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

National Marine Fisheries Service (NMFS) Evaluation of Three Hatchery and Genetic Management Plans for Early Winter Steelhead in the Dungeness, Nooksack, and Stillaguamish River basins under Limit 6 of the Endangered Species Act Section 4(d) Rule

NMFS Consultation Number: WCR-2015-2024

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 three hatchery programs in the Dungeness, Nooksack, and Stillaguamish river watersheds submitted for review by the Washington Department of Fish and Wildlife (WDFW), with the Jamestown S'Klallam, Lummi, Nooksack, Stillaguamish, 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 three 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 three hatchery programs that release early winter steelhead (EWS) into the Dungeness, Nooksack, and Stillaguamish river basins under limit 6 of the ESA 4(d) rule as joint state-tribal plans (Table 3 of Scott 2014a) (Table 1). The "early winter steelhead" (previously "Chambers Creek lineage steelhead") that would be propagated through the three 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; 2014b; 2014c), all of the hatchery programs would be operated as isolated[1] 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 (isolated) steelhead 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[1]
Dungeness River Early Winter Steelhead Hatchery Program (Isolated) (WDFW 2014a)	WDFW	Dungeness/SJF-Hood Canal
Kendall Creek Winter Steelhead Hatchery Program (Isolated) (WDFW 2014b)	WDFW	Nooksack/North Cascades
Whitehorse Ponds (Stillaguamish River) Winter Steelhead Hatchery Program (Isolated) (WDFW 2014c)	WDFW	Stillaguamish/North Cascades

[1] "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] 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 summer steelhead (early summer steelhead [ESS]) isolated 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). After reviewing available scientific information, NMFS proposed to list the Puget Sound Steelhead DPS as a threatened species under the ESA (FR 15666; March 29, 2006). NMFS considered public comment and on May 11, 2007, it issued a final determination that Puget Sound steelhead would receive protection as a threatened species (72 FR 26722). The final listing was followed by the issuance of protective regulations and on September 25, 2008, NMFS issued a final 4(d) rule adopting protective regulations for the listed Puget Sound steelhead DPS (73 FR 55451). In the final rule, NMFS applied the same 4(d) protections to steelhead as were already adopted for other ESA-listed Pacific salmonids in the region. Accordingly, the co-manager hatchery plans became subject to review for effects on ESA-listed salmon and steelhead.

To comply with the requirements of the National Environmental Policy Act (NEPA) associated with NMFS's 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 revise their HGMPs and to resubmit them, sequentially, bundled by individual Puget Sound watersheds (Unsworth and Grayum 2015). 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. The agency is moving forward with a revised NEPA approach that includes, generally, watershed-scale analyses. 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 RMPs received from the co-managers, generally on a watershed-specific basis. The co-managers have indicated that they are revising their joint resource management plans to reflect this new watershed-scale approach and will continue to submit their revised plans to NMFS for review under NMFS's ESA §4(d) regulations (50 CFR 223.203). 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 draft 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 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, originally included among the six HGMPs submitted in April 2014, covering 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 the EWS hatchery programs described in Table 1 as priorities (Scott 2015). WDFW also requested that NMFS defer processing of the Snohomish/Skykomish Winter Steelhead and Snohomish/Tokul Creek Winter Steelhead HGMPs until later in 2015, although these latter plans remain a high priority to the co-managers for ESA consultation (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.

After reviewing the HGMPs submitted jointly by state and tribal co-managers for the Dungeness River Hatchery, Kendall Creek Hatchery, and Whitehorse Ponds programs, NMFS determined that they included information sufficient[2] for the agency to complete its determination of whether the HGMPs

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[2] "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.

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 plans.

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 of these other plans 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.

This consultation evaluates effects of the proposed action on ESA-listed Puget Sound Chinook salmon and Puget Sound steelhead and their critical habitat, as described in more detail in Section 2.2 and Table 2. The effects associated with implementation of Dungeness River Hatchery salmon production on the Hood Canal Summer Chum Salmon ESU were previously evaluated by NMFS through a separate ESA section 7 consultation process (NMFS 2002). The hatchery actions proposed in the 2014 EWS HGMPs are substantively the same as the actions evaluated and authorized in the previous NMFS biological opinion. The previous evaluation and authorization of hatchery plan effects on Hood Canal summer chum salmon therefore remain valid. For these reasons, effects on Hood Canal summer chum salmon associated with the proposed EWS HGMPs will not be discussed further in this biological opinion.

This biological opinion evaluates information provided in the Dungeness, Nooksack, and Stillaguamish river basins hatchery EWS HGMPs (WDFW 2014a; 2014b; 2014c). The evaluation of the HGMPs is also based on 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 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 three hatchery programs in the Dungeness, Nooksack, and Stillaguamish river basins submitted for review by the WDFW with the Jamestown S'Klallam, Lummi, Nooksack, Stillaguamish, and Tulalip tribes as the *U.S.* v. *Washington* (1974) fish resource co-managers.

NMFS describes a hatchery program as 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, the proposed EWS hatchery salmon programs described in the joint HGMPs (WDFW 2014a; 2014b; 2014c) were determined sufficient for formal consultation (Jones 2014). The three hatchery programs propose to release non-ESA listed steelhead into the Dungeness, Nooksack, and Stillaguamish river basins respectively. All of the programs are currently operating however, smolts 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). .

The primary purpose or reason for the hatchery programs is to help meet adult fish loss mitigation responsibilities, partially offsetting adverse impacts on natural-origin steelhead and their habitat resulting from past and on-going human developmental activities in the Dungeness, Nooksack, and Stillaguamish river basins, and from climate change. The goal for the programs is to produce EWS for recreational and tribal fisheries (WDFW 2014a; 2014b; 2014c). All of the programs would implement steelhead population monitoring activities in freshwater areas that are important for tracking implementation of the hatchery programs and effect of the programs on ESA-listed natural-origin populations. Fisheries are not included as part of the proposed actions and consequently are only discussed in this opinion to the extent they are part of the environmental baseline or are determined to be interrelated or interdependent with this action (see discussion in Section 1.3.2). The co-managers propose fishery management plans for Puget Sound and associated freshwater areas on either an annual or multi-year basis, and NMFS generally consults on these plans and addresses the take effects of the EWS recreational and commercial fisheries (and other salmon-directed fisheries in the action area and Puget Sound) through a ESA section 7 consultation for the duration of the relevant plan. NMFS's most recent authorization for 'take' of ESA-listed fish associated with fisheries in the Nooksack, Stillaguamish, and Dungeness rivers (NMFS 2015a) analyzed a 2015 Puget Sound harvest plan assembled by the co-managers (PSTT and WDFW 2015). Most recently, NMFS issued a biological opinion for harvest plans that have remained relatively similar over the past several years and are expected to continue to do so.

1.3.1 Describing the Proposed Action

Activities included in the plans are as follows:

- Broodstock collection at WDFW's Dungeness River, Kendall Creek, and Whitehorse Ponds hatcheries through operation of off-channel traps and weirs from mid-November to January 31. All trapping sites will remain open until at least March 15 to remove hatchery-origin fish returning to the hatchery release locations after January 31;
- Potential broodstock collection using hook and line methods in the mainstem N.F. Nooksack River (WDFW 2014b);
- Holding, identification, and spawning of adult fish at Dungeness River, Hurd Creek, Kendall Creek, and Whitehorse Ponds hatchery facilities;
- Egg incubation at Hurd Creek, Kendall Creek, and Whitehorse Ponds hatchery facilities and fish rearing at Dungeness River, Hurd Creek, Kendall Creek, McKinnon Pond, and Whitehorse Ponds hatchery facilities;
- Release of up to: 10,000, 150,000, and 130,000 juvenile EWS from Dungeness River Hatchery, Kendall Creek Hatchery, and Whitehorse Ponds Hatchery, respectively;
- Monitoring and evaluation activities to assess the performance of the programs in meeting conservation, harvest augmentation, and listed fish risk minimization objectives.

1.3.1.1 Proposed hatchery broodstock collection

- Broodstock origin and number:
  - Dungeness River Hatchery: Hatchery broodstock are more than moderately diverged from the natural population and are not included in the Puget Sound Steelhead DPS. Up to 30 pairs or 50,000 green (unfertilized) eggs would be collected from hatchery-origin adults (distinguished by an adipose fin-clip).
  - Kendall 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 200,000 green eggs would be collected from hatchery-origin adults (distinguished by an adipose fin-clip).
  - Whitehorse Ponds Hatchery: Hatchery broodstock are more than moderately diverged from the natural population and are not included in the Puget Sound Steelhead DPS. Up to 60 pairs or 200,000 green eggs would be collected from hatchery-origin adults (distinguished by an adipose fin-clip).

- Proportion of natural-origin fish in the broodstock (pNOB): None, no ESA-listed natural-origin fish would be used by any of the programs.

- Broodstock selection: Protocols common to all programs: Hatchery-origin steelhead returning to hatchery traps would be selected based on 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:
  - Dungeness River Hatchery: Broodstock would be collected from hatchery-origin adults (distinguished by an adipose fin-clip) captured at the Dungeness River Hatchery off-channel trap (WDFW 2014a).
  - Kendall Creek Hatchery: Broodstock would be collected from hatchery-origin adults (distinguished by an adipose fin-clip) returning to the hatchery trap, reconditioned kelts, or captive brood at the Kendall Creek Hatchery until the egg take goal is met (WDFW 2014b, and following). Broodstock collection by "hook and line" for hatchery steelhead within the basin may be considered if additional broodstock are needed.
  - Whitehorse Ponds: Broodstock would be collected from hatchery-origin adults returning to the Whitehorse Ponds hatchery trap, reconditioned kelts, or captive brood (WDFW 2014c).

- Duration of collection:
  - Dungeness River Hatchery: Broodstock would be collected mid-November through January 31 (WDFW 2014a, and following). The trap would remain open through March 31 to provide an opportunity for all returning hatchery fish to enter the hatchery trap. Any marked hatchery-origin steelhead volunteering to the trap after January 31 would be removed from the system.
  - Kendall Creek Hatchery: Broodstock would be collected from December through January 31 (WDFW 2014b, and following). The trap would remain open from late-May through March

15 to collect spring Chinook salmon, fall chum salmon, and winter steelhead broodstock and for the removal of excess hatchery-origin steelhead from the system. Hatchery-origin steelhead returning after January 31 would be removed from the system.
  - Whitehorse Ponds: Broodstock would be collected from December through January 31 (WDFW 2014c, and following). The trap would be operated from June through March 15 or later if conditions allowed, accommodating summer-and winter-run steelhead broodstock collection and removal of hatchery-origin fish from the system. Marked, hatchery-origin steelhead returning after January 31 would be removed from the system.

- Encounters, sorting and handling, with ESA listed fish, adults and juveniles: Any natural origin Chinook salmon, 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

- None of the steelhead produced by the proposed programs are part of the ESA-listed Puget Sound Steelhead DPS, and mating protocols applied are therefore not of concern regarding effects on ESA-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 Dungeness River and Kendall Creek hatchery programs, steelhead yearlings at 5 fish per pound (fpp) and 210 mm fork length (fl) (WDFW 2014a; 2014b). For Whitehorse Ponds hatchery program steelhead yearlings at 6 fpp and 198 mm fl (WDFW 2014c).

- Acclimation (Y/N): Yes, length of acclimation would vary by program.
  - Dungeness River Hatchery: Juveniles would be transferred from the Hurd Creek Hatchery rearing ponds to the Dungeness River Hatchery in March. After the fish are transferred, they would be reared for at least two months on Dungeness River water at the Dungeness River Hatchery (WDFW 2014a).
  - Kendall Creek Hatchery: Juveniles would be reared and acclimated on well water if final rearing were to take place in the asphalt lined Ponds. A mix of well and creek water would be used if the final rearing were to take place in the super raceways (dependent upon creek water availability) (WDFW 2014b).
  - Whitehorse Ponds Hatchery: Juveniles would be reared and acclimated using Whitehorse Springs Creek water. Well water would be used to supplement flow during summer low-flow months if needed.

- Volitional release (Y/N):
  - Dungeness River Hatchery: No. Juveniles are forced released; they are reared in ponds that are connected to the coho rearing ponds, necessitating release of the two species together.
  - Kendall Creek and Whitehorse Ponds hatchery programs: Yes. Screens will be removed no earlier than April 15. Screens will remain open for up to 1.5 months (unless all fish out-migrate). Fish that do not volitionally out-migrate will be removed from the ponds and transported for release into landlocked lakes.

- External mark(s): All programs: All juveniles released would be marked with an adipose fin clip.
- Internal marks/tags: All programs: No juveniles would be marked with internal marks or tags.
- Maximum number released: Proposed maximum annual smolt release numbers are: Dungeness River Hatchery: 10,000, Kendall Creek Hatchery: 150,000, Whitehorse Ponds Hatchery: 130,000.

- Release location(s):
  - Dungeness River Hatchery: River Mile (RM) 10.5 on the Dungeness River.
  - Kendall Creek Hatchery: RM 0.25 on Kendall Creek, tributary to the North Fork Nooksack River at RM 45.8 (the Nooksack River continues as the N.F. Nooksack River at RM 36.6).
  - Whitehorse Ponds Hatchery: RM 1.5 on Whitehorse Springs Creek, tributary to the N.F. Stillaguamish River at RM 28, the N.F. Stillaguamish enters the mainstem Stillaguamish at RM 17.8 (the mainstem Stillaguamish continues as the S.F. Stillaguamish).

1.3.1.4 Proposed research, monitoring, and evaluation

- Adult sampling, purpose, methodology, location, and the number of ESA-listed fish handled: The three HGMPs include monitoring and evaluation (M&E) actions designed to identify the performance of the programs in meeting their fisheries harvest augmentation and listed fish risk minimization objectives. Specific M&E actions for the three HGMPs affecting steelhead are described in section 1.10 and section 11.0 of each hatchery plan. 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 also include extensive monitoring, evaluation, and adaptive management measures, designed to monitor and reduce incidental effects on natural populations. An adult steelhead monitoring program (spawning ground surveys) would be conducted annually to document abundance and spatial structure of steelhead escaping to natural spawning areas and the hatcheries in the action area basins (WDFW 2014a; 2014b; 2014c). In addition, within the Dungeness River system adult genetic samples will be collected and analyzed to compare the number of hybrid and hatchery-ancestry fish observed from smolt sampling (Anderson et al. 2014, and following). Within the Nooksack system, genetic sampling of adults will occur as available for the winter-run population, and on a rotating basis every three years for the S.F. Nooksack summer-run population. Within the Stillaguamish system, adult genetic sampling will be conducted in the Deer Creek subbasin on a rotating basis every three years.

- Juvenile sampling, purpose, methodology, location, and the number of ESA-listed fish handled: Specific M&E actions for the three HGMPs affecting juvenile salmonids are described in section 1.10 and section 11.0 of each HGMP (WDFW 2014a; 2014b; 2014c). Although the results of these juvenile fish M&E actions would be used to guide implementation of the proposed steelhead hatchery programs, juvenile salmonid sampling occurring outside of the hatchery locations have been previously authorized through separate ESA consultation processes (NMFS 2009; 2015). The co-managers propose to 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 outmigrant trapping by WDFW and Jamestown S'Klallam, Lummi, and Stillaguamish tribes is also proposed, using rotary screw traps and a channel spanning panel weir (Matriotti Creek only) in the Dungeness River and Matriotti Creek, the Nooksack River, and the Stillaguamish River, 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 steelhead natural populations will obtain a mixed sample at trapping sites (Anderson et al. 2014, and following). In cases of multiple natural populations (e.g., Stillaguamish 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 Dungeness, Nooksack, and Stillaguamish smolt traps. Results from the juvenile outmigrant 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: Five hatchery facilities are currently used by the proposed three EWS hatchery programs. Two of the facilities use surface water exclusively (Dungeness River Hatchery and McKinnon Rearing Ponds) and three facilities (Hurd Creek, Kendall Creek, Whitehorse Ponds) use a combination of groundwater and surface water.
    - Dungeness River Hatchery Program: The Dungeness River Hatchery facility uses surface water exclusively, withdrawn through three water intakes on the Dungeness River and one on Canyon Creek, an adjacent tributary. The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. Dungeness River Hatchery may withdraw up to 40 cfs of surface water from the Dungeness River and up to 8.5 cfs from Canyon Creek. Hurd Creek Hatchery may withdraw up to 6.4 cfs from Hurd Creek and the five wells. Surface water withdrawal rights are approved through Washington State water right permits # S2-06221 (25 cfs) & S2-21709 (15 cfs) for the Dungeness River and # S2-00568 (8.5 cfs) for Canyon Creek. Hurd Creek Hatchery water rights are approved through permit # G2-24026 (6.4 cfs). Monitoring and measurement of water usage are reported in monthly National Pollutant Discharge Elimination System (NPDES) reports to Washington State Department of Ecology (WDOE).
    - Kendall Creek Hatchery Program: The Kendall Creek Hatchery facility uses well and surface water (when available). Surface water rights are approved through Washington State trust water right permits #G1-10562c, G1-2361c, and S1-00317 (up to 23.8 cfs surface water and 27.2 cfs well water). The McKinnon Rearing Ponds uses gravity fed surface water from a stream locally known as "Peat Bog Creek" (WRIA 01.0352). Surface water rights are approved through Washington State trust water right permit #S1-27351 (up to 2.0 cfs). Monitoring and measurement of water usage are reported in monthly NPDES reports to WDOE.

  - Whitehorse Ponds Hatchery: Whitehorse Ponds Hatchery facility uses well and surface water. Surface and well water rights are approved through Washington State trust water right permits #S1-00825 (up to 5.6 cfs) and G1-28153P (1.1 cfs).

- Water diversions meet NMFS screen criteria (Y/N):
  - Dungeness River Hatchery Program: No. The main water intake on the Dungeness River mainstem where most water is currently withdrawn for fish production at Dungeness River Hatchery is not screened in compliance with current NMFS guidelines (NMFS 1994; 1995; 1996) to protect juvenile fishes (WDFW 2014a). However, screening at this location is only out of compliance during high flow events. Screening for a siphon water intake upstream from the mainstem Dungeness River intake is out of compliance with NMFS screening guidelines. Compliance for Canyon Creek water intake structure screening where additional water for fish rearing may be withdrawn has been addressed through a separate NMFS consultation (NMFS 2013c). The surface water emergency backup intake screens for Hurd Creek Hatchery are in compliance with earlier federal guidelines (NMFS 1995; 1996), but do not meet criteria specified more recently by NMFS (2011a).
  - Kendall Creek Hatchery Program: No/Yes. The intake screens at the Kendall Creek Hatchery are in compliance with state and federal guidelines (NMFS 1995; 1996), but do not meet the current guidelines (NMFS 2011a) to protect juvenile salmonids. The screens have been identified for replacement, but are a lower priority than at other hatcheries, as listed fish do not occur above the rack on Kendall Creek. The gravity water intake screens at McKinnon Ponds meet the current NMFS guidelines (NMFS 2011a) to protect juvenile salmonids.
  - Whitehorse Ponds Hatchery: No. The intake screens at the Whitehorse Spring facility are in compliance with state and federal guidelines (NMFS 1995; 1996), but do not meet the current anadromous salmonid passage facility design criteria (NMFS 2011a).

