and temporally. As overlap decreases, the proportion of NxH matings decreases and with no overlap the proportion of NxN matings is (1-pHOS) and the proportion of HxH matings is pHOS. RRS does not affect the mating type proportions directly, but changes their effective proportions. Overlap and RRS can be related. In the Wenatchee River, hatchery spring Chinook salmon tend to spawn lower in the system than natural-origin fish, and this accounts for a considerable amount of their lowered reproductive success (Williamson et al. 2010). In that particular situation, the hatchery-origin fish were spawning in inferior habitat.

Ecological effects included under 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 of hatchery fish on the spawning grounds may be positive or negative. In 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; Wipfli et al. 1998; Gresh et al. 2000; Murota 2002; and Quamme and Slaney 2002). As a result, the growth and survival of juvenile salmonids may increase (Hager and Noble 1976; Bilton et al. 1982; Holtby 1988; Hartman and Scrivener 1990; Johnston et al. 1990; 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 in that to the extent there is spatial overlap between hatchery and natural spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (Fukushima et al. 1998, and references therein).

2.4.1.3 Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas

NMFS also analyzes the potential for competition, predation, and premature emigration when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas. Generally speaking, competition and a corresponding reduction in productivity and survival may result from direct interactions when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish or through indirect means, when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (SIWG 1984). Naturally produced fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, when hatchery fish take up residency before naturally produced fry emerge from redds, and if hatchery fish residualize. Hatchery fish might alter naturally produced salmon behavioral patterns and habitat use, making them more susceptible to predators (Hillman and Mullan 1989; Steward and Bjornn 1990). Hatchery-origin fish may also alter naturally produced salmonid migratory responses or movement patterns, leading to a decrease in foraging success (Hillman and Mullan 1989; Steward and Bjornn 1990). Actual impacts on naturally produced fish would thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward and Bjornn 1990).

Competition may result from direct interactions, or through indirect means, as when utilization of a limited resource by hatchery fish reduces the amount available for naturally produced fish (SIWG 1984). Specific hazards associated with competitive impacts of hatchery salmonids on listed naturally produced salmonids may include competition for food and rearing sites (NMFS 2012). In an assessment of the potential ecological impacts of hatchery fish production on naturally produced salmonids, the Species

Interaction Work Group (SIWG 1984) concluded that naturally produced coho and Chinook salmon and steelhead are all potentially at “high risk” due to competition (both interspecific and intraspecific) from hatchery fish of any of these three species. In contrast, the risk to naturally produced pink, chum, and sockeye salmon due to competition from hatchery salmon and steelhead was judged to be low.

Several factors influencing the risk of competition posed by hatchery releases: whether competition is intra- or interspecific; the duration of freshwater co-occurrence of hatchery and natural-origin fish; relative body sizes of the two groups; prior residence of shared habitat; environmentally induced developmental differences; and, density in shared habitat (Tatara and Berejikian 2012). Intraspecific competition would be expected to be greater than interspecific, and competition would be expected to increase with prolonged freshwater co-occurrence. Although newly released hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitat. Tatara and Berejikian (2012) further reported that hatchery-induced developmental differences from co-occurring natural-origin fish life stages are variable and can favor both hatchery- and natural-origin fish. They concluded that of all factors, fish density of the composite population in relation to habitat carrying capacity likely exerts the greatest influence.

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

A proportion of salmon and steelhead smolts released from a hatchery may not migrate to the ocean but rather reside for a period of time in the vicinity of the release point. These non-migratory smolts (residuals) may directly compete for food and space with natural-origin juvenile salmonids of similar age. They also may prey on younger, smaller-sized juvenile salmonids. This behavior has been studied and observed most frequently in the case of hatchery steelhead, and residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well. Adverse impacts from residual Chinook and coho hatchery salmon on naturally produced salmonids are generally a possibility. The issue of residualism for these species has not been as widely investigated compared to steelhead, and given that the number of smolts released from Chinook and coho salmon programs is generally higher than for steelhead programs, ecological impacts on co-occurring natural-origin fish may be heightened if the species residualize. Therefore, for all species, the monitoring of natural stream areas downstream of hatchery release points is necessary to determine significance of hatchery smolt residualism on the natural-origin juvenile salmonids.

The risk of adverse competitive interactions between hatchery-origin 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 naturally produced fish in freshwater (Steward and Bjornn 1990; California HSRG 2012).

- Releasing all hatchery fish at times when natural-origin fish vulnerable to resource competition are not present in downstream areas in substantial numbers.
- Releasing all hatchery fish after the majority of sympatric natural-origin juveniles have emigrated seaward to reduce the risk of competition for food and space.
- Operating hatcheries such that hatchery fish are reared to sufficient size, that smoltification occurs in nearly the entire population (Bugert et al. 1991).
- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing naturally produced juveniles.
- Monitoring the incidence of non-migratory smolts (residuals) after release and adjusting rearing strategies, release location and timing if substantial competition with naturally rearing juveniles is documented.

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area,[14] 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-origin 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.

Another important possible ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (direct consumption) or indirect (increases in predation by other predator species due to enhanced attraction) can result from hatchery fish released into the wild. Considered here is predation by hatchery-origin fish and by the progeny of naturally spawning hatchery fish (direct predation effects), and predation by avian and other predators attracted to the area by an abundance of hatchery fish (indirect effects). 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 as smolts that emigrate quickly to the ocean can prey on fry and fingerlings that are encountered during the downstream migration. As mentioned above, some of these hatchery fish do not emigrate and instead take up residence in the stream (residuals) where they can prey on stream-rearing juveniles over a more prolonged period. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat. In general, the threat from predation is greatest when natural populations of salmon and steelhead are at low abundance and when spatial structure is already reduced, when habitat, particularly refuge habitat, is limited, and when environmental conditions favor high visibility.

SIWG (1984) rated most risks associated with predation as unknown, because there was relatively little documentation in the literature of predation interactions in either freshwater or marine areas. More studies are now available, but they are still too sparse to allow many generalizations to be made about

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[14] "Action area" 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.

risk. Newly released hatchery-origin yearling salmon and steelhead may prey on juvenile fall Chinook and steelhead, and other juvenile salmon in the freshwater and marine environments (Hargreaves and LeBrasseur 1985; Hawkins and Tipping 1999; Pearsons and Fritts 1999). Low predation rates have been reported for released steelhead juveniles (Hawkins and Tipping 1999; Naman and Sharpe 2012). Hatchery steelhead timing and release protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook fry, which had already emigrated or had grown large enough to reduce or eliminate their susceptibility to predation when hatchery steelhead entered the rivers (Sharpe et al. 2008). Hawkins (1998) documented hatchery spring Chinook salmon yearling predation on naturally produced fall Chinook salmon juveniles in the Lewis River. Predation on smaller Chinook salmon was found to be much higher in naturally produced smolts (coho salmon and cutthroat, predominately) than their hatchery counterparts.

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

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

Large concentrations of migrating hatchery fish may attract predators (birds, fish, and seals) and consequently contribute indirectly to predation of emigrating wild fish (Steward and Bjornn 1990). The presence of large numbers of hatchery fish may also alter natural-origin salmonid behavioral patterns, potentially influencing their vulnerability and susceptibility to predation (Hillman and Mullan 1989; USFWS 1994; Kostow 2008). Hatchery fish released into natural-origin fish production areas, or into migration areas during natural-origin fish emigration periods, may therefore pose an elevated, indirect predation risk to commingled listed fish. Alternatively, a mass of hatchery fish migrating through an area may overwhelm established predator populations, providing a beneficial, protective effect to co-occurring natural-origin fish. Newly released hatchery-origin smolts generally exhibit reduced predator avoidance behavior relative to co-occurring natural-origin fish (Bori and Davis 1989; and as reviewed in Flagg et al. 2000). Also, newly released smolts have been found to survive at a reduced rate during downstream migration relative to their natural-origin counterparts (Flagg et al. 2000; Melnychuk et al. 2014). These studies suggest that predator selection for hatchery-origin and natural-origin fish in commingled aggregations is not equal. Rather, the relatively naïve hatchery-origin fish may be preferentially selected in any mixed schools of migrating fish until they acclimate to the natural environment, and hatchery fish may in fact sate (and swamp) potential predators of natural-origin fish, shielding them from avian, mammal, and fish predation.

There are several steps that hatchery programs can implement to reduce or avoid the threat of direct or indirect predation:

- Releasing all hatchery fish as actively migrating smolts through volitional release practices so that the fish migrate quickly seaward, limiting the duration of interaction with any co-occurring natural-origin fish downstream of the release site.
- Releasing all hatchery fish at times when natural-origin fish of individual sizes vulnerable to direct predation are not present in downstream areas in substantial numbers.
- Releasing all hatchery fish after the majority of sympatric natural-origin juveniles have emigrated seaward to reduce the risk that avian, mammal, and fish predators may be attracted to commingled abundances of hatchery and natural-origin salmon or steelhead.
- Ensuring that a high proportion of the population have physiologically achieved full smolt status. Juvenile salmon tend to migrate seaward rapidly when fully smolted, limiting the duration of interaction between hatchery fish and naturally produced fish present within, and downstream of, release areas.
- Releasing hatchery smolts in lower river areas near river mouths, and below upstream areas used for stream-rearing young-of-the-year naturally produced salmonid fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.
- Operating hatchery programs and releases to minimize the potential for residualism.

2.4.1.4 Hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, in the estuary, and in the ocean

Based on a review of the scientific literature, NMFS' conclusion is that the influence of density-dependent interactions on the growth and survival of salmon and steelhead is likely small compared with the effects of large-scale and regional environmental conditions and, while there is evidence that large-scale hatchery production can effect salmon survival at sea, the degree of effect or level of influence is not yet well understood or predictable. The same thing is true for mainstem rivers and estuaries. NMFS will look for new research that identifies and measures the frequency, intensity, and resulting effect of density-dependent interactions between hatchery and natural-origin fish. In the meantime, NMFS will monitor emerging science and information and will consider that re-initiation of section 7 consultation is required in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

2.4.1.5 Research, monitoring, and evaluation

NMFS also analyzes proposed RM&E for effects on listed species and on designated critical habitat. Generally speaking, negative effects on the fish from RM&E are weighed against the value or benefit of new information, particularly information that tests key assumptions and that reduces critical uncertainties. RM&E actions including but not limited to collection and handling (purposeful or inadvertent), holding the fish in captivity, sampling (e.g., the removal of scales and tissues), tagging and fin-clipping, and observation (in-water or from the bank) can cause harmful changes in behavior and reduced survival. These effects should not be confused with handling effects analyzed under broodstock collection. In addition, NMFS also considers the overall effectiveness of the RM&E program. There are five factors that NMFS takes into account when it assesses the beneficial and negative effects of hatchery RM&E: (1) the status of the affected species and effects of the proposed RM&E on the species and on designated critical habitat, (2) critical uncertainties over effects of the Proposed Action on the species, (3) performance monitoring and determining the effectiveness of the hatchery program at achieving its goals and objectives, (4) identifying and quantifying collateral effects, and (5) 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 agencies, 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.

Hatchery actions also must be assessed for masking effects. For these purposes, masking is when hatchery fish included in the Proposed Action mix with and are not identifiable from other fish. The effect of masking is that it 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. 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.

2.4.1.6 The operation, maintenance, and construction of hatchery facilities

Operation, maintenance, and construction activities can alter fish behavior and can injure or kill eggs, juveniles and adults. They can also degrade habitat function. Here, NMFS analyzes a hatchery program for effects on listed species from encounters with hatchery structures and for effects on habitat conditions that support and promote viable salmonid populations. For example, NMFS wants to know if the survival or spatial structure of ESA listed fish (adults and juveniles) is affected when they encounter weirs and other hatchery structures or by changes in the quantity or quality of streamflow caused by diversions. NMFS analyzes changes to riparian habitat, channel morphology and habitat complexity, and in-stream substrates attributable to operation, maintenance, and construction activities and confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria.

2.4.1.7 Fisheries

Regarding hatchery-related effects, there are two aspects of fisheries that NMFS considers. One is when listed species are inadvertently and incidentally taken in fisheries targeting hatchery fish, and the other is when fisheries are used as a tool to prevent hatchery fish, including hatchery fish included in an ESA-listed ESU or DPS that are surplus to recovery needs, from spawning naturally. In each case, the fishery must be strictly regulated based on the take, including catch and release effects, of natural-origin ESA-listed species.

2.4.2 Effects of the Proposed Action

Analysis of the Proposed Actions identified three risk factors that are likely to have negative effects on ESA protected Puget Sound steelhead and/or Puget Sound Chinook and on designated critical habitat: 1) interactions between hatchery fish and their progeny and wild fish on spawning grounds; 2) interactions between hatchery fish and their progeny and wild fish in juvenile rearing areas; and 3) operation, maintenance and construction of hatchery facilities. For all other risk factors, the Proposed Actions would have either a negligible effect, or effects would not be applicable. A summarized analysis of all applicable (i.e., negative, beneficial, or negligible) hatchery effect factors is presented below (Table 12), followed by an expanded discussion of effects assigned for each applicable factor. The framework NMFS followed for analyzing effects of the proposed hatchery programs is described in Section 2.4.1 of this opinion.

Table 12. Summarized effects of Snohomish River basin EWS hatchery programs on Puget Sound steelhead and Puget Sound Chinook salmon and their designated critical habitat.

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
Broodstock origin and collection	Negligible effect	**Puget Sound Steelhead: Negligible effect** Broodstock collected for the programs originated from a stock native to Puget Sound, but since then, are more than moderately diverged from any natural population, and not included in the Puget Sound Steelhead DPS. All steelhead adults collected for broodstock are from the extant, non-listed, EWS stock localized to each hatchery site. All broodstock voluntarily enter off-channel hatchery traps during a time (December through January) when other listed species are not typically present. Operational protocols are in place to maximize collection and removal of returning EWS adults. Protocols are also in place to return any incidentally captured natural-origin steelhead back to the natural environment unharmed, and as quickly as possible, when and where encounters inadvertently occur. **Puget Sound Chinook salmon: Negligible effect** The species is not collected as broodstock or propagated as part of the proposed actions. EWS broodstock collection activities under the proposed actions occur well after the adult Chinook migration and spawning periods and/or in areas well removed from Chinook salmon migration and spawning areas. Incidental captures and effects on Chinook salmon from those activities are therefore highly unlikely.
Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds	Negligible to negative effect	Puget Sound Steelhead: Genetic Diversity (A): Negative effect; Spawning Ground Competition/Redd Superimposition (B): Negligible effect; Population Viability (C): Negligible effect. Marine-derived Nutrients (D): Negligible effect. A: Steelhead produced from the two hatchery programs are likely to have limited negative effects on the genetic diversity and fitness of associated steelhead natural populations. The magnitude of any negative effects may be indicated by the level of gene flow occurring when hatchery-origin fish stray and spawn in areas where natural-origin steelhead are present. Based on NMFS's consideration of the present level of empirical and theoretical information currently available on the subject, gene flow levels resulting from these programs is unsubstantial, and indicative of very low, and unsubstantial associated genetic effects. For the two proposed programs, two credible and independent analytical approaches indicate that gene flow (measured either as *PEHC* or *DGF*) should be

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		under 2% in all natural-origin steelhead populations affected by the two programs. Measures are included as terms and conditions in this opinion to validate this performance criterion. The hatchery programs will be managed to minimize unintended natural spawning by hatchery-origin steelhead, and to continue to limit gene flow from the hatchery populations to the natural populations. Extensive monitoring and evaluation actions will be implemented to establish and track the abundance of naturally spawning steelhead by origin (hatchery and natural-origin) and their temporal and spatial distribution. Levels of gene flow between EWS and natural-origin steelhead in the Snohomish River basin will be monitored (Anderson et al. 2014) to verify whether the programs remain below the 2% gene flow level which NMFS believes poses low, unsubstantial genetic effects to natural populations of steelhead in the vicinity. B: The very latest returning hatchery-origin steelhead adults from the hatchery program may spawn in the same areas where Snohomish River basin populations of natural-origin steelhead spawn, potentially leading to adverse spawning ground competition and redd superimposition effects. However, the large majority of hatchery steelhead spawning is much earlier in the season, so there is very little temporal overlap between naturally spawning hatchery-origin and natural origin steelhead. C: Early timed hatchery winter steelhead are produced for fisheries harvest augmentation purposes and are managed to be isolated from the listed populations. The adult fish produced are not intended to benefit the viability of any natural-origin steelhead population. Because of the origin of the EWS stock, measures are applied in the hatcheries to isolate the hatchery populations from the listed populations, including reducing the potential for negative effects of gene flow from the hatchery populations to the natural populations (see “A” above). The steelhead hatchery programs would have negligible beneficial contribution to the viability statuses of the listed populations within the action area. D: The carcasses of naturally spawning hatchery-origin steelhead and spawned broodstock originating from the hatchery programs would benefit the listed steelhead population's productivity in the watersheds by increasing the amount of marine derived nutrients. However, the level of benefit would be negligible relative to contributions afforded by naturally spawning natural-origin salmonids. Puget Sound Chinook Salmon: Marine-derived Nutrients: Negligible effect; Other factors: Not Applicable The carcasses of any stray, naturally spawning steelhead and spawned broodstock originating from the hatchery steelhead programs would benefit listed Chinook salmon population productivity in the watersheds by increasing the amount of marine derived nutrients. However, the level of benefit would be negligible relative to contributions afforded by naturally spawning natural-origin steelhead.

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		There would be no genetic diversity or ecological effects on Chinook salmon in the Snohomish River basin. The much later spawn timing for steelhead relative to Chinook salmon makes adult fish interactions including competition or redd superimposition effects very unlikely. The proposed steelhead programs would have negligible effects on ESA-listed Chinook salmon population viability.
Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas	Negligible to negative effect	**Puget Sound Steelhead: Negative effect** **Puget Sound Chinook: Negative effect** Interactions of concern in juvenile rearing areas are fish disease pathogen transfer and amplification; competition between hatchery-origin steelhead and natural-origin Chinook salmon and steelhead for food and space; and hatchery fish predation on natural-origin fish. In general, fish health, size, behavior, population individual size uniformity, and morphology will be monitored at the hatchery rearing locations to assess readiness of the fish for release as healthy, seawater-ready smolts. BMPs included in the HGMPs will reduce the likelihood and level of adverse ecological interaction effects (competition and predation) on natural populations in the action area, while promoting high juvenile fish to adult return survival rates consistent with meeting proposed program sustainable harvest objectives. All EWS would be marked with an adipose fish clip, and monitoring programs would be implemented to determine the degree of spatial and temporal overlap between newly released steelhead smolts and natural-origin fish downstream of the release sites. *Fish Disease Pathogen Transfer and Amplification* - The two proposed HGMPs address general threats from fish disease pathogen transfer and amplification. The plans describe fish disease pathogen issues of concern and actions that would be implemented to minimize risks of disease transfer and amplification. All hatchery actions would be implemented in accordance with the “The Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State" (WDFW and WWTIT 1998, updated 2006). Protocols described in the policy and applied through the programs will reduce risks of fish disease to propagated and natural fish populations through regular fish health monitoring and reporting, and application of BMPs to reduce fish health risks. Consistent with these protocols, all hatchery-origin steelhead will be released in healthy condition. For these reasons, the risk of fish disease pathogen transfer and amplification associated with steelhead production through the programs will be unsubstantial. *Competition* – Substantial adverse resource competition effects on natural-origin fish from EWS yearling releases are unlikely because of size and hence prey differences between the hatchery yearlings and natural-origin salmonids, and the demonstrated tendency for hatchery yearling smolts to emigrate rapidly from the watershed and disperse into marine areas. The hatchery steelhead smolts released in spring

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		are much larger in size than co-occurring juvenile Chinook salmon and steelhead parr that would be encountered, and the two groups would likely have different diet preferences. Hatchery yearling steelhead released in spring and co-occurring natural-origin juvenile steelhead smolts are similar in size, and are likely to have similar diet preferences during seaward emigration. EWS yearlings will be released as uniform-sized, seawater-ready smolts as a measure to foster rapid emigration seaward, and clearance from watershed areas where they may interact with natural-origin steelhead (and Chinook salmon). Because of the BMPs, the duration of any interactions between EWS smolts and natural-origin fish will be limited to a few days for the vast majority of steelhead migrants, leading to unsubstantial competition effects. The co-managers have included additional hatchery management measures in the proposed HGMPs designed to reduce competition with juvenile natural-origin fish. Results from juvenile outmigrant monitoring in watershed areas downstream of the hatchery release sites will be used to verify that EWS smolts (mass marked with an adipose fin clip as an identifier) disperse from freshwater areas rapidly, and as expected. Alternate hatchery steelhead release timings or other mitigation measures will be developed in response to deviations from expected freshwater exodus timings. *Predation* –Hatchery-origin steelhead released from the three hatchery facilities are likely to have a substantial spatial and temporal overlap with juvenile Chinook salmon of an average individual size vulnerable to predation. Hatchery yearlings are released relatively high in the Skykomish and Snoqualmie river subbasins: Wallace River (RM 4.0, tributary to the Skykomish River at RM 35.7), Reiter Ponds (fish would be released into the Skykomish River at RM 46.0), and Tokul Creek (RM 0.5, tributary to the Snoqualmie River at RM 39.6, tributary to Snohomish River at RM 20.5). All smolts are released into these watershed areas in months when emigrating Chinook salmon fry and parr are present. Hatchery yearling steelhead are not likely to encounter juvenile steelhead of a size vulnerable to predation, as young-of-the-year steelhead fry emerge later in the season and months after the hatchery yearlings will leave the area for the ocean. Only larger yearling and two-year old natural-origin steelhead would be present in freshwater areas downstream of the hatchery release sites and the size of these natural-origin fish make predation by hatchery smolts highly unlikely. The EWS hatchery programs will reduce the level of co-occurrence and potential for predation on natural-origin juvenile Chinook salmon and steelhead by releasing only uniform-sized smolts that emigrate seaward and disperse into pelagic waters rapidly. Results from juvenile outmigrant monitoring in watershed areas downstream of the hatchery release sites will be used to verify whether the EWS smolts (mass marked with an adipose fin clip as an identifier) disperse from freshwater areas rapidly, and as expected. Alternate hatchery steelhead release timings or other mitigation measures will be developed and implemented in response to deviations from expected freshwater exodus timings.
Hatchery fish and	Negligible	**Puget Sound Chinook salmon and Puget Sound steelhead -**

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
the progeny of naturally spawning hatchery fish in the migration corridor, estuary, and ocean		**Negligible effect** Effects for this category of the Proposed Action are not detectable. Available information does not show the level of hatchery production that leads to measureable ecological effects in the Salish Sea and the Pacific Ocean, including fish disease pathogen disease transfer, competition, and predation, nor does it identify how and to what extent ESA-listed species would be disadvantaged. The conditions under which any ecological interactions occur are unknown, and advantages and disadvantages for different fish origins, life-history stages, populations, ESUs, and DPSs are not detectable.
Hatchery research, monitoring, and evaluation	Beneficial to negative effect	**Puget Sound Chinook salmon and Puget Sound steelhead - Negligible effect** The primary monitoring and evaluation objectives for the hatchery plans are to: assess the effects of artificial propagation on natural-origin salmonids, including listed Chinook salmon and steelhead populations; and to report on the performance of the programs in producing adult steelhead for harvest as mitigation for lost natural-origin steelhead production. Monitoring and evaluation actions that will be implemented to determine whether these objectives are met include spawning ground/redd surveys and hatchery escapement monitoring to determine total steelhead spawning abundances and adult return levels to the basins and the hatcheries. The number of marked and unmarked steelhead harvested in fisheries and the total number of naturally spawning steelhead escaping to the basin each year will be monitored to determine the status of the natural- and hatchery-origin steelhead total return and escapement abundances. In addition to regular foot surveys to census salmonid spawning abundance, redds will be enumerated and any carcasses encountered will be sampled to identify fish origin in natural spawning areas. Annual data on the number of adult hatchery-origin steelhead returning to program hatcheries will be collected through monitoring trap counts at program hatcheries. Adult steelhead return abundance, timing, sex ratio, mark status, disposition, holding mortality, and fish health condition data will be collected at all hatchery facilities to monitor the effects of the programs. Juvenile fish outmigrant data collected by the Tulalip Tribes through annual operation of downstream-migrant traps in the mainstem Skykomish and Snoqualmie rivers will provide annual estimates of natural-origin smolt production and emigration rates for hatchery-origin fish. Juvenile outmigrant trapping programs and carcass sampling in natural spawning areas will provide sources of tissue samples that will be analyzed to determine gene flow levels between EWS and associated natural populations. The effects of these RM&E actions on listed Chinook salmon and steelhead are expected to be negligible.
Operation, maintenance, and construction of hatchery facilities	Negligible to negative effect	**Puget Sound Chinook salmon and Puget Sound steelhead - Negative to negligible effect** No new construction is proposed through this consultation. Water intakes and discharge structures are screened to protect juvenile fish but not with the latest technology. The hatchery water intake screens on the Wallace River and May Creek are in compliance with state and federal guidelines (NMFS 1995; 1996), but they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). Updating these facilities to

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		meet the most stringent protection standards will be completed by the fall 2020. Similarly, for Tokul Creek, the hatchery water intake screens are in compliance with state and federal guidelines (NMFS 1995; 1996), but they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). In addition, the water intake for Tokul Creek Hatchery on Tokul Creek relies on impoundment of water by a small dam with a non-functioning fish ladder that currently blocks access to Chinook salmon spawning habitat. The water intake structure and dam limit Chinook salmon access to the lowest 0.3 of Tokul Creek. Updated screens and fish passage facilities are scheduled for completion in 2016 (WDFW 2014b). NMFS completed consultation on water intake structure renovation and construction of a fish ladder (NMFS 2016a) and issued a finding that this work was not likely to jeopardize ESA-listed salmon and steelhead or destroy or adversely modify the species' critical habitat. NMFS, through its approval, expects that the ladder as designed will allow the hatchery water intake structure on Tokul Creek to be brought into compliance with the latest NMFS fish passage criteria (NMFS 2016a). Screening at the Reiter Ponds facility does not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). However, Austin and Hogarty Creeks do not have ESA-listed fish upstream of the screens, and therefore there are no effects on ESA-listed steelhead and Chinook salmon. Assuming hatchery water withdrawals at maximum permitted levels during summer-time low flow periods, high proportions of total flows in the Wallace River, May Creek and Tokul Creek could theoretically be temporarily diverted to support the two EWS hatchery programs. However, these high hatchery water withdrawal proportions of total flows during low flow periods are worst case estimates that are unlikely to be realized. Like river flows, surface water withdrawal needs for the hatchery program fluctuate seasonally, with the highest hatchery water withdrawal needs occurring in the spring months when stream flows from rainfall and/or snow melt are highest, because that is when fish are at their largest size and need high rearing flows for fish health maintenance. Hatchery water withdrawal needs for fish rearing are lowest in the late summer months when stream flows are at their lowest level. Water withdrawal effects on migrating fish in bypass reaches adjacent to the hatcheries would therefore be negligible. Operation of the hatchery programs would have negligible adverse effects on water quality. Water used for hatchery operations at the Wallace River, Reiter Ponds, and Tokul Creek facilities is monitored, treated, and discharged in accordance with current NPDES permits that limit effects on downstream aquatic life. No construction activities are proposed for the hatchery actions, and no routine hatchery maintenance activities are expected to adversely modify designated critical habitat for listed species.

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
Fisheries	Beneficial to negative effect	**Puget Sound Chinook salmon and Puget Sound steelhead** Fisheries are not included as part of the proposed actions. Marine fisheries catch EWS only incidentally, and are therefore not interrelated or interdependent with this action. Steelhead fisheries in the three basins in the action area target EWS, are dependent on the continued production of these fish, and are therefore interrelated and interdependent with this action. NMFS's authorization for 'take' of ESA-listed fish associated with fisheries in Puget Sound and associated freshwater, including all waters accessible to anadromous fish in the Snohomish River basin, is addressed annually or on a multi-year basis through a separate ESA section 7 consultation (most recently NMFS 2015a) on the current Puget Sound harvest plan assembled by the co-managers (most recently PSTT and WDFW 2015). Past effects of fisheries in the Snohomish River basin are discussed in the Environmental Baseline. Similar fisheries and effects are expected going forward.

2.4.2.1 Broodstock origin and collection

All steelhead collected for use as hatchery broodstock are adult EWS hatchery-origin fish returning to Wallace River Hatchery, Reiter Ponds, and Tokul Creek Hatchery. EWS are not included in the Puget Sound Steelhead DPS. All broodstock voluntarily enter off-channel hatchery traps during a time period (December through January) when other listed species are not typically present. The hatchery traps will remain open from February 1 through April 15 as a measure to remove as many EWS returning to the release sites as possible and therefore reduce the number of EWS that escape to spawn naturally. No EWS recruiting to the traps after January 31 would be used as broodstock. Operational protocols are in place to return natural-origin fish back to the stream system as quickly as possible when and where encounters inadvertently occur.

Chinook would not be collected as adults for use in hatchery propagation as part of the proposed hatchery actions. Because Chinook salmon have a much earlier spawn timing (Skykomish population: late-August through October; Snoqualmie population: mid/late September through early-November), ESA-listed Chinook salmon are unlikely to be encountered or affected during the December through mid-March periods when hatchery broodstock collection actions directed at steelhead would be implemented.

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

A) Negative Effect- Genetic diversity:

The hatchery programs under consideration in the Skykomish (Unsworth 2016; WDFW 2014a) and Snoqualmie (WDFW 2014b) Basins are isolated harvest programs that release fish that are not included in the Puget Sound steelhead DPS. The program operators will use only EWS (identified by early return timing and presence of an adipose fin clip mark) as hatchery broodstock and no natural-origin steelhead will be collected and spawned. The intent of management of these programs is to have few returning fish in excess of broodstock needs escape to spawn in the wild. Those that do spawn in the wild are expected to have low reproductive success relative to the natural-origin fish because they spawn earlier than natural-origin fish, and thus are presumed to spawn under non-optimal conditions. They may also be less successful than natural-origin fish due to other aspects of domestication. To the extent they do reproduce and contribute to the next generation of natural-origin fish, however, they have negative effects on natural steelhead populations. In this section, we analyze the effects of this gene flow. NMFS considers three areas of effects caused by gene flow from hatchery-origin fish: within-population diversity, outbreeding effects, and hatchery-influenced selection.

Within-Population Diversity Effects

Risk to within-population diversity is much less of a concern in isolated programs such as those in the Proposed Action than in integrated programs, so we will deal with this risk briefly. Within-population diversity is influenced strongly by the genetically effective size of the population[15]. Effective size depression is generally a concern only if the relative abundance of hatchery-origin fish on the spawning grounds far exceeds that of natural-origin fish, so that a disproportionate share of the progeny come from a small number of hatchery-origin parents (Ryman et al. 1995). We do not expect this to be the case with the five EWS hatchery programs. An additional potential concern is that diversity in the natural population could be lowered by gene flow from a hatchery population with a lower background level of diversity. This is not the case with these programs: the background levels of genetic diversity[16] are essentially identical in the hatchery and natural steelhead populations (Warheit 2014a). In general, we expect the risk posed by the Proposed Action to within-population diversity to be negligible.

However, a concern that has been raised in connection with these isolated steelhead programs is that, due to the low expected reproductive success of EWS spawning in the wild, the reproductive potential of natural-origin fish that spawn with hatchery-origin fish would be reduced or wasted. Reductions in the reproductive output of these natural-origin fish thus reduces the size of the spawning population and therefore the genetically effective size of the population. Figure 9 is a generalized schematic of the expected distribution of hatchery-origin and natural-origin spawners over time. Although the difference varies from basin to basin, EWS have an earlier spawn timing than natural Puget Sound winter steelhead (Table 3 of Myers et al. 2015). This means there will be a time during the spawning season when hatchery-origin steelhead can only spawn with other hatchery-origin steelhead (Region A), an overlap period when hatchery-origin and natural-origin steelhead can spawn amongst themselves or with each other (Region B), and a period when natural-origin steelhead can spawn only with natural-origin steelhead (Region C).

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[15] Genetic effective size is basically the census size of the spawning population adjusted for variation in reproductive success and sex ratio. Effective size is an important concept in conservation biology because the rate at which a population loses genetic diversity depends on it rather than census size. See Section 2.4.1 and references cited therein for additional detail.

[16] The Chambers Creek steelhead used in the EWS have undoubtedly diverged genetically from the original (extirpated) Chambers Creek winter steelhead population at genes subject to hatchery-influenced selection. This aspect of diversity change is treated in following sections of this document from the perspective of its effect on fitness. The diversity referred to in the discussion above is genetic diversity reflective of geographical origins.

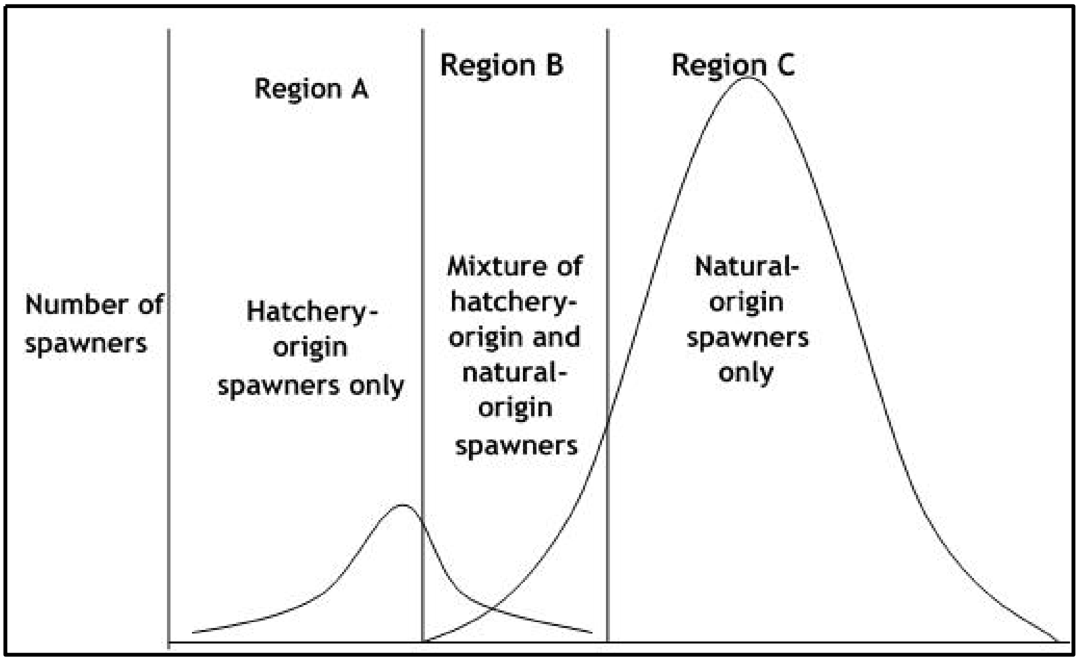

Figure 9. Schematic of temporal spawning overlap between EWS and natural-origin winter steelhead. Shape, sizes and placement of curves is conceptual and is not meant to represent any specific situation (Scott and Gill 2008a, Fig. 4-7).

Assuming random mating[17], the expected proportion of different mating types can easily be determined. In this case, since the only matings that are of interest are those that occur in Region B, and of those, only the matings in which natural-origin fish mate with hatchery-origin fish are of interest.
The expected proportion of the natural-origin escapement actually mating with hatchery-origin fish is given by Equation 1:

$$\frac{pHOS*O_N*O_H}{pHOS*O_H+(1-pHOS)*O_N},$$

where; pHOS is the proportion of natural spawners that are of hatchery origin, and O_N and O_H are the proportions of the natural-origin spawners, and the hatchery-origin spawners, respectively that spawn in region B. The proportion of the natural-origin spawners involved in HxN[18] matings is expected to be low under the proposed action, at most 1.4% in the Skykomish population (Table 13). Thus, under the assumption that the reproductive output of a natural-origin fish mating with a hatchery-origin fish is a complete loss, the impact to the population in terms of demographic and effective population size would be less than 2%. This loss would be expected to occur repeatedly, but the effects would not be

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[17] Random mating is assumed in a number of basic population genetic models for mathematical simplicity. The models in this section are based on simple population genetic models, and use the random mating assumption for the same reason. Mating dynamics of steelhead and salmon is in fact non-random, but attempting to include all the deviations from random mating would be a major modelling exercise in itself. We assume that the results of our modelling is robust to the typical deviations from random mating found in nature.

[18] The HxN notation is meant to include matings in which a hatchery-origin male mates with a natural-origin female, and vice versa.

cumulative. In this respect, its demographic impact would be the same as a loss due to harvest or an ecological interaction. An effect this small would not be detectable, given current monitoring methods.

Table 13. Expected proportion (expressed as %) of natural-origin escapement involved in HxN matings for winter steelhead populations affected by the Proposed Action. Data are based on basin-specific spawning ground surveys and hatchery return information (see explanation in Hoffmann 2014).

	Population	
Metric/Data	**Skykomish**	***Snoqualmie***
O_N	1.96	2.10
O_H	27.90	16.88
Max Proposed Action pHOS	14.6	13.5
Expected proportion of natural-origin fish mating with hatchery-origin fish	1.39	1.17

All parameters used in the modeling just presented are subject to uncertainty, as will be discussed in other sections below. We present a simple evaluation of the effects of this uncertainty in Figure 10, which shows the proportion of natural-origin fish participating in HxN matings as a function of pHOS and overlap. For simplicity, in this analysis we assumed that O_N and O_H were equal (Table 13). Overlap and pHOS must be considerable before the proportion of natural-origin spawners in HxN matings reaches even 1%, and this proportion has a maximum value of pHOS if overlap is complete (equation 1). This additional analysis reinforces the result that the effect of loss of reproductive capacity due to natural spawners mating with hatchery fish would be small. This would translate to an even smaller percentage decrease in effective size, and consequent effect on genetic diversity that would be unmeasurably small.

A potential limitation of this "region" approach to analysis of spawning used in the example above is that it assumes that all the spawners are returning anadromous adults. Resident *O. mykiss* (rainbow trout) and precocious residual hatchery juveniles may also be involved in spawning, both of which would not have been counted as part of the escapement. McMillan et al. (2007) noted both types of males participating in mating in the later part of the spawning season in an Olympic Peninsula stream. In fact, residual males accounted for less than 1% of the observed mating attempts, and only late in the season. Measurable reproductive success of non-anadromous male *O. mykiss* was noted in another Olympic Peninsula stream that has no hatchery program (Seamons et al. 2004). In Puget Sound, the relative abundance of anadromous and non-anadromous O. *mykiss* is not well known in most streams (Myers et al. 2015), and residualism rates for the hatchery programs in the Proposed Action are not known. A recent meta-analysis of steelhead hatchery programs throughout the Pacific Northwest found an average residualism rate of 5.6%, ranging from 0 to 17% (Hausch and Melnychuk 2012). Although residualism per se may have ecological consequences, residual males are not a genetic concern unless they are sexually mature. Although high rates of precocious maturation in Pacific Northwest steelhead have been reported in the past (e.g., Schmidt and House 1979) fish cultural methods have been developed to control precocious maturation. At present, the occurrence of precocious males in WDFW steelhead releases tends to vary from 1 to 5% (Tipping et al. 2003). At these levels, both the demographic and genetic influence of these fish would be insignificant.

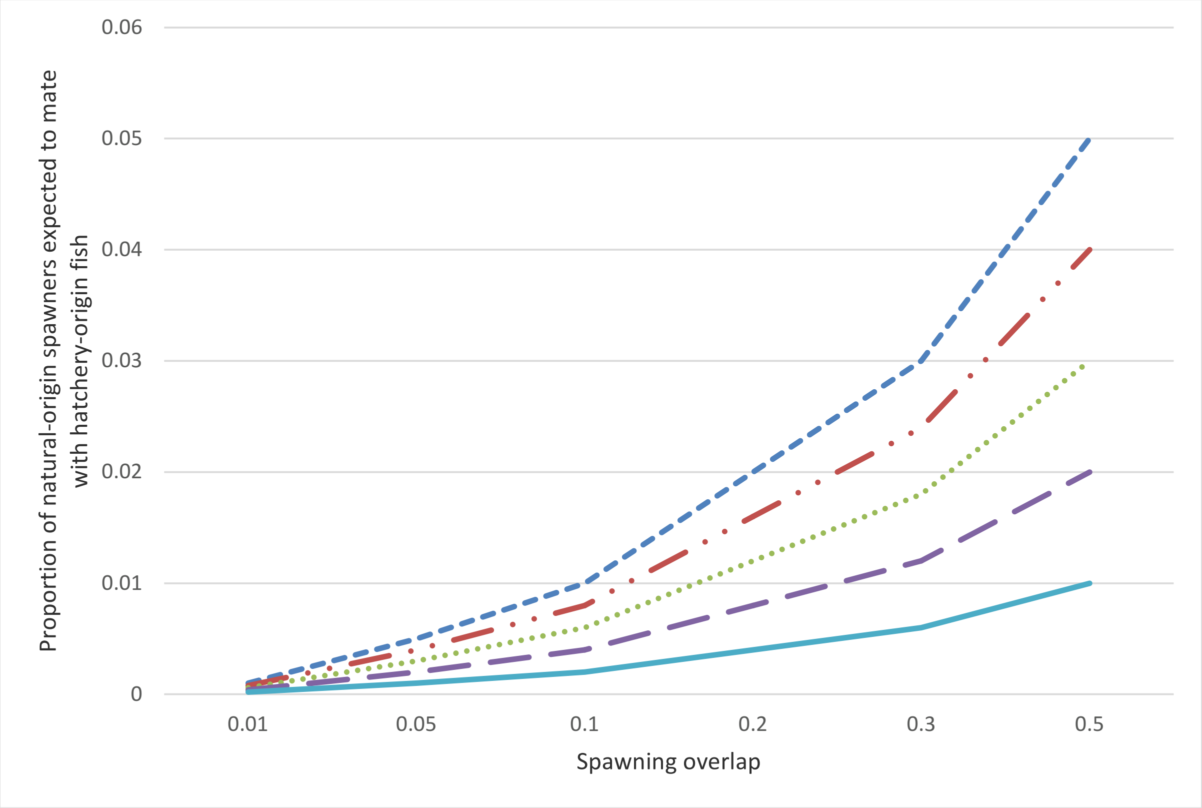

Figure 10. Proportion of natural-origin fish expected to be involved in HxN matings as a function of pHOS, and proportion of spawners in overlap zone. For simplicity we have assumed that the overlap is the same for natural-origin and hatchery-origin fish; e.g., for the 0.05 level, $O_N=O_H=0.05$. Isopleths represent pHOS=0.1 (small dashes), 0.08 (dots and dashes), 0.06 (dots), 0.04 (large dashes), and 0.02 (solid).

This additional analysis of possible effective size reduction reinforces our original conclusion, of the proposed action having a negligible effect to within-population diversity.

Outbreeding Effects and Hatchery-Influenced Selection Effects

Although we conclude that the effects of the Proposed Action on within-population diversity will be negligible, the Proposed Action may pose non-negligible effects to natural steelhead populations through outbreeding effects and hatchery-influenced selection. Outbreeding effects are a concern whenever the hatchery-origin and natural-origin fish are from different populations, and this is certainly the case with the EWS and the natural populations considered in this Proposed Action. In fact, the EWS are considered so diverged genetically from natural steelhead that they are not considered part of any steelhead DPS (NMFS 2003). The basis of this is the fact that they have been subjected to so many years of intense artificial selection for early smolting, which has resulted not only in smolting predominantly at one year of age, compared to two years, or more, in natural populations, but also earlier spawning time (Crawford 1979). Of all the salmon and steelhead hatchery populations used on the West Coast, NMFS considers the EWS population the most altered by artificial selection. NMFS has previously voiced concerns about the genetic risks of EWS programs (Hard et al. 2007; McMillan et al. 2010).

As explained in Section 2.4.1, evaluation of outbreeding effects is very difficult. The best existing management guidance for avoiding outbreeding effects is the conclusion of the 1995 straying workshop (Grant 1997), that gene flow between populations (measured as immigration rates) should be under 5%. The HSRG (2009a) generally recommended that for primary populations (those of high conservation value) affected by isolated hatchery programs that the proportion of natural spawners consisting of hatchery-origin fish (pHOS) not exceed 5%, and more recently (HSRG 2014) suggested that this level should be reduced. While not addressing them specifically in their guidelines, the HSRG earlier discussed risks posed by highly diverged hatchery populations such as the EWS, concluding that "…if non-harvested fish spawn naturally, then these isolated programs can impose significant genetic risks to naturally spawning populations". WDFW used the Ford (2002) model to evaluate the hatchery-influenced selection risk of EWS programs, and concluded they posed less risk than integrated native-stock programs at gene flow levels below 2%, but greater risk at levels above that (Scott and Gill 2008a). WDFW's statewide steelhead management plan states that isolated programs will result in average gene flow levels of less than 2% (WDFW 2008).

Some explanation is needed at this point of the relationship between pHOS and gene flow, because the two can easily be confused. Genetic impacts from hatchery programs are caused by gene flow from hatchery fish into a naturally spawning population. Thus, if hatchery-origin fish equal natural-origin fish in reproductive success, pHOS represents the maximum proportionate contribution of hatchery-origin parents to the next generation of natural-origin fish. In the absence of other information, pHOS is an estimate of maximum gene flow on the spawning grounds, and thus is a surrogate for gene flow. Although the EWS-specific modeling by Scott and Gill (2008a) used the Ford model, NMFS feels the Ford model may not be a good fit to the situation of EWS spawning in the wild for two reasons. First, highly domesticated steelhead stocks are known to have low fitness in the wild (e.g., Araki et al. 2007; Chilcote et al. 1986), so gene flow is nearly certain to be lower than that predicted by the Ford model. This is the situation that inspired the HSRG (2014) to develop the "effective pHOS" concept. Second, even if it is assumed that the EWS are equal in fitness to the natural-origin fish, the Ford model does not consider the effects on gene flow of partially overlapping spawning distributions, which will decrease the proportion of HxN matings and increase the proportion of HxH matings relative to what it would be with total temporal overlap of hatchery-origin and natural-origin spawners. Focusing attention on gene flow rates rather than pHOS is thus always advisable if feasible, and especially in the case of EWS spawning in the wild, in which pHOS levels may considerably overestimate gene flow levels because of the previously reported low reproductive success of these fish.

In discussing gene flow from hatchery programs, it is important to distinguish EWS programs from most other hatchery programs. Although some divergence from natural life history can be expected over time in hatchery programs, the EWS stock represents a situation in which the fish have been subjected to intensive artificial selection over many years for a divergent life history (Crawford 1979). The prospect of gene flow from such highly domesticated stocks seems intuitively risky, as is reflected in the cautionary statement of the HSRG that was cited above. However, studies have only recently begun to compare the relative impact of highly domesticated stocks, such as those considered in this review, with those that are less domesticated. A modeling effort by Baskett and Waples (2013) demonstrated that the effects of programs using "different" broodstocks could be quite different than those from "similar" programs, and depending on the circumstances, could pose more or less risk. The key element in determining risk level is an understanding of the impact of the gene flow on fitness. This is discussed in the next section.

Gene flow and fitness

In attempting to understand the risks posed by EWS spawning in the wild, three distinctive characteristics of this phenomenon must be considered: 1) the hatchery-origin fish are known to have low reproductive success in the wild relative to natural-origin fish; 2) the hatchery-origin fish comprise a small portion of the spawning population; and 3) a level of temporal isolation exists between hatchery-origin and natural-origin spawners, resulting in hatchery-origin and natural-origin fish mating among themselves at higher levels than expected under random mating. We know of no empirical information that is applicable to the fitness consequences of natural spawning of EWS in this situation. Similarly, we also know of no modelling that adequately simulates the phenomenon of EWS spawning in the wild, although elements of existing models, such as those of Ford (2002) and Baskett and Waples (2013) would be useful in modeling the EWS situation. Therefore, we decided to develop a new model. In developing the model out intent was above all to capture the maximum fitness impact that could be expected from EWS spawning in the wild, while simulating the conditions mentioned above. We also wanted to do this in as simple a model as possible, as every element added to increase mimicry of biological reality can also create parameterization and interpretation complexity.

The new model, EWS Sim, is fundamentally an individual-based version of the Ford model[19], with selection occurring only at reproduction[20] that also simulates zones of NxN, NxH, and HxH matings. Like the Ford model, EWS Sim tracks phenotypic change due to interbreeding with hatchery fish at a trait subject to stabilizing selection[21]. Fitness of an individual fish is determined by the distance of its phenotype from an optimum Θ, and by the strength of selection. In application, as in the Ford model, the trait under selection is a surrogate for a complex of traits that collectively contribute to fitness, rather than a representation of a specific trait. The model was developed with input and review from geneticists at NMFS' Northwest Fisheries Science Center (NWFSC). A brief description of how the model works is provided in the paragraphs below; more detail can be found in Appendix 1.

To run EWS Sim, the user inputs key management elements: total number of spawners, pHOS, and overlap of hatchery and natural-origin fish spawning. The user also inputs two "unknown" values which control the fitness in general, and especially that of the hatchery-origin fish: selection strength and difference between natural and hatchery trait optima. Here we used Ford (2002) for initial guidance. Ford used selection strengths of 3σ[22] and 10σ for strong and weak selection, respectively[23], and distances between the two optima ranging from approximately 3σ to 15σ. We used approximately the

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[19] The Ford model simulates groups of fish; EWS Sim simulates individual fish. This lessens the need for assumptions about phenotypic and fitness distributions.

[20] This means that selection is expressed only as varying ability of parental fish to produce offspring; e.g., one pair might produce zero or one, and another pair might produce five. But all progeny produced have an equal opportunity to survive to adulthood. See Appendix 1 for model details.

[21] Stabilizing selection is a form of natural selection in which fitness of individuals decreases as their phenotypes deviate from an optimal value.

[22] σ is the phenotypic standard deviation.

[23] Selection strength values indicate the width of the selection curve, and the smaller the curve width, the stronger the selection.

same range for selection strength, but used a more limited range for the difference between optima. Heritability is also an "unknown" input, but one that has considerably less impact on results than selection strength and difference between optima; here we used 0.25, based on the recommendation of NWFSC geneticists.
Using these input values, EWS Sim then simulates a mating among natural-origin and hatchery-origin fish, with the number or progeny produced per mating determined by the fitness values of the parents. The phenotypic mean of the progeny generation is then compared to the parental generation, and the difference is expressed in in terms of fitness. Two other key outputs are gene flow (the proportion of the naturally produced progeny gene pool from matings involving hatchery fish), and reproductive success of hatchery-origin fish relative to natural-origin fish (RRS). This process is done for a user-specified number of iterations, with results averaged over all iterations.

After some initial exploration of the model, we did a series of simulations (500 iterations each), holding the total number of parental fish constant at 500 and heritability constant at 0.25. The following values were used for other parameters:

- pHOS: 2%, 5%, 8%, 10%, 15%, and 20%
- overlap: $O_H = O_W$ in both cases, 20% and 40%
- selection strength (ω) in units of σ : 2,3,4,5,10
- distance between θ_W and θ_H , in units of σ : 3, 4.5, 6

Our goal in this initial series of runs was to narrow the range of parameter values to combinations that resulted in biologically plausible outcomes, with the goal of finding the relationship between gene flow and fitness loss, and then to examine these cases more carefully. RRS was the sole criterion used for biological plausibility. The low RRS of long-domesticated steelhead hatchery-origin fish is established in the literature (e.g., Araki et al. 2008); we considered any outcome with an RRS above 0.5, as unrealistic.

For the plausible subset of scenarios, we used a multiple-generation modification of EWS Sim (100 iterations/scenario) to examine long-term fitness loss, comparing mean fitness after 25 generations to original fitness. We chose 25 generations because it is approximately a century, the default timeline for ESA viability analysis (McElhany et al. 2000). Fitness loss over 25 generations is plotted against the mean gene flow for a single-generation run of the same scenario[24] (Figure 11).

| The fitness-gene flow relationship is a shallow power curve that can be well approximated by the equation $y = 19.055x^{1.4115}$, where *y* is fitness loss and *x* is gene flow, so expected fitness loss is not a simple linear function of gene flow. The simulations show that gene flow levels of 2% or less should result in no more than 8% fitness loss over 25 generations, but that 4% gene flow could result in three times as much. An important result not apparent from the figure is that the pace of fitness loss changes over time, with the largest decline in the first generation and then the proportionate loss decreasing every generation. The relationship between first-generation loss and cumulative loss over 25 generations can be approximated by an almost identical power curve to that presented above, where *y* is the 25-generation loss and *x* is the first-generation loss[25]. First-generation fitness loss ranged from less than half a percent to nearly 5%; in runs that approximated the gene flow *levels* expected under the

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[24] Because of time constraints, the additional programming required for multiple generation tracking of variables other than phenotype and fitness have not yet been incorporated into the multiple-generation version of EWS Sim

[25] The relationship becomes less precise as modeled fitness loss increases.

proposed programs (see below). This phenomenon of fitness loss diminishing in magnitude each generation has an interesting consequence in that if this actually occurs, then populations already subjected to EWS programs (which is the case with the proposed action) will have already suffered some fitness loss. If so, then into the future the fitness loss 25 generations out will be less than that modeled.

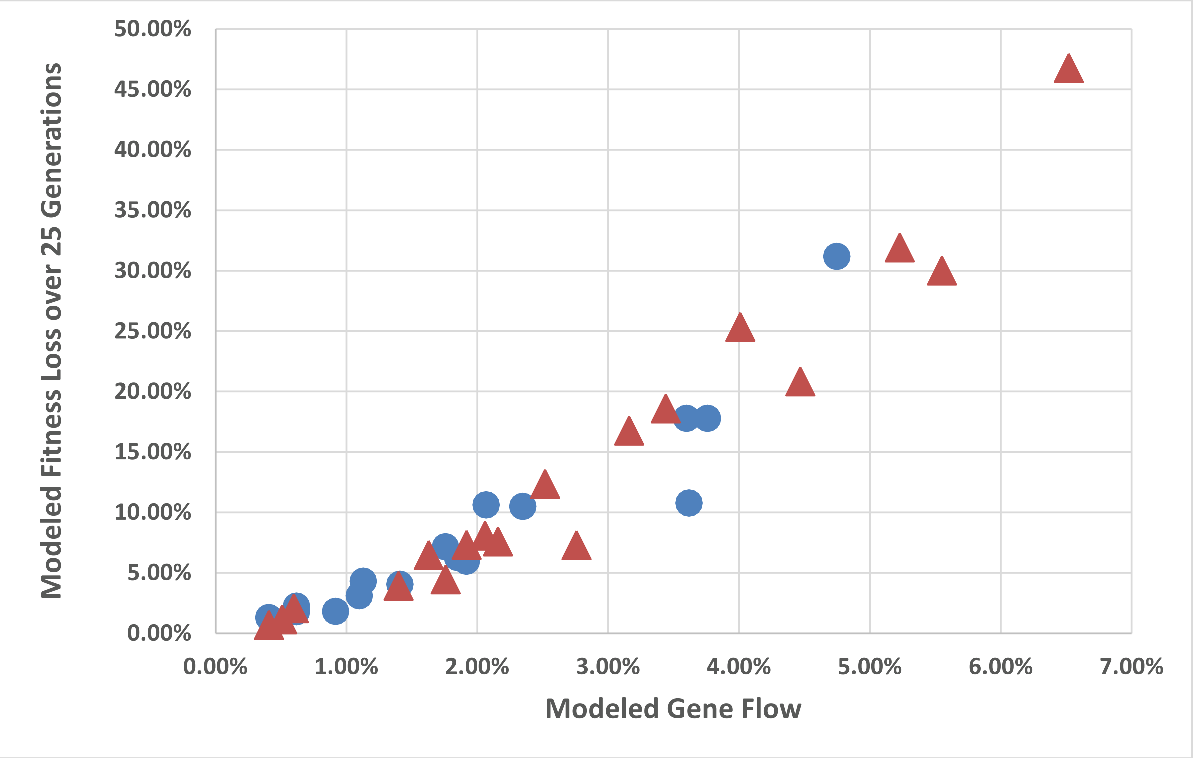

Figure 11. EWS Sim results: percent fitness loss over 25 generations as a function of gene flow. Circles and triangles denote data points from scenarios in which modeled spawning overlap is 20% or 40%, respectively.

Interestingly, the effect of different levels of spawning overlap seemed to have only a minor effect on fitness loss, especially at low levels of gene flow. Figure 11 is deceptive in this respect. Although fitness of hatchery-origin spawners (driven by selection strength and difference between optima) was the main determinant of gene flow and thus fitness loss, it is important to note that the higher levels of gene flow were achieved only at the 40% overlap level.

A noteworthy but subtle consequence of the way the multiple generation model works is that although fitness losses will make the model generate relatively fewer offspring, every generation begins with the same user-specified number of spawners and pHOS values. Thus, the fitness loss is based on pHOS levels being maintained, even if the population is becoming smaller. In a real situation, unless release numbers were adjusted downward as population productivity declined, pHOS levels would increase.

EWS Sim is by no means a complete depiction of reality. Like virtually all mathematical models of complex biological processes, EWS Sim is a simplification of reality developed to explore one or more biological phenomena. It incorporates genetic processes as probability distributions, so contains no explicit genetic mechanism. It uses non-overlapping generations, and ignores age structure. It greatly simplifies mating dynamics, and generation of varying numbers of progeny per mating. None of these simplifications can be regarded as out of the ordinary for modelling of this sort, and their consequences to results are likely minor. EWS Sim also does not explicitly consider the consequences of life history variations such as residual males and mating with resident males; we assume that these are adequately covered by the spawning overlap parameter. Most importantly, the model assumes that all the poor reproductive behavior of EWS is genetic in origin, which is almost certainly a simplification of the true situation. However, these simplifications likely overestimate the fitness impact of EWS hatchery programs, especially in that the upper level of spawning overlap modeled (40% in both directions) allows higher rates of mating of interbreeding between hatchery-origin and natural-origin fish than are thought to be possible under the proposed action.

The basic result from the EWS Sim runs, that low rates of gene flow can result in relatively minor fitness loss, are consistent with earlier simulations by Ford, who showed that low level gene flow from isolated programs could result in long-term fitness of approximately 85% relative to the original level (Ford 2002, Fig. 3A,3B). The EWS Sim results are also consistent with recent HSRG thinking. In the past, discussions about effects of gene flow from hatchery programs have been dominated by the HSRG gene flow guidelines (HSRG 2009a; HSRG 2014), which are based on phenotypic means, not directly on fitness. More recently, however, the HSRG has equated its guidelines with long-term (equilibrium) fitness loss, and concluded that existing guidelines for integrated programs affecting primary populations are consistent with a 15% long-term fitness loss, and found that the corresponding level of fitness loss would be achieved by an *effective* pHOS of 2% in an isolated program affecting a primary natural population (HSRG 2014, Table 3-2)[26]. Because the intent of the HSRG's use of effective pHOS is to more closely reflect gene flow, their 2% pHOS equates approximately to 2% gene flow in EWS Sim. Although we did not run EWS Sim to equilibrium, this level of correspondence with Ford's work and that of the HSRG indicates that EWS Sim does not conflict with previous modeled results of fitness loss caused by gene flow from isolated hatchery programs.

Translating a fitness loss (e.g., relative reproductive success) determined empirically or theoretically to population demographics is not straightforward. The most conservative approach would assume that a fitness reduction of x% would mean that the population would be now be capable of producing on average x% fewer progeny. The alternative would be to apply the fitness loss to a Beverton-Holt, Ricker, or some other production function involving compensatory mechanisms, in which case the loss to population abundance would be less than x%. A good example of this approach is the HSRG AHA model, in which fitness loss is applied to both the capacity and the productivity parameters of a Beverton-Holt function (RIST 2009). Alternatively, in very small populations, a depensatory effect might occur, in which case the abundance loss would be greater than x%.

Our approach in evaluating hatchery programs with respect to EWS Sim results is to consider the fitness loss, a direct measure of population productivity decrease, assuming other factors remain constant. This last consideration is very important because the productivity of a population is likely heavily influenced by freshwater and ocean habitat conditions. How much of the total population productivity is

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[26] The HSRG modelling differed from ours in that in using effective rather than census pHOS, they explicitly incorporated a specified RRS value for EWS (0.11), whereas in our EWS Sim runs RRS was a function of selection strength and difference between optima. RRS from the EWS Sim runs we deemed biologically plausible averaged 0.17.

genetically determined is unknown but it is likely to be highly variable. Thus, highly productive populations may be able to incur considerable fitness losses and still remain highly productive, whereas low-productivity populations may be highly impacted by further reductions, making population status a key consideration in determination of acceptable fitness loss.

Steelhead may have more potential for genetic change through selection relative to other Pacific salmon species that have been studied (Araki et al. 2008). Given the uncertainty regarding the magnitude of fitness loss expected, this possible higher susceptibility to selection argues for a conservative approach to determining acceptable fitness loss in the species in general due to gene flow from hatchery programs. Populations comprising the Puget Sound steelhead DPS vary in viability status, but few could be considered highly productive, which also argues for a generally conservative approach to acceptable fitness loss in these populations. Although viability criteria have been developed for the DPS, requiring that a specified proportion of populations in each MPG within the DPS reach viable status, choices between populations and the desired viability status are undetermined. This also argues for a conservative approach to acceptable fitness loss, at least until such choices are made. A final consideration is the conservation value of the programs under consideration. EWS programs may facilitate steelhead harvest while offering some measure of protection to the natural populations. However, they offer no net benefit to the status of these populations, posing genetic risk with no offsetting demographic benefit.