- Permanent or temporary barriers to juvenile or adult fish passage (Y/N):

- Dungeness River Hatchery Program: Yes. The Canyon Creek water intake is adjacent to a small dam that completely blocks access to upstream salmon spawning habitat. NMFS has completed informal consultation with the U.S. Army Corps of Engineers (Corps) on their issuance of a permit to the WDFW for construction of a vertical slot fish ladder in the diversion dam on Canyon Creek (NMFS 2013c), and it is expected to be complete by fall 2017 (Andy Carlson, WDFW, pers. comm., April 24, 2015). NMFS concluded that effects of the construction would not be likely to adversely affect ESA-listed species. When completed, the ladder will allow unimpeded upstream and downstream passage by migrating salmon and steelhead encountering the Canyon Creek diversion dam, and the water intake structure will be in compliance with NMFS (2011a) fish passage criteria. WDFW operates a temporary weir and trap on Dungeness River at RM 2.5 to collect Chinook salmon broodstock from May (if flows allow weir placement) through September. This temporary weir structure will be a barrier to upstream fish migration when in operation (WDFW 2013a).

- Kendall Creek Hatchery Program: No. The intake screens at the Kendall Creek Hatchery are in compliance with state and federal guidelines (NMFS 1995; 1996), but do not meet the current guidelines (NMFS 2011a) to protect juvenile salmonids. The screens have been identified for replacement, but are a lower priority than at other hatcheries, as listed fish do not occur above the rack on Kendall Creek.

- Whitehorse Ponds Hatchery: No. The intake screens at the Whitehorse Spring facility are in compliance with state and federal guidelines (NMFS 1995; 1996), but do not meet the current anadromous salmonid passage facility design criteria (NMFS 2011a).

- Instream structures (Y/N): There are no structures beyond those addressed above.

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

- Pollutant discharge and location(s):
  - Dungeness River Hatchery Program: All Dungeness River Hatchery programs operate under NPDES permit number WAG 13-1037. Under its NPDES permit, Dungeness River Hatchery operates an off-line settling pond and artificial wetland to remove effluent before the water is released back into the Dungeness River (WDFW 2014a). The Hurd Creek Hatchery program operates under the 20,000 pounds per year fish production criteria set by WDOE as the limit for concern regarding hatchery effluent discharge effects. However, at Hurd Creek Hatchery, WDFW has constructed a two-bay pollution abatement ponds to treat water prior to its release back into Hurd Creek.
  - Kendall Creek Hatchery Program: All Kendall Creek Hatchery programs operate under NPDES permit number WAG 13-3007. McKinnon Ponds has fish production well under the 20,000 pounds per year fish production criteria set by WDOE as the limit for concern regarding hatchery effluent discharge effects.
  - Whitehorse Ponds Hatchery: Effluent from the Whitehorse Ponds is regulated through NPDES permit # WAG 13-3008. Consistent with the permit, effluent quality is monitored and reported to maintain downstream water quality and operates within established limits.

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 Dungeness River, Kendall Creek, and Whitehorse Ponds EWS 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 tribes[3], and occur within the Dungeness, Nooksack, and Stillaguamish River watersheds. Outside of these areas, there are no directed fisheries for EWS, and

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[3] Jamestown S’Klallam Tribe in the Dungeness River basin; Lummi Nation and Nooksack Tribe in the Nooksack River basin; and Stillaguamish and Tulalip Tribes in the Stillaguamish River basin.

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 Dungeness, Nooksack, and Stillaguamish River basins 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.

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 and adjacent to the Dungeness, North Fork Nooksack, and North Fork Stillaguamish watersheds where EWS may migrate and spawn naturally, and where they would be collected as broodstock, spawned, incubated, reared, acclimated, and released (Figure 1; Figure 2; Figure 3).

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

- Dungeness River Hatchery (RM 10.5 on the Dungeness River).
- Hurd Creek Hatchery (RM 0.2 on Hurd Creek, tributary to the Dungeness River at RM 2.7).
- Kendall Creek Hatchery: RM 0.25 on Kendall Creek, tributary to the North Fork Nooksack River at RM 45.8 (the Nooksack River continues as the N.F. Nooksack River at RM 36.6).
- McKinnon Ponds acclimation facility: Located just downstream from the Mosquito Lake Road Bridge on the left bank of the river with water from and outlet to a creek (WRIA 01.0352, known locally as “Peat Bog Creek”), which emanates from Peat Bog, tributary to M.F. Nooksack River (WRIA 01.0339) at RM 4.4.
- Whitehorse Ponds Hatchery: RM 1.5 on Whitehorse Springs Creek, tributary to the N.F. Stillaguamish River at RM 28, the N.F. Stillaguamish enters the mainstem Stillaguamish at RM 17.8.

In addition, for the Kendall Creek Hatchery program, adult hatchery steelhead may be collected for use as broodstock from the mainstem N.F. Nooksack River using hook and line methods in areas and during periods when the fishery is open. Monitoring and evaluation activities would be implemented at the hatcheries and in their immediate vicinities, in Hurd and Canyon creeks and extending from the mouth of the Dungeness River upstream to the limits of anadromous fish access; in Kendall and McKinnon creeks and extending from the mouth of the Nooksack River upstream to the limits of anadromous fish access in the South, Middle, and North fork subbasins; and, in Whitehorse Springs Creek and extending from the mouth of the Stillaguamish River upstream to the limits of anadromous fish access in the North and South fork subbasins.

NMFS considered whether the marine areas of Puget Sound, outside of the Dungeness, Nooksack, and Stillaguamish River estuaries, 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. However, NMFS 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.

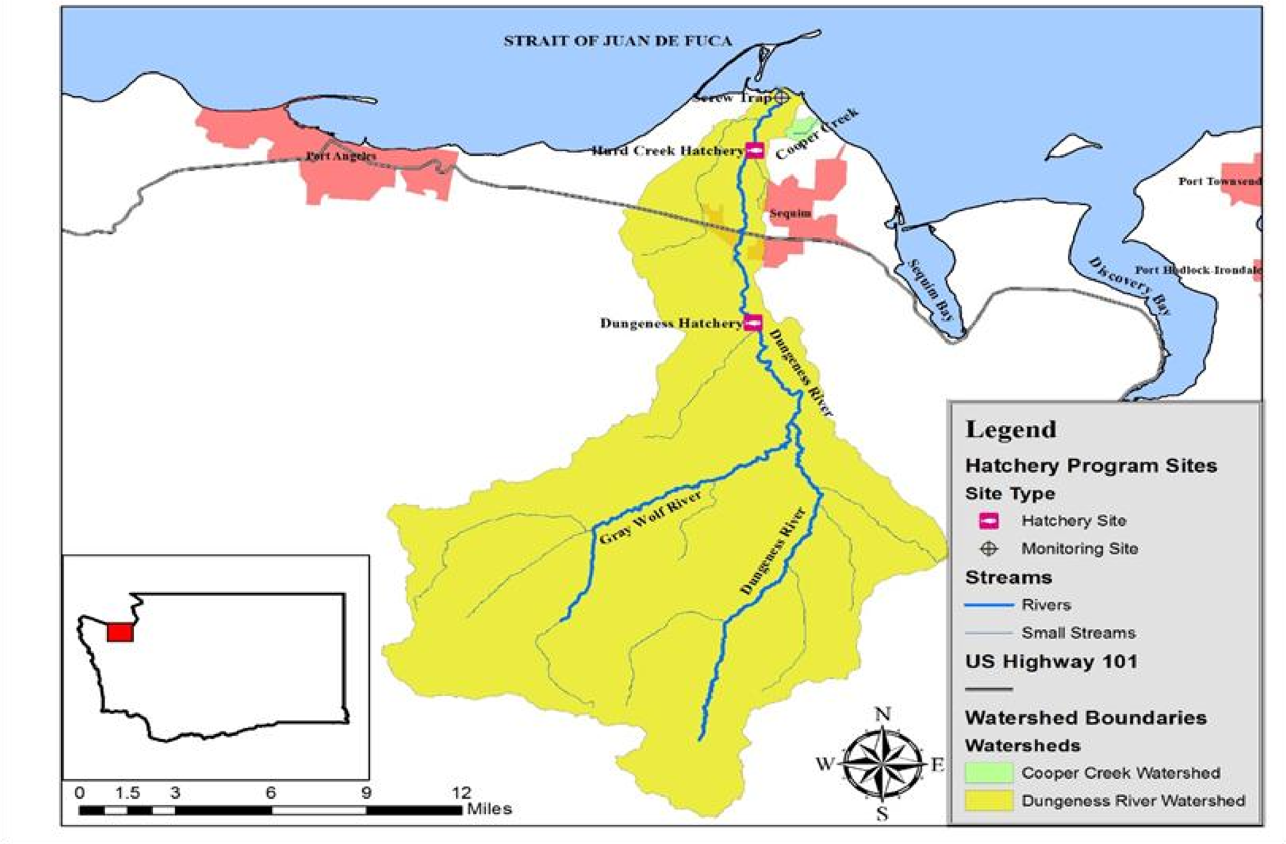

Figure 1. The Dungeness River watershed, adjacent eastern Strait of Juan de Fuca tributaries, and the location of Dungeness River Hatchery facilities where the proposed Dungeness River EWS hatchery program would be implemented.

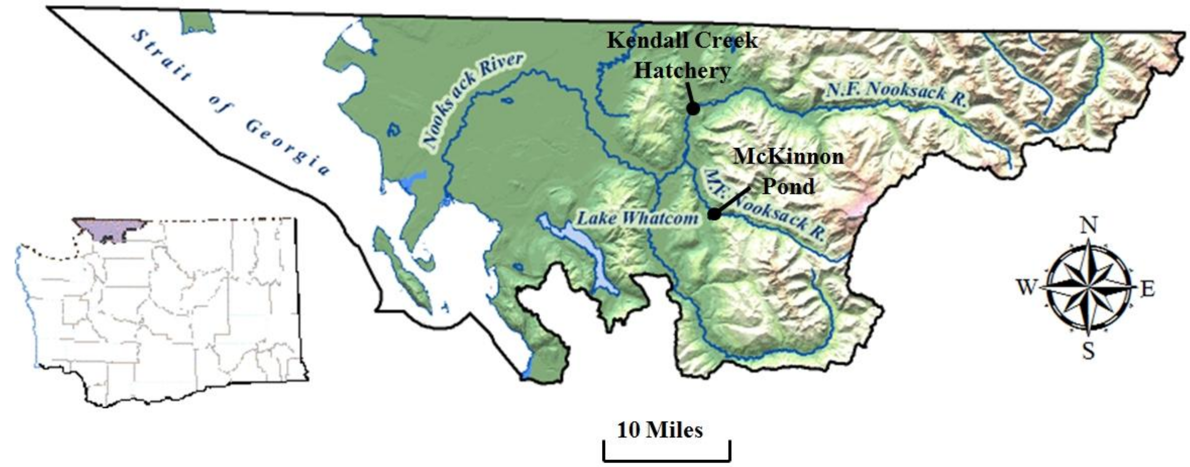

Figure 2. Map depicting the Nooksack River watershed and the location of Kendall Creek Hatchery facilities, and adjacent tributaries where the EWS program would be implemented (source: ttps://fortress.wa.gov/dfw/score/score/maps/map_details.jsp?geocode=wria&geoarea=WRIA01_Nooksack).

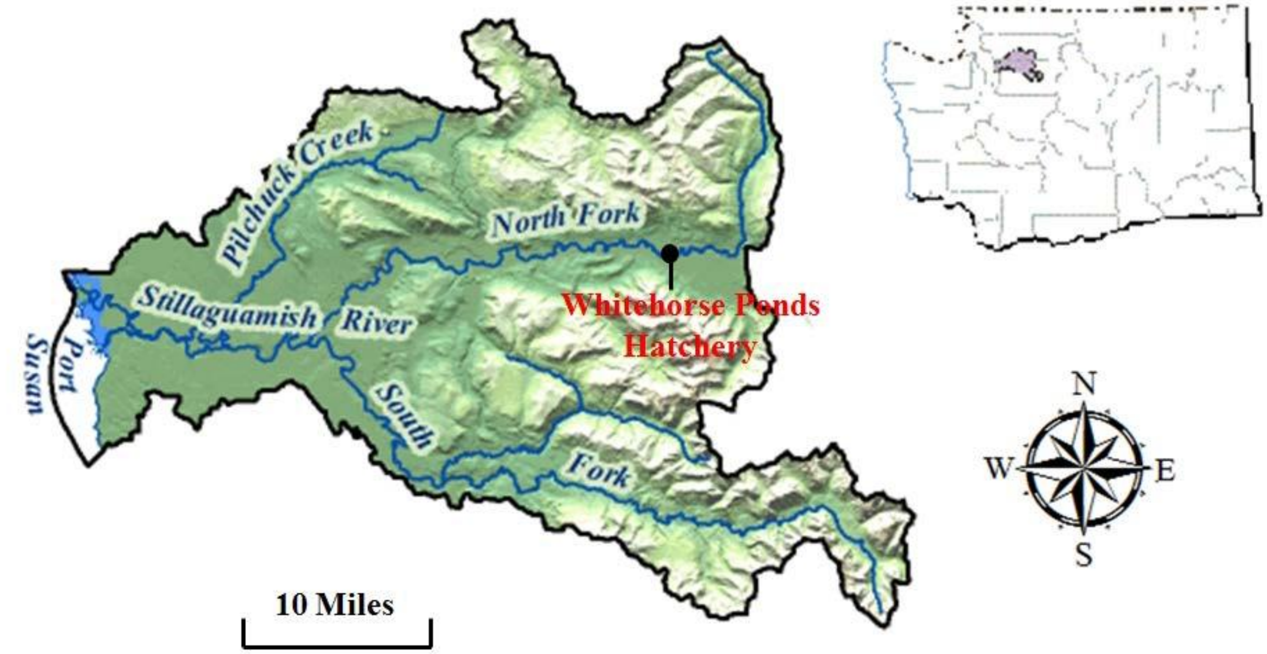

Figure 3. Map depicting the Stillaguamish River watershed and the location of Whitehorse Ponds Hatchery, where the EWS program would be implemented (source: https://fortress.wa.gov/dfw/score/score/maps/map_details.jsp?geocode=wria&geoarea=WRIA05_Stillaguamish

2 Endangered Species Act: Biological Opinion and Incidental Take Statement (ITS)

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. On January 28, 2015, NMFS requested formal consultation with the USFWS regarding the effects on listed species regulated by USFWS (e.g., bull trout) of NMFS's proposed 4(d) limit 6 determination that the three EWS HGMPs met all of the requirements specified under Limit 6 of the ESA 4(d) Rule for salmon and steelhead. NMFS subsequently reassessed the effects of the Whitehorse Ponds (Stillaguamish) EWS program. Based on information indicating effects on bull trout would be negligible or very low, and on March 3, 2016, NMFS requested that the previous request for formal consultation for the Whitehorse Ponds program be rescinded, and that the Service concur with a "not likely to adversely affect" (NLAA) determination for the program (Jones 2016). In a March 29, 2016 letter, USFWS concurred with the NMFS NLAA determination for the Whitehorse Ponds EWS program (USFWS 2016a). "Take" of bull trout associated with NMFS's determination under the 4(d) rule for the proposed Dungeness River Hatchery and Kendall Creek Hatchery EWS programs was subsequently authorized by USFWS through two separate section 7 consultations (consultation reference numbers Dungeness: 01EWFW00-2014-F-0132 (USFWS 2016b), and Nooksack: 01EWFW00-2015-F-0366 (USFWS 2016c). 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 early winter 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 three proposed programs (see Section 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 survive spawning to return to the ocean are 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 or 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 programs that could affect both summer-and winter-run populations in the Dungeness, Nooksack, and Stillaguamish river basins.

The Puget Sound steelhead DPS was listed as threatened in May of 2007 (Table 2). 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 PSSTRT has produced considerable new science that is available for management and affects evaluation purposes. Their final report describing natural population structure was released in March, 2015 (Myers et al. 2015) and viability criteria for Puget Sound steelhead were issued in May, 2015 (Hard et al. 2015).