Currently there are no formal benchmarks for acceptable fitness loss due to gene flow from hatchery programs. However, the HSRG gene flow guidelines (HSRG 2009a; HSRG 2014) can be considered benchmarks by virtue of their widespread dissemination and implementation. As previously mentioned, the HSRG (2014) recently modeled the long-term fitness loss expected from application of these guidelines, and the fitness loss expected for the highest-level guidelines was approximately 15%. Given all the specific considerations just mentioned, 15% long-term fitness loss seems insufficiently conservative for the proposed EWS programs. At this time, considering the state of scientific knowledge (including uncertainties inherent in the modeling above) and currently undetermined recovery importance of the individual affected populations, the acceptable modeled 25-generation fitness loss for these populations should generally not exceed 10%. We feel this is sufficiently conservative because the model likely over predicts true fitness loss. Fitness change each generation is likely very small, so if future research determines that this value should be lower, the impact of an insufficiently conservative level will have been unsubstantial. It is doubtful that fitness loss will be measurable directly, at least in the short term, so management will have to be based on gene flow estimation. The modeled 10% fitness loss level corresponds to gene flow of approximately 2%.

Estimation of gene flow

Gene flow is a seemingly simple concept, but developing straightforward ways to measure it is not simple. For one thing, gene flow from hatchery fish into natural populations is commonly referred to as interbreeding or hybridization. This is an oversimplification. In reality, gene flow occurs by two processes: hatchery-origin fish spawning with natural-origin fish and hatchery-origin fish spawning with each other. How well the hatchery-origin fish spawn and how well their progeny survive, determines the rate at which genes from the hatchery population are incorporated into the natural population. The importance of including the progeny of HxH matings (i.e., the progeny of two hatchery fish spawning in the wild) as a potential "vector" for gene flow is illustrated by the observation that these fish may have a considerably longer and later spawning season than hatchery-origin fish (Seamons et al. 2012). An appropriate metric for gene flow needs to measure the contributions of both types of matings to the natural population being analyzed. Another consideration is temporal scale. Although there may have been effects from gene flow from earlier more intensive and widespread hatchery activities, for the purposes of analyzing these proposed programs, what must be measured is the current rate of gene flow, which is best represented as the proportion of the current naturally produced progeny gene pool:

$Gene\ flow = (2f(HH) + f(NH))/2$, where *f(HH)* is the proportion of naturally produced progeny produced from HxH matings, and *f(NH)* the proportion of progeny produced by NxH[27] matings

WDFW has developed two metrics for measuring gene flow in this way. The first is based on actual genetic data, and is called proportionate effective hatchery contribution (*PEHC*) (Warheit 2014a). WDFW also has developed an alternative demographic method, hereafter called the Scott-Gill method, for calculating the expected gene flow that is based on demographic and life history data rather than genetic data (Scott and Gill 2008a).

Below we discuss in detail these two methods for estimating gene flow and results from applying them to data on Puget Sound steelhead. It is important to understand in reading this material that the Warheit and Scott-Gill methods estimate the current rate of gene flow and expected rate of gene flow, respectively, not cumulative gene flow. In other words, the effects analysis is aimed at how much gene flow is occurring or will occur, not how much may have occurred in the past, nor what the cumulative genetic contribution of EWS to the natural steelhead populations has been. Our analysis thus assumes that natural-origin fish in either analysis may have some level of hatchery ancestry. In the case of the Scott-Gill method, the natural-origin fish considered in the equation may include the progeny of HxH or HxN matings.

Estimation of gene flow using genetic data

Introduction to Warheit method

Estimation of *PEHC* in Puget Sound steelhead is difficult because, in terms of genetic markers that are currently available, the differences between the hatchery-origin fish and natural-origin fish are slight, because of common ancestry and likely gene flow in the past. WDFW has struggled with this problem for several years. Dr. Ken Warheit, director of the Molecular Genetics Laboratory at WDFW, in association with Dr. Shannon Knapp (formerly at WDFW, now at the University of Arizona), has developed a method for estimating *PEHC* in situations like this. The method is new, still undergoing refinement, and for that reason has received limited peer review[28]. Because of this, the method has been extensively reviewed by NMFS staff, and refined in response to that review.

The Warheit method involves, in part, comparing genotypes of natural-origin and hatchery-origin fish using the Structure program (Pritchard et al. 2000; Pritchard et al. 2010). Structure is one of the most widely used programs for inferring population structure, and has also been used for detecting hybrid individuals, frequently between wild and domestic populations. The WDFW Molecular Genetics

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[27] As in earlier usage in this document, this is meant to represent both matings between natural-origin females and hatchery-origin males, and vice versa/

[28] Drs. Warheit and Knapp are currently developing a manuscript for submission to a peer-reviewed journal.

Laboratory has many years' experience using the program. Structure makes use of each individual's multilocus genotype to infer population structure (e.g., hatchery versus wild), given an a priori assumed number of groups or populations. The program will probabilistically assign individuals to populations, or if the admixture option is used, will assign a portion of an individual's genome to populations.

Structure is the basic analytical engine of the Warheit method, but the full method is far more complex than a basic *Structure* analysis. Realizing that assigning portions of an individual's genome to populations must involve error if the genetic distance between the populations involved in the admixture is small, Warheit first investigated this assignment uncertainty in a study of genetic effects of EWS on Skagit winter steelhead. He simulated populations of hatchery-origin and natural-origin fish and their hybrids, then applied *Structure* analysis to determine how well the program classified fish of known ancestry (Warheit 2013). He found that depending on the situation, the proportion of hybrid fish could either be seriously over- or underestimated, and concluded that he lacked sufficient power with 15 microsatellite loci to reliably quantify introgression from EWS into the natural Skagit River winter steelhead populations, or reliably identify pure unmarked hatchery-origin or hatchery-ancestry fish. Warheit's current (2014a) method applies and extends the lessons learned from the Skagit work. The data set consists of genotypes from up to 192 single-nucleotide polymorphism (SNP) loci. Simulation methods were refined to better model the genetic composition of populations. In addition, Warheit used a likelihood approach to adjust the Structure-based assignment proportions, based on the assignment error from analysis of the simulated populations.

NMFS NWFSC staff reviewed a report provided to NMFS in March 2014 that described the method and the results of its application to several Puget Sound steelhead populations (Warheit 2014c). They commented extensively on many aspects of the document (Hard 2014). Because of these comments and additional discussion with NMFS Sustainable Fisheries Division (SFD) staff, the method was refined and the document extensively revised. WDFW provided NMFS with the new draft (Warheit 2014a) in October 2014, which we submitted to NWFSC for review, along with a document by Warheit (Warheit 2014b) detailing his responses to the earlier review. The NWFSC responded with a new review in January 2015 (Ford 2015).

Briefly, the NWFSC reviewers found Warheit's method to be a reasonable, thoughtful and innovative effort to address genetic introgression from closely related hatchery populations. Importantly, Warheit's approach demonstrated that a naïve application of the *Structure* program would provide misleading results, probably overestimating introgresion. However, they were concerned, as in their previous review, that Warheit's approach may overstate the precision and possibly the accuracy of the estimates. In other words, the confidence intervals may be larger than reported, and point estimates may be biased. They singled out two potential sources of uncertainty. The first was uncertainty associated with sampling, which did not seem to have been taken into account. The second was sensitivity to the many assumptions and choices about model parameters that Warheit used.

These NWFSC comments were expected. The Warheit approach is an innovative complex method that attempts something very difficult, and necessarily involves many assumptions and sources of uncertainty. NMFS staff and Warheit discussed the method and revisions to it extensively during the consultation process. Confidence intervals were developed, in fact, at the urging of NMFS staff, with the full understanding that they were underestimates. NMFS considers that although sensitivity analysis is necessary, which may spur further refinement of the technique, the Warheit method is not only a reasonable approach to measuring gene flow in this situation, but is best available science.

The Warheit method continues to be refined. In response to the comments from NWFSC and others, Warheit and Knapp (University of Arizona) revised aspects of the method (Knapp and Warheit 2016) and WDFW (WDFW 2015a) provided new *PEHC* estimates and confidence intervals based on the revision. The latest update has not yet been reviewed by NWFSC.

Application of Warheit method to Snohomish River basin steelhead populations

WDFW has applied the Warheit method to the Skykomish and Snoqualmie natural steelhead populations, as well as several other Puget Sound steelhead populations. Table 14 reports *PEHC* information provided by WDFW (2015a) for the Snohomish River watershed natural steelhead populations, along with sampling details[29]. We have labeled these values "recent past" because they are based on samples collected between 1994 and 2013, so may not reflect current *PEHC* levels, and as well may not reflect recent or planned program changes. However, the table also reports projected *PEHC* values (Hoffmann 2014), which do take into consideration recent and proposed program. The projected values rely a great deal on the *PEHC* estimate, which is subject to imprecision, but are important in that they reflect the proportionate change expected[30].

Table 14. *PEHC* estimates and confidence intervals (CI) based on recent past practices, and projected *PEHC* estimates from proposed EWS hatchery programs, and sampling details for the Skykomish and Snoqualmie steelhead populations (WDFW 2015a). All values presented as percentages.

Basin	**Listed Population**	**Sample Size and Details**	**Recent Past *PEHC* and 90% CI**	**Projected *PEHC* (%) under Proposed HGMPs**
Skykomish/ Snohomish	Skykomish (W)	21 (2013 adult)	0 (0-20)	0
	Pilchuck (W)	49 (2012 adult)	2 (0-16)	0
	N.F. Skykomish (S)	145 (2004, 2012, and 2013 juveniles and adults)	1 (1-3)	1
Snoqualmie	Snoqualmie (W)	166 (2010-2013 juveniles and adults)	4 (0-12)	1
	Tolt (S)	74 (2010-2012 juveniles)	1 (0-3)	0

With one exception, the *PEHC* estimates based on recent past practices are 2% or less, although confidence intervals range up to 16% in the Pilchuck winter steelhead population and 20% in the Skykomish winter population (Table 14). Both of these estimates were based on very small samples, and this is likely the major cause of the large confidence interval, but the large confidence is still a concern. Clearly, a new larger genetic sample is needed from the Skykomish. In the case of the Pilchuck population however, *PEHC* is projected to be 0% in the future, because no releases into the Pilchuck have occurred since 2009, and none are expected to occur under the HGMPs (WDFW 2014a; 2014b).

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[29] The HGMPs also presented this information, but it was updated during the consultation.

[30] Projected gene flow is determined by adjusting the current or recent past estimate for changes that are expected under the proposed action. Simple example: if *PEHC* is estimated to be 2%, and the program is expected to be reduced 50%, the projected *PEHC* would be 1%. The equation for projected values is presented in Hoffmann (2014).

The largest point estimate, 4% for the Snoqualmie winter-run population, also has a high upper confidence limit (12%), and is based on a large sample size, indicating a higher level of gene flow than in the other populations affected by the EWS hatchery programs. However, this *PEHC* estimate was a result of the previous program (recent past practices); and the revised hatchery programs differ in several respects from previous operations, including discontinuation of off-station releases and a reduction in smolt releases from Tokul Creek Hatchery. The projected *PEHC* under the existing programs is 0%. For Snoqualmie, we would expect that *PEHC* estimates going forward could initially be higher than 2%, because *PEHC* estimates to some extent reflect past gene flow. As more time goes by and the signal from past gene flow recedes, *PEHC* estimates for Snoqualmie should more closely reflect reality.

PEHC estimates are likely always overestimates of gene flow. The Warheit method is intended to estimate current gene flow, but it is inevitable that some mixed lineage fish that are not the immediate result of HxH or HxN matings will be identified as such (Warheit 2014a), inflating the *PEHC* estimate. The degree to which these misidentifications inflate *PEHC* has not been explored, and the effect on confidence intervals is unknown. It seems logical, however, that the effect will increase with increasing gene flow. These issues all need to be clarified in further development and updating of the method. However, assuming that *PEHC* has not been systemically underestimated in some way due to a bias in the estimation process, and considering the confidence intervals, recent gene flow from EWS programs into these basins appears to have been on the order of a few percent, and quite possibly averaging well less than 2%. Furthermore, the expectation is that if anything, *PEHC* will remain at these levels. Thus, these results are consistent with low fitness loss. However, it must be kept in mind that these results are based on a new method, which will require a commitment to testing its application and likely further development and adjustment.

Gene flow can be expected to vary from year to year, even if the numbers of spawners and proportion of hatchery fish on the spawning grounds are constant, because mating patterns will vary by chance and survival of progeny will vary. Estimation of gene flow via *PEHC* will also vary from year to year, even if gene flow was truly constant, because of sampling variation. Therefore, it makes sense to manage gene flow based on average *PEHC* values over a period of years, rather than on fluctuating annual estimates. Since genetic effects are often expressed in terms of per-generation impacts, a logical time period over which to average *PEHC* estimates is one steelhead generation. Generation length in anadromous salmonids is calculated as the average age of the spawners. For Puget Sound steelhead, this is approximately four years. Therefore, conclusions based on *PEHC* should be based on a four-year average.

In addition to the questions about the method already expressed in the NWFSC reviews (Hard 2014; Ford 2015) we have concerns about sample composition. As can be seen in Table 14, Warheit's analysis largely used pooled samples from multiple years, and multiple life stages. Given the difficulties inherent in sampling steelhead, pooling seems reasonable, but it may have implications for *PEHC* estimates. We discuss this concern in detail in the section below.

Genetic Monitoring

A key part of the Proposed Action is a genetic monitoring plan described in Anderson et al. (2014), which is intended to verify that *PEHC* is being maintained at or below the stipulated levels. The plan includes sampling in several Puget Sound basins. Table 15 presents sampling details for the Snohomish River basin steelhead populations.

Table 15. Genetic sampling plan for Snohomish River basin steelhead populations Anderson et al. (2014).

Basin	Sample site	Life stage	Number	Population(s) sampled
Skykomish / Snohomish	Mainstem Skykomish R.	Smolts	≤ 100 annually	Skykomish (W) and N.F. Skykomish (S)
	Pilchuck River	Adults	≤ 50 every third year	Pilchuck (W)
Snoqualmie	Mainstem Snoqualmie R.	Smolts	≤ 100 annually	Snoqualmie (W) and Tolt (S)
	Snoqualmie R.	Adults	≤ 50 annually	Snoqualmie (W)

This level of sampling is impressive, especially coupled with sampling efforts elsewhere in Puget Sound. But the plan lacks important details. The plan commits to sampling a maximum specified number of either smolts or adults on a regular basis, but the numbers are the same in all basins, so it appears to that there is no link between sample size and analytical power. In the Pilchuck River, for example, is a sample of up to 50 adults collected every third year large enough to generate a *PEHC* estimate of the desired precision and accuracy? It is also unclear, given that the specified sample sizes are maxima, how many samples can actually be collected in a season at the various locations. This is especially an issue with the Skykomish and Snoqualmie smolt traps, which will collect smolts from multiple populations.

Based on the sample pooling evident in the Warheit report (Warheit 2014a), it seems likely that either analytical demands or sampling difficulties will necessitate that samples be pooled. The implications of this procedure are unclear. If *PEHC* is constant over time, then unweighted pooling seems reasonable in principle. However, *PEHC* will undoubtedly vary to some degree, possibly necessitating weighting of samples. In addition, sample sizes may vary widely from year to year. Perhaps samples should be weighted based on size. Finally, it makes sense that in a given population, a *PEHC* estimate based on adults could differ from one based on smolts, simply because the progeny of hatchery-origin fish are expected to be less fit than the progeny of natural-origin fish and thus some of them may die before they can be sampled as adults. The implications of pooling adult and juvenile samples are thus unclear. It should also be noted that there is no directed sampling of the N.F. Skykomish and Tolt summer steelhead populations. Summer steelhead populations within the Snohomish River basin are at low abundance levels, with very limited available escapement estimates for the N.F. Skykomish population. Therefore, it can be expected that both populations would be sampled at low rates at the smolt traps, but at this point sampling these populations effectively seems very difficult.

Estimation of gene flow using demographic methods

Scott-Gill Method

The Scott-Gill method for estimating gene flow using demographic and life history data is based on the schematic diagram presented above in Figure 9. The method assumes random mating within mating region, and uses estimates of the proportion of spawners that are of hatchery origin (pHOS[31]), the proportion of hatchery-origin and natural-origin spawners in region B, and the relative reproductive success (RRS) of the HxH and NxH mating types to compute the proportion of the offspring gene pool produced by hatchery-origin fish. Although the value produced by the equation appears to be analytically identical to *PEHC,* we will call it *DGF* (demographic gene flow) to prevent confusion as to which metric we are discussing, and to distinguish the metric from the concept.

Hoffmann (2014) presents *DGF* estimates for several Puget Sound winter steelhead populations, along with details on estimation of parameters. Considerable effort went into population-specific development of the overlap parameters, especially in modeling the timing of natural spawning. In Washington, steelhead spawning surveys are ordinarily not started before March 15. Hoffmann (2014) used the temporally truncated information to model pre-March 15 spawning. Because spawning distributions are not known with precision for either the EWS or natural steelhead populations in most cases, basin specific information on overlap was bracketed with information from the Tokul Creek hatchery population, the best-studied winter steelhead hatchery population, and the natural winter steelhead populations in Snow Creek and the Clearwater River.

Hoffmann used literature values for the RRS of EWS, including a range for HxH matings. The parameter most susceptible to error is pHOS, which was estimated from spawning ground surveys and from the number of hatchery-origin fish returning to the hatchery. The total number of fish returning to the hatchery was assumed to be 70-80% of the escapement. This assumption of 20-30% of the hatchery-origin escapement remaining in the river to spawn was considered to be conservative (i.e., greater or higher) in comparison to earlier estimates by the HSRG of 10-20% (Hoffmann 2014).

During the review, an algebraic error was discovered in the Scott-Gill equation (Busack 2014), so all previously published *DGF* values were slightly inaccurate. Table 16 presents updated *DGF* values for steelhead natural populations in the Skykomish and Snoqualmie Basins computed with the same assumed values about RRS (0.13 for HxH matings and 0.54 for HxN), and pHOS as proportion of hatchery-origin escapement (30%) (Hoffmann 2015a; Hoffmann 2015b). No Scott-Gill analysis was possible for the summer steelhead populations because these populations are not monitored (WDFW 2014d), and thus no abundance or timing data exists. Note that the “recent past” escapement years used in the *DGF* analysis may differ from those in the *PEHC* analysis. *PEHC* estimates were based on whatever samples were available and deemed appropriate, rather than data collected on a regular schedule over the years. The years of demographic data used for DGF estimates were selected by us from those available to best represent existing demographic variation.

The Scott-Gill results indicate that gene flow has been above 2% in the Snoqualmie winter-run steelhead natural population, and may have been above 2% in the Skykomish/Snohomish steelhead natural populations, but it is likely to decline and be under 2% in both areas under the proposed action. However, note that the range for projected DGF extends from under 1%, under the assumptions of 20% “stray” rate and “lower” RRS values, to over 2% under the assumptions of 30% “stray” rate and “higher” RRS values. We consider projected gene flow (based on *DGF*) to likely be under 2%, which agrees with the *PEHC* analysis. However, the possibility exists that gene flow will be over 2% if in fact the worst case 30% “stray” rate assumption used to determine the high end of the DGF range reflects reality. WDFW developed the 30% assumption for the “worst case” stray rate based on an HSRG

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[31] Symbolized by *q* in the equation in WDFW documents.

Table 16. *DGF* values generated from the Scott-Gill equation for the Skykomish and Snoqualmie winter-run steelhead natural populations (revised from Hoffmann 2015a; Hoffmann 2015b). All values are expressed as percentages. For historical pHOS and *DGF*, means are reported with maxima in parentheses. pHOS under the proposed action is calculated based on 2010-2015 spawning escapement and smolt-to-adult hatchery rack returns assuming 20- and 30- percent "stray rates". Proposed action *DGF* values are presented as ranges based on combinations of the two assumed stray rates and of the two assumed RRS values for hatchery-origin fish, and as the mean of those four scenarios. Historical pHOS and *DGF* values assume the 30% stray rate and higher of the assumed RRS values.

	Population	
Metric/Data	**Skykomish/ Snohomish**	**Snoqualmie**
Escapement years	2003-2014, except 2007 - 2009	2002-2015
O_N	1.96	2.1
O_H	27.9	16.88
Recent past pHOS	8.7 (24.2)	30.0 (56.0)
Recent past *DGF*	1.21 (4.62)	3.98 (14.91)
Projected pHOS	9.0-14.6	8.4-13.5
Projected *DGF*	1.58 (0.79-2.73)	1.28 (0.55-2.34)

assumption of a 20% stray rate (Hoffmann 2014). The 30% appears to be an informed guess at the high end of the potential range of stray rates and it is unclear whether it is substantiated by any data, thus it is possibly unrealistically high. In summary, although it is likely that projected DGF is under 2%, there is a moderate amount of uncertainty around this conclusion. The "stray" parameter, which is critical for pHOS determination, and other parameters used in the Scott-Gill analysis, need to be validated by monitoring, as discussed below.

Sensitivity analysis

Whatever error exists in the *DGF* estimate is predominantly due to parameter uncertainty, rather than error associated with assumed statistical distributions, so no confidence intervals are included with the estimates in Table 16. We did not complete a comprehensive sensitivity analysis, but did look at the effect of varying overlap values. As in the EWS Sim modelling, we found DGF results to be relatively insensitive to differences in overlap values. Hoffmann (2014) used a more structured sensitivity analysis to evaluate the effects of parameter uncertainty on the Scott-Gill results rather than a basin- or population-specific analysis.

Average parameter values for overlap, pHOS, and RRS[32] over all the Puget Sound steelhead populations were analyzed in the document to arrive at an average *DGF*. Each parameter average was then varied

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[32] Hoffmann used two values for the RRS of HxH matings (0.02 and 0.13), and an average of 0.07 in the sensitivity analysis.

individually up and down 50% (Table 17) to determine the effect on that average *DGF* estimate (Figure 12). Based on this analysis, results seem most sensitive to pHOS, but are reasonably sensitive to large changes in RRS and overlap values. Although the Hoffmann sensitivity analysis is informative, additional sensitivity analysis is necessary to improve the level of certainty of the *DGF* estimates. First, although basing the analysis on average values makes sense in several ways, it should be done on a population specific basis as well, as the situation for a particular population may deviate considerably from an average value. Second, multiple parameters should be varied simultaneously. We realize that varying combinations of parameters presents a huge number of options, but this can be limited by focusing on those subject to the greatest uncertainty or variability. Third, variation should be done on a biologically realistic basis rather than using an arbitrary scale such as 150% and 50%, because some variables are more subject to variation/uncertainty than others.

Table 17. Input parameter values used in sensitivity analysis of Scott-Gill method applied to Puget Sound steelhead natural populations (from Table 11 of Hoffmann 2014). All values are expressed as percentages.

Input Parameter	Average value over watersheds and cases	Parameter value at a 50% increase	Parameter value at a 50% decrease
O_N	3.63	5.44	1.81
O_H	12.19	18.29	6.10
K1 (RRS of HxH matings)	8	12	0.04
K2 (RRS of HxN, NxH matings)	54	81	27
On Station pHOS (q)	5.05	7.58	2.53

An adequate sensitivity analysis may require the dissection of the input parameters into components and investigating their individual variability/uncertainty. An excellent example is pHOS, which is obviously a function of the estimated number of hatchery-origin and natural-origin fish on the spawning grounds. The former is assumed to be a constant proportion of the escapement, calculated from the known number returning to the hatchery, and the latter is based on redd counts and assumptions about the proportion of the run that spawns before redd surveys begin, itself an input parameter to the Scott-Gill equation. Given this, it is unclear that sensitivity analysis based on varying pHOS up and down 50% adequately captures all the uncertainty/variability in pHOS. Possibly, the major source of imprecision and bias is in the redd counts. Another obvious candidate for closer scrutiny is the overlap in hatchery and natural-origin steelhead spawn timing.

The need for better estimation of the parameters used in the Scott-Gill method and understanding the uncertainty around them is underscored by the visibility of the Seamons et al. (2012) study of performance of EWS at Forks Creek, a small tributary to the Willapa River on the Washington coast. This study, frequently cited in discussions of effects from naturally spawning EWS, particularly the failure of assumptions about spawning overlap and the resulting high proportion of HxN progeny. Given the high visibility for this work, and the obvious potential for applying the conclusions to Puget Sound EWS hatchery programs, we consider it important to discuss in detail the potential applications of this research. NMFS requested that WDFW provide supplementary information dealing with this issue (Tynan 2015), and the following discussion is based on WDFW's response (WDFW 2015b), which should be consulted for additional detail.

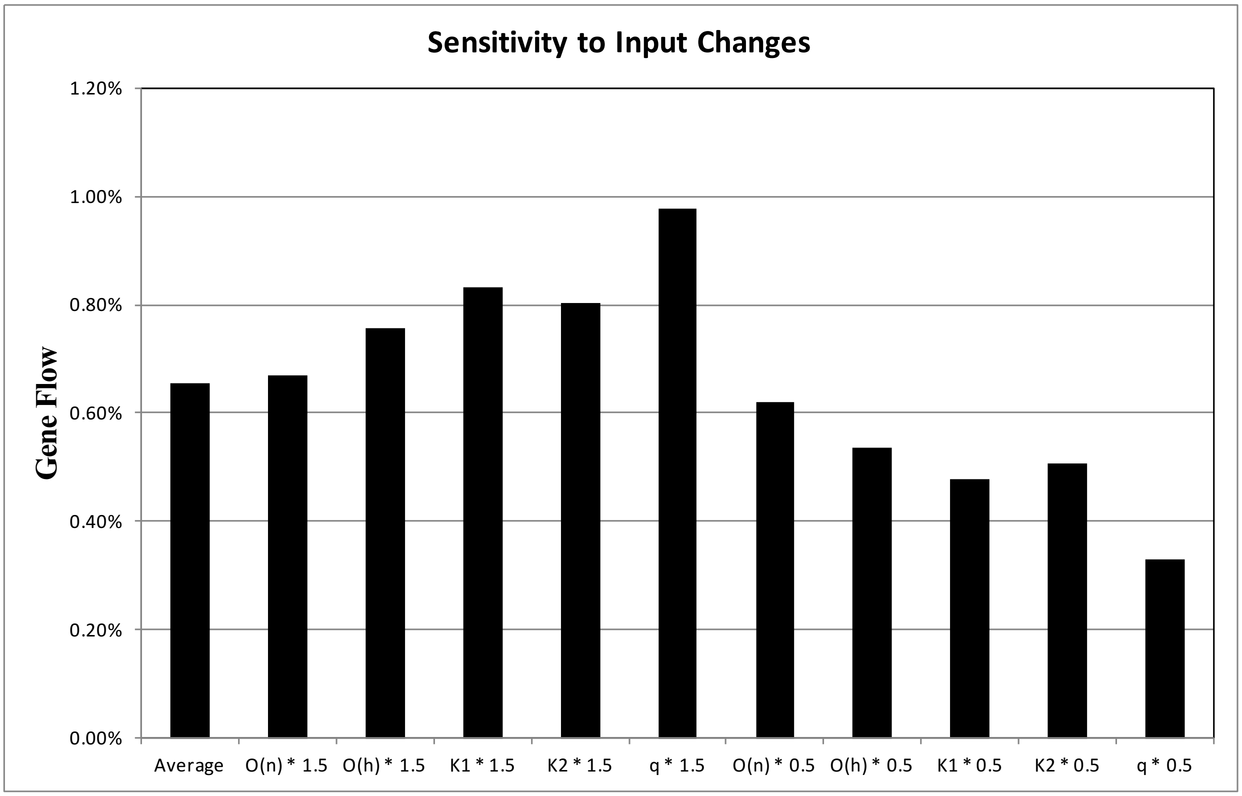

Figure 12. *DGF* values resulting from varying each Scott-Gill parameter in isolation by a 50% increase and a 50% decrease over the input value averaged over all watersheds and all cases (from Figure 11 in Hoffmann 2014).

In evaluating the Forks Creek study, there are two primary issues spawning overlap of natural-origin and hatchery-origin fish, and the presence of HxN hybrids resulting from that overlap. In the Seamons et al. (2012) study, the median day of arrival for hatchery-origin adults was early to middle January, and the median day of arrival for natural-origin (unmarked) adults assigned by Seamons et al. (2012) to the wild category was middle to late April. There was no overlap between the hatchery and wild distribution quartiles, and very little overlap between the 95% CIs (Seamons et al. 2012, Fig. 5). Thus, the spawning overlap in Forks Creek does not appear to be different from the values used in the Scott-Gill modelling (Hoffmann 2015a; Hoffmann 2015b). Because there is no evidence for more spawning, the question is why does the Forks Creek research indicate a considerably larger number of hatchery-wild hybrids than are detected (based on Warheit 2014a) in the Skykomish and Snoqualmie rivers? The most likely explanation is higher spawner overlap than would be expected in Puget Sound. The spawner overlap argument is based on size of the system and hatchery location, hatchery fish were more likely to be attracted back to Forks Creek, increasing the spatial overlap of spawning, thus the highest possible amount of introgression would be expected in the creek as hatchery-origin adults return to their home stream to spawn. Forks Creek is entirely dissimilar to the watersheds being considered in the proposed action; it would be expected that a coastal, lowland, rain-dominated watershed like Forks Creek would, in general, have a much earlier spawn timing than the watersheds within the proposed action (transitional hydrographs with bi-modal peaks). There is no estimate of the Willapa River steelhead population's introgression with EWS, therefore any population scale effects are conjecture. The proposed programs operate as isolated programs and no natural-origin fish are used as broodstock, whereas the Forks Creek program did not operate as an isolated program- the program incorporated an undocumented number of natural-origin steelhead into the hatchery broodstock. Forks Creek also passed excessive numbers of hatchery-origin steelhead onto the spawning grounds, allowing interaction with the earliest natural-origin steelhead spawners. A final possibility is an upward bias in assignment of fish to the hybrid category.

This discussion of the Seamons et al. (2012) is in no way intended to weaken the argument for empirical verification of key biological parameters used in the Scott-Gill modelling. In fact, by emphasizing the importance of considering program-specific factors, it strengthens the argument. . However, as mentioned above in the discussion of within-population diversity, the model that forms the basis for the equation assumes that the spawning events of interest involve only returning adult hatchery-origin and natural-origin steelhead: matings involving precocious juvenile male hatchery steelhead and resident O. *mykiss* are not included. The model should be expanded, as appropriate, to include these gene-flow pathways, as not including contributions from precocious males could underestimate *DGF*. However, it is important to remember that all gene flow, regardless of whether the donor was a returning adult or a precocious male, even if it is not being tracked correctly by the current version of the Scott-Gill equation, would be reflected in the *PEHC* estimate.

Summary

Table 18 presents the *PEHC* and *DGF* values for the Skykomish/Snohomish and Snoqualmie steelhead natural populations together to facilitate comparison of the two metrics. Recent past *PEHC* estimates were under 2% or less, except for the Snoqualmie winter-run steelhead population, and projected *PEHC* values for all Skykomish/Snohomish and Snoqualmie steelhead populations are 1% or less. Although the recent past PEHC estimate for Snoqualmie winter-run steelhead was considerably higher than 2%, large- scale program changes described in the HGMP make the projected *PEHC* value reasonable. However, as discussed above, although mean projected *DGF* is under 2% for both programs, ranges for both programs exceed 2%. While this fact does not undermine our conclusion that the level of gene flow from the proposed action is likely below 2% based on the best available science, it does call for the reduction of this uncertainty through the gathering and analysis of new data.

In earlier sections we have discussed at some length the need for additional development of the Warheit method (which is ongoing) and associated sampling plans, and the need for a more thorough sensitivity analysis, along with validation monitoring of the input parameters used in the Scott-Gill method. The space devoted to detailing those issues should not overshadow the fact that for these hatchery programs, two credible and independent approaches indicate that gene flow, measured either as *PEHC* or *DGF*, is likely less than 2% in natural steelhead populations affected by the proposed action. And although we have questions about the precision of the *PEHC* results, and questions about both precision and bias of the *DGF* results, we conclude that there would have to be unreasonably large errors in methods or parameter estimation to have achieved these results if the gene flow was actually larger than the *PEHC* and *DGF* estimates. Thus, NMFS concludes that gene flow from the proposed action has little negative effect on the Skykomish/Snohomish and Snoqualmie steelhead natural populations. However, given the level of uncertainty regarding the gene flow estimates, our conclusion that the estimates are likely below 2% must be confirmed through further monitoring, described in the ITS.

Table 18. Summary of analyses of gene flow from EWS into Skykomish/Snohomish and Snoqualmie steelhead natural populations. (Data from Table 14 and Table 16). All values are expressed as percentages.

		PEHC (%)		***DGF (%)***	
Basin	**Listed Population**	**Past Practices (90% CI)**	**Projected**	**Past Practices**	**Projected**
Snohomish/ Skykomish	Pilchuck (W)	2 (0 - 16)	0	1.21	1.58 (0.79-2.73)
	Skykomish (W)	0 (0 - 20)	0		
	N.F. Skykomish (S)	1 (1 - 3)	1		
Snoqualmie	Snoqualmie (W)	4 (0 - 12)	1	3.98	1.28 (0.55-2.34)
	Tolt (S)	1 (0 - 3)	0		

One final issue that must be dealt with is the affect through gene flow from ESS hatchery programs in North Puget Sound. These hatchery programs are not part of the proposed action, but have been discussed as part of the Environmental Baseline (Section 2.3.2). The following more detailed discussion of their genetic effects is located in this section because it relies on the analytic methods discussed above; however, this is not intended to suggest that the effects of these programs are effects of the proposed action. Recent past *PEHC* estimates are available for the Skykomish/Snohomish and Snoqualmie basins, which are affected by the in-basin Wallace/Reiter ESS program, and are presented in Table 19. During this ESA consultation, NMFS requested that WDFW downsize the Wallace/Reiter program to reduce the combined gene flow from all hatchery programs into Snohomish steelhead natural populations and WDFW committed to do so (Unsworth 2016). This and the previously mentioned discontinuation of all tributary-level outplants of ESS, are expected to substantially reduce ESS hatchery effects on the Snohomish steelhead natural steelhead populations, and this is reflected in the projected *PEHC* values in the table. Additional program modifications in terms of fish removal at the Sunset Fall trap should reduce gene flow even more.

Table 19. *PEHC* estimates based on recent past practices and projected *PEHC* estimates for EWS and ESS hatchery programs in the Skykomish/Snohomish and Snoqualmie steelhead populations (Unsworth 2016; Warheit 2014a; WDFW 2015a).

		EWS		**ESS**	
Basin	**Listed Population**	**Recent past *PEHC* and 90% CI**	**Projected *PEHC***	**Recent past *PEHC* and 90% CI**	**Projected *PEHC***
Skykomish/ Snohomish	Skykomish (W)	0 (0-20)	0	5 (0-31)	2
	Pilchuck (W)	2 (0-16)	0	2 (0-14)	0
	N.F. Skykomish (S)	1 (1-3)	1	95 (88-99)	NA
Snoqualmie	Snoqualmie (W)	4 (0-12)	1	3 (1-10)	0
	Tolt (S)	1 (0-3)	0	68 (55-79)	0

The most dramatic reduction in gene flow is expected in the Tolt summer steelhead natural population. Based on the *DGF* computational method, changes in the hatchery program will result in a projected *PEHC* of 0% (Table 19). However, estimated *PEHC* will actually remain high in the Tolt population, because of the high level of past gene flow. As explained earlier, the Warheit method will erroneously identify some fish from earlier generations as the progeny of HxH or HxN matings, inflating PEHC estimates, and this effect increases with increasing gene flow. Past gene flow from ESS programs into the Tolt and North Fork Skykomish summer steelhead natural populations has been so high that (Warheit 2014a) considers them "feral" natural-origin populations of ESS. Accurate Warheit-method based estimates of current gene flow into these populations from the Wallace/Reiter ESS hatchery program are likely impossible at this time, and likely for many years into future. Nevertheless, reduction in the number of fish released and other programming changes are expected to substantially decrease gene flow.

Based on the information available in Table 19, NMFS concludes that the effects of the proposed action combined with the effects of the ESS program do not appear at this time to pose significant negative effects through gene flow or other genetic effects to the survival or recovery of all ESA-listed steelhead natural populations in the Skykomish/Snohomish and Snoqualmie Basins, except for North Fork Skykomish summer steelhead. Projected *PEHC* for ESS and EWS programs combined for the other four listed populations is 2% or less. However, NMFS also feels that this conclusion must be validated as indicated above by 1) consultation on the Wallace/Reiter ESS program in the very near future, 2) further development of the Warheit method to answer questions raised in the NWFSC review and in this analysis, 3) further development of the genetic monitoring plan, and 4) expanded sensitivity analysis of the Scott-Gill method. These measures are detailed, along with time frames for completion in the Terms and Conditions section (2.8.4) of this document.

The North Fork Skykomish population is a special case, because gene flow from the ESS program in the basin has been so extensive that WDFW regards it as a feral population of Skamania steelhead. The effects of the EWS program on this population (projected *PEHC* of 1%) are trivial, possibly even undetectable compared to the much larger effects of the ESS program. Given this, while the status of this population in light of the extremely high past gene flow from the ESS program has not been fully resolved, gene flow from the EWS program is low risk, posing no risk to the North Fork Skykomish population's viability. WDFW is currently implementing changes to the ESS program (Unsworth 2016) that are expected to reduce the risk from the ESS program.

B) Negligible Effect - Spawning ground competition and redd superimposition:

EWS that escape to spawn naturally have a negligible effect on ESA- listed Chinook salmon and ESA listed steelhead through redd superimposition. The exact spawn timing of EWS in the action area is unknown. The first hatchery egg takes over the last 10 years (2004/05 to 2013/14) have averaged December 28 at the Tokul Creek Hatchery (WDFW, unpublished weekly in-season hatchery escapement reports from 2004-2015, and following). During this period, no egg takes were conducted at the Reiter Ponds and Wallace River hatchery facilities. The earliest first egg take during this 10-year period was December 18, and the latest first egg take was January 14. The 2014/15 spawning season was the first year of EWS egg takes at the Wallace River Hatchery. The first EWS egg take at the Wallace River Hatchery was on December 16, 2014 with the last egg take of the season on January 14, 2015.

Older (2000-2010) weekly WDFW in-season hatchery escapement reports indicate last egg takes and fish captures typically occurred from early-February to mid-March (median date February 25). Hoffman (2014) determined that during the most recent years when hatchery traps were operated well into the month of March, that 16.9 and 49.5 percent of the total hatchery-origin steelhead returns entered Tokul

Creek Hatchery and Reiter Ponds Hatchery after January 26, respectively. Newer (2011-2015) weekly in-season hatchery escapement reports indicate last egg takes occurred between January 15 and January 21.

Figure 13 depicts brood year 2010 through 2015 average cumulative entry into the hatchery traps at Tokul Creek and Reiter Ponds. Approximately, 97- and 92-percent of all EWS entered the traps before March 1 at Tokul Creek and Reiter Ponds, respectively. EWS spawn timing was therefore assumed to occur from late-December through mid-March. The number of EWS that stray to spawn naturally is unknown. However, the 12-year average exploitation rate estimate (harvest/harvest + hatchery escapement) for hatchery fish has averaged 83 percent in the Snohomish River basin. The number (harvest and hatchery escapement) of EWS returning to action area watersheds is large, averaging 5,344 adults over the last twelve years in the Snohomish River basin (WDFW 2014a; 2014b). Projected returns (harvest plus hatchery escapement) based on the 12 year average smolt-to-adult-return (SAR) and the number of projected smolt releases are expected to be 4,257. Thus, given the approximately 83% exploitation rate on EWS, the potential numbers of EWS returning to the hatcheries or terminal areas would be approximately 727 for the Snohomish River basin. Most of these fish would return to the hatcheries and be used as hatchery broodstock or surplused.

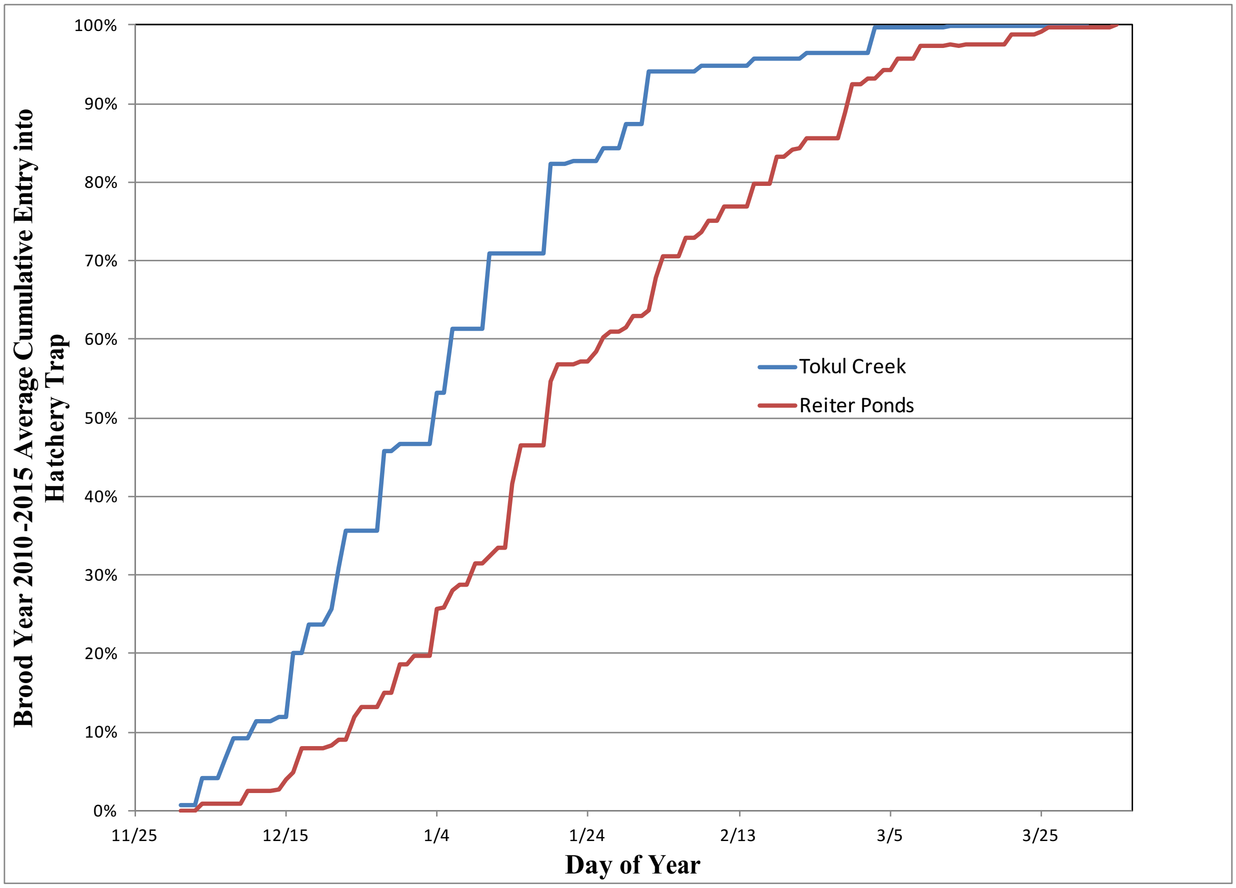

Figure 13. Brood year 2010 through 2015 average cumulative entry into hatchery traps at Tokul Creek and Reiter Ponds hatchery facilities.

Chinook salmon spawning takes place much earlier than any potential spawning by stray EWS. The earliest spawning Chinook salmon spawn from late August through October (Skykomish population) and the latest spawning Chinook salmon spawn from mid-September through early-November (Snoqualmie population; see Table 20). The earliest and latest Chinook salmon spawning therefore is six to eight weeks prior to the initiation of EWS spawning. In addition, Chinook salmon redds are typically constructed in larger substrate than that preferred by steelhead; although there is some overlap in substrate size utilized by the two species (Kondolf and Wolman 1993). The anticipated number of EWS escaping to spawn naturally, differences in substrate size used between the two species, and the significantly earlier spawn timing for Chinook salmon would make substantial spawning ground redd superimposition effects on Chinook salmon populations unlikely.

Table 20. Terminal area/river entry timing, spawn timing, and spawning location for natural-origin Snohomish River basin's Chinook salmon and steelhead populations.

Species (Population)	Terminal Area/River Entry Timing	Spawn Timing	Spawning Locations
Chinook Skykomish	May - July	September - October	Skykomish, Pilchuck, Wallace, and Sultan rivers; Woods, Elwell, Olney, Proctor, and Bridal Veil creeks; and the North and South Forks of the Skykomish River
Chinook Snoqualmie	August - October	Mid-September - early-Nov.	Snoqualmie, Tolt, and Raging rivers, and Tokul Creek
Steelhead Pilchuck (W)	Mid-October - May	March - early-June	Pilchuck River and Worthy, Dubuque, and Little Pilchuck creeks
Steelhead Skykomish (W)	Mid-October - May	Late- February - early-June	Skykomish, Wallace, and Sultan rivers; Woods, Elwell, Olney, Proctor, Lewis, and Salmon creeks; and the North and South Forks of the Skykomish River
Steelhead Snoqualmie (W)	Mid-October - May	Late- February - early-June	Snoqualmie, Tolt, and Raging rivers, and Tokul, Cherry, Harris, Griffin, Patterson, Canyon, and Deep creeks
Steelhead N.F. Skykomish (S)	May - October	February - May	N.F. Skykomish River and tributaries upstream of Bear Creek Falls
Steelhead Tolt (S)	May - October	February - May	S.F. Tolt River between RM 3.3 and 7.8; N.F. Tolt River upstream of partial barrier.

Data sources: Williams et al. 1975; WDF, WDG, and WWTIT 1993; Haring 2002; WDFW 2002; R2 Resource Consultants 2008; PSIT and WDFW 2010; Mike Crewson and Pete Verhey, Tulalip Tribes and WDFW unpublished escapement data 2014; WRIA 7 WDFW spawning ground database, accessed December 2014 (updated through 2012).

EWS straying onto the natural spawning grounds are likely to use the same or similar habitat used by natural-origin winter-run steelhead. Summer-run steelhead within the action area have earlier spawn timing on average than that of the winter-run natural populations (see Table 20), and their primary spawning habitats are thought to be isolated by cascades and waterfalls that are not passable to winter-run steelhead during higher winter stream flows (WDFW and WWITT 1994, Myers et al. 2015). Hoffman (2014) estimated that 1.9, 2.0, and 2.1 percent of all natural-origin steelhead spawning occurred prior to March 15, in the Pilchuck, Skykomish, and Snoqualmie basins, respectively.

While spatial overlap likely exists between stray hatchery-origin steelhead and natural-origin steelhead, the temporal separation likely limits competition for spawning sites and makes redd superimposition unlikely.

C) Negligible Effect - Population viability:

EWS are produced for fisheries harvest augmentation purposes, and are managed to be isolated from the ESA-listed steelhead populations in the Snohomish River basin. The programs are not intended to benefit the viability status of any natural steelhead population. Adult fish produced by the programs are not intended to spawn naturally, and they are not the proper stock to contribute to the viability of any natural-origin steelhead population. Because of the out-of-DPS status of EWS and the stock's non-native status in the watersheds where they are released, rather than benefitting population viability, the program may have negative effects on natural steelhead genetic diversity (see "Genetic Diversity" discussion in "A)" above). Responsive measures are applied through the hatchery programs to isolate juvenile and adult hatchery fish spatially and temporally from their associated natural-origin populations, including reducing the potential for gene flow from the hatchery populations to the natural populations (see Section 2.4.2.2).

D) Negligible Effect - Marine-derived nutrients:

ESA-listed Chinook salmon and steelhead in the Snohomish River basin will benefit from the deposition of hatchery program-origin steelhead carcasses resulting from straying (when mortality occurs), and carcass distribution after spawning at the hatcheries. Decaying carcasses of spawned adult hatchery-origin fish will contribute nutrients that increase productivity in action area basins, providing food resources for naturally produced Chinook salmon and steelhead (WDFW 2014a; 2014b). Diminished numbers of salmonids returning to spawn in most Puget Sound watersheds have resulted in nutrient deficiencies compared to historical conditions, reducing salmon and steelhead productivity. Adult salmon and steelhead spawning escapements have significantly declined to a fraction of their historic abundance in many watersheds, raising concerns about a lack of marine-derived nutrients returning back to the systems in the form of salmon carcasses.

The historical amounts of nutrients available to streams in the Snohomish River basin derived from salmon carcasses was likely large and contributed to the enhancement of many forms of aquatic life (WDFW 2013). The return of marine-derived nutrients (particularly nitrogen and phosphorous) from salmon carcasses provides an important nutrient source to the oligotrophic waters and riparian areas in the higher elevations of the Snohomish River watershed (Haring 2002). The basin has greater returns of anadromous salmonid spawners relative to other Puget Sound areas, in particular coho salmon, but the ability of upper watershed areas to retain marine-derived nutrients from spawned salmon may be compromised by degraded riverine habitat, potentially resulting in carcasses being washed out before imparting nutrient benefits (Haring 2002).

Natural spawning by stray hatchery-origin fish, and hatchery carcass seeding that will be implemented for a portion of annual adult returns through the proposed action (WDFW 2014a; 2014b), will benefit marine derived nutrient deposition in the Snohomish River basin.

2.4.2.3 Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas

Negligible effect: Fish disease pathogen transfer and amplification:

Best hatchery management practices that will be implemented to address fish health are described in each of the steelhead HGMPs. Fish health protection and maintenance measures, and hatchery sanitation procedures will be applied during the steelhead broodstock collection, mating, incubation, rearing, and release phases of the proposed programs. Proposed measures and procedures are described in performance standards and indicators, adult management, and fish rearing and release sections of each HGMP. Proposed fish health monitoring and evaluation measures are also described in those HGMP sections.

The hatchery programs will be operated in compliance with "The Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State" protocols (WDFW and NWIFC 1998, updated 2006). The co-manager policy delineates Fish Health Management Zones and defines inter and intra-zone transfer policies and guidelines for eggs and fish that are designed to limit the spread of fish pathogens between and within watersheds (WDFW and NWIFC 1998, updated 2006). The proposed hatchery programs will implement standard methods for the prevention, diagnosis, treatment, and control of infectious fish pathogens and BMPs for standard hatchery maintenance and sanitation practices as referenced in the co-manager's fish health policy (as per Pacific Northwest Fish Health Protection Committee (PNFHPC) 1989and AFS 1994 guidelines) to reduce the risk of fish disease pathogen amplification and transfer within the hatchery and to fish in the natural environment. For all steelhead propagated through the WDFW steelhead hatchery programs, fish health specialists and pathologists from the WDFW Fish Health Section will provide fish health management support and diagnostic fish health services. Following is a summary of fish health management procedures that will be applied during operation of the EWS hatchery programs (from WDFW 2014a; WDFW 2014b).

Minimally invasive fish health maintenance procedures will be conducted during the periods when adult steelhead collected as broodstock would be held at the hatcheries before they are spawned. Behavior and external condition of the fish will be routinely observed by hatchery staff, and non-lethal sampling will be conducted as needed to observe gross external condition in conjunction with standard fish handling (e.g., broodstock sorting). Any fresh, pre-spawning steelhead mortalities will be removed from holding ponds and examined. If necropsy is warranted, the carcass will be either examined immediately by fish health staff (if present on-site), retained fresh, or frozen and examined during the next fish health professional monitoring visit (depending on how soon that will be possible). WDFW fish health professional staff will visit the hatchery fish rearing sites at least monthly, or more often if needed, to perform routine monitoring of juvenile fish, advise hatchery staff on pathogen findings and disease diagnoses, and recommend remedial or preventative treatments through administration of therapeutic and prophylactic treatments when appropriate. Appropriate actions, including drug or chemical treatments are recommended as necessary. Consistent with the co-manager fish health policy, representative samples from the hatcheries will be examined for the presence/absence of infectious fish pathogens within one month of release or transfer. The co-managers maintain a fish health database to identify trends in fish health and disease at the hatcheries. Fish health management plans for each facility will be assembled and implemented based on health and disease incidence trend findings.

Implementation as proposed in BMPs specified in the co-managers' fish health policy for monitoring the health of fish in hatcheries will reduce the likelihood of disease transmission from program hatchery steelhead to naturally produced fish. When implemented, those practices will help contain any fish disease outbreaks in the hatcheries, minimize release of infected fish from hatcheries, and reduce the risks of fish disease pathogen transfer and amplification to natural-origin fish (NMFS 2012). BMPs applied to minimize risks of adverse effects on listed steelhead and Chinook salmon associated with fish disease pathogen transfer and amplification for the two proposed steelhead HGMPs are based on best available science, and are expected to be sufficiently protective of listed natural-and hatchery-origin fish populations. Further, high egg-to-smolt survival rates for fish propagated in the proposed hatchery programs as reported in Sections 9.1.1 and 9.2.1 of the HGMPs indicate that protocols for monitoring and addressing the health of fish in hatcheries have been successful in containing disease outbreaks, minimizing the release of fish carrying infectious pathogens and reducing the risk of transferring disease to natural-origin fish populations. For these reasons, fish pathogen and disease transmission and amplification risks that will be associated with HGMP implementation appear to be adequately addressed and minimized.

Negligible effect: Competition

Competition occurs when the demand for a resource by two or more organisms exceeds the available supply. If the resource in question (e.g., food or space) is present in such abundance that it is not limiting, then competition is not occurring, even if both species are using the same resource. For salmonids, adverse impacts of competition in freshwater areas may result from direct interactions, whereby a hatchery-origin fish interferes with the accessibility to limited resources by naturally-produced fish, or through indirect means, as when utilization of a limited resource by hatchery-origin fish reduces the amount that would otherwise be available for naturally-produced fish (SIWG 1984). Release of hatchery–origin salmonids derived from a non-indigenous stock into a listed fish species' freshwater habitat, or where they may access freshwater habitat for the listed species, may harm the listed species and therefore constitutes a "take" under the ESA (NMFS 1999). The major hazards of concern regarding freshwater competitive impacts of hatchery salmonids on listed naturally produced salmonids are food resource competition and competition for juvenile rearing sites (NMFS 2012). For these competition risks between fish origins or fish species to occur, substantial levels of spatial and temporal overlap, and limited resources shared by the fish, must exist.

The Wallace River Hatchery is located at RM 4.0 on Wallace River, tributary to the Skykomish River at RM 35.7 (continues as the Snohomish River at RM 20.5); the Reiter Ponds facility is located adjacent to the Skykomish River at RM 46.0; and Tokul Creek Hatchery is located at RM 0.5 on Tokul Creek, tributary to the Snoqualmie River at RM 39.6, the Snoqualmie River enters the mainstem Snohomish River at RM 20.5. EWS smolts must travel a minimum 39.7, 46.0, and 60.1 miles from their respective release sites in freshwater to reach seawater. The number of miles of freshwater habitat the hatchery-origin fish must transit during their seaward migration presents opportunities for interactions, including competition, with any rearing and emigrating natural-origin, listed Chinook salmon and steelhead occupying the same freshwater habitat. The degree to which ESA-listed natural-origin juvenile salmon and steelhead and hatchery-origin steelhead interact in these freshwater areas, potentially leading to competition effects, depends on temporal overlap between the two groups, considering natural-origin fish emigration timings, and hatchery-origin fish release timings (Table 21).

Table 21. Comparative individual sizes and freshwater occurrence timings for rearing and/or emigrating natural-origin salmon and steelhead juveniles by species and life stage, and hatchery-origin salmon juveniles proposed for release from the Snohomish River basin EWS hatchery programs.

Species/Origin	***Life Stage***	***Individual Size (mm FL avg. and range)***	***Occurrence or Release Timing***
Chinook salmon (wild)	Fry	*40 (35-67)*	*Mid-February - April*
Chinook salmon (wild)	Parr/Sub-yearling	*64 (39-95)*	*May - June*
Chinook salmon (wild)	Yearling	*103 (78-179)*	*Mid-March - mid-May*
Chinook salmon (hatchery)	Sub-yearling	*83 (57-103)*	*June*
Chinook salmon (hatchery)	Yearling	*181 (155-196)*	*April*
Steelhead (wild)	Fry	*60 (23-100)*	*June - Oct.*
Steelhead (wild)	Parr	*96 (65-131)*	*Oct.- mid May*
Steelhead (wild)	Smolt	*165 (109-215)*	*late April - June*
Coho (wild)	Fry	*30 (29-36)*	*February - March*
Coho (wild)	Parr	*56 (37-70)*	*April - April*
Coho (wild)	Yearling	*95 (70-150)*	*May - June*
Coho (hatchery)	Yearling	*140 (131-156)*	*May and June*
Chum (wild)	Fry	*38 (33-50)*	*March - May*
Chum (hatchery)	Fed Fry	*56 (50-65)*	*April - mid May*
Pink (wild)	Fry	*34 (32-43)*	*March - April*

- Wild Chinook salmon data from Beamer et al. 2005 (yearling data), and Tulalip Tribes juvenile out-migrant trapping reports for the Skykomish River (average individual fish size, size range, and emigration timing data from Nelson et al. 2003; Nelson and Kelder 2005a; Nelson and Kelder 2005b).
- Wild steelhead individual size data and occurrence estimates from Shapovalov and Taft (1954) and WDFW juvenile out-migrant trapping reports (Volkhardt et al. 2006a; 2006b; Kinsel et al. 2008).
- Wild coho data for Skykomish River from Nelson and Kelder 2005b (smolts); Beachum and Murray 1990 and Sandercock 1991 (fry); parr size range extrapolated from smolt and fry data considering year-round residence.
- Wild chum data from Volkhardt et al. 2006a (Green River fall-run), and Tynan 1997 (Hood Canal summer-run).
- Wild pink salmon data from Topping and Kishimoto 2008 (Dungeness River pink salmon).
- Hatchery-origin fish release size and timing data are average individual fish size and standard release timing targets proposed in the Wallace River Hatchery and Tulalip Hatchery salmon HGMPs, and average size and size range data for regional hatcheries from WDFW and PNPTT 2000 (estimated mm fish lengths converted from fish per pound data using conversion tables in Piper et al. 1982.

The relative sizes of EWS smolts and natural-origin salmon and steelhead (and size- determined diet preference differences), and their relative densities in migration reaches, would also determine competition risks in freshwater areas where the groups overlap spatially and temporally. Adverse resource competition effects on natural-origin ESA-listed Chinook salmon and steelhead fry and parr associated with EWS hatchery releases are unlikely because of substantial size and hence prey differences (SIWG 1984) between the hatchery yearlings and natural-origin salmonids that would be encountered in watershed areas when and where the hatchery-origin fish are released. The potential exists for adverse resource competition effects on natural-origin ESA-listed steelhead smolts from EWS smolts, because of the similar size and hence similar prey preferences for EWS and natural-origin steelhead where they co-occur.

A key ecological risk reduction strategy implemented in the Reiter Ponds, Wallace River Hatchery, and Tokul Creek Hatchery programs is volitional release of EWS smolts. EWS smolts would be volitionally released from hatchery rearing ponds - and non-migrating fish would be culled - to minimize residualization risks. The HGMPs provide sufficient information, some of which is based on 30 years of hatchery program implementation and monitoring, supporting the efficacy of those actions for meeting actively migrating smolt release objectives (WDFW 2015; WDFW 2016). As indicated in the HGMPs, WDFW is conducting research on the effects of volitional release practices in the Upper Columbia River region. Preliminary results suggest faster downstream migration for volitionally released smolts, and substantially reduced rates of residualism relative to force-released steelhead (Snow et al. 2013). Snow et al. (2013) reported that steelhead smolts released volitionally resulted in one stream-resident fish recaptured for every 7.8 adults returned, while forced releases produced one stream-resident fish recaptured for every 0.48 adults returned. These results indicate that the volitional release and non-migrating fish culling strategy significantly reduces the abundance of residual steelhead, thereby reducing risks of associated negative ecological interactions between hatchery steelhead and natural steelhead and salmon. Further support for this finding is provided by a recent study in the upper Columbia River region comparing volitional versus forced steelhead release effects on hatchery fish survival and migration.

Tatara et al (2016) found that volitional migrants exhibited significant apparent survival advantages over volitional non-migrants; defined as fish that did not exit raceways after screens were dropped, and were forced released. The authors concluded that the practice of volitional release (and culling of non-migrants) was useful for removing both fish that failed to reach a size threshold for smoltification or that matured precociously (Tatara et al (2016). They found that a volitional release strategy was successful at segregating migrants from non-migrants in yearling steelhead release groups, further reducing risks of ecological interactions and genetic introgression caused by precocious male hatchery fish interbreeding with natural-origin females. They also reported that downstream travel times were faster in years when yearling steelhead smolt study groups were volitionally released compared to years when the smolts were force released. These findings support implementation of volitional release practices for the EWS programs for the purposes of meeting ecological risk reduction and adult EWS production objectives of the HGMPs. Within the Skykomish and Snoqualmie river basins from 2009 through 2014[33], on-station volitional releases took place over an average of 13 (range 8 to 18 days) and 10 days (range 6 to 12 days), respectively. Smolt trapping data from 2009 through 2014 indicate that 75 and 72 percent of the hatchery-origin steelhead captured were trapped during the period when the hatchery screens were open

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[33] Skykomish River release year 2013 was excluded from analysis due to more than one release period. The proposed action includes one release within each release location.

in the Skykomish and Snoqualmie basins, respectively (Tulalip Tribes, unpublished smolt trap data 2015). Hatchery release and smolt trap data indicate that during the three to six week outmigration period required for most volitionally released hatchery steelhead in the Skykomish and Snoqualmie river watersheds to exit freshwater (Tulalip Tribes, unpublished smolt trap data 2015), there is clear temporal and spatial overlap with outmigrating natural-origin steelhead.