No new estimates of productivity and spatial structure and diversity for Puget Sound steelhead have been made available since the 2007, when the BRT concluded that low and declining abundance and low and declining productivity were substantial risk factors for the 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 extant summer steelhead populations in the Puget Sound DPS (Hard et al. 2007). The 2011 status review (Ford et al. 2011) retained the risk category for the DPS based upon the extinction risk of the component natural populations. 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 completed a set of population viability analyses (PVAs) for these populations and major population groups (MPGs) within the DPS (Hard et al. 2015). The roles of individual populations in recovery of the DPS have not yet been defined. However, the PSSTRT developed interim abundance-based guidelines for various potential recovery scenarios stating that in order for the DPS to achieve full recovery, steelhead 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 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 4). Also included as part of the ESA-listed DPS are six hatchery-origin stocks derived from native 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

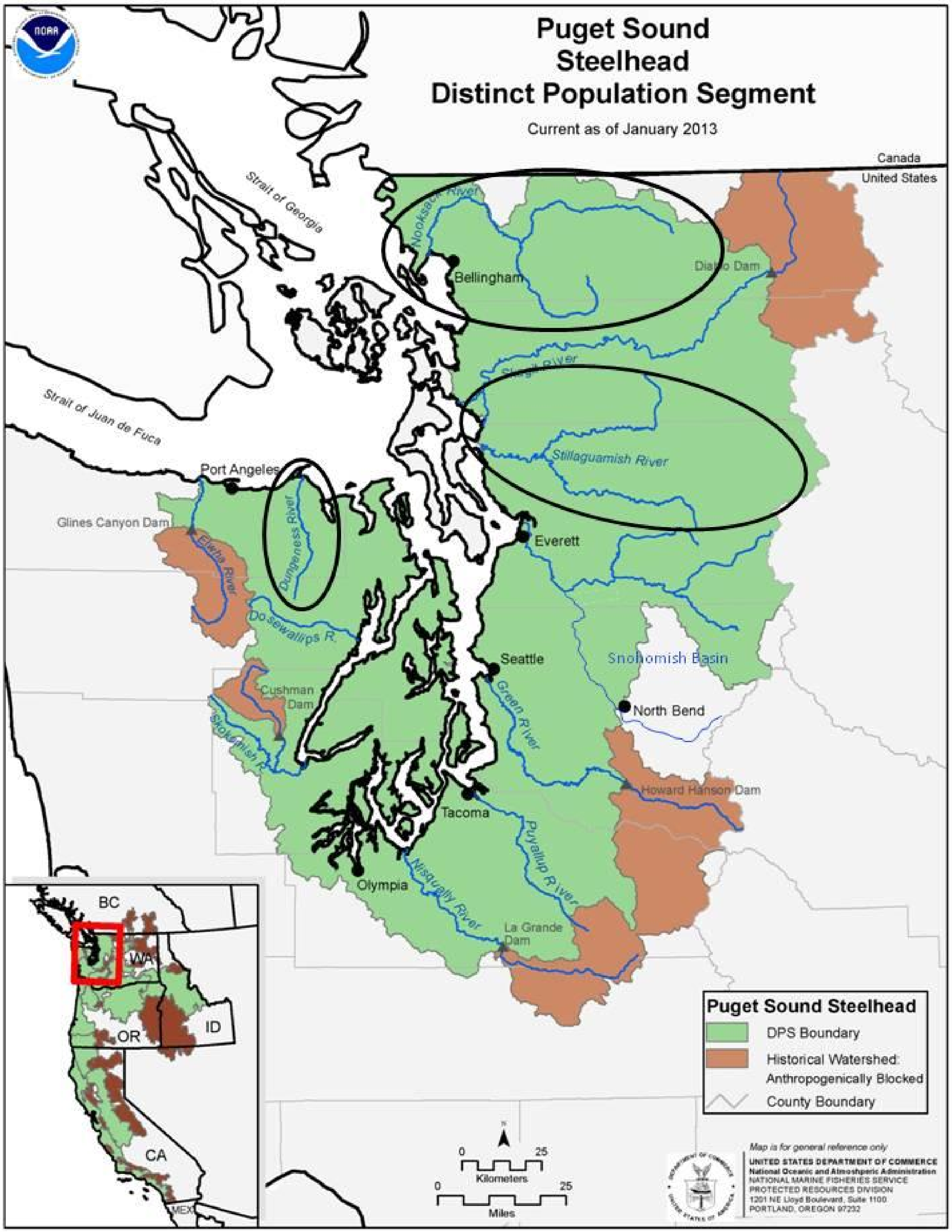

Figure 4. Location of the Dungeness, Nooksack, Stillaguamish, and Snohomish basin steelhead natural populations in the Puget Sound Steelhead DPS (generalized locations indicated by black ovals).

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). The 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; however, most of these improvements are viewed as small and abundance and productivity throughout the DPS remain at levels of concern from demographic risk. For all but a few putative PS steelhead populations, estimates of mean population growth rates obtained from observed spawner or redd counts are declining—typically 3 to 10 percent annually—and extinction risk within 100 years for most populations in the DPS is estimated to be moderate to high, especially for populations in the Central and South Puget Sound and Hood Canal and Strait of Juan de Fuca MPGs (Table 3). NWFSC (2015) found that recent increases in abundance observed in a few populations have been within the range of variability observed in the past several years and trends in abundance of natural spawners remain predominately negative. Declining production of both summer-run and winter-run hatchery steelhead, as well as reduced harvest have limited biological risks to the natural spawners in recent years. In general, the biological risks faced by the Puget Sound Steelhead DPS have not substantively changed since the listing in 2007, or since the 2011 status review (NWFSC 2015).

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:

- In addition to being a factor that contributed to the present decline of Puget Sound steelhead 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 steelhead 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.

Table 3. Puget Sound steelhead populations and risk of extinction (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)[5]	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)

- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris.

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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.

[5] Note the Hard et al. 2015 did not incorporate recent escapement estimates for the Dungeness River when they evaluated extinction risk.

- 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.

Hood Canal and Strait of Juan de Fuca MPG: The Hood Canal and Strait of Juan de Fuca MPG has eight DIPs including two summer/winter, and six winter DIPs (Figure 4; Table 4). Larger rivers share a common headwater source in the Olympic Mountain Range and are largely snowfield and/or glacially influenced. Most of these systems are dominated by relatively constrained high gradient reaches. In addition, there are numerous small tributaries, and those draining lowland areas are rain-dominated or rely on ground water (Myers et al. 2015). This MPG currently accounts for 12 percent of the steelhead spawner abundance in the DPS (NWFSC 2015), based on available data. Steelhead abundance appears to be very low and relatively similar among the populations (Table 3), with the Dungeness and Skokomish DIPs comprising the majority of steelhead in the MPG. In the 2010 five year status review, NMFS found that the MPG showed a negative long-term growth rate of 1.3% per year (Ford et al. 2011). One natural population in this MPG was found to have a long-term positive growth rate (west Hood Canal) (Ford et al. 2011). In the 2015 status review, long-term (1999 through 2014) trends were evaluated for three DIPs within the MPG, and all were found to be negative (NWFSC 2015). Between the two most recent five-year periods (2004-2009 and 2010-2014), the geometric mean of estimated abundance for six DIPs were found to have increased by an average of 4.5% in the Hood Canal and Strait of Juan de Fuca MPG (NWFSC 2015). This percent increase in abundance within the MPG reported in NWFSC (2015) may be underestimated, as trends derived for years for which data are actually available for individual stocks grouped within several DIPs indicate substantially higher mean abundance increases between the two five year periods (e.g., for Morse Creek and McDonald Creek within the Strait of Juan de Fuca Independent DIP). Risk assessment by the PSSTRT indicated five steelhead populations within the MPG are at high risk of extinction, including the Dungeness DIP, and two are at low risk (Table 3).

Dungeness River population: The PSSTRT delineated one extant steelhead population that is native to the Dungeness River watershed and part of the listed Puget Sound steelhead DPS: Dungeness River Winter-Run (Myers et al. 2015). A summer-run component of the steelhead return to the Dungeness River is thought to have existed historically in the upper accessible reaches of the mainstem Dungeness River and Gray Wolf River (Haring 1999), but it is uncertain whether the race still persists in the watershed. In a recent evaluation of Washington steelhead populations, WDFW listed the summer-run race in the Dungeness River as still extant (Scott and Gill 2008). Further monitoring is needed to establish whether native summer-run fish are still present and if they are part of a combined summer/winter natural population or represent an independent population (Myers et al. 2015). Steelhead recovery viability criteria recommend that at least one winter-run and one summer-run population of the six populations in the Hood Canal and Strait of Juan de Fuca MPG need to be restored to a low extinction risk status for recovery and delisting of the DPS (Hard et al. 2015). Hatchery-origin steelhead released from Dungeness River Hatchery are not included as part of the listed DPS (Jones 2011).

Table 4. Naturally spawning steelhead abundance and trends for DIPs within the Hood Canal and Strait of Juan de Fuca MPG for which information is available. Populations within the action area are bolded. Note WR=winter-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]
Dungeness R SWR	**>100[2]**	**743[3,4]**	**NA**
East Hood Canal WR	62	60	-3%
Elwha R SWR	>100[2]	>100	
Sequim/Discovery Bay WR[5]	17	19	12%
Skokomish R WR	351	580	65%
S. Hood Canal Tribs WR	113	64	-43%
Strait of Juan de Fuca WR[6]	244	147	-40%
West Hood Canal WR	149	74	-50%

Sources: NWFSC 2015[1]; Hard et al. 2015[2]; C. Burns, Jamestown S'Klallam Tribe, and M. Haggerty, Haggerty Consulting, unpublished draft escapement estimates, February 2016 [3]

[4] Reported as 141 in NWFSC 2015. However, the NWFSC abundance estimates for the Dungeness River assumed that index area redd counts equated to individual steelhead escapement abundances. The natural steelhead abundance estimates reported in NWFSC (2015) are therefore minimal estimates (or underestimates) of actual natural steelhead escapement abundances (for years after 1996). To account for individual steelhead numbers, the index area redd count-based estimates reported in NWFSC (2015) have been expanded by the percent of the total available spawning habitat encompassed by the index area, survey timing and redd construction curves, and an average fish per redd. All estimates from 1999-2015 were expanded using identical methods which were at least in part based on methods used to generate estimates from 1988 through 1996 (see Figure 5).

[5] Snow Creek only

[6] Morse and McDonald creeks only

The majority of the Dungeness River winter-run steelhead population includes fish spawning in the mainstem Dungeness and Gray Wolf rivers (Myers et al. 2015). The extent of spawning is confined to areas downstream of naturally impassable barriers. Dungeness winter steelhead spawning distribution extends from the Dungeness River mainstem at RM 18.7, downstream to the upper extent of tidewater (Haring 1999). Winter steelhead distribution is assumed to also include the Bell, Gierin, Cassalery, Cooper, Meadowbrook, Matriotti, Beebe, Lotsgazell, Woodcock, Mud, Bear, Hurd, Bear, Canyon, and Gold creek subbasins.

Adult winter-run steelhead enter the river on their spawning migration from November to early June. Spawning occurs from March through June, with peak spawning in May (Myers et al. 2015). Although age at spawning data are lacking for the Dungeness population, most natural-origin winter-run steelhead in Puget Sound return to spawn as four year-old fish, with five year-olds comprising a significant proportion of total returns (Myers et al. 2015, citing WDFW 1994). WDFW juvenile out-migrant trapping data from the 2005 through 2007 indicate that natural-origin Dungeness River basin steelhead juveniles emigrate seaward as smolts between February and early July, with peak migration during the first two weeks of May (Volkhardt et al. 2006; Topping et al. 2008a; Topping et al. 2008b). Steelhead smolt individual sizes observed in the WDFW trapping studies ranged from 85-mm to 290-mm (fl) and averaged 170 mm (fl).

In the 1940s, winter-run steelhead fishing in the Dungeness River was considered among the best in Washington State (Myers et al. 2015). In 1903, during its second year of operation, the Dungeness

Hatchery produced 3,100,840 steelhead fry or fingerlings, representing egg contribution from approximately 2,200 females; assuming a 1:1 sex ratio, the total return that year to the river could have exceeded 4,400 steelhead. Because of turbid water conditions in the Dungeness River during the months that steelhead return to spawn, there was no measure of adult returns until catch records became available. As a surrogate indicator of relative abundance, annual catch estimates based on adjusted catch record card returns from sport harvest averaged 348 steelhead from 1946 to 1953. These estimates of adult returns were prior to the introduction of “large numbers of hatchery fish” released as smolts (Myers et al. 2015). Natural-origin winter-run steelhead escapement estimates for return years 2009/10, 2010/2011, 2012/2013, 2013/2014, and 2014/15 averaged 750 fish; ranging from 484 fish (2009/2010) to 1,001 fish (2012/2013) (C. Burns, Jamestown S'Klallam Tribe, and M. Haggerty, Haggerty Consulting, unpublished draft escapement estimates, February 2016). Dungeness River steelhead spawning escapement estimates are available for 17 years over the period 1988 through 2015 (Figure 5).

An estimate of the intrinsic potential based on spawner capacity indicates that the Dungeness River watershed could support the production of 2,465 natural-origin steelhead, or 24,650 smolts (Myers et al. 2015). Smolt production from 2005 through 2014 has ranged from 5,521 (2012) to 19,600 (2011), averaging 12,717 (Figure 6). Current smolt production is approximately 52-percent of the intrinsic potential estimated by Myers et al. 2015. The critical threshold for winter-run steelhead natural spawners identified by the co-managers’ is 125 fish and the viable threshold, reflecting a level of population abundance associated with a very high probability of persistence, or conversely, a very low risk of extinction, for a period of 100 years, is between 500 and 750 natural-origin spawners (PSIT and WDFW 2010b).

In a recent review by the PSTRT, productivity for the Dungeness DIP was considered to be declining, and the estimated probability that the Dungeness River winter-run steelhead population would decline to 10% of its current fish abundance, within 100 years was determined to be very high (Hard et al. 2015) (Table 3). However, this analysis does not account for steelhead escapements after 2001, and incorporates unexpanded redd counts for 1996 (expands for 1.62 steelhead per redd) and raw redd counts for 2000 and 2001. For example, for spawn year 2001, the model input used by Myers et al. (2015) is the raw steelhead redd count observed after March 15, estimated at 183 redds. Based on best available scientific information, the actual expanded redd count for the index reaches was estimated to be 323 (201 redds observed in index reaches). When the estimate of 323 redds is expanded for supplemental and unsurveyed river and tributary reaches, 386 steelhead redds would be estimated to have been created in the watershed in 2001. Expanding this total watershed redd count by 1.62 steelhead adults per redd yields as estimated spawner escapement of 626 fish in 2001.

Limited information on both spawning escapements and juvenile production preclude accurate serial estimates of productivity. Annual steelhead smolt productivity appears to be trending upwards based on the short-term annual observations (Hard et al. 2015; Figure 6).

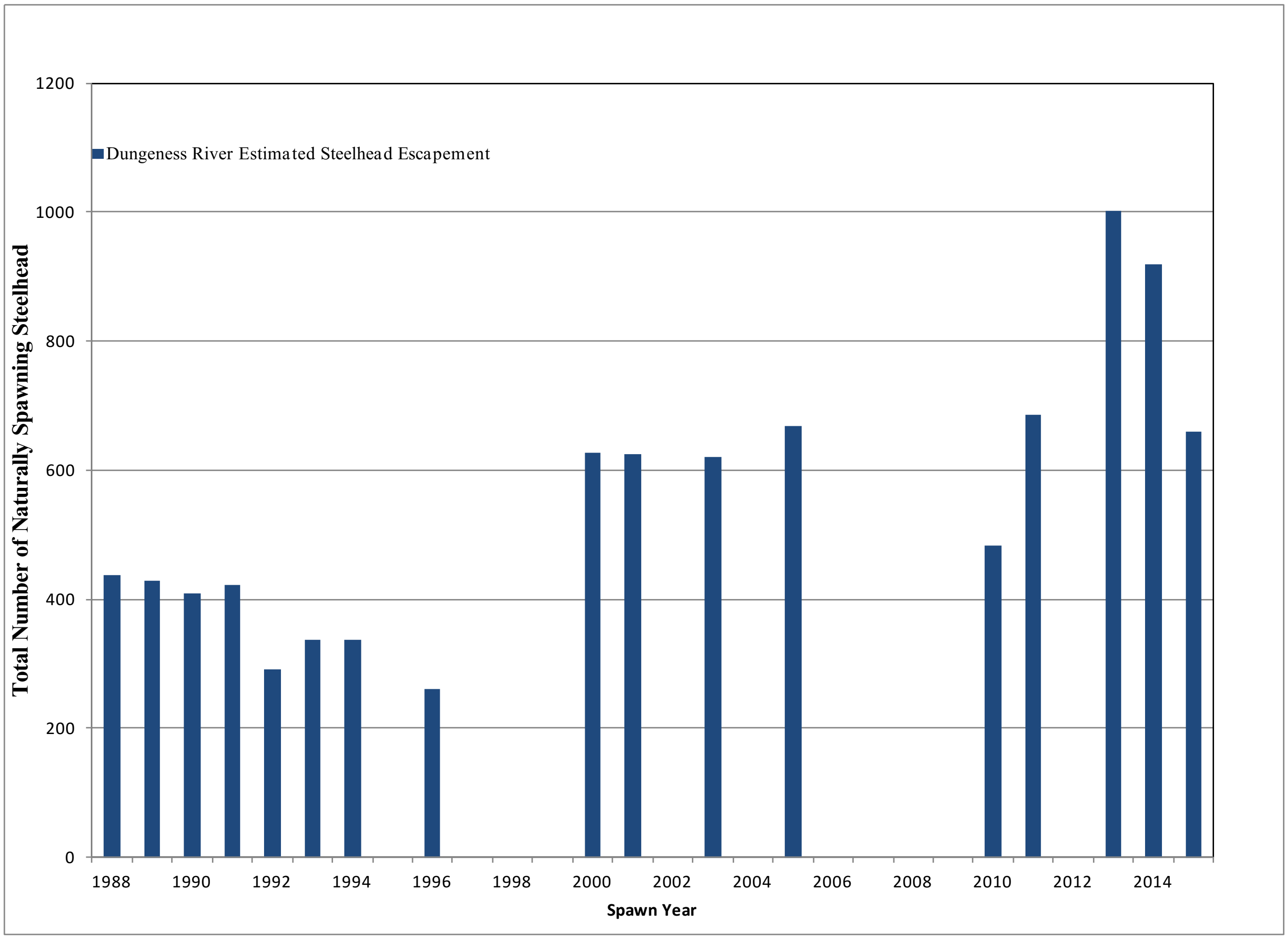

Figure 5. Dungeness River expanded estimated number of naturally spawning steelhead (natural-origin and hatchery-origin combined). source: 1988 - 1996 WDFW Score Database (note the 1996 estimate is unexpanded and based on a raw redd count of 162); 2000-2005 expanded estimates from WDFW spawning ground survey database; 2010-2015 C. Burns, Jamestown S'Klallam Tribe, and M. Haggerty, Haggerty Consulting, unpublished draft escapement estimates, February 2016.

Spatial structure of the winter-run steelhead natural population has been reduced by habitat loss and degradation in the Dungeness River watershed. Dikes, levees and other actions to control the lower reaches of the river and tributaries have reduced natural population spatial structure, particularly through adverse impacts on side channel habitat and increased scour of redds (Haring 1999). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile steelhead. Water withdrawals for irrigation and residential use have substantially reduced flows needed during the adult steelhead upstream migration and spawning periods, forcing adults to construct spawning redds in channel areas that are extremely susceptible to sediment scour and aggradation. Due to their late-winter and spring adult migration timing, spatial structure for the extant winter-run steelhead population was not thought to have been affected by seasonal operation of the Dungeness River Hatchery weir from the 1930s through the 1980s. Summer-run steelhead, if they still existed (Myers et al. 2015), may have been adversely affected by the weir when it was in operation over that period through migration delay and blockage.

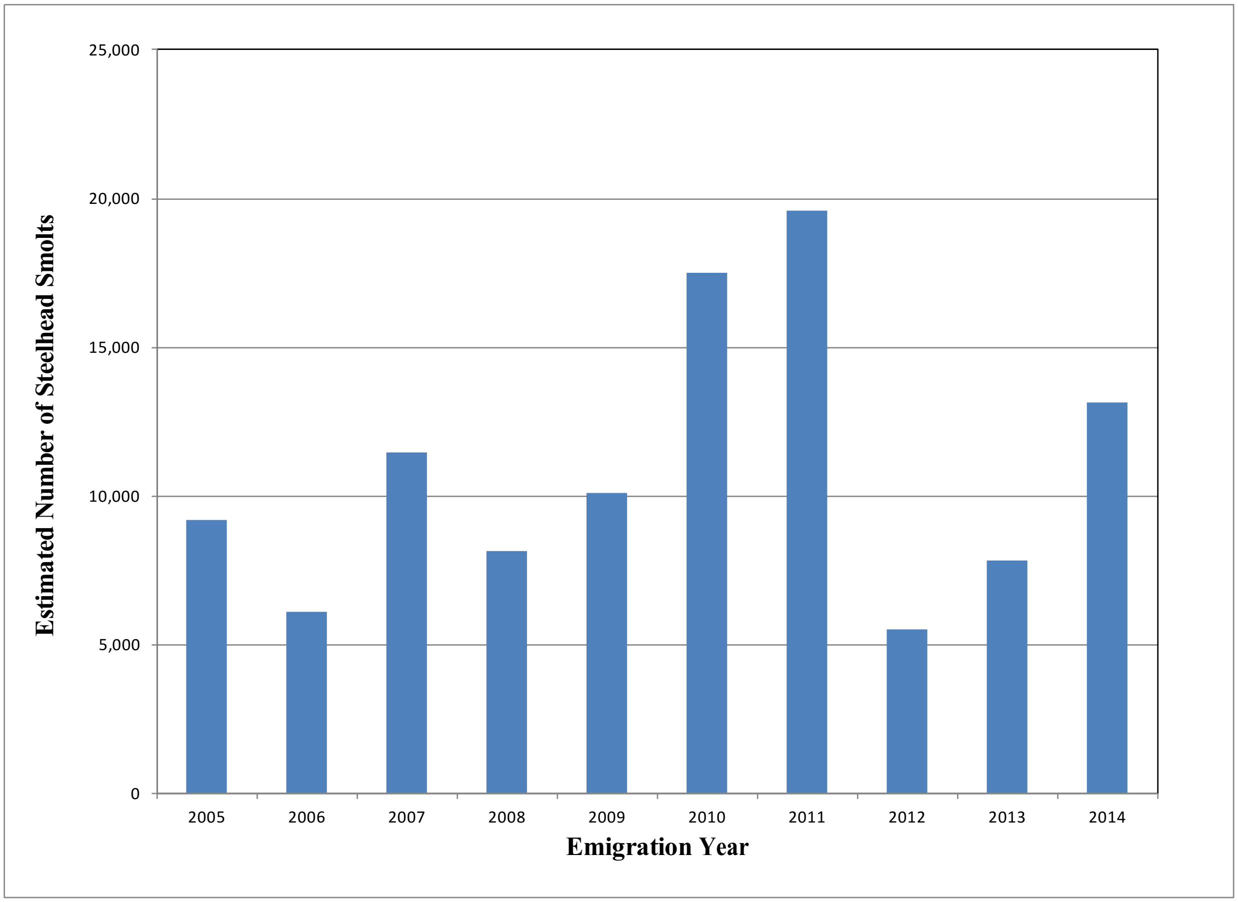

Figure 6. Dungeness River basin annual natural-origin steelhead smolt production.
Source: http://wdfw.wa.gov/conservation/research/projects/puget_sound_salmonids/dungeness/index.html

Available data indicate that steelhead diversity in the Dungeness River watershed has declined relative to historical levels. It is likely that the historically extant summer-run component of the steelhead return has declined to very low levels or has become extirpated (based on discussion in Myers et al. 2015). As with Chinook salmon in the watershed, degradation and loss of habitat in the watershed, and past harvest practices, have reduced the diversity of the species in general relative to historical levels. Releases of non-native EWS from Dungeness River Hatchery have likely reduced genetic diversity of the native winter-run population in watershed areas where spawn timings for natural and hatchery-origin fish have over-lapped. However, there are no genetic data indicating that introgression associated with planting of the non-native stock has occurred (WDFW 2013).

Northern Cascades MPG: The Northern Cascades MPG has 16 DIPs including eight summer or summer/winter, and eight winter DIPs (Figure 4; Table 5). Differences in bedrock erodability throughout the Northern Cascades MPG create cascades and falls that may serve as isolating mechanisms for summer-and winter-run natural 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 leading to better passage conditions.

Table 5. Naturally spawning steelhead abundance 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.

Eight of the 10 DIPs in the DPS with extant summer run-timing or summer components are in this MPG. This MPG accounts for 75 percent of the steelhead abundance in the DPS considering all DIPs for which data are available (NWFSC 2015). Although information on the DIPs within the Northern Cascades MPG is extremely limited, abundance appears to be highly variable among the natural populations (Table 5) with the Skagit and Snohomish 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 populations are at lower risk in this MPG than the other MPGs in the DPS. In summary, the North Cascades MPG is a stronghold of the DPS in terms of life history diversity and abundance, and has a relatively lower extinction risk.

Nooksack River populations: The Nooksack River basin includes two steelhead DIPs: Nooksack winter-run and South Fork Nooksack summer-run (Myers et al. 2015). As explained previously for the other steelhead natural populations addressed in this opinion, criteria exists to guide Puget Sound steelhead survival and recovery and the DPS viability criteria developed by NMFS (Hard et al. 2015), require at least 40 percent of steelhead populations within each MPG to 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 to achieve viability.

Winter-run steelhead in the Nooksack River basin enter freshwater as adults between November and May (Hard et al. 2007). Spawning occurs from February through June, with peak spawning in May (Hard et al. 2007). Others have reported spawn timing from January through June (Maudlin et al. 2002). Recent spawning ground survey data (most data is from 2005-2011) suggests that the bulk of natural spawning occurs from mid-February through June; peaking in May (Figure 7). Winter-run steelhead spawn throughout the mainstem, South Fork, North Fork, and Middle Fork, as well as in side-channels and the larger tributaries (e.g., Skookum, Kenny, Racehorse, Kendall, Maple, Boulder, Canyon, Cornell, Thompson, and Deadhorse creeks).

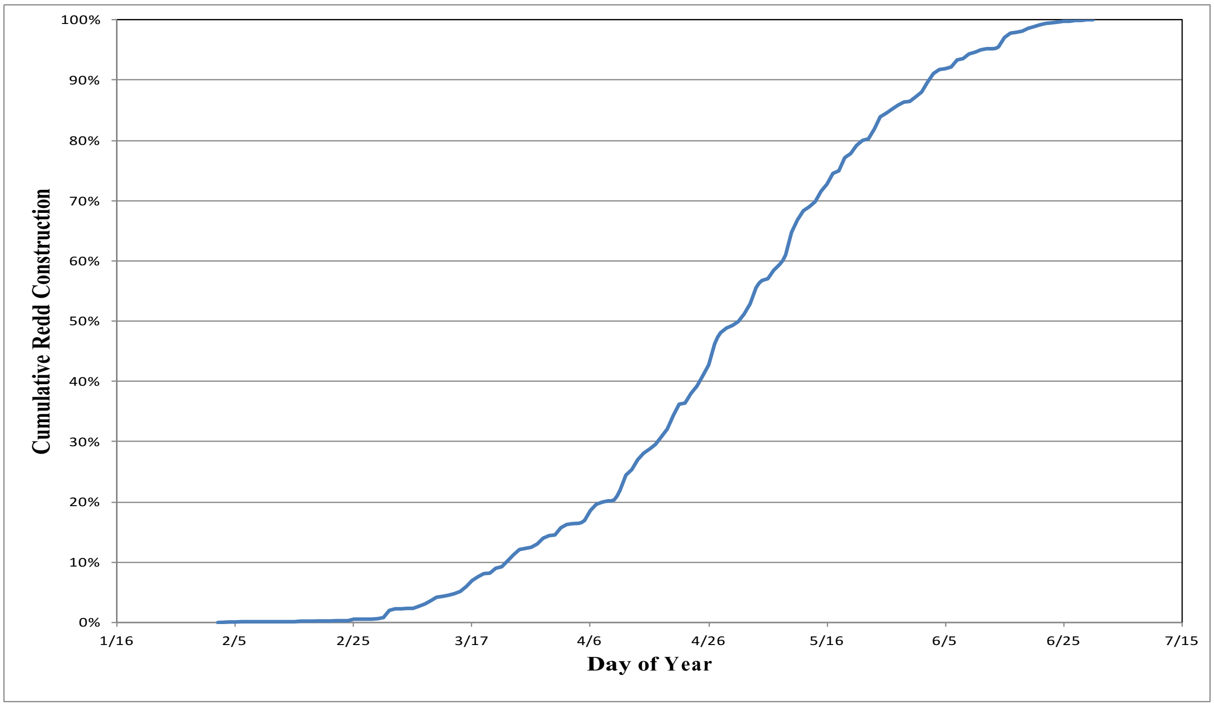

Figure 7. Nooksack River basin cumulative steelhead redd construction versus day of year (source: WDFW unpublished spawning ground survey database).

Little is known about the South Fork summer-run steelhead natural population. It is assumed they have a river entry timing from late-April through October, with an extended holding period in freshwater prior to spawning (Mauldin et al. 2002, and following). Their primary spawning habitat is thought to be quite limited and upstream of a partial barrier at RM 25. They also access spawning habitat upstream of another partial barrier at RM 30.4, which limits access of spring Chinook and winter-run steelhead. Spawning has been observed upstream Wanlick Creek (RM 34.1) in March. The summer-run stock likely comprises an important genetic reserve because it has not been influenced by ESS, as has occurred for long periods with many other summer-run natural populations within the region.

Steelhead scale data from 1978 through 1980 indicate that most winter-run steelhead return to spawn as four year-old (79%) and five year-old fish (20%) (Myers et al. 2015 citing WDFW 1994b). Juvenile out-migrant trapping data indicate that natural-origin Nooksack River basin steelhead juveniles emigrate seaward from January through November with a peak emigration occurring in April and May (Lummi

Natural Resources 2013). No age at emigration data are available for Nooksack River steelhead smolts. From 2011 through 2013, the length of natural-origin smolt captured in the Lummi Tribe's screw trap have averaged 147 mm (LNRD 2012; 2013).

Historically, the Nooksack River basin was one of the primary producers of steelhead in Puget Sound (Myers et al. 2015). Abundance estimates for the species 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. For the 1895 fishery (Wilcox 1898 in Myers et al. 2015) note that 660,000 pounds of steelhead were caught in the Nooksack River. If the fish averaged 10 pounds in individual weight, this catch estimate equates to a harvest of 66,000 steelhead.

Intrinsic potential (IP) production estimates based on basin geological, hydrologic, and ecological characteristics indicate the Nooksack River basin could support a total winter-run steelhead abundance of approximately 22,045 to 44,091 adults; or 220,450 smolts (Myers et al. 2015). By comparison, the recent year (2010-2015) combined mean escapement for the winter-run population in the Nooksack River basin is 1,820 fish (WDFW Score Database; Ned Currence, pers. comm. Feb 2016), or 8.2 and 4.1 percent of the low and high IP capacity for the basin. No long-term escapement estimates are available for Nooksack River winter-run steelhead. IP production estimates indicate that the S.F. Nooksack River basin could support a total summer-run steelhead abundance of approximately 1,137 to 2,273 adults; or 11,370 smolts (Myers et al. 2015). Natural-origin smolt production in 2012 and 2013 for the entire Nooksack River watershed was estimated to average 77,128 smolts (LNRD 2013), which is approximately 33 percent of the estimated IP capacity for the basin (including both summer- and winter-run populations).

Human developmental activities in the Nooksack River basin have reduced steelhead population spatial structure. Scott and Gill (2008) reported that the distribution of winter-run steelhead in the basin has been reduced from 1% to 14% (currently 407 miles) from the pre-development distribution of 411 to 474 miles of riverine habitat.

Data are not available to evaluate changes in the diversity of steelhead in the Nooksack 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. In addition, releases of EWS from basin hatcheries has likely reduced the genetic diversity of the native winter-run population in watershed areas where spawn timings for natural and hatchery-origin fish have over-lapped. There have been no releases of ESS into the South Fork Nooksack River that would affect genetic diversity of the native South Fork Nooksack River summer-run population.

Stillaguamish River population: The Stillaguamish Basin includes three steelhead DIPs: Stillaguamish River winter-run; Deer Creek summer-run; and Canyon Creek summer-run (Myers et al. 2015). A non-native summer-run population (Skamania hatchery-origin [ESS]) spawns above Granite Falls and is not part of the DPS. The criteria for DPS viability developed by NMFS (Hard et al. 2015), require at least 40 percent of the steelhead populations within each MPG to achieve viability (restored to a low extinction risk). At least 40 percent of each major life history type (e.g., summer-run and winter-run) historically present within each MPG must also be restored to a low extinction risk for the DPS to be considered viable.

Winter-run steelhead in the Stillaguamish River basin enter freshwater as adults between November and April (Washington State Conservation Commission 1999). Spawning occurs from mid-March through mid-June, with peak spawning in May (Myers et al. 2015). Winter-run steelhead spawn throughout the mainstem, South Fork, and North Fork, as well as in the larger tributaries (e.g., French, Squire, Pilchuck, Jim, and Canyon creeks).

Summer-run steelhead in the Stillaguamish River basin enter freshwater as adults between May and October (WCC 1999). Spawning occurs from mid-January through mid-May (WCC 1999; WDFW and WWTIT 1994). The Deer Creek summer-run population has a July through mid-October run-timing, with spawning from early to mid-April through May (WDFW and WWTIT 1994). Most spawning takes place in the upper portion of the subbasin (Myers et al. 2015). Steep canyons and cascades from RM 1.5 to 5.1 may present a temporal barrier to winter-run steelhead (Myers et al. 2015). Ninety-five percent of the adult steelhead return as age-3 fish spending 2 years in freshwater and one in saltwater, and the remainder are four years old (having spent 3 years in freshwater and one in saltwater), or repeat spawners (WDFW and WWTIT 1994). The Canyon Creek summer-run population has a June through October run-timing; spawn timing remains unknown but is assumed to take place from February through April (WDFW and WWTIT 1994). A series of cascades and falls at RM 1.2 is thought to be a partial barrier to most adult salmon (Williams et al. 1975). Myers et al. (2015) speculated that this series of cascades may be a barrier to separate winter- and summer-run steelhead. The non-native South Fork Stillaguamish summer-run stock has a May through October run timing, with most spawning taking place from mid-January to mid-April (WDFW and WWTIT 1994).

Abundance estimates for the species are lacking for the pre-developmental period, but steelhead harvest levels during the late 1800s and early 1900s indicate that steelhead abundance was moderately high. For the 1895 fishery (Wilcox 1898 in Myers et al. 2015), 182,000 pounds of steelhead were caught in the lower Stillaguamish. If the average steelhead was 10 pounds in individual size, this catch estimate equates to a harvest of 18,200 steelhead. Escapement surveys by the Washington Department of Fish and Game in 1929 found large aggregations of steelhead in the North Fork and South Fork Stillaguamish rivers, and in Deer and Canyon creeks (Myers et al. 2015, citing WDFG 1932). IP production estimates based on basin geological, hydrologic, and ecological characteristics indicate the Stillaguamish River basin, not including the Deer and Canyon creek DIPs, could support a total winter-run steelhead abundance of approximately 19,118 to 38,236 adults; or over 191,180 smolts (Myers et al. 2015). There are no estimates of annual steelhead smolt production for the basin. There are no basin-wide estimates of spawning escapement; currently escapement estimates only cover index areas (Figure 8). However, applying the estimated expansion factor of 4.06 to index area abundance for 2010 through 2015 yields a basin wide winter-run steelhead average escapement of 1,700, which is 8.9 and 4.4 percent of the low and high IP capacity for the basin. IP production estimates indicate the Deer Creek DIP could support a total summer-run steelhead abundance of approximately 1,572 to 3,144 adults; or over 15,720 smolts (Myers et al. 2015). There are no recent escapement estimates for this population, and the last census was conducted in October 1994 and yielded an estimate of 460 adult steelhead (Kraemer 1994 in Myers et al. 2015). IP production estimates indicate the Canyon Creek DIP could support a total summer-run steelhead abundance of approximately 121 to 243 adults; or over 1,210 smolts (Myers et al. 2015).

Data are not available to evaluate changes in the diversity of steelhead in the Stillaguamish River basin. However, it is likely that the degradation and loss of habitat in the watershed, and past harvest practices that disproportionately affected earliest returning fish, have reduced the diversity of the species relative to historical levels. Similarly, releases of EWS from basin hatcheries have likely reduced genetic diversity of the native winter-run population in watershed areas where spawn timings for natural and hatchery-origin fish have over-lapped. The introduction of ESS into the South Fork Stillaguamish has created a non-native, self-sustaining population (Myers et al. 2015). In an analysis of genetic samples collected from hatchery and natural-origin steelhead juveniles in the Stillaguamish River watershed, Warheit (2014a) found that the Whitehorse Ponds EWS and ESS hatchery programs affected the genetic structure of natural-origin steelhead populations in the basin to varying degrees. Warheit (2014a) reported no Whitehorse Ponds EWS hatchery influence (measured as "Proportion Effective Hatchery Contribution" or "PEHC") among aggregate samples of juvenile winter and summer-run fish, but a large hatchery-origin summer-run influence in a collection of steelhead smolts analyzed (see Section 2.4.2.2).