Included with volitional release practices applied by hatchery operators to promote rapid downstream migration are slot limit size at release criteria for EWS smolts. Largely derived from studies in the Columbia River basin, these size-at-release criteria help ensure that the fish are not released at too small or too large of a size such that the incidence of residuals and precocious males would be promoted. Based on a review of available information, NMFS has recommended a steelhead smolt size at release range of 180 mm to 250 mm TL (NMFS 1999). This size range was based primarily on the work of two IDFG researchers, Cannamela (1992, 1993) and Partridge (1985). The maximum size recommendation was based on reports of higher residualism among steelhead over 240 mm TL and higher predation rates by residual steelhead over 250 mm TL (Jonasson et al. 1996). With regards to minimum size, Rhine (1997) reported that smaller steelhead had a significantly greater tendency to residualize than larger smolts. Of steelhead smolts carrying PIT tags, 52.1% of the fish released from hatcheries at sizes ranging from 163 to 211 mm migrated downstream and were detected at downstream dams; 66% of steelhead at sizes from 212-250 mm TL were detected downstream, and 83.3% of steelhead greater than 250 mm TL were detected. Bigelow (1997) reported similar results for PIT tagged steelhead smolts released from Dworshak Hatchery in the Clearwater Basin, a major tributary of the Snake River. Over 70% of the steelhead under 180 mm TL were not detected at downstream sites, while approximately 85% of smolts over 180 mm TL were detected. This information indicates that release of juvenile steelhead less than 180 mm TL will contribute to residualism, and that the ideal release size may be larger than 220 mm TL. Under the proposed EWS programs, the target average smolt size at release for yearling fish produced each year will be 5.0 fish per pound, or 210 mm FL (225 mm TL), with a CV for this average size of 10%. This average size target is encompassed by the individual fish size at release range of 180 mm to 250 mm TL recommended by NMFS to adequately minimize residualization risks, including precocious male production.

When EWS reach the targeted average individual size at the hatcheries, volitional releases would begin when steelhead display cues of outward physical signs and behaviors reflecting a state of active smoltification, including loss of parr marks, banding of the caudal fin, and increased attraction to pond edges and inflow, and outflow areas. When these conditions are observed, sometime between mid-April and mid-May, rearing pond end-screens would be removed to provide the opportunity for migration-ready steelhead smolts to exit the hatchery for their trip to the ocean. Steelhead that do not volitionally migrate out of the rearing vessels would be collected and transported for release into non-anadromous lakes to enhance recreational fisheries. Implementation of these actions, including culling of non-migrating steelhead from rearing ponds, will substantially reduce the likelihood for creation of residuals that could potentially compete with natural steelhead and Chinook salmon juveniles.

Although it is reasonable to assume, based on available juvenile outmigrant trapping data, that most (90%) of the volitionally released EWS smolts would have exited the rivers after three weeks (21 days), there is clear temporal and spatial overlap with outmigrating natural-origin steelhead smolts in downstream areas. While the effects of hatchery steelhead releases on natural-origin steelhead smolts remains unclear, there exists an opportunity for competitive interactions for food and space to occur in freshwater areas downstream of the release sites.

Beamer (2013) examined the effects of EWS production on steelhead natural populations in the Skagit River basin using a meta-analysis approach of genetics, fish behavior, and statistical trends in abundance or survival, and concluded that EWS production in the basin may be negatively affecting natural steelhead populations as a result of competition for food and space among hatchery and natural-origin juveniles. In a similar correlative analyses of Skagit River EWS production and natural steelhead productivity trends, Pflug et al. (2013) concluded that EWS smolt releases have had a negative effect on natural steelhead population growth rates from ecological interactions including competition and predator attraction in river areas were EWS and natural-origin steelhead juveniles commingle. The Pflug et al (2013) authors acknowledged that habitat quality in the Skagit River watershed is likely a major factor explaining variability in natural population productivity. On-going correlative analyses by the co-managers in the Skagit River basin (C. Ruff et al., unpublished data) also found a negative statistical relationship between the number of hatchery fish released and natural-origin steelhead productivity.

Although these Skagit River studies demonstrated statistical correlation between EWS release numbers and natural-origin steelhead productivity, causation for declining trends in steelhead productivity remains in question. It is possible that low productivity of natural-origin Skagit River steelhead that coincided with a period of high EWS production might be due to some factor not included in the models. The model used by the Skagit River co-managers incorporated as variables, the annual number of natural-origin steelhead spawners, winter-time river flow, EWS release numbers, and a single index of marine environment conditions, that was measured at the scale of the Pacific Ocean. There are likely other variables, not incorporated in the modelling, that have affected natural-origin steelhead productivity. For example, Moore et al. (2015) showed that Skagit River hatchery-origin steelhead survived at the same or higher rate from release point to river mouth compared to natural-origin steelhead (H=89%; W=86%), despite the fact that hatchery fish had a much greater distance (10km vs 102 km) to migrate in the river to reach seawater. They concluded that short residence times, coupled with observed high freshwater and low Puget Sound steelhead survival probabilities suggest a source of mortality that acts quickly on a large number of smolts in the early marine environment (Moore et al. 2015). If juvenile steelhead predators are abundant, predation may be responsible for the observed pattern and may explain the low freshwater and early marine survival probabilities measured in the first two weeks of steelhead migrations. Over this short two week period, it is unlikely that lack of suitable prey (for example, as induced by EWS smolt releases) that may lead to starvation in migrating smolts was the cause of the observed survival levels (Moore et al. 2015). Skagit River natural-origin steelhead smolts were observed to have experienced their highest marine mortality from the river mouth to the marine waters of Deception Pass. The more rapidly migrating EWS survived at a higher rate (20%) compared to natural-origin steelhead (15%) in this marine segment, further suggesting competition is an unlikely limiting factor and that predation by marine mammals, birds or other fish species is the likely cause for low natural-origin Skagit River steelhead survival. Further, a recent study comparing a tributary where hatchery steelhead were planted with a tributary lacking hatchery releases did not find that freshwater abundance, growth, survival, and migration behavior of naturally produced winter steelhead were negatively impacted by naturally spawning hatchery winter steelhead and their progeny (Kavanaugh et al. 2016). One reason for these findings may be differences in juvenile hatchery-origin fish diet preferences and behavior. Steward and Bjornn (1990) concluded that hatchery-origin fish maintained under propagation for an extended period prior to release as smolts (e.g., yearling steelhead) may have different food and habitat preferences than natural-origin salmonids, making the hatchery fish less likely to affect the natural-origin fish through competition during their seaward migration.

Review of natural-origin steelhead return abundance trends for other Puget Sound and Washington coastal watersheds indicates that effects associated with EWS releases are unlikely to be substantial factors driving natural population survival and productivity (Figure 14). In general, the period during the mid-2000s of low productivity of the natural-origin Skagit River steelhead and high EWS production was one in which a number of steelhead natural populations in Puget Sound experienced declining abundances. From the Moore et al (2015) study, natural-origin steelhead smolts originating from the Nisqually River, where no hatchery steelhead production occurs, were found to have the lowest freshwater survival rates of all steelhead natural populations studied, including Skagit River steelhead. Natural steelhead population abundance trends for the Nisqually River, and for other watersheds where no hatchery steelhead smolts are released closely mirror trends observed in watersheds (including the Skagit River) where EWS have been produced and released. Considering shared life history factors and resources for the steelhead natural populations reviewed, marine survival conditions rather than competition in freshwater are likely an over-riding factor in effecting annual variability of natural steelhead population abundance and productivity.

To reduce competition effects, the co-managers have proposed management practices that are expected to reduce the length of time that hatchery fish co-occur with fish from the local natural populations. Through these measures, the risk of interaction, and consequent food resource and other types of competition between EWS and fish from natural populations in the action area will be reduced. These proposed practices include:

- All juvenile hatchery steelhead produced by the programs will be released as seawater-ready smolts as a measure to foster rapid emigration seaward. The release of seawater-ready smolts only is expected to reduce the duration of interaction with any co-occurring natural-origin steelhead and salmon that are at a life stage vulnerable to competition for food or space.
- All smolt release groups will meet the minimum size criteria of 5 to 6 fish per pound (fpp), or 198 to 210 mm fork length (fl) established by Tipping (2001) (as cited in WDFW 2014a; 2014b) to ensure the fish are at size that will promote downstream migration. The hatchery EWS smolt populations will be released at a uniform size closely adhering to the 5 to 6 fpp minimum to reduce the risk of residualism.
- Hatchery- and natural-origin juvenile steelhead and salmon emigration timing and abundance will be monitored each year through operation of tribal juvenile outmigrant trapping programs to evaluate hatchery fish emigration rates, co-occurrence levels with natural-origin fish, and the potential for harmful ecological interactions. Information collected will be used to develop as needed, alternate hatchery EWS release timings or other mitigation measures that will avoid or limit the risk of interactions that may lead to competition.
- All hatchery-origin steelhead smolts produced by Wallace River Hatchery, Reiter Ponds Hatchery, and Tokul Creek Hatchery will be volitionally released from hatchery rearing ponds to minimize residualization, and associated competitive interactions with natural-origin fish. The HGMPs provide sufficient information, some of which is based on 30 years of hatchery program implementation and monitoring, supporting the efficacy of volitional release for meeting actively migrating smolt release and residual minimization objectives. As indicated in the HGMPs, WDFW is conducting research on the effects of volitional release practices in the Upper Columbia River

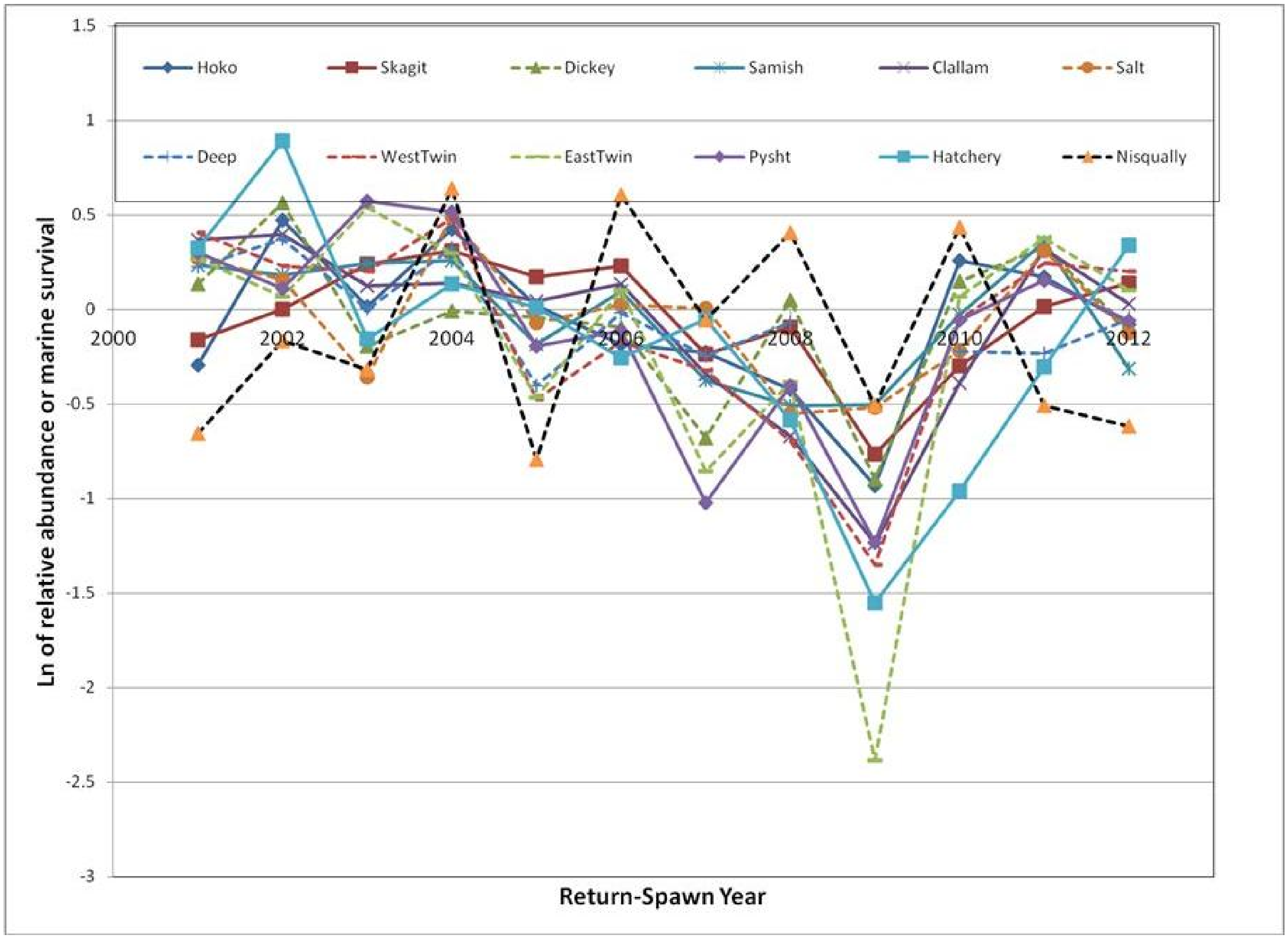

Figure 14. Comparative abundance or marine survival levels (SAR - smolt to adult return estimates) for natural steelhead populations in watersheds where hatchery steelhead are or were released (solid lines) and in watersheds lacking hatchery steelhead production (dashed lines). Included for comparison as "Hatchery" are SAR data points representing a composite of rates estimated for EWS released from WDFW's Kendall Creek Hatchery, Whitehorse Ponds Hatchery, the Snohomish hatcheries, and Dungeness River Hatchery).

region. Preliminary results suggest faster downstream migration for volitionally released smolts, and substantially reduced rates of residualism relative to force-released steelhead (Snow et al. 2013). Volitional releases will begin when steelhead display cues of outward physical signs and behaviors reflecting a state of active smoltification, including loss of parr marks, banding of the caudal fin, and increased attraction of the fish to pond edges, inflow, and outflow areas. When these conditions are observed after May 1st, rearing pond end-screens will be removed to provide the opportunity for migration-ready steelhead smolts ready to exit downstream. Any EWS smolts that do not exit rearing ponds volitionally will be removed (culled) and planted into landlocked lakes to enhance recreational fishing opportunities.

For the above reasons, for the two programs reviewed in this opinion, EWS smolt competition effects on ESA-listed natural-origin salmon and steelhead in freshwater are likely short in duration, and unsubstantial, however they may rise to a low level of take. The HGMPs include numerous measures to prevent significant spatial and temporal overlap between EWS smolts and Chinook salmon juveniles. Further, juvenile outmigrant trapping data indicating that EWS smolts migrate out of the Snohomish River watershed quickly (the majority exiting within one week). The duration of time that EWS smolts may interact with natural steelhead and Chinook salmon in downstream areas, potentially leading to competition, is unsubstantial. Smolt release only and volitional release measures implemented to reduce the duration of interaction between newly released EWS smolts and natural-origin fish, and monitoring proposed to verify whether EWS smolts are rapidly exiting freshwater areas as expected, will help ensure that competition effects are adequately minimized, and take remains unsubstantial.

Negligible effect: Predation

Effects to natural-origin salmon and steelhead attributable to direct predation (direct consumption) or indirect predation (increased predation by other predator species due to enhanced attraction) can result from hatchery salmonid releases (NMFS 2012). Hatchery-origin fish may prey upon juvenile naturally produced salmonids at several stages of their life history. Newly released hatchery smolts have the potential to consume naturally produced fry and fingerlings that are encountered in freshwater during downstream migration. Hatchery smolts (usually steelhead) that do not emigrate and instead take up stream residence near the point of release (residuals) have the potential to prey on rearing natural-origin juvenile fish over a more prolonged period. Hatchery salmonids planted as non-migrant fry or fingerlings also have the potential to prey upon natural-origin salmonids in the freshwater where they co-occur. In general, naturally produced salmonid populations will be most vulnerable to predation when their abundance is depressed and predator abundance is high, in small streams, where migration distances are long, and/or when environmental conditions favor high visibility (NMFS 2012).

The risk of hatchery-origin smolt predation on natural-origin juvenile fish in freshwater is dependent upon three factors: 1) hatchery fish and their potential natural-origin prey must overlap temporally; 2) hatchery fish and their prey must overlap spatially; and, 3) the prey should be less than 1/3 the length of the predatory fish. Table 21 compares the relative individual sizes and freshwater occurrence timings for emigrating natural-origin juvenile Chinook salmon and steelhead, and hatchery-origin steelhead juveniles released from action area hatcheries. Based on comparative fish sizes and timings, EWS smolts would have substantial spatial and temporal overlap with smaller juvenile ESA-listed Chinook salmon, posing a risk for predator-prey interactions. An additional basis for this predation risk assignment for Wallace River Hatchery, Reiter Ponds, and Tokul Creek Hatchery EWS smolt releases is the upper-watershed release locations, RM 4.0 on the Wallace River, RM 46 for the Reiter Ponds location, and RM 39.6 for Tokul Creek Hatchery. Risk is further indicated by the large individual fish size of EWS smolts relative to the much smaller size of natural-origin juvenile Chinook salmon that they would encounter (Table 21). The yearling steelhead will not encounter juvenile steelhead of a size vulnerable to predation, as young-of-the-year steelhead fry emerge later in the season, are often in different portions of the watersheds, and are present as parr in migration reaches used by the hatchery yearlings months after the yearlings will be released (Subsection 2.2.1.1). Only large, rearing yearling steelhead parr, and emigrating two-and three-year old steelhead smolts, that are similar in size to the hatchery-origin yearlings, will be present in freshwater areas downstream of the hatchery release sites (Table 21). Pflug et al. (2013) found that migrating hatchery-origin steelhead in the Skagit River preyed on two main prey items, fish and insects, but juvenile *O. mykiss* were not among the fish species consumed by hatchery-origin steelhead.

The 12-year average size of EWS yearlings released from the Reiter Ponds facility is 198 mm fl, with an average release date of May 6 (WDFW 2014a). The 12-year average size of EWS yearlings released from the Wallace River Hatchery is 190 mm fl, with an average release date of May 2 (WDFW 2014a). Emigrating and rearing natural-origin Chinook salmon present in watershed reaches downstream of Wallace River Hatchery and the Reiter Ponds facility during the May yearling EWS release period have a median size of 48 mm fl during the first week of May (statistical week 19) and a median size of 60 mm fl during the last week of May (statistical week 22) (Kubo et al. 2013). From 2000 through 2012, the average weekly May median fork length averaged 54 mm (range 32-92 mm fl) (Kubo et al. 2013). Assuming that fish predators can consume fish prey that are 1/3 or less in size relative to the length of the predator, the average natural-origin sub-yearling juvenile Chinook salmon in the Skykomish River is small enough to be vulnerable to predation by newly released EWS yearling smolts from both hatchery locations.

The 12-year average size of EWS yearlings released from the Tokul Creek Hatchery is 206 mm fl, with an average release date of May 6 (WDFW 2014b). Emigrating and rearing natural-origin Chinook salmon present in watershed reaches downstream of Tokul Creek Hatchery during the May yearling EWS release period have a median size of 56 mm fl during the first week of May (statistical week 19) and a median size of 64 mm fl during the last week of May (statistical week 22) (Kubo et al. 2013). From 2001 through 2012, the average weekly May median fork length averaged 54 mm (range 32-92 mm fl) (Kubo et al. 2013). The average natural-origin sub-yearling juvenile Chinook salmon in the Snoqualmie River is small enough to be vulnerable to predation by EWS yearling smolts released from Tokul Creek Hatchery.

Because EWS smolts are on their way to the ocean, they move quickly through freshwater areas and there is little opportunity for predation by hatchery-origin steelhead on natural-origin Chinook salmon. Although review of relative fish size and co-occurrence data, and information from other Pacific Northwest watersheds (e.g., Flagg et al. 2000) would indicate a risk of predation, the majority of diet studies from other Puget Sound watersheds indicate that newly released hatchery-origin yearling salmonids do not prey on other fish, to any substantial extent. One exception, although it is unclear whether predation that occurred in the trap live box where the fish were collected and confined for sampling was considered as a potential bias, Pflug et al. (2013) reported that migrating hatchery-origin steelhead in the Skagit River preyed extensively on fish, with 80 percent of the prey being fish, primarily pink salmon, during 2010. During the 2009 juvenile emigration period, hatchery-origin steelhead consumed Chinook (n=13), chum (n=17), and coho (n=3) salmon (50 smolts stomachs examined per year; 0.13 Chinook fry per steelhead smolt sampled) (Pflug et al. 2013). In contrast, stomach content analyses of hatchery-origin yearling coho salmon sampled near the mouth of the Elwha River in 1996, 2006, and 2007 showed no sign of piscivorous behavior (Peters 1996; Duda et al. 2011). Seiler et al. (2002) reported that none of the yearling Chinook salmon sampled for stomach contents at the Green River smolt trap in 2000 had consumed co-occurring juvenile Chinook salmon. Topping et al. (2008a) reported none of the hatchery-origin, yearling Chinook salmon sampled (n=168) for stomach contents at the Dungeness River smolt trap in 2006 had consumed any fish. Other diet studies (in addition to those mentioned above) have also shown that newly released hatchery-origin steelhead smolts are generally not piscivorous (Cannamela 1993; Sharpe et al. 2008). For example, Sharpe et al. (2008) and Cannamela (1993) reported very low hatchery steelhead predation rates, with only 0.00166 and 0.00148 Chinook fry consumed per steelhead smolt sampled, respectively.

As discussed above, although volitional release-non-migrant culling or lower river release practices reduce the risk of residualization, a variable proportion of the EWS smolts released from the hatcheries will not migrate to the ocean, but rather reside for a period of time in the vicinity of the release location. This is an undesirable behavior because these non-migratory smolts (residuals) can directly prey on natural-origin juvenile salmonids of sizes vulnerable to predation. This behavior has been studied and observed most frequently in the case of hatchery steelhead. Monitoring of stream reaches downstream of hatchery release points is necessary to determine the extent of hatchery steelhead smolt residualism and effects on natural-origin juvenile salmonids.

To reduce predation risks, all yearling steelhead released from WDFW hatcheries will be seawater-ready smolts, propagated using methods to ensure that the fish are of uniform, large size and are physiologically ready to emigrate downstream and not residualize in freshwater. This is an effective technique, but it is not one hundred percent effective. Downstream smolt trapping data (2009 -2014) in the Skykomish and Snoqualmie rivers indicates that newly released yearling steelhead migrate downstream rapidly, on average 96 and 88 percent of hatchery-origin steelhead captured are trapped within the first week following the end of volitional releases in the Skykomish and Snoqualmie watersheds, respectively (Tulalip Tribes, unpublished smolt trap data 2015). These same data indicate that on average 1-percent or less of hatchery-origin steelhead captured are trapped after the first three weeks following release (Tulalip Tribes, unpublished smolt trap data 2015). For these reasons, it is reasonable to assume that the majority (90%) of EWS smolts will have exited freshwater within three weeks (21 days).

In a review of available literature on predation by hatchery-origin yearling salmonids on natural-origin salmonid juveniles, Naman and Sharpe (2012) concluded that managers can effectively minimize predation by reducing temporal and spatial overlap between the two groups. As described in the HGMPs, the EWS steelhead hatchery programs will reduce temporal and spatial overlap and the potential for predation on ESA-listed juvenile salmon and steelhead through application of the following measures:

- All EWS steelhead smolts will be released no earlier than mid-April, and concentrated in May, immediately after a freshet (when possible), to foster rapid seaward emigration, reducing the duration for interactions with co-occurring juvenile Chinook salmon of sizes vulnerable to predation.
- All juvenile hatchery steelhead produced by the programs will be released as seawater-ready smolts that are expected to move downstream rapidly to the estuary where they will disperse seaward. The release of seawater-ready smolts only is expected to reduce the duration of interaction with any co-occurring natural-origin steelhead and salmon that are at life stages and sizes vulnerable to predation by EWS smolts. Based on juvenile outmigrant trapping data, almost all of the EWS smolts produced by the programs would exit freshwater areas downstream of the hatchery release sites within three weeks (21 days) of their release date. These release practices will minimize the potential for hatchery steelhead residualization that would exacerbate predation effects.
- All smolt release groups will meet the minimum size criteria of 5 to 6 fpp (198 to 210 mm fl) established by Tipping (2001) (as cited in (WDFW 2014b; WDFW 2014c; WDFW 2014g) to ensure the fish are at size that will promote downstream migration. The hatchery EWS smolt populations will be released at a uniform size closely adhering to the 5 to 6 fpp minimum to reduce residualism.

- Hatchery- and natural-origin juvenile steelhead and salmon emigration timing and abundance will be closely monitored each year through operation of tribal juvenile outmigrant trapping programs to verify hatchery-fish emigration rates, co-occurrence levels with natural-origin fish, and the potential for harmful ecological interactions. If naturally-produced smolt outmigration timing, determined by downstream juvenile migrant monitoring in the mainstem rivers, suggests that the release timing for yearling hatchery steelhead will result in predation on ESA-listed, natural-origin fish, alternate release timings or other mitigation measures will be required to minimize such effects.
- All hatchery-origin steelhead smolts produced by Wallace River Hatchery, Reiter Ponds Hatchery, and Tokul Creek Hatchery will be volitionally released from hatchery rearing ponds to minimize residualization, and associated predation risks to natural-origin fish. The HGMPs provide sufficient information, some of which is based on 30 years of hatchery program implementation and monitoring data, supporting the efficacy of volitional release for meeting actively migrating smolt release and residual minimization objectives. As indicated in the HGMPs, WDFW is conducting research on the effects of volitional release practices in Upper Columbia River region. Preliminary results indicate faster downstream migration for volitionally released smolts, and substantially reduced rates of residualism relative to force-released steelhead (Snow et al. 2013). Volitional releases will start when steelhead display cues of outward physical signs and behaviors reflecting a state of active smoltification, including loss of parr marks, banding of the caudal fin, and increased attraction to pond edges, inflow, and outflow areas. When these conditions are observed after May 1st, rearing pond end-screens will be removed so that migration-ready steelhead smolts can leave freshwater for the ocean. Any EWS smolts that do not exit rearing ponds volitionally will be removed (culled) and planted into landlocked lakes to enhance recreational fishing opportunities.

In summary, although there will be some degree of overlap between EWS smolts and natural-origin Chinook salmon juveniles of sizes where predation by EWS smolts is a risk, particularly in the month of May, and there are studies showing that hatchery steelhead smolts can be piscivorous, NMFS does not expect that predation by newly released EWS smolts will pose any substantial effects to ESA-listed Chinook salmon in freshwater areas downstream from the hatchery releases sites. This conclusion is based on the fact that the majority of studies have shown that newly released hatchery steelhead smolt predation on natural-origin juvenile salmonids is uncommon. Further, the HGMPs include numerous measures to prevent significant spatial and temporal overlap between EWS smolts and Chinook juveniles. Juvenile outmigrant trapping data indicating that EWS smolts migrate out of the Snohomish River watershed quickly (the majority exiting within one week) and also indicate freshwater predation effects are unsubstantial. While a small amount of take through predation is expected to occur, the number of Chinook salmon juveniles expected to be consumed by EWS smolts is quite low and unsubstantial.

2.4.2.4 Hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, estuary, and ocean

Negligible effect

The potential for newly released hatchery-origin steelhead smolts to compete with and prey on natural-origin Chinook salmon and steelhead in estuarine and marine waters has been considered here. As juvenile steelhead released from the proposed programs arrive in the estuary, they could compete with natural-origin Chinook salmon and steelhead in areas where they co-occur, but only if shared resources are limiting. EWS could also prey on natural-origin fish, but only if they share the same habitat and are the right size. The first place to look for competition and predation would be in nearshore areas adjacent to river mouths where hatchery-origin steelhead and fish from natural populations first enter marine waters and may initially be concentrated. Interactions and effects likely diminish as hatchery- and natural-origin fish disperse into the main body of the Puget Sound and Salish Sea, and then into the Pacific Ocean.

Regarding competition effects in estuarine and marine waters, the main limiting resource for natural-origin Chinook salmon and steelhead that could be affected through competition posed by hatchery-origin fish is food. In Puget Sound, EWS have the greatest potential for dietary overlap with comparably sized natural-origin steelhead (SIWG 1984). The early estuarine and nearshore marine life stage, when natural-origin fish have recently entered the estuary and populations are concentrated in a relatively small area for short durations, is a critical life history period during which there may be short term instances where food is in short supply, and growth and survival declines as a result (SIWG 1984; Duffy 2003; Pearcy and McKinnell 2007). The degree to which food is limiting after the early marine portion of a natural-origin fish's life depends upon the density of prey species. This does not discount effects on natural-origin fish in more seaward areas as a result of competition by hatchery-origin fish, as data are available that suggests that marine survival rates for salmonids are density dependent, and thus possibly a reflection of the amount of food available (SIWG 1984; Brodeur 1991; Holt et al. 2008). Researchers have looked for evidence that marine area carrying capacity can limit salmonid survival (Beamish et al. 1997; HSRG 2004). Some evidence suggests density-dependence in the abundance of returning adult salmonids (Emlen et al. 1990; Lichatowich 1993; Bradford 1995), is associated with cyclic ocean productivity (Nickelson 1986; Beamish and Bouillon 1993; Beamish et al. 1997). Collectively, these studies indicate that competition for limited food resources in the marine environment may affect survival (also see Brodeur et al. 2003). Large-scale hatchery production may exacerbate density dependent effects when ocean productivity is low. Puget Sound region-origin salmonid survival may be intermittently limited by competition with almost entirely natural-origin odd-year pink salmon originating from Puget Sound and the Fraser River watersheds (Ruggerone and Goetz 2004), particularly when ocean productivity is low (Nickelson 1986; Beamish and Bouillon 1993; Beamish et al. 1997; Mahnken et al. 1998). However, in recent studies of post-release migration and survival for natural-origin and hatchery-origin steelhead smolts in Hood Canal and Central Puget Sound, predation by birds, marine mammals, and perhaps, other fish appears to be the primary factor limiting the abundance of smolts reaching ocean rearing areas, not competition (Moore et al. 2010).

Complicating any assessment of marine area predation and competition effects from EWS is that the temporal distribution, trophic interactions, and marine area limiting factors to survival for Puget Sound steelhead populations in marine waters are poorly understood (Duffy 2003; Moore et al. 2010). Assessment of the effects of hatchery-origin steelhead on natural-origin steelhead and Chinook salmon in Puget Sound is problematic because there is a lack of basic information about what shoreline habitats are preferred by steelhead and for how long, and whether the early marine life stage contributes significantly to growth and survival through subsequent life stages (Moore et al 2010). There is also little knowledge regarding the carrying capacity of Puget Sound for juvenile steelhead and salmon on which to base analyses of food resource competition risks. Naish et al. (2008) could find no systematic, controlled study of the effects of density on natural-origin salmon, or of interactions between natural-origin and hatchery salmon, nor on the duration of estuarine residence and survival of salmon. Further complicating any assessment of ecological effects of EWS on natural-origin steelhead and Chinook salmon in Puget Sound is the existence of temporal and spatial fluctuations in the carrying capacity of the marine environments. The Puget Sound marine ecosystem was until recently believed to be stable, internally regulated and largely deterministic. The current view is that Puget Sound is dynamic with much environmental stochasticity and ecological uncertainty (Mahnken et al. 1998; Francis 2002).

For these reasons, best available science does not, as yet, lead to any calculated and reasoned judgment regarding the carrying capacity of Puget Sound and the Pacific Ocean, and whether ecological effects associated with hatchery-origin steelhead production are adversely affecting natural-origin steelhead and Chinook salmon productivity and survival. The limited information available is insufficient to calculate and predict what the effects are for different species and life histories (e.g., subyearling releases versus yearling releases) and different release levels of hatchery fish on different species and life history forms of natural-origin fish under very dynamic and highly variable environmental conditions. In addition, assigning marine area ecological and demographic effects, specifically for hatchery-origin EWS production, would be highly speculative since hatchery-origin fish intermingle at the point of ocean entry with natural-origin fish and hatchery-origin anadromous salmonids migrating into Puget Sound from many other Pacific Northwest regions. At best, it can be said that, during years of limited food supply, there is likely some competition between hatchery and natural-origin fish but resultant effects (i.e., natural-origin fish leaving one area for another, increased stress, reduced fecundity, or survival) are not yet possible to determine or predict. There are no studies that demonstrate, or even suggest, the magnitude of EWS smolt release numbers into Puget Sound that might result in reduced natural-origin steelhead and Chinook salmon survival rates in the estuary, the Puget Sound, or in the Pacific Ocean.