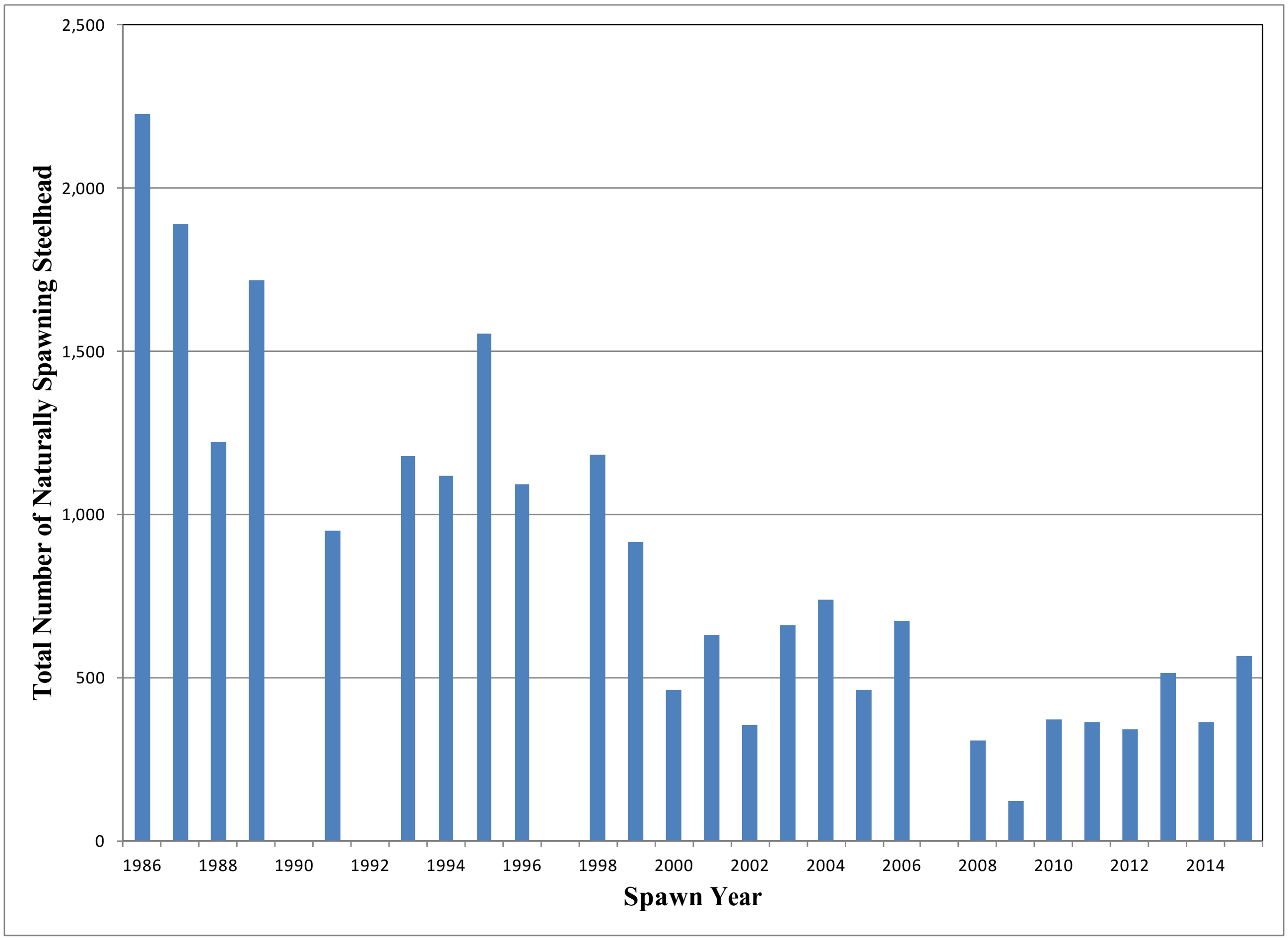

Figure 8. Estimated number of naturally spawning steelhead (natural-origin and hatchery-origin combined) in the North Fork Stillaguamish River index segments for 1986 through 2015 (source: WDFW unpublished data 2016, accessed via: https://fortress.wa.gov/dfw/score/score/species/population_details.jsp?stockId=6091)

2.2.1.2 Status of Critical Habitat for Puget Sound Steelhead

Critical habitat for Puget Sound steelhead was designated on February 24, 2016 (81 FR 9252). 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 (78 FR2726, January 14, 2013). The designation does not identify specific areas in the nearshore zone in Puget Sound because steelhead move rapidly out of freshwater and into offshore marine areas, unlike Puget Sound Chinook and Hood Canal summer chum, for which nearshore critical habitat areas were designated. Critical habitat 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 subbasins within the action area (Dungeness River, upper North Fork Nooksack, Middle Fork Nooksack, South Fork Nooksack, Lower North Fork Nooksack, Nooksack River, North Fork Stillaguamish, South Fork Stillaguamish, and Lower Stillaguamish River), seven received high and two medium (upper N.F. and M.F. Nooksack River) conservation value ratings (78 FR 2726, January 14, 2013).

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 (81 FR 9252, February 24, 2016). 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 steelhead in the action area include:

(1) Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development;

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

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

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

(5) Nearshore marine areas free of obstruction and excessive predation with: (i) Water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and

maturation; and (ii) Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

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

Critical habitat is designated for Puget Sound 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 ESU, is at high risk and is threatened with extinction (Ford 2011; Table 2). The NMFS issued results of a 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.

The NMFS adopted the recovery plan for Puget Sound Chinook on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan (SSPS 2005c) prepared by the Shared Strategy for Puget Sound and NMFS’ Final Supplement to the Shared Strategy Plan (NMFS 2006b). 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 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 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 9) (Table 6).

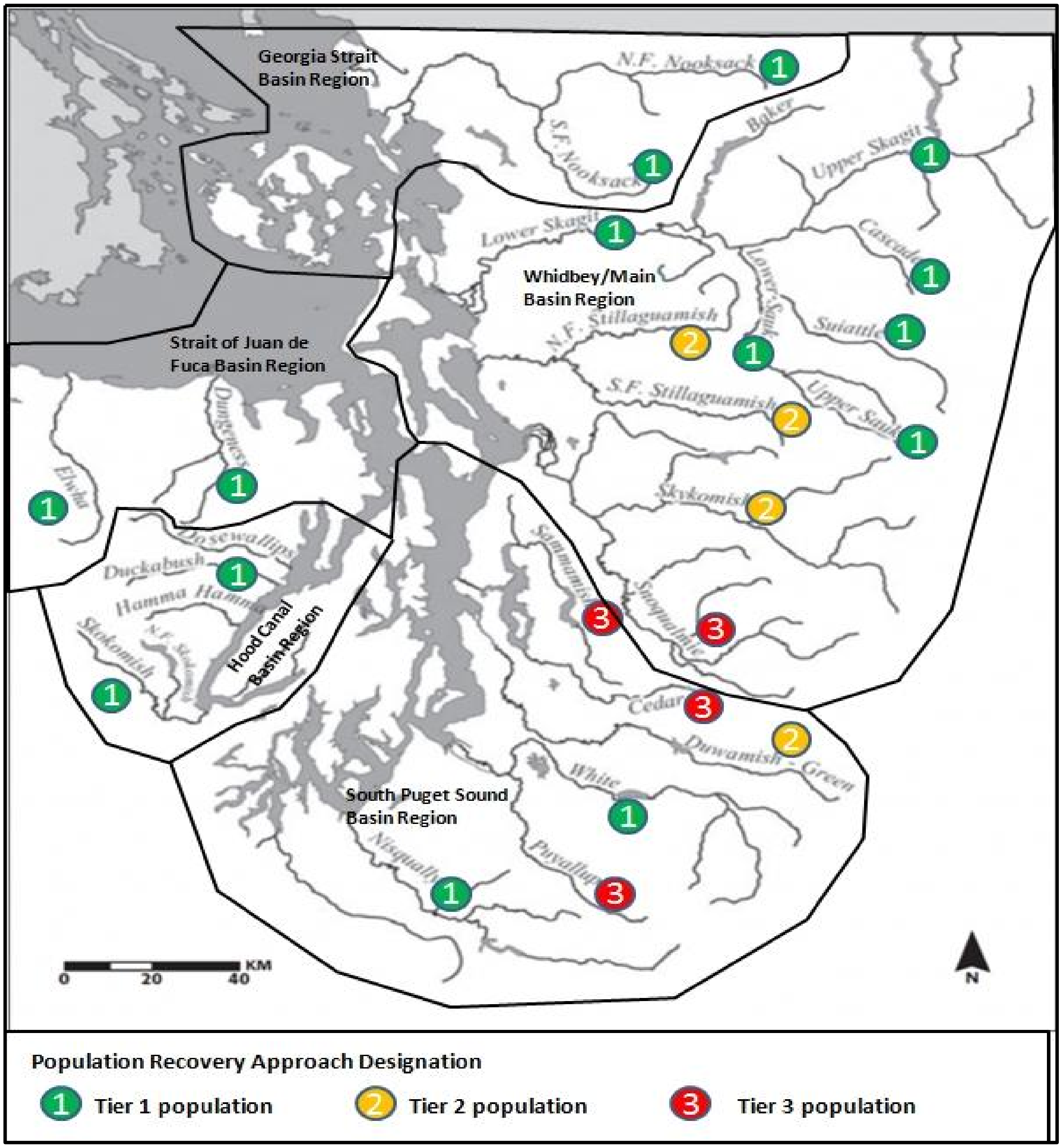

Figure 9. Populations delineated by NMFS for the Puget Sound Chinook salmon ESU. (Modified from SSPS 2005c). Includes population recovery approach tiered populations from NMFS (2010) [6]. Note: Dosewallips, Duckabush and Hamma Hamma River Chinook salmon are aggregated as the Mid Hood Canal population.

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[6] The assigned tier indicates the relative standing of each of the 22 populations composing the ESU to the viability of the ESU and its recovery. Tier 1 populations are most important for preservation, restoration, and ESU recovery. Tier 2 populations are managed in a less risk-averse manner by NMFS. Tier 3 populations would require ESA protection to the degree that the populations would improve in status but at a slower trajectory toward recovery compared to populations in the other two tiers.

Table 6. Extant Puget Sound Chinook salmon natural 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 populations, in particular, are essential to recovery of the Puget Sound ESU (NMFS 2006b). In addition, at least one other population 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.

Based on genetic and historical evidence reported in the literature, the TRT also determined that there were 16 additional spawning aggregations or populations in the Puget Sound Chinook Salmon ESU that are now putatively extinct[7] (Ruckelshaus et al. 2006). The ESU encompasses all runs of Chinook salmon from rivers and streams flowing into Puget Sound, including the Strait of Juan de Fuca from the Elwha River eastward, and rivers and streams flowing into Hood Canal, South Sound, North Sound, and the Strait of Georgia in Washington. We use the term ‘‘Puget Sound’’ to refer to this collective area of the ESU. As of 2014, 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

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[7] 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.

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 population level, though diversity at the ESU level is declining. Abundance is becoming more concentrated in fewer 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).

NMFS further classified Puget Sound Chinook salmon 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; 2011b)(Figure 8). 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 populations are of primary importance for preservation, restoration, and ESU recovery. Tier 2 populations play a secondary role in recovery of the ESU and Tier 3 populations play a tertiary role. When NMFS analyzes proposed actions, it evaluates impacts at the individual population scale for their effects on the viability of the ESU. Impacts on Tier 1 populations would be more likely to affect the viability of the ESU as a whole than similar impacts on Tier 2 or 3 populations, because of the primary importance of Tier 1 populations to overall ESU viability. The Dungeness, N.F Nooksack, and S.F. Noosack populations are classified as Tier 1 populations and the N.F. and S.F. Stillaguimish populations are classified as Tier 2 populations (NMFS 2010; 2011b).

Abundance and Productivity. Table 7 and Table 8 summarize the available information on current abundance and productivity and their trends for the Puget Sound Chinook salmon natural populations including NMFS' critical and rebuilding thresholds[8] 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 2011) and recent escapement and fisheries data provided by tribal and state co-managers (data summarized in NMFS 2015a).

Most Puget Sound Chinook populations are well below escapement levels identified as required for recovery to low extinction risk (Table 7). All populations are consistently below productivity goals identified in the recovery plan (Table 7). 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 8). 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

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[8] 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).

rate of natural-origin abundance indicating some stabilizing influence on escapement from past reductions in fishing-related mortality (Table 8). Survival and recovery of the Puget Sound Chinook Salmon ESU will depend, over the long term, on effective 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 populations based on an assessment of current habitat and environmental conditions (NMFS 2000; 2004; 2011b). 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 abundance 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 7). 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 7). The most recent geometric mean (2010-2014) natural-origin escapements indicate that 8 populations are currently below their critical thresholds.

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 natural-origin Chinook salmon 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 the risk of overharvest.

Table 7. 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; 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 8. Trends in abundance and productivity for Puget Sound Chinook salmon populations. Long-term, reliable data series for natural-origin contribution 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.

The severity and relative contribution of these factors varies by population. One theory for the declines in fish populations in Puget Sound in the 1980s and into the 1990s is that they may reflect broad-scale shifts in natural limiting conditions, such as increased predator abundances and decreased food resources in ocean rearing areas. These factors are discussed in more detail in the Environmental Baseline (Section 2.3).

Strait of Juan de Fuca BGR: The Strait of Juan de Fuca BGR contains two Chinook salmon populations: Dungeness and Elwha. Both populations would need to be viable for recovery of the ESU (NMFS 2006b). The Dungeness and Elwha are early and late-timed populations, respectively, although both basins historically exhibited components across the run-timing spectrum (Ruckelshaus et al. 2006). Evidence suggests that much of the life-history diversity represented by early-type populations or population components that existed historically in the Puget Sound Chinook ESU has been lost (Ruckelshaus et al. 2006) so protection of the remaining early-type populations like the Dungeness is particularly important to recovery of the ESU. Genetic and ocean distribution data indicate the Elwha population is intermediate between Puget Sound and Washington coastal populations and considered to be a transitional population between the Puget Sound and Washington Coastal Chinook salmon ESUs (Myers et al. 1998). The BGR currently accounts for 1.5% of the natural-origin Chinook salmon escapement in the ESU (from Table 56 *in* NWFSC 2015). Based on the available information, both populations in the BGR are below their critical thresholds; and spawning escapements are supplemented with hatchery fish to reduce short-term demographic risk. Escapement trends and growth rates derived by NMFS NWFSC through its Abundance and Productivity Puget Sound TRT database indicate the trend and rate for the Dungeness population is above 1.0 and increasing. The same analyses indicate the escapement trend and growth rate are stable or declining for the Elwha population (Table 8). Both populations have on-going conservation supportive breeding programs to increase the number of natural spawners and reduce extinction risk, in the short-term. These supportive breeding programs are considered essential components to the recovery strategies for both populations (SSPS 2005a; Ward et al. 2008; NMFS 2012). The Elwha River watershed is undergoing a substantial restoration effort associated with removal of the two dams, which will restore salmon access to 70 miles of spawning and rearing habitat (Ward et al. 2008). In summary, populations within the Strait of Juan de Fuca BGR exhibit life history components unique within the ESU and present significant challenges to ESU recovery, given their critical status.

Dungeness River Chinook: The extant Dungeness Chinook salmon population is considered a spring/summer-run timed (or “early”) population, based on spawn timing. The population spawns in the watershed from mid-August to mid-October (WDFW and WWTIT 1994). Chinook salmon spawn in the mainstem Dungeness River up to RM 18.7, where natural falls block further access. Spawning distribution in recent years has been weighted toward the lower half of the accessible river reach, with approximately two-thirds of redds located downstream of RM 10.8. There have been no major shifts in spawning distribution from lower to mid and upper river areas over the periods 1991-1999 (44% of redds in the lower 6.4 miles) and 2000 to 2013 (40% in the lower 6.4 miles) (M. Haggerty, Haggerty Consulting, and R. Cooper, WDFW, unpublished WDFW data, September 17, 2014). Chinook salmon also spawn in the Gray Wolf River (confluence with Dungeness at RM 15.8) up to RM 5.1 (WDFW and WWTIT 1994). When including the Gray Wolf River, total spawning distribution in the lower river decreased from 44% to 38% over the two above periods. Chinook salmon typically spawn first in the upstream reaches. As the season progresses, spawning occurs further downstream in the lower mainstem reaches (WDF et al. 1993). .

Dungeness Chinook salmon predominantly exhibit an ocean-type life history trajectory (Myers et al. 1998), with juveniles emigrating seaward from mid-February through the end of July (Volkhardt et al. 2006). A small portion of the population (< 5 %) may rear in the river for a year and emigrate seaward as yearlings (Marlowe et al. 2001; SSPS 2005a). Adults mature primarily at age four (63%), with age 3 and age 5 adults comprising 10% and 25%, of the annual returns, respectively (PSIT and WDFW 2010a). Recent data indicate that Dungeness River Hatchery-origin sub-yearlings return as adults at the following age class proportions: Age 2 (8%), 3 (36%), 4 (48%), 5 (8%), and 6 (0%) (M. Haggerty, pers. comm., September 16, 2014). Dungeness River Hatchery yearling Chinook salmon adults return at Age 2 (1%), 3 (17%), 4 (56%), 5 (23%), and 6 (3%).

The current abundance of Dungeness Chinook salmon is substantially reduced from historical levels (SSPS 2005a) (Table 7). Between 2001 and 2014, the geometric mean total annual naturally spawning Chinook salmon escapement was 94 natural-origin spawners compared with the recovery goal at high productivity of 1,200 natural-origin spawners (see Table 7; Figure 10) (Ruckelshaus et al. 2002; NMFS 2006b). Assessments of current habitat productivity in the watershed suggest that the Dungeness River can theoretically support 699 (SSPS 2005a) to 925 (B. Sele, WDFW, pers. comm.) spawning Chinook salmon. Hatchery-origin Chinook salmon associated with the Dungeness conservation hatchery program make up a sizeable fraction of the annual naturally spawning adult abundance, averaging 72% for the basin (range=39-96%) Figure 10). The proportion of the total naturally spawning Chinook salmon escapements that were of natural-origin within the following 3 time periods - 2000-2004, 2005 - 2009, and 2010-2014 - averaged 15%, 43%, and 24%, respectively (WDFW, unpublished spawning ground survey data). Total naturally spawning fish escapements have fluctuated with changes in the conservation hatchery program with the highest escapements reflecting years when adult progeny from the hatchery program returned to spawn (WDFW and PSIT 2010). Between 2001 and 2014, the geometric mean total annual naturally spawning Chinook salmon escapement was approximately 391 fish (Figure 9). Total annual naturally spawning Chinook salmon escapement for the most recent 6 years has averaged 297 (range 535 to 98); with 213 and 85 fish on average being hatchery-origin and natural-origin, respectively.

Estimates derived from the Puget Sound TRT Abundance and Productivity table database suggest that productivity for Dungeness Chinook salmon has increased since the Puget Sound Chinook salmon ESU was listed in 1999 (Table 8). The most recent NMFS status review for the ESU found that productivity trends for the Dungeness Chinook population, as measured by recruit per spawner and spawner to spawner rates, are positive(NWFSC 2015). Although increases in these rates indicate productivity has increased, other recent estimates of egg to juvenile outmigrant and recruit per spawner survival rates reflect a general low productivity for the population (1999-2008 average: R/S = 0.7; S/S = 0.28) (NMFS 2013a). Estimates for juvenile Chinook salmon outmigrant production for brood year 2004-2014 ranged from a high of 164,814 out-migrating fish in 2013 to a low of 3,870 outmigrants in 2015 (Volkhardt et al. 2006; Topping et al. 2008a; Topping et al. 2008b) (updates to annual juvenile abundance estimates presented in these reports accessed at: http://wdfw.wa.gov/conservation/research/projects/puget_sound_salmonids /dungeness/index.htm and from Pete Topping personal communication 2016). Estimated egg to juvenile outmigrant survival has ranged from 1.4% to 14.7%, and averaged 4.9% for return years 2004 through 2014. For comparison, in the Skagit River, where natural habitat is in better condition for Chinook salmon productivity, egg to smolt survival estimates averaged over 10% from brood year 1990 to 2006 (Kinsel et al. 2008).

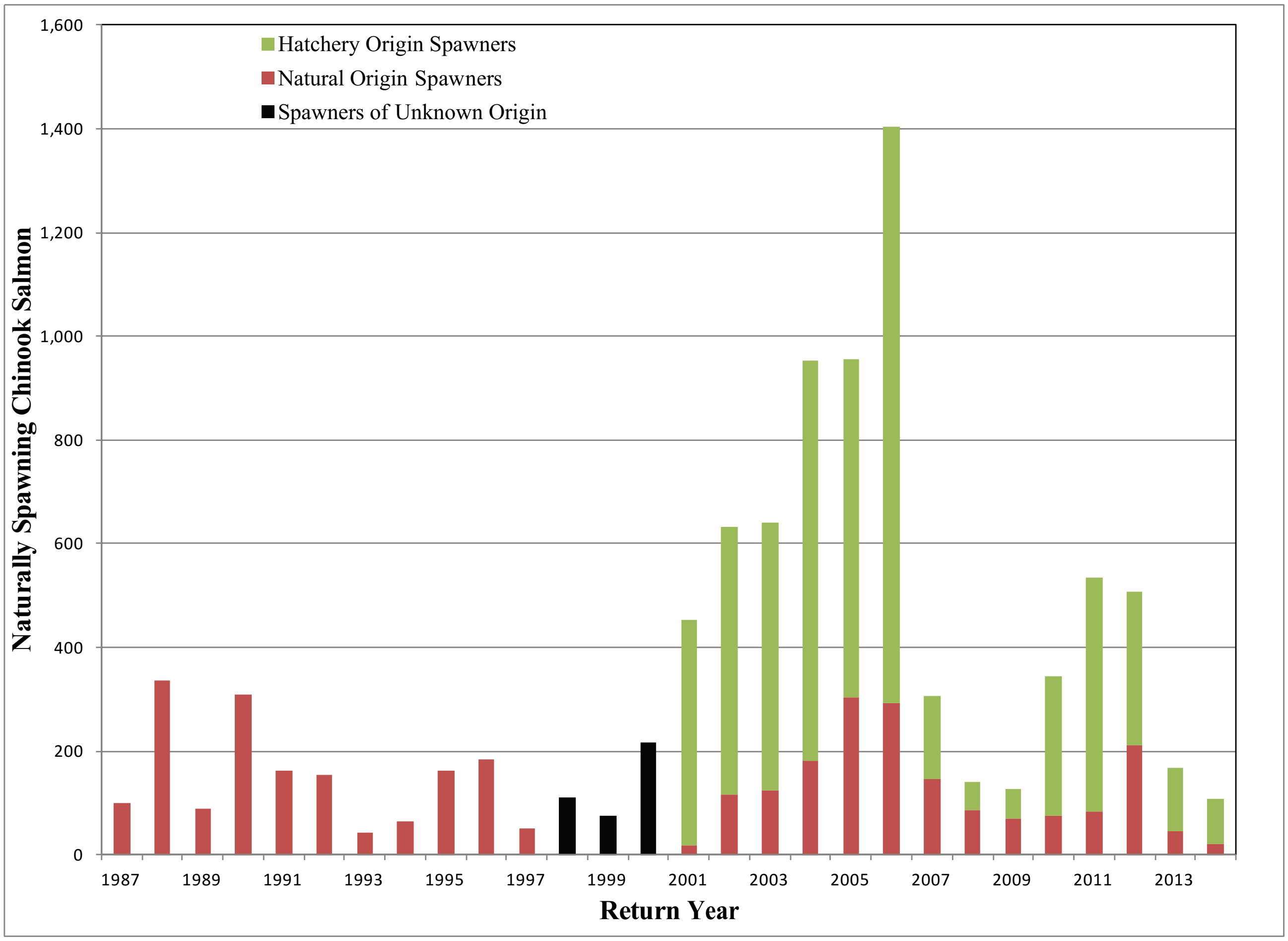

Figure 10. Estimated annual naturally spawning Chinook salmon escapement abundance (natural and hatchery-origin salmon combined) in the Dungeness River for 1987 – 2014. Data sources: PSIT and WDFW 2010; WDFW unpublished data 2015, accessed via: https://fortress.wa.gov/dfw/score/score/species/population_details.jsp?stockId=1240

Spatial structure for the Dungeness Chinook population has also been affected over time relative to historical levels. A full spanning weir at RM 10.8 operating in association with the Dungeness River Hatchery program from the 1930s to the 1980s, precluded unrestricted upstream access by Chinook salmon and spawning in the upper Dungeness River watershed for 50 years, although some Chinook salmon were known to have regularly escaped upstream during that period (Haring 1999; SSPS 2005a). Chinook salmon continue to have access to their historic geographic range of habitat, and now spawn throughout the entire watershed. Low adult return levels in recent years have led to underutilization of accessible areas, especially in the Gray Wolf River (SSPS 2005a). As discussed above for steelhead in the Dungeness River watershed, dikes, levees and other actions to control the lower reaches of the river and tributaries have reduced spatial structure, particularly through adverse impacts on side channel habitat and increased scour of redds (Haring 1999). These actions have degraded available spawning and migration areas for adult fish, and refugia for rearing juvenile salmon. Additionally, water withdrawals have substantially reduced flows needed during the adult salmon upstream migration and spawning periods, forcing adults to construct spawning redds in channel areas that are extremely susceptible to sediment scour and aggradation.

Genetic diversity of the Dungeness Chinook salmon population has been substantially impacted by anthropogenic activities over the last century. Although run-timing appears to be unchanged, a number of life-history pathways have been lost (Clallam County and Jamestown S'Klallam Tribe 2005). Genetic diversity has been reduced, as modeling estimates that only 70% of the historic pathways remain available to the Dungeness River Chinook salmon natural population (Clallam County and Jamestown S'Klallam Tribe 2005)). Diversity of the natural population has been impacted, not by loss of sub-populations, but through the loss of life history pathways associated with specific habitat types (Clallam County and Jamestown S'Klallam Tribe 2005)). Extensive human disruptions in the watershed, including sporadic releases of non-native hatchery fall Chinook salmon in the last century, have likely impacted (but to an unknown extent) a late-returning life history of Chinook salmon that existed in the watershed; a significant part of the historical diversity of the population (Ruckelshaus et al. 2006, citing Williams et al. 1975; Jamestown S'Klallam Tribe 2007).

A recent captive broodstock program that was terminated in 2004, could have also affected genetic diversity of the Dungeness River Chinook salmon population. In founding the original hatchery program, the risk of within population genetic diversity loss was reduced by selecting the indigenous Chinook salmon population for use as captive broodstock. Further, the duration of the captive broodstock program was limited to a six-year period (1992 through 1997 broods) to reduce the risk of genetic diversity loss that may occur as a result of captive breeding. Continuing effects of hatchery operations in the action area are discussed in Section 2.3.2, below.

Recent assessments indicate that only one Chinook salmon stock with no discontinuity in spawning distribution through time or space exists in the basin (Ruckelshaus et al. 2006, citing Marlowe et al. 2001). As discussed previously, the disproportionate loss of early-run life history diversity represents a particularly significant loss of the evolutionary legacy of the historical ESU. The substantially reduced abundance of the Dungeness spring/summer-run population relative to historic levels represents a risk to remaining ESU diversity.

Georgia Strait Basin BGR: The Georgia Strait Basin BGR contains two Chinook salmon natural populations: North Fork and South Fork Nooksack. Both populations would need to be viable for recovery of the ESU (NMFS 2006b). Both the North Fork and South Fork Nooksack populations are early-timed populations. Genetic population differentiation evidence indicates that there are two separate populations with few genetically effective migrants exchanged between populations annually. Supportive breeding programs are operating as a means to preserve and help restore both populations using native fish as broodstock. Fish produced by the two conservation programs – Kendall Creek Hatchery Program, and Skookum Creek Hatchery Spring-run Program - are ESA-listed (79 FR 20802, April 14, 2014). The Nooksack River may have lost some of the Chinook salmon diversity that once occurred, as historical evidence suggests that a later-returning life history was once present (Ruckelshaus et al. 2006). Williams et al. (1975) describe a summer-fall Chinook salmon run, which entered the river starting in July, with spawning occurring in mid-September through October. The presence of a summer-fall return timing component likely reflects adult returns and straying resulting from long term propagation of non-native Green River lineage stock at several hatcheries in the Nooksack River basin and immediately adjacent areas. In the most recent 5-year period (2010-2014) the two extant early-timed populations accounted for 4.9 and 1.3 percent of the natural-origin Chinook salmon escapement in the ESU, respectively (Table 56 *in* NWFSC 2015). During the most recent five-year period, both populations were below the critical abundance threshold (Table 56 *in* NWFSC 2015). Escapement trends and growth rates derived by NMFS NWFSC through its Abundance and Productivity Puget Sound TRT database indicate the trend and rate for both populations is above 1.0 and increasing (Table 8). The Puget Sound Technical Recovery Team (PSTRT) determined that recovery of both populations to a viable level (low risk of extinction) is essential for recovery of the ESU (Ruckelshaus et al. 2002; NMFS 2006b). The 2015 status review found that the Strait of Georgia BGR has had an increasing hatchery influence, particularly in the last 5-years when hatchery-origin fish made up nearly 85% of the spawners and the number of natural origin fish declined by 54% relative to the previous 5-year period (NWFSC 2015).

Nooksack River Chinook: As described above, the two Nooksack River basin Chinook salmon populations – North Fork Nooksack (also referred to as North/Middle Fork Nooksack early Chinook) and South Fork Nooksack are the only Chinook populations within the Georgia Strait Basin BGR (SSPS 2005b; NMFS 2006b). In addition, there is a non-native (Green River origin) fall Chinook population originating from hatchery releases that also spawns within Nooksack River basin (WDF et al. 1993). Both ESA-listed Nooksack River basin natural populations are primarily ocean-type Chinook salmon, with juveniles largely emigrating seaward in March through early-July (Lummi Natural Resources Department [LNRD] 2013). Yearling smolts made up less than 1% of juvenile Chinook captured in the Lummi Nation's smolt trap from 1999 through 2013. However, these results are confounded by the complexity of contributing stocks (e.g., non-native fall Chinook) and differences in trap efficiencies for yearling and sub-yearling smolts. An earlier analysis of scales collected from North Fork spawners showed that a large proportion (91%) emigrated from freshwater at age-0 (PSIT and WDFW 2010). Other assessments have estimated that 69 percent of S.F. Nooksack Chinook emigrated as yearlings (Myers et al. 1998). A more recent analysis of scales using only years when a minimum of 40 samples were available determined that the sub-yearling and yearling outmigration percentages for natural-origin South Fork Nooksack Chinook salmon were 62 and 38 percent respectively (WRIA 1 Salmon Recovery Board 2005 citing PSTRT 2003). More recent sampling indicated that the North Fork Nooksack population was composed of 71 and 29 percent sub-yearlings and yearlings respectively (WRIA 1 Salmon Recovery Board 2005 citing PSTRT 2003). Myers et al. (1998) concluded that some spring Chinook salmon populations have a high proportion yearling smolt emigrants, but the proportion varies and appears to be environmentally mediated rather than genetically determined.

Age composition of returning natural-origin Chinook salmon adults from 1993 to 2002 indicates that the majority return at age-4 (PSIT and WDFW 2010, and following). Age distributions for the two populations are: North Fork: age-2 (<1%), age-3 (19%), age 4 (59%), age-5 (22%), and age-6 (<1%); South Fork: age-2 (0%), age-3 (12%), age 4 (72%), age-5 (16%), and age-6 (0%). There is less confidence in the age distribution estimates in the South Fork Nooksack population due to low sample sizes.

Adult spring Chinook salmon return to the Nooksack River from February through July with peak entry occurring in May and June (Mauldin et al. 2002). Upstream migration occurs in four stages: river entry, upriver migration, holding, and spawning (WRIA 1 Salmon Recovery Board 2005 citing Barclay 1980; 1981, and following). Some of the spring Chinook salmon that were radio-tagged in the lower river in 1980 and 1981 moved directly upriver after tagging, while others remained in the lower river, even moving back to the marine environment. Upon acclimation, they moved upriver at uniform rates of 1.7 (1980) and 1.5 (1981) miles per day, for a total of 30 to 40 day transit time to the confluence of the North and South forks. The early Chinook hold for long periods, with some fish holding in individual pools for up to 4 weeks.

The North Fork natural population spawns from late-July through September in the North Fork from the confluence with the South Fork (RM 36.6) to Nooksack Falls (RM 65), and in the lower Middle Fork to RM 7.2 (where a diversion dam blocks migration), as well as in numerous larger tributaries including: Deadhorse, Boyd, Thompson, Cornell, Canyon, Boulder, Maple, Kendall, MacDonald, Racehorse, and Canyon Lake creeks (WRIA 1 Salmon Recovery Board 2005, and following). The highest spawning densities are in the North Fork from RM 45.2 to 63. The South Fork population spawns from mid-August through September in the South Fork from the confluence with the North Fork (RM 0) to Sylvester's Falls (RM 25), and in many years spawning occurs upstream of the 11 to 12 foot falls to RM 30.4. The highest spawning densities are typically between RM 8.5 and RM 20.7. Spawning also occurs in the larger tributaries including: Hutchinson, Skookum, Deer, and Plumbago creeks. Peak spawning in the South Fork is typically two to three weeks later than in the North Fork (WRIA 1 Salmon Recovery Board 2005, citing Barclay 1980).

Abundance of Nooksack River basin Chinook salmon is a fraction of historical levels (SSPS 2005b), with the South Fork at critical status and the North Fork near critical (critical status for the last five years where data are available; geometric mean =154). The most recent NMFS status review estimates of escapement, hatchery contribution, and productivity for the Nooksack Basin Chinook salmon natural populations are summarized in Table 7 and Table 8. A recovery hatchery program for the North Fork population has operated at the Kendall Creek Hatchery since 1981 (PSIT and WDFW 2010). Peak production included up to 142,500 unfed fry, 2.3 million fingerlings, and 348,000 yearlings. The program has evolved through time and now releases a total 750,000 sub-yearlings divided between three release locations: Kendall Creek, Boyd Creek (tributary to the North Fork at RM 63), and McKinnon Ponds (tributary to the Middle Fork at RM 4.4 (WDFW 2013b). Natural spawning escapement from 1998 through 2013 has ranged from 370 (1998) to 3,741 (2002); averaging 1,611 (Figure 11). Natural-origin spawners during this period have ranged from 37 (1998) to 334 (2007); averaging 213. The proportion hatchery-origin Chinook spawning naturally has ranged from 94 percent (2002) to 63 percent (2012). The 5-year geometric mean abundance for the North Fork Nooksack population was 277 natural -origin adults from 2005 through 2009 and only 154 from 2010 through 2014; indicating an overall decline of -44% (from Table 56 *in* NWFSC 2015). Many of the fish from the North Fork Nooksack Chinook salmon population spawn in the South Fork Nooksack River; these fish are not counted in the trend analysis included in the 2015 status review. Approximately 21% (range 0-45%) of the natural-origin North Fork Nooksack Chinook spawned in the South Fork Nooksack River from 2000 through 2013 (WDFW and PSTIT 2013; 2014).

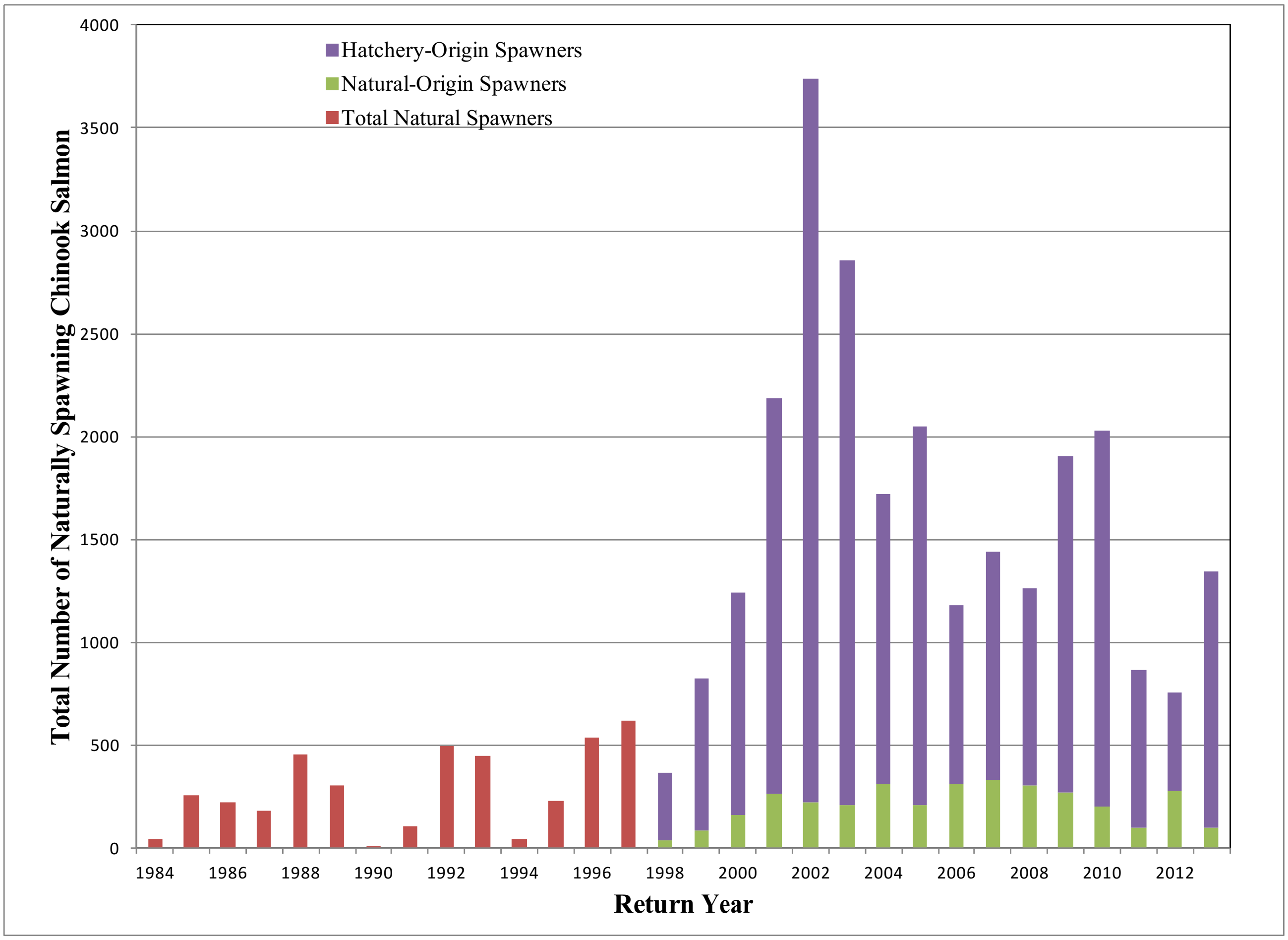

Figure 11. Estimated annual naturally spawning Chinook salmon escapement abundance in the North and Middle Forks Nooksack River and tributaries for return years 1984 – 2013. Data sources: (WDFW and PSTIT 2013; 2014).