Available knowledge and research abilities are insufficient at the present time to discern the role and contribution of hatchery fish in any density-dependent interactions affecting salmon and steelhead growth and survival in Puget Sound and in the Pacific Ocean. From the scientific literature reviewed above, the conclusion seems to be that the influence of density-dependent interactions on growth and survival is likely small compared with the effects of large scale and regional environmental conditions. While there is evidence that hatchery production of pink and chum salmon in Alaska, Japan, and Russia on a scale many times larger than production from all the steelhead hatcheries in Puget Sound combined can negatively affect natural-origin salmon survival and productivity in the Northeast Pacific Ocean (Ruggerone et al. 2011; Ruggerone et al. 2010), the degree of affect and level of influence is not yet understood or predictable. Which species in Puget Sound, under what complex of variable environmental conditions and to what degree fish would be affected is beyond our understanding or knowledge to determine. NMFS will however monitor emerging science and information and will reinitiate section 7 consultation in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner, or to an extent, not considered in this consultation.

Evidence indicates that because steelhead attain a relatively large size in freshwater prior to smoltification (approximately 150–220 mm [Ward et al. 1989]), migrants may move rapidly through estuaries (Quinn 2005) or use deeper water habitat offshore (Moore et al. 2010). Beamish et al (2003) reported that juvenile steelhead entering the Salish Sea generally migrate offshore into oceanic waters of the Gulf of Alaska, and are rarely found close to shore (citing Pearcy and Masuda 1982; Hartt and Dell 1986). In a telemetry study of steelhead migration behavior and survival in Hood Canal and Puget Sound, Moore et al. (2010) reported that steelhead did not favor migration along shorelines. In 2006, smolts were distributed across Hood Canal as they migrated seaward, and in 2007, there was a slight preference for the middle portions of the canal (Moore et al. 2010 and following). Mean travel rates were lower and variation among individuals greater in Hood Canal than through more seaward marine areas (e.g., North Puget Sound and the Strait of Juan de Fuca). Seaward travel speeds in these latter marine areas were rapid, averaging 26.0 to 27.2 km/day through Admiralty Inlet and Strait of Juan de Fuca. Migratory behavior within Hood Canal suggests Hood Canal provides rearing habitat for steelhead and does not function simply as a migratory corridor. The average residence time in Hood Canal for one study population was 17.4 days in 2006 and 15.1 days in 2007. Smolts were able to reach the terminus of Hood Canal in as short as 1.4 days indicating their capability to migrate quickly through Hood Canal. In Puget Sound, an acoustic telemetry study of Green River steelhead smolt migration behavior reported hatchery fish migration rates of 10.6 km/day in the estuary and 9.3 km/day in nearshore areas (Goetz et al. 2015). Green River hatchery-origin smolts migrating in marine waters exhibited an early offshore movement and a strong northward and westward seaward-bound orientation.

Acoustic telemetry data from Skagit River EWS indicates that smolts travel at a rate of over 20 km/day from the river mouth to Deception Pass and that hatchery and wild Skagit River migration rates increase to 32 km/day within the Strait of Juan de Fuca (Moore et al. 2015). Moore et al. (2015) found that natural-origin steelhead emigrating in early-April and late-May had a higher probability of survival than those migrating in early-and mid-May, which had the lowest apparent survival; they speculated that lower survival in the first half of May was related to consistent hatchery releases of coho and EWS during the first week of May. However, their findings are confounded by results from the Skagit River, which indicate that hatchery-origin fish had higher freshwater and early-marine survival rates than natural-origin steelhead, making it difficult to speculate how hatchery-releases, which survived at a higher rate, could reduce the survival rate of natural origin fish. In addition, when Hood Canal hatchery and natural-origin survival rates are compared (excluding Skokomish River natural-origin and hatchery fish), hatchery-origin fish had slightly higher overall survival to the Strait of Juan de Fuca. In Hood Canal, steelhead experienced high early marine mortality rates, averaging 2.7 percent per day and the mortality appeared to be strongly related to the distance they traveled and less related to their rate of travel. In all three studies, mortality was found to be greater during the first few weeks of their marine residences, and decreasing substantially after the migrating steelhead enter the Pacific Ocean (Moored et al. 2010; Goetz et al. 2015; Moore et al. 2015). Competition and predation from EWS in Puget Sound appears to be short in duration because steelhead are actively migrating offshore and seaward into areas where the fish may disperse more widely and where food resources are more plentiful.

Regarding predation by hatchery-origin steelhead in estuary and marine areas, NMFS (2002) concluded that predation by hatchery-origin fish on natural-origin smolts or sub-adults is less likely to occur than predation on younger life stages when natural-origin fish are in freshwater. Salmonids, after entering the marine environment, generally prey upon fish one-half their length or less and consume, on average, fish prey that is less than one-fifth of their length (Brodeur 1991). During early marine life, predation on natural-origin juvenile salmon will likely be highest in situations where large, yearling-sized hatchery fish encounter fry (SIWG 1984). Studies by Seiler et al. (2002) have shown that natural- origin Chinook salmon transitioning to the marine environment are too large for predation by co-occurring hatchery-origin fish, including yearling steelhead smolts. Likely reasons for apparent low predation rates on Chinook salmon juveniles by larger salmon and steelhead are described by Cardwell and Fresh (1979). These reasons included: 1) due to rapid growth, natural-origin Chinook salmon are better able to elude predators and are accessible to a smaller proportion of predators due to size alone; 2) because Chinook salmon have dispersed, they are present in low densities relative to other fish; and 3) there has either been learning or selection for some predator avoidance. In a literature review of Chinook salmon food habits and feeding ecology in Pacific Northwest marine waters, Buckley (1999) concluded that cannibalism and intra-generic predation by Chinook salmon are rare events. However, based on indirect calculations, Beauchamp and Duffy (2011) estimated that if cannibalism did occur, older Chinook salmon (>300 mm FL; blackmouth) during June-August could potentially consume 6 to 59 percent of age-0 juvenile Chinook salmon recruiting into marine waters in Puget Sound, depending on whether a very conservative estimate (6% Chinook in the diet) or reasoned assumption (20% Chinook in the diet in May and June and then allowed to decline daily via linear interpolation) were used. Similar studies regarding steelhead diet preferences and predation effects on juvenile salmonids in Puget Sound marine areas are lacking. In other Pacific Northwest estuarine areas, natural-origin steelhead smolts are reported to prey on chum and pink salmon fry, but the steelhead were seldom numerous enough to substantially influence the abundance of those species (Beamish et al. 2003, citing Slaney et al. 1985).

Hatchery-origin steelhead predation on natural-origin steelhead in the estuarine environment are unlikely, due to the large size of natural-origin steelhead smolts relative to the co-occurring hatchery steelhead (Table 21), which precludes consumption. Substantial hatchery steelhead-related competition effects on steelhead in the estuary are also unlikely. Hatchery- and natural-origin steelhead (Moore et al. 2010) smolts tend to disperse into the pelagic waters of the Salish Sea soon after entering seawater, limiting the duration of interactions, and the potential for food resource competition between the groups in nearshore areas where they may co-occur for short durations. Subyearling Chinook salmon tend to use nearshore habitat areas that are not preferred by the much larger steelhead smolts, which may also have different diet preferences because of their larger size. This partitioning of estuary and marine areas reduces the likelihood that hatchery-origin steelhead would pose a substantial competition risk to subyearling Chinook salmon in marine waters.

The proposed EWS smolt release hatchery programs will lead to unsubstantial changes in the total number of anadromous salmonids encountered by ESA-listed salmon species in Puget Sound and Pacific Coastal marine waters. The total number of EWS smolts that will be released from the two hatchery programs is 241,600 yearlings and half or less of these fish would actually survive to arrive in nearshore marine areas. For example, the total number of smolts released from the EWS hatchery programs are equal to only 3-4% of the estimated 9.0 million natural-origin juvenile Chinook salmon entering Puget Sound each year. EWS smolts commingle with many other hatchery- and natural-origin juvenile salmon and steelhead besides those from Puget Sound in marine waters (e.g., fish from the Fraser River; Columbia River; Washington Coast), making their contributions to total juvenile salmonid abundance in the Salish Sea and Pacific Ocean inconsequential. It is also important to note that the number of hatchery steelhead smolts that survive to reach seawater would be substantially less than the number produced and released from the hatchery programs. Exposure to natural conditions, including predation by piscivorous fish, bird, and mammal species, leads to high levels of mortality to juvenile hatchery-origin fish immediately upon their release into the natural environment (B. Berejikian, NMFS, unpublished data, February 2015). For example, Melnychuck et al. (2014) found that only 26 to 40 percent of the hatchery steelhead released in the Cheakamus River reached the marine environment and that only 3.5 to 6.7 percent of hatchery released fish transited through the Strait of Georgia towards the Pacific Ocean. Studies in Puget Sound indicate that 13 percent to 70 percent of the yearling steelhead released from upstream hatcheries in the Green River each year survived to reach a trapping operation at RM 33 (Seiler et al. 2004).

The number of adult fish produced by the proposed hatchery actions would also represent a small proportion of the total abundance of steelhead present in Puget Sound and in Pacific Coastal marine areas. As shown in Table 22, the recent year (2000/01-2010/11) average total annual return of Snohomish River winter-run hatchery-origin steelhead was 5,716 fish, or 15.8 percent of the Puget Sound run size. During the period described above, annual winter-run steelhead releases averaged 420,000, as compared to the proposed release of 241,600. Assuming similar survival rates and total adult steelhead returns to the Puget Sound region, the proposed action would result in annual returns of 3,288 adult steelhead (~9.1% of Puget Sound average terminal run-size for the species).

Table 22. Average total adult returns of Snohomish basin hatchery-origin steelhead to Puget Sound compared with the total adult returns from all Puget Sound areas.

Species	Average Puget Sound Adult Return Hatchery-Origin Fish	Average Total Puget Sound Adult Return	Hatchery-Origin Steelhead Percent of Total PS Adult Return
Snohomish Steelhead	5,716[1/]	36,223[2/]	15.8%

1/ Estimated total terminal area adult return of winter-run hatchery-origin Snohomish River steelhead from WDFW 2014a; WDFW 2015b- assumes a post-harvest 30% stray rate applied to hatchery escapement.

2/Estimated terminal area adult return of natural- and hatchery-origin summer- and winter-run steelhead to Puget Sound streams. Data sources include the WDFW SCORE database (https://fortress.wa.gov/dfw/score/score/species/species.jsp); WDFW 2014a; WDFW 2014b; WDFW 2014c; WDFW 2014d; WDFW 2014e; WDFW 2014f; Myers et al. 2015; Hard et al. 2015; Pflug et al. 2013; WDFW and Long Live the Kings 2012; Scott and Gill 2008; WDFW 2005b; WDFW 2005c; WDFW 2003a; and WDFW 2003b. Missing escapement data were interpolated based on relative watershed areas, an index of average escapements divided by intrinsic potential, or proportions of base year escapements to adjacent watersheds to solve for missing years. For hatchery returns, smolt to adult returns (SARs) were taken from HGMPs and adjusted based on a post-harvest 30% stray rate applied to hatchery escapement. Hatchery release data were obtained through the RMIS database (http://www.rmpc.org/). For releases without corresponding SAR data, sub-regional or Puget Sound averages were applied to estimate terminal run-size. Spawning escapements were estimated to be 97.5% of the terminal run-size.

For the above reasons, NMFS does not believe it is possible to meaningfully measure, detect, or evaluate the specific effects of Skykomish and Snoqualmie basin hatchery-origin juvenile and adult steelhead production on ESA-listed species in Puget Sound and the Pacific Ocean, due to the low magnitude of, and low likelihood for, effects in those locations.

2.4.2.5 Research, monitoring, and evaluation

Negligible effect

The proposed hatchery program actions address the five factors that NMFS takes into account to analyze and weigh the beneficial and negative effects of hatchery-related research, monitoring, and evaluation (RM&E) (see Section 2.4.1.5). The programs include RM&E to monitor compliance with this opinion and to inform future decisions regarding how the hatchery programs can and should adjust and improve to further reduce negative effects to ESA-listed Chinook salmon and steelhead. Negligible lethal and sub-lethal effects on listed species are expected to occur as a result of implementing RM&E actions.

The effects of the proposed adult and juvenile steelhead sampling described in the HGMPs are covered in separate biological opinions (NMFS 2009, NMFS 2015b). Take of ESA-listed fish is not expected for other RM&E actions implemented under the proposed actions.

The two HGMPs include RM&E actions designed to verify the performance and compliance of the programs in meeting their fisheries harvest augmentation and listed fish risk minimization objectives. Specific RM&E actions for the two HGMPs are described in section 1.10 and section 11.0 of each plan. Although monitoring the benefits of the programs to fisheries harvest through effective hatchery production of juvenile fish to ensure harvestable returns of adult fish is an important objective (e.g., smolt to adult survival rate and fishery contribution level monitoring), all of the action area steelhead hatchery programs include extensive RM&E and adaptive management measures designed to monitor and address hatchery-related effects on natural-origin fish populations. In particular, the co-managers will monitor interactions between juvenile hatchery- and natural-origin salmonids in freshwater and marine areas to evaluate and manage program ecological effects. The co-managers will also collect tissue samples from juvenile and adult steelhead in each watershed as a means to analyze and limit gene flow effects of the EWS programs on associated natural-origin steelhead populations (Anderson et al. 2014), and validate low (less than 2%) gene flow levels previously estimated for the programs.

An adult steelhead monitoring program (spawning ground surveys) will be conducted annually to document origin, abundance and spatial structure of steelhead escaping to natural spawning areas and the hatcheries in the action area basins (WDFW 2014a; 2014b). In addition, within the Pilchuck River subbasin, adult genetic sampling will be conducted every three years. Previously authorized for effects on ESA-listed fish through separate consultation processes (NMFS 2009; NMFS 2015b), the effects of these activities on listed adult steelhead will generally be confined to visual observations of spawning fish during spawning ground surveys that may lead to avoidance behavior and temporary displacement of listed fish from preferred areas until surveyors move through a stream reach. Steelhead carcasses will be removed from the water, and sampled for biological data and tissues (for DNA analyses) before being returned to the recovery location. These activities will not substantially harm listed steelhead, and their effects will be negligible. The Terms and Conditions of this Biological Opinion require the completion and distribution of annual reports describing adult salmon RM&E activities and results.

Specific RM&E actions for the two HGMPs affecting juvenile salmonids are described in section 1.10 and section 11.0 of each HGMP (WDFW 2014a; 2014b). Although the results of these juvenile fish RM&E actions will be used to guide implementation of the proposed steelhead hatchery programs, juvenile salmonid sampling occurring outside of the hatchery locations has been previously analyzed and authorized under the ESA (NMFS 2009; 2015b). The co-managers will monitor interactions between juvenile hatchery- and natural-origin salmonids in freshwater and marine areas to evaluate and manage hatchery program related ecological effects. Continued juvenile outmigrant trapping by the Tulalip Tribes is also proposed, using rotary screw traps in the lower Skykomish and Snoqualmie rivers, to provide important information on the co-occurrence, out-migration timing, relative abundances, and relative sizes of hatchery-origin fish, listed natural-origin Chinook salmon and steelhead, and non-listed natural-origin coho, chum, and pink salmon. Smolt traps are positioned downstream from multiple steelhead populations and will obtain a mixed sample at trapping sites (Anderson et al. 2014, and following). Due to the fact that both smolt traps will be fished downstream of multiple populations, monitoring introgressive hybridization at the population scale will rely upon genetic stock identification; however, current genetic tools may not permit assignments at this resolution. In these cases, ongoing efforts to improve the Puget Sound genetic baseline by adding more single nucleotide polymorphism samples to the database will improve upon genetic stock identification; if this effort is ineffective then introgressive hybridization will be measured at the watershed scale rather than at the population scale. WDFW has developed a ten year monitoring plan to sample up to 100 unmarked juvenile steelhead annually from the Skykomish and Snoqualmie river smolt traps. Under the ESA authorization provided for the juvenile steelhead and salmon RM&E activities described in the HGMPS, completion and distribution of annual reports describing actions and results are required (NMFS 2009; 2015b).

Other effects of the proposed hatchery steelhead programs on listed salmon and steelhead populations will also be monitored and considered with other habitat- and harvest-related effects. These actions will help track the extent to which the hatchery programs are harming juvenile and adult Chinook salmon or and steelhead as a result of facility operations, the collection of broodstock, and the production of juvenile fish that would return as adults. In general, actions taken at the hatcheries to meet this objective will include monitoring of water withdrawal and effluent discharge to ensure compliance with permitted levels; monitoring of broodstock collection, egg take, fish survival rates, and smolt release levels for each program to determine compliance with program goals; and fish health monitoring and reporting in compliance with "The Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State" (WDFW and WWTIT 1998, updated 2006). None of these monitoring activities are expected to have any substantial effects that would rise to the level of take of listed fish.

2.4.2.6 Operation, maintenance, and construction of hatchery facilities

Negative to negligible effect

Effects on listed fish from operation and maintenance activities associated with the proposed hatchery programs will range from negative (screening at Wallace River Hatchery) to negligible (effluent discharge at all hatchery facilities). There is no new construction included in the proposed actions, so there will be no listed fish effects from new construction for hatchery purposes. Withdrawal of surface and groundwater for use in the hatchery programs will have no substantial effect on listed fish in the watershed. All water used by the hatcheries will be returned to the watercourses near the points of withdrawal. No stream reaches will be dewatered to the extent that natural-origin fish migration and rearing will be impaired, and there will be no net loss in river or tributary flow volume. However, the hatchery water intake structures supplying Wallace River Hatchery and Tokul Creek Hatchery do not meet the latest federal water intake screening or fish passage criteria, and will have negative effects to listed salmonids until they are updated.

Wallace River Hatchery

The hatchery water intake screens on Wallace River and May Creek are in compliance with state and federal guidelines (NMFS 1995; 1996), however, they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). WDFW will modify screening at Wallace River Hatchery to comply with NMFS screening requirements to protect natural-origin fish from entrainment and impingement that may lead to injury and mortality. Intake screens on both tributaries are scheduled for rebuild in the 2019-2020 funding biennium to bring the screens into compliance with those criteria. Retrofitting of the Wallace River Hatchery screens is to be completed by fall 2020.

The Wallace River Hatchery facility uses surface water exclusively, withdrawn through water intakes on the Wallace River and May Creek, an adjacent tributary. Wallace River Hatchery may withdraw up to 40 cfs of surface water from the Wallace River and up to 14 cfs from May Creek. Surface water withdrawal rights are formalized through Washington State water right permits S1-00108C (16 cfs) and S1-00109C (24 cfs) for the Wallace River and permits S1-05617 (10 cfs) and S1-23172C (4 cfs) for May Creek. Current pumping capacity from the Wallace River and May Creek are 26.7 cfs and 1.8 cfs, respectively. Assuming hatchery water withdrawals at maximum pumping capacity, 73 percent of the 95 percent exceedance low flow (36.4 cfs based on scaled USGS streamflow records) in the Wallace River would be diverted into Wallace River Hatchery to support the EWS program, and 12 percent of the water in the river could be withdrawn during median flows (220 cfs). For May Creek, assuming maximum water withdrawals based on maximum pumping capacity, 30 percent of the 95 percent exceedance low flow (6.0 cfs based on scaled USGS streamflow records) would be diverted into the Wallace River Hatchery, and 3 percent of the water in May Creek would be withdrawn at median flows (65 cfs). However, these scenarios of hatchery water withdrawal are extremely unlikely. No listed fish originate above the hatchery in May Creek, and withdrawal of water up to permitted levels from the Wallace River would not lead to stream dewatering that would affect listed fish migration and survival. All water withdrawn for use in the freshwater fish rearing locations would be returned to surface waters in close proximity to the point of withdrawal or impoundment.

Fish rearing at Wallace River Hatchery is implemented consistent with NPDES permit number WAG 13-3006 issued by WDOE (WDFW 2014a). Under its NPDES permit, the effluent at Wallace River Hatchery would be passed through a pollution abatement pond to settle out any uneaten food and fish waste before being discharged into receiving waters (WDFW 2014a). Structures and measures proposed for adult steelhead broodstock collection will not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. All EWS used as broodstock will be collected as volunteers to Wallace River Hatchery, Reiter Ponds, and/or Tokul Creek Hatchery. The facility is removed from listed Chinook salmon and steelhead migration and rearing areas and there will be no effects resulting from operation of broodstock collection actions at the facility.

Reiter Ponds Facility

Screening for the hatchery water intake structure at Reiter Ponds is in compliance with state guidelines but does not meet the latest Anadromous Salmonid Passage Facility Design criteria (NMFS 2011c). The screens have not been identified for replacement. However, listed fish do not utilize Austin or Hogarty creeks, or habitat upstream of the water intake structures (WDFW 2014a), and listed fish effects are therefore negligible. The Reiter Ponds facility uses surface water diverted from Austin and Hogarty creeks. Flows fluctuate depending on weather conditions and time of year: Austin Creek stream flow ranges from 6.7 to 300 cfs, and Hogarty Creek stream flow ranges from 1.3 to 100 cfs (WDFW 2014a). The Reiter Ponds program can divert up to 10 cfs from Austin and Hogarty creeks. Surface water withdrawal rights are formalized through Washington State water right permits S1-00667C (10 cfs) and S1-00313C (10 cfs) for Austin and Hogarty creeks, respectively. Monitoring and measurement of water usage are reported in monthly NPDES reports to WDOE.

Fish rearing at the Reiter Ponds is implemented consistent with NPDES permit number WAG 13-3005 issued by WDOE. Under its NPDES permit, the Reiter Ponds facility operates a water cleaning treatment system to remove pollutants before effluent is discharged back into natural waters (WDFW

2014a). Structures and measures proposed for adult steelhead broodstock collection will not substantially affect the migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. All EWS used as broodstock will be collected as volunteers to Reiter Ponds, Wallace River Hatchery, and/or Tokul Creek Hatchery. The facility is removed from listed Chinook salmon and steelhead migration and rearing areas, and there will be no effects resulting from operation of broodstock collection actions at the facility.

Tokul Creek Hatchery

The hatchery water intake screens on Tokul Creek are in compliance with state and federal guidelines (NMFS 1995, 1996), however, they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). The screens will be modified to comply with the NMFS (2011c) screening requirements to protect natural-origin fish from entrainment and impingement that may lead to injury and mortality (WDFW 2014b). The water intake for Tokul Creek Hatchery on Tokul Creek relies on impoundment of water by a small dam with a non-functioning fish ladder that currently blocks access to Chinook salmon spawning habitat. The area of Tokul Creek upstream of the hatchery water intake structure and dam is limited to about 0.55 miles or 2 acres of potential habitat below a barrier cascade (NMFS 2016a). Further, the high gradient of this upstream habitat limits its value or productivity for Chinook salmon spawning and rearing. WDFW is in the process of renovating hatchery screening and correcting fish passage problems at the location, and this work is to be complete by fall, 2016. NMFS has analyzed the effects of this work and authorized it in an ESA consultation (NMFS 2016a). As mentioned in earlier in this opinion, the construction work on the ladder and dam may be interrelated and interdependent with the ongoing operation of the EWS program. Therefore, the Effects analysis in the biological opinion for that construction is incorporated by reference into this opinion. The construction work was determined to have only very minor adverse effects on listed fish, specifically from a temporary turbidity plume and gathering fish for removal during instream work (NMFS 2016a). NMFS expects that the ladder as designed will allow the hatchery water intake structure on Tokul Creek to be brought into compliance with NMFS fish passage criteria

The Tokul Creek Hatchery facility uses mainly surface water with a backup source of groundwater pumped from a single well (WDFW 2014b). Surface water is withdrawn from an unnamed spring and from Tokul Creek itself. Water rights are formalized through Washington State trust water right permits #S1-08944C (unnamed spring; 6 cfs), S1-03416C (Tokul Creek; 3 cfs), and S1-21399C (Tokul Creek; 9 cfs). Up to 0.9 cfs of well water is available for emergency use when needed. Monitoring and measurement of water usage are reported in monthly NPDES reports to WDOE. Assuming hatchery water withdrawals at maximum permitted levels (12 cfs), up to 92 percent of the water during the lowest streamflow on record (13 cfs; discontinuous USGS stream gage records from 1907 to 1945) or 75 percent of the 99 percent exceedance low flow (16 cfs) in Tokul Creek would be diverted into Tokul Creek Hatchery to support the EWS program and 17 percent of the water in the stream would be withdrawn at median flows (72 cfs). However, these scenarios for hatchery water withdrawal are extremely unlikely. The highest hatchery water withdrawal needs, during the spring months when hatchery fish are at their largest size and need high rearing flows for fish health maintenance do not coincide with periods when natural flows are low.

Fish rearing at Tokul Creek Hatchery is implemented consistent with NPDES permit number WAG 13-3004 issued by WDOE (WDFW 2014b). Under its NPDES permit, the Tokul Creek Hatchery operates a water cleaning treatment system to remove pollutants before effluent is discharged back into natural waters (WDFW 2014b). Structures and measures proposed for adult steelhead broodstock collection will not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. All EWS used as broodstock will be collected as volunteers to Tokul Creek Hatchery, Reiter Ponds, and/or Wallace River Hatchery. The facility is removed from listed Chinook salmon and steelhead migration and rearing areas, and there will be no effects resulting from operation of broodstock collection actions at the facility.

2.4.2.7 Fisheries

EWS hatchery fish are produced for harvest only and steelhead fisheries in the Snohomish River basin target them. As discussed earlier, these fisheries 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 (NMFS 2015a) (PSTT and WDFW 2015). The effects of fisheries on ESA-listed species to date are described in the Environmental Baseline. There are no changes to those baseline effects as a result of the proposed action, and effects are expected to continue at similar levels to those described in the Environmental Baseline.

2.4.2.8 Effects of the Action on Critical Habitat

Negligible effect

The effects of the proposed hatchery actions on designated critical habitat were analyzed through this consultation and NMFS determined that operation of the hatchery programs will have a negligible effect on PCEs for listed steelhead and Chinook salmon in the action area.

No hatchery operation and maintenance activities associated with the proposed programs are expected to adversely modify designated critical habitat. Operation and maintenance of the hatchery facilities used by the two EWS programs have not and will not result in: altered channel morphology and stability; reduced and degraded floodplain connectivity; excessive sediment input; or the loss of habitat diversity. No new facilities or construction are included as part of the proposed actions considered in this opinion. With the exception of water intake structures, all hatchery facilities used for EWS propagation are removed from action area river and tributary channels, and do not affect designated critical habitat for listed Chinook salmon and steelhead. Operation of the hatchery programs could affect PCEs for steelhead and Chinook salmon from water withdrawals (water quantity), effluent discharge (water quality), and migration delay, migration blockage, or fish injury occurring at hatchery water intake structures.

Proposed surface water diversions and withdrawals for rearing EWS, the return of that water to the Wallace River, Skykomish River, and Tokul Creek, will not affect water quantity to the extent that freshwater spawning, rearing, and migration corridor PCEs for steelhead and Chinook salmon would be substantially affected. The hatchery programs will operate consistent with Washington State water right permit limits and NPDES permit criteria for diverting and withdrawing water from streams and wells. Water withdrawal for use in fish rearing at the hatcheries will not have any discernible effect on, or result in any adverse modification of freshwater flows used for steelhead and Chinook salmon spawning, rearing and migration. Permitted water withdrawal quantities required for fish rearing at the hatchery facilities are a small fraction of average annual flows in the mainstem river and tributaries where the programs are located (Section 2.4.2.6), and water withdrawn for hatchery use is non-consumptive, and returned within yards of the points of withdrawal. Again, the previously stated hatchery water withdrawal proportion of total flows during low flow periods are worst case estimates and are unlikely to be realized. Like river flows, surface water withdrawal needs for the hatchery programs fluctuate seasonally, with the highest hatchery water withdrawal needs occurring in the spring months because that is when fish are at their largest size and need high rearing flows for fish health maintenance. Hatchery water withdrawal needs for fish rearing are lowest in the late summer months when river flows are at their lowest level.

Hatchery effluent discharged into receiving waters after use in EWS rearing will not affect water quality to the detriment of freshwater spawning, rearing, and migration corridor PCEs for steelhead and Chinook salmon. Effluent discharge is regulated consistent with applicable NPDES permits for the hatchery operations, and no adverse effects on water quality are expected. Water used for fish production at the WDFW hatchery facilities will be treated before it is returned to surface waters/rivers and streams. Wallace River, Reiter Ponds, and Tokul Creek hatcheries have current NPDES permits.

Hatchery water intake structures and associated screening will be operated so that PCEs for steelhead and Chinook salmon are not substantially affected. All water intakes are operated to protect listed juvenile Chinook salmon and steelhead from entrainment and injury. The structures and associated screening either meet NMFS's fish passage criteria (NMFS 2011c), or are scheduled for retrofitting, at least where ESA-listed fish are present. Water intake structures and fish screens at Wallace River Hatchery and Tokul Creek Hatchery will be updated to ensure compliance with NMFS fish passage and screening criteria by fall 2020 and fall 2016, respectively. Upstream passage for anadromous fish above the Tokul Creek dam impounding water for use at Tokul Creek Hatchery will also be restored by fall 2016, before adult Chinook salmon and steelhead for the 2016-2017 migration year return to spawn in the Snoqualmie River watershed, and no substantial effects on PCEs for these listed species are expected for the interim period. Also, effects to ESA-listed salmonids are expected to be inconsequential because of the small proportion of anadromous salmonid habitat represented by the area in Tokul Creek upstream of the dam, not at a level that affects viability.

2.5 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the Proposed Action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. For the purpose of this analysis, the action area is described in Section 1.4. Future Federal actions, including the ongoing operation of the hydropower system, hatcheries, fisheries, and land management activities will be reviewed through separate section 7 consultation processes. Non-Federal actions that require authorization under section 10 of the ESA, and are not included within the scope of this consultation, will be evaluated in separate section 7 consultations.