The South Fork Nooksack Chinook salmon population comprises only a fraction of the early naturally spawning Chinook salmon that spawn in the South Fork Nooksack River, the majority are hatchery-origin fish. From 1999 through 2013, South Fork Nooksack Chinook salmon natural-origin spawners comprised 16 percent (minimum 4% [2010 and 2013], maximum 38% [2001]) of the natural-spawners that spawned prior to October 1 (Figure 12). During the most recent five years, the South Fork Nooksack population has averaged only 56 natural-origin spawners (13% of the naturally spawning Chinook salmon) (WDFW and PSTIT 2013; 2014). The 5-year geometric mean abundances for the South Fork Nooksack population were 42 natural-origin adults for 2005 through 2009, and 39 adults from 2010 through 2014. These data indicate there has been an overall decline in abundance for the population for the most recent ten years of -7% (data from WDFW and PSTIT 2013; 2014).

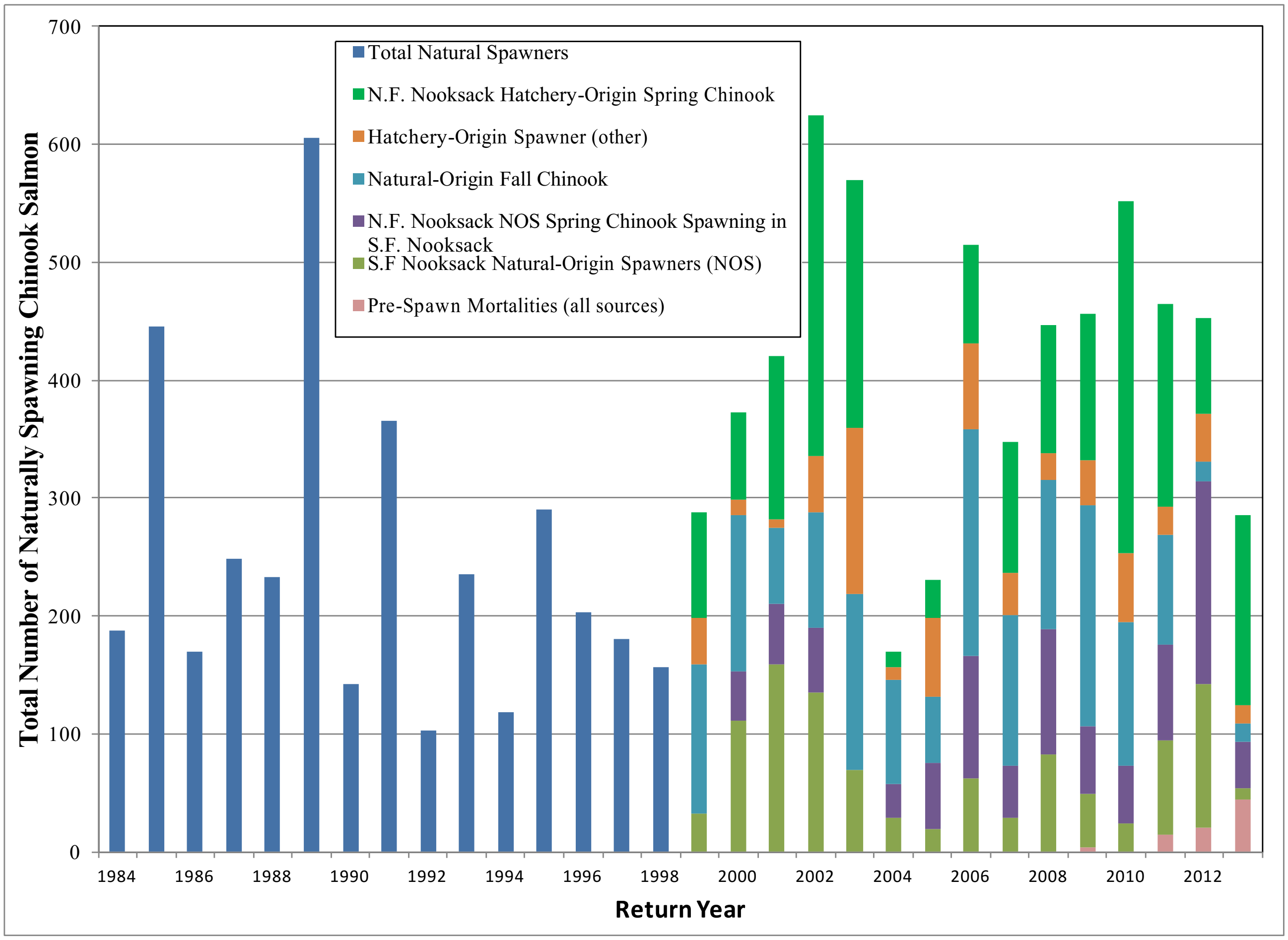

Figure 12. Estimated annual naturally spawning Chinook salmon escapement abundance in the South Fork Nooksack River and tributaries for return years 1984 – 2013. Data sources: WDFW and PSTIT 2013; 2014.

Due to low abundance, a captive broodstock-based hatchery recovery program was established in 2006 (PSIT and WDFW 2010a). The program is now transitioning to a program where fish are held for one year and released as smolts, based at the Lummi Nation's Skookum Creek Hatchery, located on the South Fork Nooksack River. The first release of captive broodstock-origin subyearlings into the South Fork Nooksack River occurred in the spring of 2011, and fish releases have continued annually since then. Adult returns from the conservation program beginning in 2015 are expected to increase the abundance of naturally-spawning South Fork Nooksack early Chinook salmon.

Whidbey Basin BGR: The Whidbey Basin BGR contains 10 populations, including the two populations in the Stillaguamish River basin. 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 (NMFS 2006b). 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 populations identified (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 natural and natural-origin Chinook salmon escapement in the ESU, respectively (Table 56 *in* NWFSC 2015). Abundance varies greatly among the populations (Table 7) with the Skagit populations comprising the majority (76%) of Chinook salmon in the BGR (NWFSC 2015). Based on estimates of the 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 at critical status (WDFW Score Database; NWFSC 2015). As described above, only 5 populations in the ESU 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 8). Long-term growth rates for pre-harvest abundance 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.

Stillaguamish River Basin Chinook -The two Stillaguamish River basin Chinook salmon populations – North Fork summer Chinook and South Fork fall Chinook – are grouped with eight other populations in the Whidbey Basin BGR for recovery planning purposes (SSPS 2005b; NMFS 2006b). Both Stillaguamish River basin populations are ocean-type Chinook salmon with 98 to 100 percent of juveniles emigrating seaward sub-yearlings (SIRC 2005; Griffith et al. 2009; Griffith and Van Arman 2010; Scofield and Griffith 2013). Peak emigration typically occurs in April or May, but some years include bimodal peaks with one in April, followed by another May to early June (Griffith et al. 2009; Griffith and Van Arman 2010; Scofield and Griffith 2013).

Age composition of returning summer Chinook from 1985 to 1991 indicates that the majority of Chinook return at age-4 (PSIT and WDFW 2010a). Age distributions for the summer Chinook population are: age-2 (5%), age-3 (32%), age 4 (55%), age-5 (8%), and age-6 (<1%) (Stillaguamish Tribe 2007).

Adult summer Chinook salmon return to the Stillaguamish River from June through August (Myers et al. 1998). Spawning starts in late August, peaking in mid-September, and extending into mid-October (Stillaguamish Tribe 2007, and following). Spawning occurs in the mainstem North Fork (RM 0.0 to 34.4), with the highest density of spawning between RM 14.3 and 30.0. The Boulder River and Squire Creek are the two tributaries with the highest density of spawners. Summer Chinook salmon also spawn in French, Deer, and Grant creeks. Adult fall Chinook salmon entry timing is much later than the summer Chinook with most fish entering the system in August and September. Spawning takes place from mid-September through October with peak spawning in early- to mid-October. Spawning takes place in the mainstem Stillaguamish River and South Fork Stillaguamish River, and Jim, Pilchuck, and lower Canyon creeks.

The most recent NFMS status review estimates of escapement, hatchery contribution, and productivity for the Stillaguamish Basin natural populations are summarized in Table 7 and Table 8. A natural stock restoration hatchery program for the North Fork population was initiated in 1986 (Stillaguamish Tribe 2007). The maximum release is 220,000 sub-yearlings from the Whitehorse Hatchery (Stillaguamish

Tribe 2007). Natural spawning escapement from 1986 through 2015 has ranged from 371 (2015) to 1,408 (2000); averaging 900 (Figure 13).

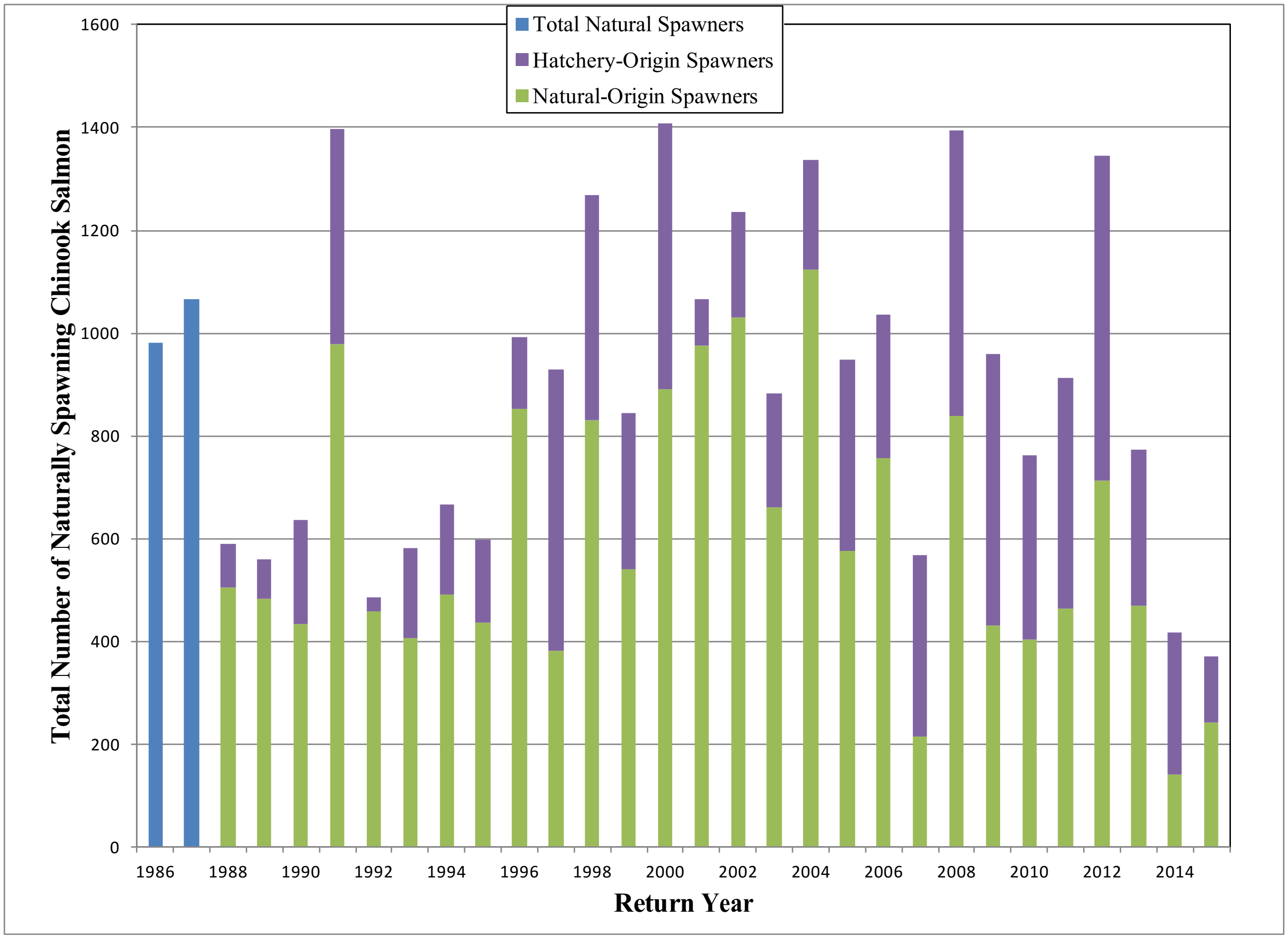

Figure 13. Estimated annual naturally spawning Chinook salmon escapement abundance in the North Fork Stillaguamish River and tributaries for return years 1986 – 2015. Data sources: PSIT and WDFW 2013; 2014; WDFW Score Database.

The lowest two spawning escapements from 1986 through 2015 occurred in 2014 (417) and 2015 (371) (PSIT and WDFW 2013; 2014; WDFW Score Database). Natural-origin spawners during this period (where estimates are available) have ranged from 141 (2014) to 1,123 (2004); averaging 598. The proportion hatchery-origin Chinook spawning naturally has ranged 66 percent (2014) to 5 percent (1992). During the most recent five years (2011-2015), the North Fork population has averaged 406 natural-origin spawners (53% of the naturally spawning Chinook) (PSIT and WDFW 2013; 2014; WDFW Score Database). The 5-year geometric mean abundance for the North Fork Stillaguamish population was 508 natural -origin adults from 2005 through 2009 and 389 from 2010 through 2014, indicating an overall decline of -23% (data from WDFW and PSTIT 2013; 2014; WDFW Score Database). The North Fork Stillaguamish natural-origin escapement has declined in recent years, despite the ongoing natural stock restoration program (PSIT and WDFW 2013). The inability of this supportive breeding hatchery program to rebuild natural abundance is of great concern to resource managers, and is caused by poor and likely deteriorating freshwater and estuarine habitat conditions (PSIT and WDFW 2013).

The abundance of South Fork Stillaguamish River basin Chinook salmon is a fraction of historical levels and is at critical status (SSPS 2005d). Spawning abundance has been below 200 adults for eleven of the last thirteen years (2003 through 2015). Due to a low effective population size, a decreasing abundance trend, low productivity, straying and potential interbreeding with non-native Chinook salmon and North Fork early Chinook salmon, and degraded freshwater and estuarine habitat conditions the population is at a high risk of extirpation (Stillaguamish Tribe and WDFW 2007). A captive broodstock hatchery program was initiated in 2007 to conserve the populations (PSIT and WDFW 2013). Natural spawning escapement from 1986 through 2015 has ranged from 15 (2014) to 353 (2002); averaging 171 (Figure 14). During the most recent five years, the South Fork population has averaged only 95 naturally spawning Chinook (PSIT and WDFW 2013; 2014). Due to the small estimated population size and low numbers of carcasses recovered each year, estimates for natural-origin Chinook are not possible for most years. The 5-year geometric mean abundance for the North Fork Stillaguamish population was 98 naturally spawning adults from 2005 through 2009 and 54 from 2010 through 2014; indicating an overall decline of -45% (data from WDFW and PSTIT 2013; 2014; WDFW Score Database).

2.2.2.2 Status of Critical Habitat for Puget Sound Chinook Salmon

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

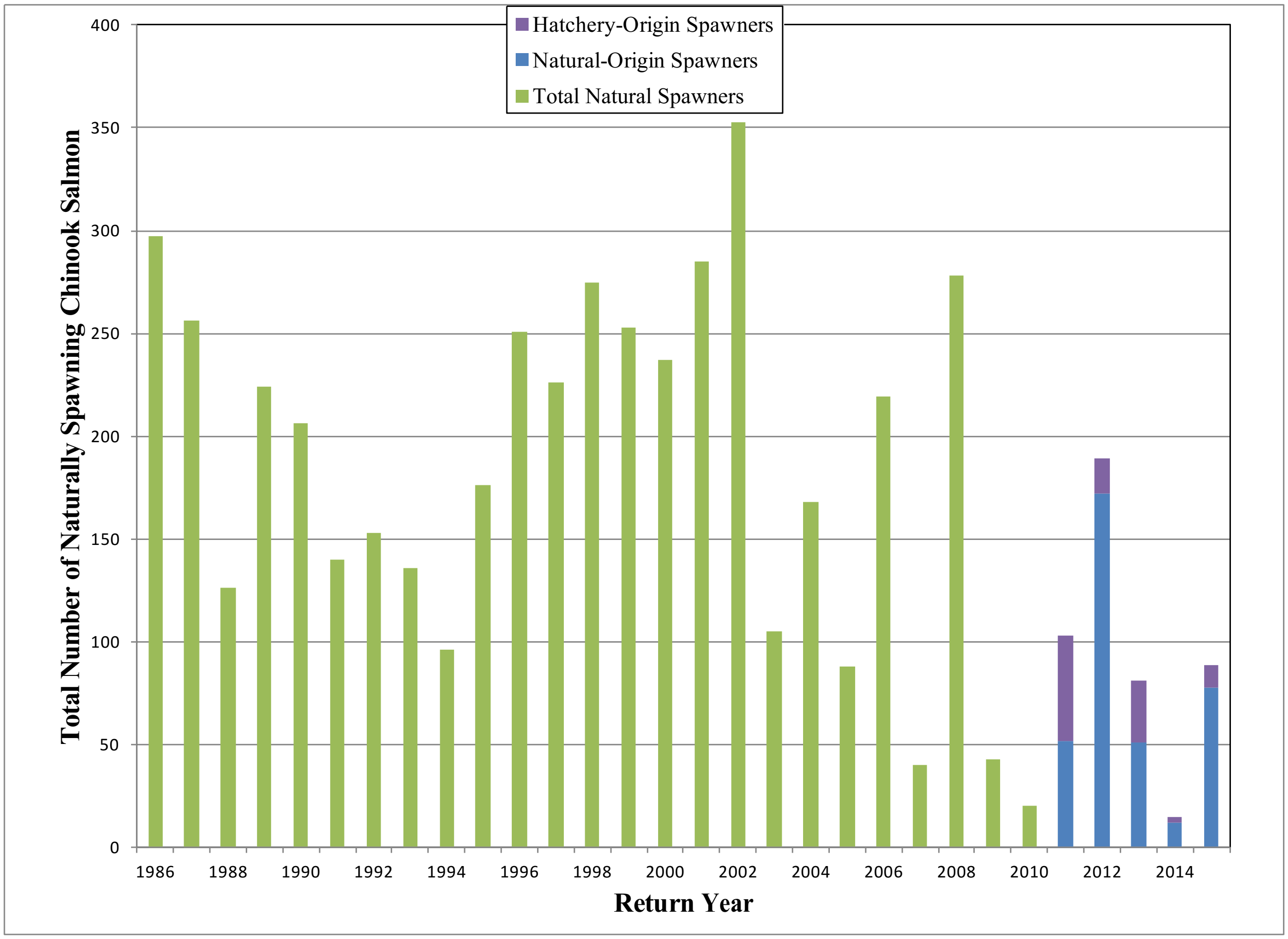

Figure 14. Estimated annual naturally spawning Chinook salmon escapement abundance in the Stillaguamish River and South Fork Stillaguamish River and tributaries for return years 1986 – 2013. Data sources: PSIT and WDFW 2013; 2014.