The federally approved Shared Strategy for Puget Sound Recovery Plan for Puget Sound Chinook Salmon (Ruckelshaus et al. 2005), Volume II of the plan (SSPS 2005), and the Snohomish River Basin Salmon Conservation Plan (SBSRF 2005) describe, in detail, the on-going and proposed state, tribal, and local government actions that would be implemented to reduce known threats to listed Puget Sound Chinook salmon in the Snohomish River basin. A recovery plan for Puget Sound steelhead, including summer- and winter-run populations in the Snohomish River basin, has yet to be fully developed, but the underlying science (i.e., population viability criteria) has been developed for managers to use 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 (Ruckelshaus et al. 2005; SBSRF 2005) and these plans must be implemented for NMFS to consider them "reasonably certain to occur" in its analysis of cumulative effects. The cumulative effects of non-Federal actions in the action area are difficult to analyze considering the geographic landscape of this opinion, the political variation in the action area, the uncertainties associated with government and private actions, and the changing economies of the region. Whether these effects will increase or decrease is a matter of speculation, with the likelihood for future effects depending on the activity affecting the species, and the non-Federal entity regulating the activity. However, we think it is prudent to plan for 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 the Shared Strategy Plan (Ruckelshaus et al. 2005) and through other associated plans and initiatives (e.g., SSPS 2005) 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 such decreases would be similar to the pace observed in recent years. 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 as the result of further habitat loss and degradation resulting from human population growth and associated developmental activities (Judge 2011). State, tribal, and local governments have developed resource use plans and initiatives that are proposed to be applied and sustained in a comprehensive way to benefit listed fish and offset any growing adverse effects, including population grow-out (e.g., SBSRF 2005). But the actions must be funded and implemented (most are not) and sustained in a comprehensive manner before NMFS can consider them "reasonably foreseeable" in its analysis of cumulative effects, and it is speculative for NMFS to do so given these uncertainties.

Numerous non-Federal projects and activities, funded with Federal and state dollars, are benefitting fish included in the Puget Sound Chinook salmon ESU and Puget Sound steelhead DPS, including populations of the species in the Snohomish River basin. Following the fish restoration strategies described in the Shared Strategy Plan (Ruckelshaus et al. 2005) and in the NMFS Supplement to the recovery plan (NMFS 2006b), non-Federal projects and activities have been implemented to address watershed-specific limiting factors to salmon viability. 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 and marine shorelines in Puget Sound; instream flow protection and enhancement; and reduction of forest practice and farming impacts to salmon habitat. Specific actions to recover listed salmon and steelhead in Puget Sound watersheds, including the Snohomish Basin, have included: implementation of land use regulations to protect existing habitat and habitat-forming processes through updating and adopting Federal, state, and local land use protection programs, as well as more effectively combining regulatory, voluntary, and incentive-based protection programs; implementation of nearshore and shoreline habitat protection measures such as purchase and protection of estuary areas important for salmon productivity; protection and restoration of habitat functions in lower river areas, including deltas, side-channels, and floodplains important as rearing and migratory habitat; implementation of protective instream flow programs to reserve sufficient water for salmon production; and implementation of protective actions on agricultural lands. 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.

2.6 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 2.4.2) to the environmental baseline (2.3) and to cumulative effects (2.5) 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) reduce the value of designated or proposed critical habitat. This assessment is made in full consideration of the status of the species and critical habitat and the status and role of the affected population(s) in recovery (Sections 2.2.1, 2.2.2, and 2.2.3).

In assessing the overall risk of the Proposed Action on each species, NMFS considers the risks of each factor discussed in Section 2.4.2, 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 appreciable reduce the likelihood of survival and recovery of the listed species.

2.6.1 Puget Sound Steelhead

After addition of the effects of the Proposed Action to the effects of all human activities in the action area, including any anticipated Federal, state, tribal, or private projects, NMFS also concludes that the Proposed Action will not appreciably reduce the likelihood of survival and recovery in the wild of the Puget Sound steelhead DPS.

Based on a review of the proposed EWS program actions (Section 1.3), the status of affected steelhead populations (Section 2.2.1), and consideration of environmental baseline conditions (Section 2.3) and cumulative effects (Section 2.5), the assigned effects of the proposed EWS hatchery actions on Puget Sound steelhead range from not applicable to negative (see Table 12). Of the seven effects factors evaluated, three – gene flow to natural steelhead populations resulting from natural spawning by hatchery-origin steelhead affecting steelhead population genetic diversity; hatchery-origin yearling steelhead competition with natural-origin steelhead juveniles affecting steelhead population abundance; and, Wallace River and Tokul Creek hatchery facility water intake screening effects on steelhead population abundance and spatial structure - were assigned as having negative effects on ESA-listed steelhead in the Snohomish River basin (see Sections 2.4.2.2, 2.4.2.3 and 2.4.2.6).

Genetic Effects (Section 2.4.2.2)
Gene flow between associated natural-origin steelhead populations and fish produced by the two EWS programs is identified as having negative effects on Puget Sound steelhead population fitness. Methods used by WDFW and considered by NMFS to be the best available science to estimate gene flow, and to gauge the level of risk, included DNA analysis of tissue samples collected from migrating natural-origin juvenile and adult steelhead in the Snohomish River basin (Warheit 2014a), as well application of a demographic-based methods for steelhead in the Skykomish, Snoqualmie, and Pilchuck river basins (Scott and Gill 2008; Hoffmann 2014; WDFW 2014a; WDFW 2014b). Based on NMFS's consideration of best available scientific information, gene flow levels of 2% into natural-origin Puget Sound steelhead populations will not pose substantial risk. For the two EWS hatchery programs, two credible and independent analytical approaches indicate that current gene should be less than 2% in natural-origin steelhead populations affected by the two programs (Table 18). However, because of the Warheit method's tendency to overestimate current gene flow, as discussed in Section 2.4.2, gene flow estimated by *PEHC* can be expected to decline from 4% but not immediately reach 2% in the Snoqualmie winter-run steelhead population. This is considered in the ITS (see Section 2.8.4).

To reduce genetic effects, measures are necessary and will be applied to minimize unintended natural spawning by hatchery-origin steelhead, and to continue to substantially limit gene flow from the hatchery populations to the natural ESA-listed populations (WDFW 2014a; 2014b). These measures will include fully acclimating smolts to the hatchery release sites with no off-station planting, to enhance returning adult fish homing fidelity and operating weirs and traps at the hatcheries for the full duration of the EWS adult return period to attract and remove hatchery fish and prevent them from spawning in the natural environment. Extensive monitoring and evaluation actions proposed in the plans are necessary and will determine the abundance of naturally spawning steelhead by origin (hatchery and natural-origin) and their temporal and spatial distribution. Levels of gene flow between EWS and steelhead from natural populations in the Snohomish River basin will also be monitored (Anderson et al. 2014).

As discussed in the Effects analysis, it is impossible at this time to assess the baseline level of genetic change in the affected steelhead populations attributable to past operation of the EWS programs. But given the very low levels of gene flow expected from the proposed action, adding such low levels to the baseline fitness levels is not likely to have more than a negligible effect on fitness in the future Consideration of the gene flow effects of EWS and ESS programs on Snohomish Basin natural steelhead has shown that, except for the North Fork Skykomish summer steelhead population, combined effects are expected to be less than 2% and thus pose low risk. As discussed in Section 2.4.2, the North Fork Skykomish population is a special case because gene flow from ESS programs has been so extensive that WDFW regards it as a feral population of Skamania steelhead. NMFS concludes that the proposed action poses little risk to the North Fork population. New information developed through the likely future consultation on the ESS programs or through development of a recovery plan for Puget Sound steelhead may require reinitiation of consultation to the extent it indicates effects of this action not considered in this opinion.

On the basis of the best available science, WDFW's gene flow findings indicating that the magnitude of EWS program effects on natural steelhead genetic diversity is likely low, consistent with analyses and findings described in Section 2.4.2.2, and considering risk minimization actions that will be implemented, the proposed action is likely to have only very minor effects to fitness. To ensure that genetic effects remain minor and at levels estimated for the proposed programs, NMFS is requiring the following actions: 1) further development of the Warheit (2014a) method to address questions stated in the NWFSC review and in the analysis in this document, 2) further refinement of the genetic monitoring plan proposed by WDFW (Anderson et al. 2014), and 3) expanded sensitivity analysis of the Scott-Gill (2008) method. These requirements stem from questions regarding the precision of the genetically based results, and both precision and bias of the demographically based results. These validation measures are detailed, along with time frames for completion in the Terms and Conditions section (Section 2.8.4) of this document. NMFS will monitor emerging science and information provided by the co-managers and other scientists related to genetic interactions between EWS and steelhead from natural-origin populations and re-initiation of consultation, under section 7 will be required in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

Competition Effects (Section 2.4.2.3)
Competition for food and habitat by newly released EWS smolts is likely to have negative effects on ESA-listed steelhead abundance and productivity. Adverse resource competition effects on natural-origin ESA-listed Chinook salmon and steelhead fry and parr associated with WDFW hatchery steelhead releases are unlikely because of substantial size and hence prey differences (SIWG 1984) between the hatchery yearlings and natural-origin salmonids that would be encountered in watershed areas when and where the hatchery-origin fish are released. The potential exists for adverse resource competition effects on natural-origin listed steelhead smolts from EWS hatchery releases because of the similar seaward emigration timings, and similar individual smolt sizes and hence similar prey preferences between that hatchery- and natural-origin steelhead in areas downstream of hatchery-origin steelhead release sites. To reduce freshwater competition effects to natural-origin steelhead smolts from hatchery-origin steelhead, the co-managers will implement several best management practices including the release of EWS juveniles as migrating, seawater-ready smolts. The practice of releasing only actively migrating smolts, that will exit freshwater rapidly, will reduce the duration of interaction with natural-origin steelhead that may be vulnerable to competition for food or space.

For these reasons, and consistent with analyses findings described in Section 2.4.2.3, the magnitude of effects to listed steelhead abundance and productivity associated with juvenile EWS competition is likely low, and the proposed actions are unlikely to pose substantial risks to the viability of ESA-listed natural steelhead populations or impede recovery of the Puget Sound steelhead DPS. To verify this low competition risk assessment, hatchery-origin and natural-origin steelhead smolt emigration timing and abundance will be monitored each year through operation of WDFW and tribal juvenile outmigrant trapping programs to evaluate whether hatchery smolt release timings avoid or reduce, to negligible levels, harmful ecological interactions with ESA-listed natural-origin steelhead. Based on monitoring results, alternate hatchery steelhead release timings or other mitigation measures will be developed to minimize such interactions. NMFS will monitor emerging science and information provided by the co-managers and other scientists related to interactions between hatchery steelhead and fish from natural populations, and re-initiation of consultation, under section 7 will be required in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

Water Intake Effects (Section 2.4.2.6)
The only aspect of hatchery operations and maintenance with potential negative effects on listed steelhead is the water intakes at the facilities. Screens at some facilities are not in compliance with the most recent NMFS guidance, but their effects to passage given compliance with prior guidelines are likely very low. Bringing the facilities into compliance with the most recent guidance will minimize effects even further.

Hatchery operation activities associated with implementation of the Wallace River Hatchery component of the Skykomish/Snohomish EWS program negatively affect ESA-listed steelhead abundance. Similar activities at Reiter Ponds are not expected to pose substantial effects (Section 2.4.2.6). The water intake and associated screens used at Wallace River Hatchery do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (WDFW 2014a; NMFS 2011c). WDFW will renovate the water intake structure by fall 2020 to bring the facility into compliance with NMFS (2011c) fish passage criteria. When renovated, the Wallace River Hatchery facility will not pose substantial fish passage risks to migrating juvenile and adult steelhead. No fish passage problems or fish mortality events have been observed during operation of the hatchery water intake. The current water intakes at the hatchery meet NMFS previous screening criteria (NMFS 1995, 1996). NMFS (2011c) states that such screening is adequately protective of natural fish from impingement and entrainment effects until the structures are renovated, at which time they must meet the latest NMFS criteria. The water intake will be in compliance with the latest NMFS criteria when construction is completed.

With regards to the Tokul Creek Hatchery surface water intake, by fall 2016, a fish ladder will be constructed in the dam that impounds water for use by the hatchery, so that the structure is passable to migrating fish (WDFW 2016a). Effects of hatchery water intake renovation and construction of the fish ladder to allow unimpeded upstream and downstream fish passage were found not likely to not jeopardize ESA-listed salmon and steelhead or destroy or adversely modify critical habitat for the species (NMFS 2016a). NMFS’ approval of the ladder construction was designed so that the hatchery water intake structure on Tokul Creek will be brought into compliance with NMFS fish passage criteria (NMFS 2016a). Upstream passage for anadromous fish above the Tokul Creek dam impounding water for use at Tokul Creek Hatchery will be restored by fall 2016, before adult Chinook salmon and steelhead for the 2016-2017 migration year return to spawn in the Snoqualmie River watershed, and no substantial effects on these listed species are expected for the interim period. Also, effects to ESA-listed salmonids are expected to be inconsequential because of the small proportion of anadromous salmonid habitat represented by the area in Tokul Creek upstream of the dam, not at a level that affects viability. Construction of the ladder will provide ESA-listed salmon and steelhead with unimpeded access to this habitat. After construction is completed, operation and maintenance of the water intake and associated dam will not result in dewatering of the creek, and water intake structure-related effects on listed salmon and steelhead will be inconsequential.

Withdrawal of surface water at maximum permitted levels for fish rearing at the EWS hatchery facilities could decrease the quantity of water available for steelhead migration and rearing, potentially leading to adverse effects. However, adverse effects on steelhead are unlikely, because water withdrawal amounts for hatchery fish rearing during the summertime low flow periods when any effects would be most pronounced will be much less than the permitted maximum levels (Section 2.4.2.6). As dictated by fish biomass at the hatchery rearing locations, required water withdrawal amounts are expected to approach the maximum permitted levels only in the late winter and spring months just prior to fish release dates when the fish are at their largest size, and flows in the Wallace River, Skykomish River, and Tokul Creek reach annual maximums. Hatchery water needs are at their lowest level during the summer and fall months, when juvenile fish biomass, and associated water supply needs, are at annual minimums. Dewatering of critical habitat for steelhead in the action area, and adverse effects on listed steelhead are therefore highly unlikely.

For these reasons, and consistent with analyses findings described in Section 2.4.2.6, the magnitude of effects on listed steelhead abundance, spatial structure, and productivity associated with EWS hatchery operation and maintenance actions is likely very low; and on-going monitoring would make possible management responses if conditions warrant. NMFS will monitor water intake and facility screening update activities, and data collected regarding effects on natural-origin fish, to ensure that negative effects on steelhead migration associated with operation of Wallace River Hatchery and Tokul Creek Hatchery are reduced in effect or adjusted to reduce effects further. Failure to complete work to bring structures into compliance with current NMFS criteria may require reinitiation of this consultation.

Summary of Effects on Steelhead

Criteria and guidance for steelhead conservation have been developed and represent best available science, in the interim, until a federally approved recovery plan for Puget Sound steelhead is completed. The most recently completed NMFS ESA status review update for the Puget Sound steelhead DPS identified primary limiting factors and threats to distinct independent populations composing the DPS, including the listed steelhead populations in the Snohomish River watershed (NWFSC 2015). Threats include the continued destruction and modification of steelhead habitat (the principal factor limiting DPS viability); widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years; threats to diversity from non-local hatchery steelhead stocks (EWS and ESS); declining diversity in the DPS, including the uncertain, but likely poor status of summer-run fish in the DPS; reduction in spatial structure for steelhead in the DPS associated with large numbers of barriers, such as impassable culverts, together with declines in natural abundance, that greatly reduce opportunities for adfluvial movement and migration between steelhead groups within watersheds; reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris; increased flood frequency and peak flows during storms, and reduced groundwater-driven summer flows in the lower reaches of many rivers and their tributaries in Puget Sound where urban development has occurred, that have resulted in gravel scour, bank erosion, and sediment deposition; and dikes, hardening of banks with riprap, and channelization, which have reduced river complexity and sinuosity, and have increased the likelihood of gravel scour and dislocation of rearing juveniles (Section 2.2.1.2).

In its latest review of the Puget Sound Steelhead DPS, the NMFS TRT concluded that EWS production has posed considerable risk to the diversity of natural steelhead populations in the Puget Sound DPS (NWFSC 2015). However, the TRT also noted that co-managers terminated several EWS hatchery programs in the region, reduced smolt release numbers, substantially in some cases, ceased off-station early-winter smolt releases altogether, stopped the practice of "recycling" adults trapped at the hatcheries downstream to enhance sport fisheries, and maintained traps open for the entire duration of the early-winter hatchery adult period to remove the fish and reduce straying risks. All of these risk minimization measures have been applied to the EWS programs reviewed in this opinion, as well as the three EWS programs analyzed in NMFS (2016b). While also considering gene flow estimates that suggest that the influence of hatchery steelhead in several populations are now low (Warheit 2014a), the TRT concluded the diversity risk posed by Puget Sound region EWS hatchery programs in the DPS has declined since the 2011 status review (NWFSC 2015). In addition, the proposed action will not contribute to any of the other limiting factors and threats to listed Puget Sound Steelhead identified in the NWFSC (2015) review in any measureable way.

This analysis has considered limiting factors identified for the DPS and the effects of the proposed action on the Puget Sound Steelhead DPS, combined with other past and ongoing activities inside the action area, including implementation of conservative harvest management actions (Section 2.3.1), the effects of past hatchery operations (Section 2.3.2), and habitat protection and restoration projects implemented to benefit DPS viability (Section 2.3.3). As discussed in the Environmental Baseline, habitat conditions in the action area have been heavily impacted by human activities, resulting in conditions that in many locations are not favorable to steelhead rearing and migration. However, the proposed action has only minimal impacts on a few aspects of the Baseline – specifically the genetic condition of the listed steelhead populations, competition with listed steelhead juveniles for rearing resources, and the minor effects of the operation of screened water intakes. The latter will be reduced further upon installation of screens meeting current NMFS guidance. The impacts of fisheries directed at EWS in the action area on listed steelhead have been significantly reduced compared to past impacts and are currently minimal. In summary, the effects of these hatchery programs have been minimized to the point where added to the Baseline and Cumulative Effects they will have no more than minor effects on listed populations in the action area.

Taken together, the proposed actions are expected to have unsubstantial negative effects on the Puget Sound steelhead DPS. As discussed above, some low, minor negative effects to the listed steelhead populations in the action area are expected, however, none of those are expected to rise to the level at which they would have more than very minor effects on population viability or more than negligible effects on DPS survival and recovery. Measures implemented to reduce EWS hatchery-related genetic, ecological and demographic effects on ESA-listed steelhead are based on best management practices designed to further lessen risks to affected natural steelhead populations. This analysis leads to a determination that the EWS hatchery programs will have negative effects on ESA-listed steelhead but they will not appreciably reduce the likelihood of survival and recovery in the wild by reducing the reproduction, number, or distribution of the DPS.

2.6.2 Puget Sound Chinook Salmon

When the effects of the Proposed Action are added to the effects of all human activities in the action area, including any anticipated Federal, state, or private projects, NMFS concludes that the Proposed Action will not appreciably reduce the likelihood of survival and recovery in the wild of the Puget Sound Chinook Salmon ESU.

Based on a review of the proposed EWS program actions (Section 1.3), the status of affected Chinook salmon populations (Section 2.2.2), and consideration of environmental baseline conditions (Section 2.3) and cumulative effects (Section 2.5), the assigned effects of the proposed EWS hatchery actions on

Puget Sound Chinook salmon range from not applicable to negative (see Table 12). Of the seven effects factors evaluated, two – hatchery-origin yearling steelhead predation on listed juvenile Chinook salmon population abundance; and Wallace River and Tokul Creek hatchery facility water intake screening effects on Chinook salmon population abundance and spatial structure - were assigned as having negative effects on ESA-listed steelhead in the Snohomish River basin (see Sections 2.4.2.3 and 2.4.2.6).

Predation Effects (Section 2.4.2.3)
To reduce predation risks to juvenile Chinook salmon in freshwater, all yearling steelhead released from the three WDFW facilities will be seawater-ready smolts, propagated using methods to ensure that the fish are of uniform, large size so that the fish are physiologically ready to emigrate downstream, and not residualize in freshwater (Section 2.4.2.3). The proposed EWS hatchery programs will also reduce temporal and spatial overlap and the potential for predation on rearing or migrating listed juvenile Chinook salmon by releasing the yearlings from late-April through May (Table 21). Volitional release of actively migrating smolts, and culling of non-migrants, at all facilities will help avoid or further limit residualism and foster rapid seaward emigration, reducing the duration for interactions with co-occurring juvenile Chinook salmon of sizes vulnerable to predation.

For these reasons, and consistent with analyses described in Section 2.4.2.3, the magnitude of effects on ESA-listed Chinook salmon abundance and productivity associated with juvenile EWS predation is likely low, and the proposed actions are unlikely to pose substantial risks to the viability of natural Chinook salmon populations in the action area, or impede recovery of the Puget Sound Chinook salmon ESU. On-going monitoring would make management responses possible if conditions warrant. To verify this low predation effects assessment, juvenile out-migrant monitoring would continue in the Skykomish and Snoqualmie Rivers to determine annual salmonid size and emigration timing by species and origin, and to identify spatial and temporal overlap among Chinook salmon from natural populations and EWS. The release programs for EWS hatchery yearlings will be revised if juvenile out-migrant monitoring in the Skykomish and Snoqualmie rivers suggests that proposed release timings for EWS yearlings would result in substantial predation on ESA-listed natural-origin fish. NMFS will monitor emerging science and information provided by the co-managers and other scientists related to interactions between hatchery fish and fish from natural populations and re-initiation of consultation, under section 7 will be required in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

Water Intake Effects (Section 2.4.2.6)
The only aspect of hatchery operations and maintenance with potential negative effects on listed steelhead is the water intakes at the facilities. Screens at some facilities are not in compliance with the most recent NMFS guidance, but their effects to passage given compliance with prior guidelines are likely very low. Bringing the facilities into compliance with the most recent guidance will minimize effects even further.

Hatchery operation activities associated with implementation of the Wallace River Hatchery component of the Skykomish/Snohomish EWS program are likely to adversely affect ESA-listed Chinook salmon abundance. Similar activities at Reiter Ponds are not expected to pose substantial effects to listed Chinook salmon, because the small, spring-fed creek where the hatchery is located is not used by the species. (Section 2.4.2.6). Although the hatchery water intake screens at the Wallace River Hatchery are in compliance with state and federal guidelines (NMFS 1995; 1996), they do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (WDFW 2014a; NMFS 2011c). The water intake structure is scheduled for renovation and updating by fall 2020 to bring the facility into compliance with NMFS (2011c) fish passage criteria. When renovated, the Wallace River Hatchery facility will not pose substantial fish passage risks to migrating juvenile and adult Chinook salmon.

For Tokul Creek Hatchery, by fall 2016, a fish ladder will be constructed in the dam that impounds water for use by the hatchery, so that the structure is passable to migrating fish (WDFW 2016a). The effects of this work have been analyzed and authorized under the ESA (NMFS 2016a). The proposed fish ladder construction was designed so that the hatchery water intake structure on Tokul Creek will be brought into compliance with NMFS fish passage criteria (NMFS 2016a). Currently, the structure impedes fish passage but, because of the small proportion of anadromous salmonid habitat represented by the area in Tokul Creek upstream of the dam, not at a level that affects viability. Construction of the ladder will provide access to additional upstream habitat for anadromous fish in Tokul Creek, including Chinook salmon. After construction is completed, effects to ESA-listed species from operation and maintenance of the water intake and associated dam will be inconsequential.

Withdrawal of surface water at maximum permitted levels for fish rearing at the EWS hatchery facilities could decrease the quantity of water available for Chinook salmon migration and rearing, potentially leading to adverse effects. However, adverse effects on Chinook salmon are unlikely, because water withdrawal amounts for hatchery fish rearing during the summertime low flow periods when any effects would be most pronounced will be much less than the permitted maximum levels (Section 2.4.2.6). As dictated by fish biomass at the hatchery rearing locations, required water withdrawal amounts would approach the maximum permitted levels only in the late winter and spring months when flows in the Wallace River, Skykomish River, and Tokul Creek reach annual maximums. Hatchery water needs are at their lowest level during the summer and fall months, when juvenile fish biomass, and associated water supply needs, are at annual minimums. Dewatering of critical habitat for Chinook salmon in the action area, and adverse effects on listed Chinook salmon are therefore highly unlikely.

For these reasons, and consistent with analyses findings described in Section 2.4.2.6, the magnitude of effects on ESA-listed Chinook salmon abundance, spatial structure, and productivity associated with EWS hatchery operation and maintenance actions is likely low; the proposed actions are unlikely to pose more than very minor effects to the listed Chinook salmon populations in the action area, and on-going monitoring would make possible management responses if conditions warrant. NMFS will monitor water intake and facility screening renovations at the Wallace River and Tokul Creek hatcheries that are designed to protect Chinook salmon migration and survival. Failure to complete work to bring structures into compliance with current NMFS criteria may require reinitiation of this consultation

Summary of Effects on Chinook Salmon

The Federally approved Recovery Plan for Puget Sound Chinook salmon (Ruckelshaus et al. 2005; SSPS 2005), the Washington Conservation Commission’s WRIA 7 Limiting Factors Analysis (Haring 2002), and the Snohomish River Basin Salmon Conservation Plan (SBSRF 2005) identified primary limiting factors and threats to Chinook salmon populations in the Snohomish River basin. These limiting factors and threats, summarized in SSPS (2005) are: loss of estuarine and marine habitats due to residential and industrial development and urbanization; poor quality riparian forests and decreased forest cover as a result of clearing land for timber, farming, road building, and residential and urban development; lack of habitat complexity that provides pools and back-eddies, providing food and refuge for salmon; loss of natural hydrologic function, resulting in scouring flood flows; loss of floodplain function, including loss of wetlands and off-channel habitats; disruption of natural sediment processes; and loss of access to habitat from poorly designed culverts and other human-made structures. The Proposed Action considered in this opinion would not affect any of these factors in a measureable way.

This analysis has considered limiting factors identified for the ESA-listed Puget Sound Chinook salmon ESU, and effects of the proposed action on the ESU, combined with other past and ongoing activities inside the action area, including implementation of conservative harvest management actions (Section Fisheries), the effects of past hatchery operations (Section Hatcheries), and habitat protection and restoration projects implemented to benefit DPS viability (Section 2.3.3). As discussed in the Environmental Baseline, habitat conditions in the action area have been heavily impacted by human activities, resulting in conditions that in many locations are not favorable to Chinook rearing and migration. However, the proposed action has only minimal impacts on a few aspects of the Baseline – specifically predation on juvenile Chinook salmon by hatchery steelhead smolts, and the minor effects of the operation of screened water intakes. The latter will be reduced further upon installation of screens meeting current NMFS guidelines. In summary, the effects of these hatchery programs have been minimized to the point where, added to the Baseline and Cumulative Effects, they will have no more than minor effects on listed populations in the action area.

As discussed above, some minor negative effects to ESA-listed Chinook salmon are expected, however, none of those are expected to rise to the level at which they would cause more than extremely minor adverse effects to, limit, or delay achievement of population viability. Therefore, we do not expect adverse effects to ESU survival and recovery. Measures implemented to reduce EWS hatchery-related ecological and demographic effects on Chinook salmon are based on best management practices that are expected to adequately reduce negative effects to levels that do not adversely impact ESU survival or recovery. This analysis leads to a determination that the proposed action will not appreciably reduce the likelihood of survival and recovery in the wild by reducing the reproduction, number, or distribution of the Puget Sound Chinook Salmon ESU.

2.6.3 Critical Habitat

Critical habitat for ESA-listed Puget Sound Chinook salmon is described in Section 2.2.2.2 of this opinion. As described in Section 2.2.1.2, critical habitat has also been designated for Puget Sound steelhead. In reviewing the Proposed Action and after conducting the effects analysis, NMFS has determined that it will not degrade habitat designated or proposed as essential for listed Chinook salmon and steelhead spawning, rearing, juvenile migration, and adult migration purposes.

The hatchery water intake structures used for the Wallace River and Tokul Creek hatchery EWS programs are in the process of being replaced to reduce injury and mortality and improve upstream and downstream passage conditions for ESA-listed Chinook salmon and steelhead. The screens for water diversions at Wallace River Hatchery will be replaced by fall, 2020 so that effects on critical habitat are discountable. At Tokul Creek, renovations to the fish screens and ladder will be completed by the fall of

2016. The hatchery intake structures, when renovated, will pose a negligible effect to designated critical habitat for Chinook salmon in the action area (section 2.4.1.6).

Withdrawal of surface water at maximum permitted levels for fish rearing is not expected to decrease the quantity of water available for fish migration and rearing between the hatchery water intake and water discharge points in areas where ESA-listed salmon and steelhead can be present (i.e., the Wallace River), and no effects on designated critical habitat are likely. All surface water withdrawn for hatchery use is returned near the points of withdrawal. Water withdrawal amounts for hatchery fish rearing during the summertime low flow periods when any effects would be most pronounced will be much less than the permitted maximum levels. Fish biomass at the hatchery rearing locations, and required water withdrawal amounts, would reach maximum permitted levels only in the late winter and spring months just prior to fish release dates, when the fish are at their largest size, and surface water flows reach annual maximums. Hatchery water needs are at their lowest level during the summer and fall months, when juvenile fish biomass, and associated water supply needs, are at annual minimums. For these reasons, dewatering of critical habitat for salmon and steelhead in the action area that may lead to substantial effects is therefore highly likely.

There are no other activities included as part of the proposed action that could substantially affect critical habitat. Existing hatchery facilities have not led to altered channel morphology and stability, reduced and degraded floodplain connectivity, excessive sediment input, or the loss of habitat diversity. Further, no new facilities or changes to existing facilities other than the water intake structures are proposed. The proposed action includes strict criteria for withdrawing and discharging water used for fish rearing. Together, these actions will not have any discernible adverse effect or result in any adverse modification to critical habitat.

2.6.4 Climate Change

Steelhead and Chinook salmon populations in the Snohomish River basin will be adversely affected by climate change (see section 2.2.3). A decrease in winter snow pack resulting from predicted rapid changes over a geological scale in climate conditions in the Cascade Mountains is expected to reduce spring and summer flows, impairing water quantity and water quality in primary fish rearing habitat located in the mainstem Skykomish, Snoqualmie, and Snohomish Rivers. Predicted increases in rain-on-snow events will increase the frequency and intensity of floods in mainstem river areas, leading to scouring flows that would threaten the survival and productivity of natural-origin and hatchery-origin listed fish species.

2.7 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 steelhead DPS and the Puget Sound Chinook Salmon ESU, or to destroy or adversely modify designated critical habitat for the DPS and ESU.

2.8 Incidental Take Statement

Section 9 of the ESA and Federal regulation 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 results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. For purposes of this consultation, we interpret "harass" to mean an intentional or negligent action that has the potential to injure an animal or disrupt its normal behaviors to a point where such behaviors are abandoned or significantly altered.[34] Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not prohibited under the ESA, if that action is performed in compliance with the terms and conditions of this Incidental Take Statement (ITS).

2.8.1 Amount or Extent of Take

NMFS analyzed seven factors for hatchery effects and found that five factors were applicable to the proposed EWS hatchery programs. Three factors analyzed are likely to result in take of listed Puget Sound steelhead: gene flow to natural-origin steelhead populations resulting from natural spawning by hatchery-origin steelhead; hatchery-origin yearling steelhead competition with natural-origin steelhead juveniles; and Wallace River and Tokul Creek hatchery facilities water intake screening effects on natural-origin steelhead survival and migration. Two factors are likely to result in take of listed Puget Sound Chinook salmon: hatchery-origin yearling steelhead predation on natural-origin juvenile Chinook salmon; and Wallace River and Tokul Creek hatchery facilities water intake screening effects on natural-origin Chinook salmon survival and migration.

Take by Genetic Effects

Implementation of the EWS hatchery programs will result in gene flow, and adverse effects on steelhead population fitness, resulting from natural spawning by hatchery fish straying into natural-origin, native steelhead production areas in the Snohomish River basin. It is not possible to quantify genetic effects directly, because it is not possible to measure the number of interactions nor their precise effect. Therefore, NMFS will rely on a surrogate consisting of estimated gene flow, based on the modelling exercise discussed in Section 2.4.2.2.

The estimated rate of gene flow is rationally related to genetic effects, since gene flow is the measure of sharing genetic material between hatchery and natural-origin fish, which in turn leads to the risk of harm

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[34] NMFS has not adopted a regulatory definition of harassment under the ESA. The World English Dictionary defines harass as "to trouble, torment, or confuse by continual persistent attacks, questions, etc." The U.S. Fish and Wildlife Service defines "harass" in its regulations as an intentional or negligent act or omission that creates 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 (50 CFR 17.3). The interpretation we adopt in this consultation is consistent with our understanding of the dictionary definition of harass and is consistent with the U.S. Fish and Wildlife interpretation of the term.

due to genetic effects. Therefore, as a means to quantify and limit ESA-listed steelhead take associated with genetic diversity and fitness reduction, for each of the programs, beginning with the 2020 smolt outmigration, (the first year smolts are produced from any natural spawning of fish released as part of the proposed action reviewed in this opinion), gene flow (measured as *PEHC*) to any associated natural-origin steelhead populations must average less than 2% over four consecutive years (a span encompassing a steelhead generation; i.e., all four natural steelhead brood line cycles, considering that most steelhead return to spawn as four-year-old adults [Section 2.2.1.1. The 2% level corresponds to a modeled fitness loss over 25 generations of approximately 10%.

Analysis of the two programs in the proposed action indicates that gene flow from both will be under the 2% level for all natural steelhead populations in the Snohomish River basin. However, because of the analytical uncertainties inherent in the Warheit method, estimated *PEHC* for the Snoqualmie winter-run steelhead population may not track "true" *PEHC* well, therefore early estimates of *PEHC* may be higher than reflects reality. To address this, the take surrogate for the Snoqualmie basin hatchery program's gene flow to Snoqualmie winter-run steelhead will require two four-year periods of monitoring that show in the first period (2020-2024) a declining trend in gene flow estimates, and in the second period (2024-2027), an average *PEHC* of less than 2%. During the first four-year period, if *PEHC* estimates for this population are not on average less than 2%, they must average less than 4% and must show a downward trend. *PEHC* estimates must average less than 2% in the next generation.

The four-year time span unit encompasses a full steelhead generation (Section 2.2.1.1), and is therefore the minimum number of return years needed to appropriately estimate gene flow effects on natural steelhead populations resulting from implementation of the proposed actions. Not meeting the four consecutive year objective (or eight consecutive years, in the case of the Snoqualmie winter-run steelhead population) would lead to reinitiation of consultation for the programs that were not in compliance.

Take by Competition Effects

NMFS has determined that EWS smolts compete with rearing and migrating natural-origin steelhead in freshwater areas downstream of the hatchery fish release sites. It is not possible to quantify the take associated with competition in these areas, because it is not possible to meaningfully measure the number of interactions between hatchery-origin steelhead smolts, and natural-origin steelhead juveniles nor their precise effects. Therefore, NMFS will rely on a surrogate take indicator showing the proportion of the estimated total annual EWS smolt release from each program that have emigrated seaward, past juvenile outmigrant trapping sites in the lower Skykomish and Snoqualmie River watersheds for the period after the hatchery fish are released.

NMFS expects a de minimis level of EWS smolts to remain in freshwater post-release to minimize the potential for competitive interactions. Therefore, as a surrogate for take, NMFS expects that annual juvenile outmigrant trap-based analysis shall indicate that 90% of the EWS smolt populations released each year will have exited freshwater areas downstream of the hatchery release sites on or after the 21st day after the last release of the EWS smolts. The estimated number of EWS smolts passing the trapping sites will be calculated by statistical week, commencing the fourth week post-hatchery release and continuing until no EWS smolts are captured, as identified through either expanded estimates or catch per unit effort (CPUE).

This standard has a rational connection to the amount of take expected from ecological effects, since the co-occurrence of hatchery-origin and natural-origin fish is a necessary precondition to competition, and the assumption that the greater the proportion of EWS hatchery smolts of total annual releases remaining in freshwater post-release, the greater likelihood that competition will occur. The number of steelhead smolts in the downstream salmon and steelhead rearing and migration areas will be monitored by standing co-manager juvenile out-migrant screw trap monitoring activities.

Take by Predation Effects

In its evaluation, NMFS has determined that EWS smolts could prey on rearing and migrating natural-origin juvenile Chinook salmon in freshwater areas downstream of the release sites. It is not possible to quantify the take associated with predation in the action area, because it is not possible to meaningfully measure the number of interactions between the hatchery-origin steelhead smolts and natural-origin Chinook salmon juveniles nor their precise effects. Therefore, NMFS will rely on a surrogate take indicator that relates to the proportion of the total abundance of emigrating juvenile salmonids comprised of EWS smolts in the lower Skykomish and Snoqualmie Rivers for the period after the hatchery fish are released.

As a surrogate for predation take, NMFS expects that annual juvenile outmigrant trap-based analysis shall indicate that 90% of the EWS smolt populations released each year will have exited freshwater areas downstream of the hatchery release sites on or after the 21st day after the last release of the EWS smolts. The estimated number of EWS smolts passing the trapping sites will be calculated by statistical week, commencing the fourth week post-hatchery release and continuing until no hatchery-origin steelhead are captured, as identified through either expanded estimates or CPUE.

This standard has a rational connection to the amount of take expected from ecological effects, since the co-occurrence of hatchery-origin and natural-origin fish is a necessary precondition to predation, and the assumption that the greater the proportion of EWS hatchery smolts of total annual releases remaining in freshwater post-release, the greater likelihood that predation will occur. The number of steelhead smolts in the downstream salmon and steelhead rearing and migration areas will be monitored by standing co-manager juvenile out-migrant screw trap monitoring activities.

Take by Facility Effects

The existing Wallace River Hatchery and Tokul Creek Hatchery water intake structures take ESA- listed Chinook salmon and/or listed steelhead through migration delay or impingement of fish on screens. Because take by water intake structures occurs in the water and effects of delay or impingement may not be reflected until the fish have left the area of the structure, it is not possible to quantify the level of take associated with operation of the current water intake structures. . Therefore, NMFS will rely on a surrogate take indicator in the form of the amount of habitat affected by the intake structures.

Currently, the intake structures affect a very small proportion of total fish habitat available to salmon and steelhead in the Skykomish River and Snoqualmie River watersheds. The Wallace River Hatchery water intake presents risks of entrainment for juvenile fish in no more than a total of 4 square meters of migration and rearing area adjacent to the intake, where intake water velocities may be high enough to cause fish to be drawn from the Wallace River into the intake screens. Following renovation of the screens planned for fall 2020, the area affected by the intake screens would not change, but the compliance with latest NMFS criteria will reduce the amount of take in that area, because intake screening would be in compliance and thereby less harmful when/if encountered by listed fish.

The dam associated with the water intake structure on Tokul Creek currently impedes upstream access to approximately 0.55 miles of potential fish habitat, where only some of the high gradient area upstream is suitable habitat for Chinook salmon spawn and rearing (NMFS 2016a). When fish ladder renovation is completed, ESA-listed Chinook salmon adults will pass above the current impediment, and therefore be exposed to the water intake structure. The effect of entrainment of juvenile fish progeny of Chinook salmon spawners will occur in no more than a total of 4 square meters of migration and rearing area adjacent to the intake, where intake water velocities may be high enough to cause fish to be drawn from Tokul Creek into the intake screens. Because Tokul Creek contains a relatively small amount of spawning and rearing habitat for Chinook salmon, as a proportion of total Snoqualmie River watershed habitat, only a small proportion of the listed Snoqualmie Chinook salmon population would be exposed to this effect. With renovation of the Tokul Creek water intake structure as described above, the area affected by the intake structure would not change, but compliance with the latest protective NMFS criteria will reduce the amount of take in that area, because intake screening will be in compliance and thereby less harmful when/if encountered by listed fish.

The surrogate indicator of incidental take is rationally connected to the take associated with operation of the water intake structures, because take occurring by blocked access to habitat or by entrainment or impingement will only occur in the areas identified. This take can be reliably measured by continuing to observe effects associated with the water intakes.

2.8.2 Effect of the Take

In Section 2.7, NMFS determined that the level of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to Puget Sound Chinook salmon and Puget Sound steelhead or in the destruction or adverse modification of designated critical habitat.

2.8.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). "Terms and conditions" implement the reasonable and prudent measures (50 CFR 402.14). These must be carried out for the exemption in section 7(a)(2) to apply.

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

1. Ensure that adverse effects on natural-origin steelhead population genetic diversity and fitness associated with implementation of the Skykomish River and Tokul Creek Hatchery EWS hatchery programs are equal to or less than program effects levels described and evaluated for the proposed actions in this opinion.

2. Ensure that methods to monitor gene flow from EWS into natural steelhead populations are optimal and reflect best available science.

3. Ensure that EWS hatchery smolt releases do not pose competition effects to juvenile natural-origin steelhead in the Snohomish River basin at levels greater than those described and evaluated for the proposed actions in this opinion.

4. Ensure that EWS hatchery smolt releases do not pose predation effects to juvenile natural-origin Chinook salmon in the Snohomish River basin at levels greater than those described and evaluated for the proposed actions in this opinion.

5. Ensure that screening for the Tokul Creek Hatchery is renovated so that all screening at the facility complies with NMFS 2011 "Anadromous Salmonid Passage Facility Design" criteria by fall 2016.

6. Ensure that screening for the Wallace River Hatchery is renovated so that all screening at the facility complies with NMFS 2011 "Anadromous Salmonid Passage Facility Design" criteria by fall 2020.

7. Ensure that any natural origin Chinook salmon, steelhead, and bull trout, encountered during EWS broodstock collection operations are released back into the natural environment unharmed, and that annual encounter levels with the species are reported.

8. Implement the hatchery programs as described in the two steelhead HGMPs and monitor their operation.

9. Document the performance and effects of the hatchery steelhead programs, including compliance with the Terms and Conditions set forth in this opinion, through completion and submittal of annual reports.

2.8.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the Action Agencies must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). The Action Agencies 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 incidental take statement (50 CFR 402.14). If the following terms and conditions are not complied with, the protective coverage of section 7(o)(2) will lapse. This opinion requires that the Action Agencies:

1a. Conduct annual surveys to determine the origin, migration timing, abundance, and spatial distribution of naturally spawning steelhead in the Snohomish River basin to the extent feasible and considering surveyor safety, based on weather and flow conditions. The purpose of this effort is to validate key parameters used in the Scott-Gill (2008) model.
1b. Annually report estimates of adult EWS and natural-origin steelhead escapement to natural spawning areas and action area hatcheries, and adult fish contributions to terminal area fisheries by origin (hatchery and natural) in the Snohomish River basin.

1c. Beginning with the 2020 smolt outmigration, annually collect demographic (natural spawning abundance, spatial and temporal spawn timing), mark/tag, and genetic (DNA) data, and conduct analyses necessary to verify the level of gene flow (as *PEHC*) between naturally spawning EWS and the associated natural-origin steelhead populations in the Snohomish River watersheds.

1d. Beginning with the 2020 smolt outmigration, annually report estimates of *PEHC* for naturally spawning steelhead populations in the Snohomish River watershed. *PEHC* estimates may be based on smolt sampling, adult sampling, or a combination of the two. Except for the Snoqualmie River winter-run steelhead natural population, sampling and annual reporting shall be required for four consecutive years, and the four-year average (2020-2023) for *PEHC* shall not exceed 2%.

1e. Beginning with the 2020 smolt outmigration, annually report estimates of *PEHC* for the Snoqualmie winter-run steelhead natural population. For four consecutive years beginning with the 2020 smolt outmigration, average estimated *PEHC* may exceed 2%, but must be sufficiently below 4% to demonstrate a downward trend to reach less than 2% in the next generation (2024-2027). Based on four consecutive years of sampling of smolt and/or adult returns of the next generation, the four-year average (2024-2027) *PEHC* for the Snoqualmie winter-run steelhead natural population shall not exceed 2%.

1f. Retain all hatchery-origin steelhead, identifiable by a clipped adipose fin, encountered during all annual broodstock collection operations at the hatchery facilities. No EWS collected at the hatcheries shall be released back into the natural environment as a measure to reduce straying and gene flow risks to the natural-origin steelhead populations.

2a. Within 16 months of the decision date for this opinion, produce a manuscript describing the simulation and bias correction processes used in the Warheit (2014a) method and dealing with the overestimation issues described in Section 2.4.1.2, and have it accepted for publication in an appropriate peer reviewed journal (e.g., Molecular Biology, Molecular Biology Methods).

2b. Within 16 months of the decision date for this opinion, conduct and submit to NMFS a report on a sensitivity analysis of the Warheit (2014a) method, evaluating the effect of model assumptions and sampling on the precision and accuracy of *PEHC* estimates.

2c. Within 12 months of the decision date for this opinion, evaluate and submit a report to NMFS on the consequences of sample pooling on precision and accuracy of *PEHC* estimates and if appropriate, include processes within the Warheit method for pooling samples.

2d. Within 12 months of the decision date for this opinion, revise and submit to NMFS the genetic monitoring plan (Anderson et al. 2014) to include sample sizes based on statistical analytical needs.

2e. Submit any revisions to the genetic monitoring plan that are identified as needed through reviews such as those specified in 2b and 2c for NMFS concurrence on or before January 1 of each year.

2f. Within 16 months of the decision date for this opinion, conduct and submit a report to NMFS on sensitivity analysis of the Scott-Gill gene flow estimation method, based on as much empirical Puget Sound specific evidence as possible of point estimates and variability in escapements of hatchery-origin and natural-origin fish, proportion of hatchery returnees remaining in the river to spawn, temporal and spatial overlap of hatchery-origin and natural-origin spawners, incident of residuals, precocity rates, and contribution of non-anadromous O. mykiss to spawning.

3a. As a means to evaluate competition risks to natural-origin steelhead juveniles, annually monitor, through ongoing Tulalip Tribal juvenile salmonid outmigrant trapping programs, the statistical week incidence, and average weekly expanded proportion of total natural-origin and hatchery-origin juvenile salmonid abundance, of EWS hatchery-origin smolts in downstream areas for at least one month after smolt release.

3b. Collect data regarding the relative proportions, emigration timings, and individual fish sizes for hatchery-origin steelhead smolts, and natural-origin juvenile steelhead, encountered through juvenile outmigrant trapping in the lower Skykomish and Snoqualmie rivers.

3c. Submit any revisions of individual fish release size and timing protocols described in the two HGMPs for EWS smolts for NMFS concurrence on or before January 1 of each year.

3d. Annually report results of monitoring and data collection activities described in 3a and 3b.

4a. As a means to evaluate predation risks to natural-origin Chinook salmon juveniles, annually monitor, through the ongoing Tulalip Tribal juvenile outmigrant trapping program, the statistical week incidence, and average weekly expanded proportion of total natural-origin and hatchery-origin juvenile salmonid abundance of EWS hatchery-origin smolts in downstream areas for at least one month after smolt release.

4b. Collect data regarding the relative proportions, emigration timings, and individual fish sizes, for hatchery-origin yearling steelhead, and natural-origin juvenile Chinook salmon, encountered through trapping in the lower Skykomish and Snoqualmie rivers.

4c. Submit any revisions of individual fish release size and timing protocols described in the three HGMPs for yearling steelhead for NMFS concurrence on or before January 1 of each year.

4d. Annually report results of monitoring and data collection activities described in 4a and 4b.

5a.Comply with the NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011) for water intake structures and screening used by the Tokul Creek Hatchery EWS programs by fall, 2016.

5b.Comply with the NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011) for water intake structures and screening used by the Wallace River Hatchery EWS programs by fall 2020.

5c. Monitor and annually report all incidences of juvenile natural-origin Chinook salmon and steelhead entrainment and mortality associated with screening at action area hatchery facilities.

5d. Ensure that new water intake structures and associated screening at Tokul Creek Hatchery and Wallace River Hatchery do not present risks of entrainment for juvenile fish in more than a total of 4 square meters of migration and rearing area adjacent to the intake structures.

6a. Immediately release unharmed at the point of capture any natural-origin steelhead and bull trout incidentally encountered in the course of EWS adult broodstock collection operations.

6b. Annually monitor and report the number, location, and deposition of any natural-origin Chinook salmon, steelhead and bull trout encountered during EWS broodstock collection operations.

7. Implement the hatchery programs as described in the HGMPs. NMFS's SFD must be notified in advance of any change in hatchery program operation and implementation that potentially would result in increased take of ESA-listed species.

8. Provide one comprehensive annual report to NMFS SFD on or before April 1st of each year that includes the RM&E for the previous year described in Term and Conditions 1b, 1d, 2e, 3d, 4d, 5c, and 6b. The numbers of hatchery-origin steelhead smolts released, release dates and locations, tag/mark information, and reports of any deviations from the actions described in the HGMPs shall

be included in the annual report. All reports, as well as all other notifications required in the permit, shall be submitted electronically to the SFD point of contact for this program:

Tim Tynan (360) 753-9579, tim.tynan@noaa.gov

Annual reports may also be submitted in written form to:

NMFS – Sustainable Fisheries Division
Anadromous Production and Inland Fisheries Program
1201 N.E. Lloyd Boulevard, Suite 1100
Portland, Oregon 97232

2.9 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a Proposed Action on listed species or critical habitat (50 CFR 402.02). NMFS has identified two conservation recommendations appropriate to the Proposed Action:

1. WDFW and the co-managing Tribes, in cooperation with the NMFS and other entities, should investigate the relative reproductive success and relative survival of naturally spawning hatchery-origin and natural-origin steelhead in the Puget Sound watersheds to further scientific understanding of genetic diversity and fitness effects resulting from artificial propagation of the species.

2. WDFW should consider implementing a delay in EWS smolt release timings for the two programs until after May 15th each year, subject to fish health maintenance requirements, as a means to further limit the risks of competition with natural-origin steelhead smolts, and predation on natural-origin Chinook salmon juveniles.

2.10 Re-initiation of Consultation

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

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

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

This analysis is based, in part, on descriptions of EFH for Pacific coast salmon (PFMC 2003) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce. Descriptions of EFH are provided in the recent update to salmon EFH in Appendix A to the Pacific Coast Salmon Fishery Management Plan (PFMC 2014).

3.1 Essential Fish Habitat Affected by the Project

The Proposed Action is implementation of two hatchery steelhead programs in the Snohomish River basin, as described in detail in Section 1.3. The action area of the Proposed Action includes habitat described as EFH for Chinook salmon, pink salmon and coho salmon. Because EFH has not been described for steelhead, the analysis is restricted to the effects of the Proposed Action on EFH for the three salmon species for which EFH has been designated. Other fish species for which EFH has been designated in the vicinity of the action area, but that would not be affected by the Proposed Action, are identified in Appendix Table 1.

The areas affected by the Proposed Action include the Snohomish River basin from RM 0.0 to the upstream extent of anadromous fish access in the Skykomish River and Snoqualmie River watersheds; Wallace River from its confluence with the Skykomish River at RM 35.7 to the upstream extent of anadromous fish access (see Figure 1, above).

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 2014). As described by PFMC (2014), 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.

The Snohomish River, Skykomish River, and Snoqualmie River and their 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 operations on adult and juvenile fish migration corridors in the Snohomish River basin; ecological interactions and genetic effects in Chinook, coho, and pink salmon spawning areas in the watershed; and ecological effects in rearing areas for the species in the Basin, 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. Salmon spawning and rearing locations and adult holding habitat are not expected to be affected by the operation of the hatchery programs, as no modifications to these areas would occur. Renovation of water intake structures at Tokul Creek and Wallace River and hatcheries that have affected fish migration will occur by fall 2016 and fall 2020, respectively (NMFS 2016a). Their repair is included as a condition through this NMFS ESA consultation. Potential effects on EFH by the Proposed Action are only likely to occur in areas where Chinook, pink and coho salmon spawn naturally and in migration areas in the Wallace River downstream from RM 4.0, in the Skykomish and Snohomish rivers downstream of RM 46.0, and in Tokul Creek and Snoqualmie rivers downstream of RM 0.5 and 39.6, respectively.

The release of yearling steelhead through programs at Wallace River, Reiter Ponds, and Tokul Creek hatcheries may lead to effects on EFH through predation on juvenile Chinook, coho, and pink salmon. The risk of hatchery-origin smolt predation on natural-origin juvenile fish in freshwater is dependent upon three factors: 1) the hatchery fish and their potential natural-origin prey must overlap temporally; 2) the hatchery fish and their prey must overlap spatially; and, 3) the prey should be less than 1/3 the length of the predatory fish.

Through a comparison of relative individual sizes and freshwater occurrence timings for emigrating natural-origin juvenile Chinook, coho, and pink salmon, and hatchery-origin steelhead juveniles released from WDFW hatcheries, NMFS determined in its opinion that the hatchery yearling steelhead would have minimal spatial and temporal overlap with coho salmon but would have substantial spatial and temporal overlap with juvenile listed Chinook salmon, posing a risk for predator-prey interactions. Steelhead smolts would be released from the hatcheries after the identified April peak pink salmon fry migration period in the Skykomish and Snoqualmie river subbasins. The small size of the pink salmon fry makes the species vulnerable to hatchery steelhead smolt predation if the species interact in Snohomish River basin areas downstream of the hatchery fish release sites. An elevated risk for predation effects on Chinook salmon EFH for hatchery steelhead yearling releases is assigned based on the upper watershed release locations, and large individual fish size relative to the size of natural-origin juvenile Chinook salmon that may be encountered during the spring release periods for the hatchery-origin fish. An elevated risk for predation effects on pink salmon EFH for hatchery steelhead releases is possible if releases are to occur in the month of April when pink salmon abundance is highest, the upper watershed release locations (Wallace River Hatchery RM 4.0, tributary to the Skykomish River at RM 35.7; Reiter Ponds tributary to Skykomish River RM 46, and Tokul Creek RM 0.5, tributary to Snoqualmie River at RM 39.6), and large individual fish size relative to the size of natural-origin pink salmon fry that may be encountered during the spring release period for the hatchery-origin steelhead.

Available data in Puget Sound indicate that newly released hatchery-origin yearling salmon and steelhead are not highly piscivorous (Section 2.4.2.3). The practice of releasing actively migrating steelhead smolts only, during freshets, from mid-April through May would limit the duration for interactions between hatchery-origin yearling steelhead and juvenile natural-origin salmon in downstream areas. Juvenile out-migrant trapping data in the Skykomish and Snoqualmie rivers indicate that the hatchery-origin steelhead smolts would disperse rapidly downstream and seaward from freshwater areas where any rearing and migrating natural-origin salmon would be most concentrated within hours or a few days post-release, opportunities for predation would be unsubstantial. For these reasons, effects are likely inconsequential to Chinook and pink salmon EFH. The co-managers will monitor and report hatchery-origin yearling and natural-origin juvenile salmonid abundance, timing, and temporal overlap data collected through an annual juvenile out-migrant trapping programs in the lower Skykomish and Snoqualmie rivers through this consultation, and one other ESA consultation (NMFS 2009). These monitoring efforts will allow for evaluation of interactions and predation risks, and the need for adjustment of yearling steelhead smolt release programs to further reduce predation risks.

As described in Section 2.4.2.6, water withdrawal for the hatchery operations can adversely affect salmon by impeding migration, reducing stream flow, or reducing the abundance of other stream-dwelling organisms that could serve as prey for juvenile salmonids. Structures used for water withdrawals can also kill or injure juvenile salmonids through impingement upon inadequately designed intake screens or by entrainment of juvenile fish into the water diversion structures. As discussed in the biological opinion, the Wallace River and Tokul Creek hatcheries water intake structures in the Wallace River, and May and Tokul creeks may affect salmon EFH through migration impacts. The level of EFH effects is unquantified, as the number, life stage, and proportion of the total migrating salmon populations in the Wallace River and Tokul Creek subbasins affected by the intake structures have not been estimated. Effects associated with the intakes in the Wallace River, and May and Tokul Creeks are surmised because actual impacts on fish have not been observed, but the structures are not in compliance with the most recent NMFS standards regarding fish passage and screening requirements for instream structures (NMFS 2011c).

Effects from the Tokul Creek water intake structure are likely because the structure currently blocks access for migrating salmon to upstream EFH. WDFW identified renovation of the water intake structures as high-priority capital projects in 2005. Funds were appropriated in 2012 to renovate the intakes to meet current NMFS fish passage and screening requirements (WDFW 2014b), with construction scheduled to be completed by the fall, 2016 (NMFS 2016a). Effects from the Wallace River and May Creek water intake structures are likely because the structures are not in compliance with the most recent NMFS standards regarding fish and screening requirements for instream structures (NMFS 2011c). WDFW has indicated the intent in their HGMP to modify screening at Wallace River Hatchery to comply with NMFS screening requirements to protect natural-origin fish from entrainment and impingement that may lead to injury and mortality. Intake screens on both tributaries are scheduled by WDFW for rebuild in the 2019 -2020 funding biennium to bring the screens into compliance with those criteria and to reduce risks to salmon EFH. Proposed retrofitting of the Wallace River Hatchery screens to be in compliance with current NMFS criteria should adequately reduce risks to Chinook, pink and coho salmon in the Wallace River watershed. Effects from the Reiter Ponds water intake structure are unlikely. The intake structures on Hogarty and Austin creeks block access for migrating salmon. However, the screens are located at the upper extent of known salmon use and therefore are unlikely to affect EFH.

The proposed hatchery programs include designs to minimize effects on migrating fish. Criteria for fish passage and surface water withdrawal are set to avoid impacts on Chinook, pink, and coho salmon spatial structure. Further, water removed at the structures for hatchery fish rearing will be largely returned near the point of withdrawal and intake screens are either in compliance with NMFS criteria, or are in the process of renovation so screens are in compliance with those criteria. Through this biological opinion, and as a condition of a previous opinion addressing salmon production in the watershed (NMFS 2016a), the co-managers will comply with NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011c) for all water intake structures supplying Tokul Creek and Wallace River hatcheries by fall 2016 and fall 2020, respectively. The hatchery program operators will also monitor and report annually hatchery facility compliance with NMFS fish passage criteria.

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 (WDFW 2014a; 2014b) and the ITS (Section 2.8), includes the best approaches to avoid or minimize those adverse effects. The Reasonable and Prudent Measures and Terms and Conditions included in the ITS constitute NMFS recommendations to address potential EFH effects. NMFS shall ensure that the ITS, including Reasonable and Prudent Measures and implementing Terms and Conditions, are carried out.

To address the potential effects on EFH of hatchery fish on natural fish in natural spawning and rearing areas, the PFMC (2003) provided an overarching recommendation that hatchery programs:

> "[c]omply with current policies for release of hatchery fish to minimize impacts on native fish populations and their ecosystems and to minimize the percentage of nonlocal hatchery fish spawning in streams containing native stocks of salmonids."

The biological opinion explicitly discusses the potential risks of hatchery fish on fish from natural populations and their ecosystems, and describes operation and monitoring appropriate to minimize these risks on Chinook, coho, and pink salmon in the Snohomish river basin.

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 from NMFS. 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, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with NMFS Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects [50 CFR 600.920(k)(1)].

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

3.5 Supplemental Consultation

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

4 DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) ("Data Quality Act") specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, document compliance with the Data Quality Act, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. NMFS has determined, through this ESA section 7 consultation that operation of the three WDFW EWS hatchery programs as proposed will not jeopardize ESA-listed species and will not destroy or adversely modify designated critical habitat. Therefore, NMFS can issue an ITS. The intended users of this opinion are WDFW (operators, with the Tulalip Tribes, as *U.S.* v. *Washington* (1974) co-managers) and NMFS (regulatory agency). The scientific community, resource managers, and stakeholders benefit from the consultation through adult returns of program-origin salmon to the Snohomish River basin, and through the collection of data indicating the potential effects of the hatchery programs on the viability of natural populations of Puget Sound Chinook salmon and Puget Sound steelhead. This information will improve scientific understanding of hatchery-origin steelhead effects on natural populations that may be applied broadly within the Pacific Northwest area for managing benefits and risks associated with hatchery operations. This opinion will be posted on the NMFS West Coast Region web site (http://www.wcr.noaa.gov). 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 600.920(j).

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

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

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

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Appendix Table 1. Species of fishes with designated EFH occurring in the Salish Sea and Northeast Pacific Ocean.

Groundfish Species	redstripe rockfish *S. proriger*	Dover sole *Microstomus pacificus*
spiny dogfish *Squalus acanthias*	rosethorn rockfish *S. helvomaculatus*	English sole *Parophrys vetulus*
big skate *Raja binoculata*	rosy rockfish *S. rosaceus*	flathead sole *Hippoglossoides elassodon*
California skate *Raja inornata*	rougheye rockfish *S. aleutianus*	petrale sole *Eopsetta jordani*
longnose skate *Raja rhina*	sharpchin rockfish *S. zacentrus*	rex sole *Glyptocephalus zachirus*
ratfish *Hydrolagus colliei*	splitnose rockfish *S. diploproa*	rock sole *Lepidopsetta bilineata*
Pacific cod *Gadus macrocephalus*	striptail rockfish *S. saxicola*	sand sole *Psettichthys melanostictus*
Pacific whiting (hake) *Merluccius productus*	tiger rockfish *S. nigrocinctus*	starry flounder *Platichthys stellatus*
black rockfish *Sebastes melanops*	vermilion rockfish *S. miniatus*	arrowtooth flounder *Atheresthes stomias*
bocaccio *S. paucispinis*	yelloweye rockfish *S. ruberrimus*	
brown rockfish *S. auriculatus*	yellowtail rockfish *S. flavidus*	**Coastal Pelagic Species**
canary rockfish *S. pinniger*	shortspine thornyhead *Sebastolobus alascanus*	anchovy *Engraulis mordax*
China rockfish *S. nebulosus*	cabezon *Scorpaenichthys marmoratus*	Pacific sardine *Sardinops sagax*
copper rockfish *S. caurinus*	lingcod *Ophiodon elongatus*	Pacific mackerel *Scomber japonicus*
darkblotch rockfish *S. crameri*	kelp greenling *Hexagrammos decagrammus*	market squid *Loligo opalescens*
greenstriped rockfish *S. elongatus*	sablefish *Anoplopoma fimbria*	**Pacific Salmon Species**
Pacific ocean perch *S. alutus*	Pacific sanddab *Citharichthys sordidus*	Chinook salmon *Oncorhynchus tshawytscha*
quillback rockfish *S. maliger*	butter sole *Isopsetta isolepis* curlfin sole *Pleuronichthys decurrens*	coho salmon *O. kisutch*
redbanded rockfish *S. babcocki*		Puget Sound pink salmon *O. gorbuscha*