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 Dungeness, Nooksack, and Stillaguamish 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 Dungeness, Nooksack, and Stillaguamish river basin action areas. Critical habitat includes the estuarine areas and the stream channels within identified stream reaches of the Dungeness, Nooksack, and Snohomish sub-basins (70 FR 52630, September 2, 2005), and includes a lateral extent of the areas and channels as defined by the ordinary high-water line (33 CFR 319.11). The Puget Sound CHART identified management activities that may affect the PCEs for Chinook salmon in the three subbasins (NMFS 2005a). These activities included forestry, grazing, agriculture, road building/maintenance, channel modifications/diking, urbanization, sand and gravel mining, mineral mining, dams, irrigation impoundments and withdrawals, river, estuary, and ocean traffic, wetland loss/removal, beaver removal, and exotic/invasive species introductions (this and following from NMFS 2005a). In the Dungeness River watershed, channel/bank modifications (from boat ramp construction, bulkhead placement, riprap, diking and/or dredging), forestry, irrigation impoundments and withdrawals, road building and maintenance, sand and gravel mining, and urbanization were the main activities affecting Chinook salmon PCEs. Forestry, agriculture, grazing, and road building and maintenance were identified as the primary activities affecting PCEs for the species in the Nooksack River watershed. Forestry and road building and maintenance were the main activities affecting Chinook salmon PCEs in the Stillaguamish River watershed. All of these activities have PCE-related impacts via their alteration of one or more of the following: stream hydrology, flow and water-level modifications, fish passage, geomorphology and sediment transport, temperature, dissolved oxygen, vegetation, soils, nutrients and chemicals, physical habitat structure, and stream/estuarine/marine biota and forage (NMFS 2005a, citing Spence et al. 1996).

2.2.3 Climate Change

Climate change has negative implications for designated critical habitats in the Pacific Northwest (Climate Impacts Group 2004; Scheuerell and Williams 2005; Zabel et al. 2006; ISAB 2007). 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 continues 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.

Dungeness River Basin:

A wide variety of human activities have affected listed Puget Sound steelhead and Puget Sound Chinook salmon, and Puget Sound Chinook salmon PCEs and proposed PCEs for steelhead, in the Dungeness River basin. These activities, more recently, include reclamation actions that are having beneficial effects. The Dungeness Basin is approximately 518 km^2 (200 $miles^2$) in area (Thomas et al. 1999), with its headwaters in the Olympic Mountains (Myers et al. 2015). Approximately 51,000 acres or 30 percent of the watershed is within the Olympic National Park (Table 9). In the lower 10 miles, the river flows through a broad valley before emptying into Dungeness Bay and the Strait of Juan de Fuca. The basin area includes over 546 miles of streams and tributaries and 33 miles of shoreline (SSPS 2005c). Geologically, the basin consists of volcanic bedrock and unstable glacial deposits that produce a high sediment load in surface flows (Haring 1999). The upper basin is glacially influenced and the flow regime in the Dungeness River is snowmelt dominated. Rainfall is the lowest of the Puget Sound basins (SSPS 2005c). Surface flows in the Dungeness River fluctuate seasonally, and there are two distinct high flow periods: snowmelt in the upper watershed resulting in high flows in the spring and early summer, and rainfall in the upper watershed resulting in high and more variable flows in the winter (Thomas et al. 1999).

In terms of resource extraction, commercial and private forestlands account for the majority of land use in the basin followed by rural and agricultural lands (21%) which dominate the floodplain (SSPS 2005c) (Table 9). Both the upper and lower watersheds have been logged over multiple generations. Formation of Olympic National Park protected headwater areas from logging but other sections of the upper watershed in the Olympic National Forest remain in commercial timber production. In these upstream

Table 9. Land use in the Dungeness River watershed[1] (Haring 1999).

Land Use	Acres	Percent of Area Watershed
Commercial Forestland	74,624	43.3
Residential High Density	1,364	0.8
Residential Low Density	5,940	3.4
Cropland	420	0.2
Pasture/Hayland	9,899	5.7
Grass/Scrub/Shrub	7,103	4.1
Private Woodlots	8,735	5.1
Conversions	2,377	1.4
Urban Lands	410	0.2
Ponds/River Channels	808	0.5
Quarries	167	0.1
Olympic National Park	51,308	29.7
Unclassified	9,362	5.4
Grand Total	**172,517**	

[1] The Dungeness "watershed" evaluated in Haring (1999) included the Dungeness River watershed, as well as several independent tributaries to the Strait of Juan de Fuca. These additional subbasins include: Gierin, Cassalery, Cooper, McDonald, Siebert, and Bagley Creeks.

areas, sediment input from unstable soils on steep slopes and forestry practices (particularly forest road management) have produced excessive sediments loads in the river (Haring 1999). These habitat impacts have led to river channel braiding and aggradation; disconnection of the river from its floodplain; blocking of access to productive side channel habitat; scouring of redds; and seasonal low flows that can severely impair salmonid stocks (EDPU 2005). Revised National Forest policies for timber management implemented in the upper watershed have become more protective of fish and wildlife species. The National Forest Service has targeted road remediation in the Dungeness River watershed to reduce the erosional and slope destabilization effects of logging road construction.

Dikes, bank armoring, and bridges confine the mainstem Dungeness River, disconnect off-channel habitat, reduce edge habitat complexity, and decrease channel stability. Beginning in the 1890s, extensive diking and conversion of historic estuary to agriculture and development lots has completely modified the Dungeness River estuary from historic condition (this and following generally from Haring 1999 and SSPS 2005). The marine nearshore habitat in Dungeness Bay has been affected by the alteration of sediment transport from the Dungeness River, by shoreline armoring, and by loss of eelgrass habitat (Haring 1999). Fish habitat in the lower 11 miles of the Dungeness River was further impacted by bank hardening to protect adjacent settled lands from erosion and flooding; clearing of riparian vegetation; gravel extractions; and operation of water diversions for irrigation purposes (Haring 1999; EDPU 2005). Dikes, levees and other actions to control the lower reaches of the river degraded rearing and migration areas for juvenile salmon. Tributaries truncated by these developmental activities harmed over-wintering habitat for coho salmon and steelhead, and contributed to scouring of redds (SSPS 2005a). Diking along the river constricted the natural process of stream channel formation and the transport of sediment. Major dikes are currently located on the east bank from RM 0 -2.6 (the “Corps” dike) as well as RM 7.6 - 8.4 (the Dungeness Meadows dike)(SSPS 2005a). Smaller dikes and embankments constructed by private property owners are located throughout the lower ten miles of the mainstem river. Five bridges currently cross the Dungeness River and constrict the river, increasing water velocities and erosion potential to the detriment of salmon spawning, rearing and migration conditions downstream. (SSPS 2005c).

A full river spanning weir has operated at the Dungeness River Hatchery at RM 10.8 beginning in the 1930s. The weir blocked Chinook salmon access to upstream spawning areas for approximately 50 years (SSPS 2005a). Although the weir was abandoned in the 1980s[9], its operation in prior years adversely affected to an unknown degree the abundance and spatial structure of the natural-origin Dungeness Chinook population.

The Dungeness River is the river system most affected by irrigation withdrawals in western Washington (Haring 1999). Water rights were severely over-appropriated in a 1924 adjudication, and biologists measuring irrigation withdrawals in September of 1987 found that 82% of the total flow was being withdrawn (Clallam County and Jamestown S'Klallam Tribe 2005)). The source for this water is the Dungeness River, and groundwater in its associated aquifer. Most of the water is diverted from the watershed for agricultural use through multiple water diversions (Figure 15) between mid-April and Clallam County's population increased by over 76 percent between 1970 and 1992 and continues to grow today (SSPS 2005c). With the increasing human population in and around the city of Sequim, the demand for water for irrigation, domestic, and business use has markedly increased (SSPS 2005a). In addition, burgeoning human development in the watershed has added contaminated run-off from a variety of urban, agricultural, residential and other sources. All these activities adversely impact water quality. The Clallam Conservation District has implemented major improvements in irrigation ditch systems to reduce or eliminate the addition of pollutants into the Dungeness River, tributaries and Dungeness Bay. Additionally, water temperatures in the Dungeness mainstem and side channels have improved by the reduction of diverted for agricultural purposes (Clallam County and Jamestown S'Klallam Tribe 2005).

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[9] Since that time, returning adults are collected primarily as volunteers to an off-channel hatchery trap.

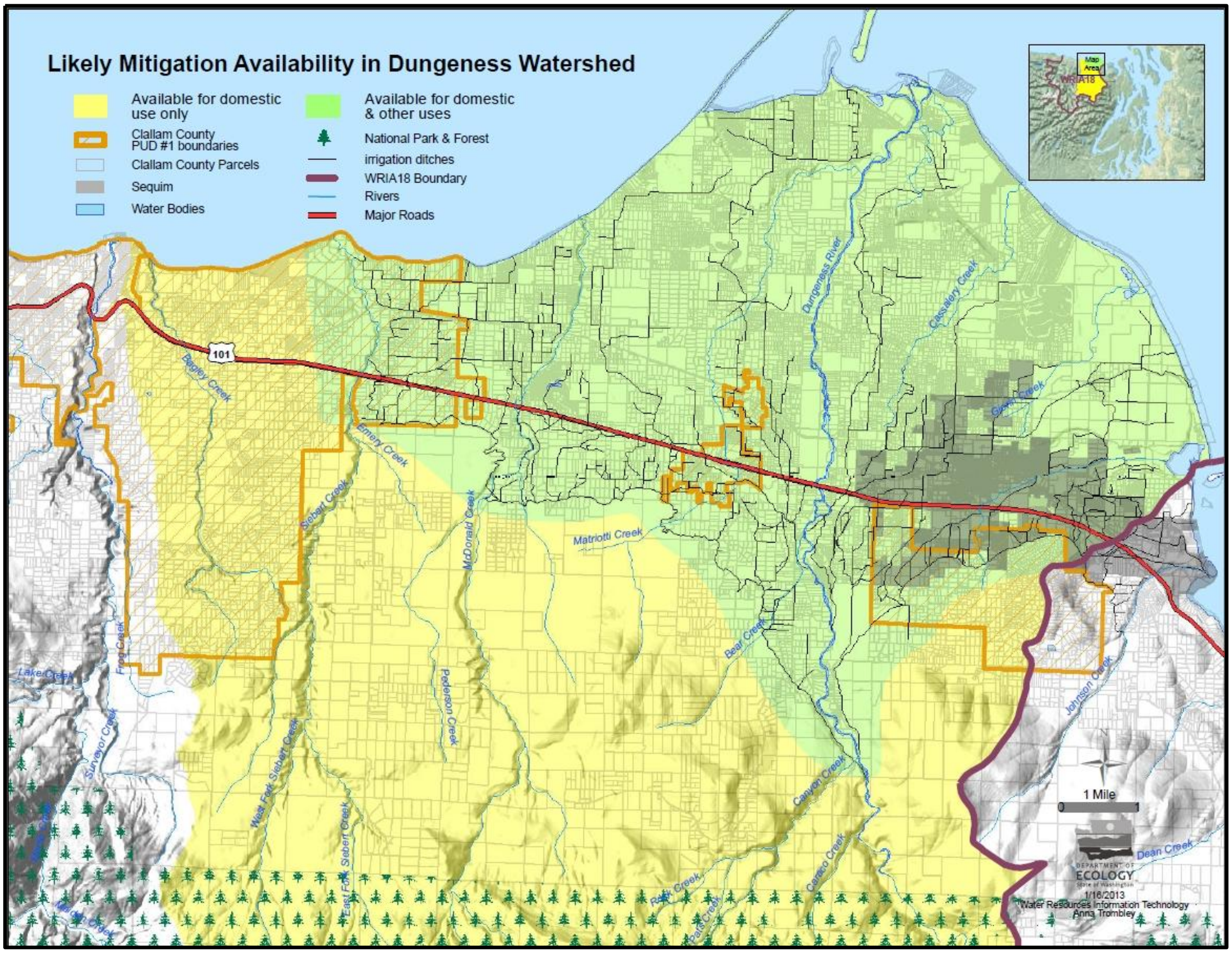

Figure 15. Irrigation water withdrawal locations and ditch systems within the Dungeness River Basin. Source: WDOE, 2014 - http://www.ecy.wa.gov/programs/wr/instream-flows/dungeness/dungeness-rule-map-avaliability.pdf

> “Water rights for irrigation and municipal purposes in the Dungeness River watershed greatly exceed summer low flows (540 cfs water rights vs. 173 cfs summer low flow) (Draft CIDMP, SDVAWUA, 8/29/03). Although these rights have never been fully utilized, in 1987 water users are estimated to have withdrawn 82% of the total river flow (~120 cfs) leaving ~25 cfs in the river (JSKT, 2003). Such a radical withdrawal of water virtually extinguished the ability of salmon to migrate upstream. In addition, spawning locations were limited to the mid-channel, where redds would be subjected to scour during winter storm events. In more recent years, water conservation measures undertaken by the irrigation districts, along with changing water needs, have dramatically reduced diversion rates. In 2001, 33% of the total river flow was diverted (~40 cfs), while ~95 cfs remained in the river (JSKT, 2003). Even with these reduced diversions, water withdrawals continue to affect salmon spawning and rearing habitat.

> Two Incremental Flow Instream Methodology (IFIM) analyses on the Dungeness River show that during summer low flow conditions, each cfs of stream flow represents about 1% of the weighted usable area (WUA) of the river (USFWS, 1991). In addition, recent work shows that side-channel habitat is very sensitive to flow (BOR and JSKT, 2003). In particular, this study found that in order to maintain conditions in most surface-fed side-channels suitable for spawning Chinook, the mainstem flow must exceed 180 cfs. When flows drop below 105 cfs, only one side-channel appears to meet spawning requirements for Chinook salmon. Juvenile Chinook rearing habitat could be maintained in these side-channels at slightly reduced mainstem flows.""

With continued population growth in the region, threats to salmon and steelhead habitat and to the fish populations themselves are likely to persist. Areas along the mainstem river and along some lowland tributaries are the most vulnerable. When riverine lands are converted to residential and urban areas, forest cover and ecosystem processes are altered or lost.

Nooksack River Basin:

The Nooksack Basin is approximately 832 sq. miles (2,155 km2) in area, including 48.9 sq. miles draining Canada (WRIA 1 Salmon Recovery Board 2005, Williams et al. 1975). The watershed is composed of five primary subbasins: lower Nooksack (27%), Lummi River (3%), South Fork Nooksack (22%), North Fork Nooksack (36%) and the Middle Fork Nooksack (12%) (WRIA 1 Salmon Recovery Board 2005). The North and Middle forks originate from Mount Baker snowfields and glaciers and are typically turbid during moderate flows during the summer months due to snow and glacial melt (Smith 2002). The South Fork drains the slopes of the Twin Sisters Mountain and summer-time streamflows are typically low and clear (Smith 2002). The North and Middle Forks flow through moderate and low gradient nested valleys bound on either side by steep mountains (WRIA 1 Salmon Recovery Board 2005). The mainstem Nooksack River forms at the confluence with the North and South Fork Nooksack Rivers, emerging from the cascade foothills, and then meanders across a broad glacial outwash plain (Easterbrook 1976; Cox and Kahle 1999) and finally terminates at its confluence with Bellingham Bay. The Lummi River is a historical tributary channel of the Nooksack River located at RM 4.5. Within the Nooksack River basin, over 654 tributary rivers and streams have been identified, totaling approximately 1,325 miles in length (Williams et al. 1975).

The Middle Fork Nooksack River has a diversion dam which serves as a supplemental water source to Lake Whatcom; Lake Whatcom is Bellingham's source of municipal water (Greenberg 2012). The lower Nooksack River also serves as the primary water source for the cities of Lynden, Everson, and Ferndale (Greenberg 2012). In addition, surface waters are diverted by Whatcom County PUD for residential, irrigation, and industrial uses. The cities of Ferndale, Lynden, and Everson, as well as the Lummi Nation and Nooksack Indian Tribe reservations are located within the Nooksack River basin (WRIA 1 Salmon Recovery Board 2005).

Forested lands or wilderness comprise approximately 80-85 percent of the land cover in the North, South, and Middle Fork subbasins (WRIA 1 Salmon Recovery Board 2005, and following). Developed land cover makes up less than 1 percent of the area in the North (0.66%), South (0.21%), and Middle Fork (0.04%) subbasins. Forested land cover in the late-seral stage is concentrated in the upper portions of the three subbasins, with a mix ranging from mid-seral stage to stand initiation phase throughout the mid- to lower-North and Middle Fork subbasins and throughout most of the South Fork subbasin downstream of the Mt. Baker-Snoqualmie National Forest boundary. Within the North and Middle Fork subbasins, approximately 32 to 35 percent of the forested land cover is in the late-seral stage, as compared to 15 percent in the South Fork subbasin. Land cover within the lower Nooksack and Lummi River subbasins is predominantly classified as agricultural. Forested uplands only comprise 26 to 28 percent of the land cover within these two subbasins. However, most of these forested areas have less than 10 percent crown cover and none are in late-seral stage. Early- and mid-seral stage forested areas comprise 22 and 11 percent of the forested acres within the lower Nooksack subbasin.

The majority of the Nooksack River valley's native forest had been burned and logged by the beginning of the 20th century (Collins and Sheikh 2004). Historically the Nooksack and Lummi rivers formed an extensive and complex delta containing numerous estuarine and riverine-tidal wetlands, with the Lummi River entering Lummi Bay and Nooksack River entering Bellingham Bay (Collins and Sheikh 2004). In the late 1800s, a diversion structure was built to permanently divert most of the Nooksack River's flow away from the Lummi River and into Bellingham Bay (Smith 2002 citing People for Puget Sound 1997). The delta and estuarine habitats were further diked and channelized in the early 20th century (Smith 2002). Channelization, channel alteration, and dikes closed off deltaic distributaries and blind-tidal channels from water influx (Collins and Sheikh 2004). By the 1930s, between 65 and 80 percent of the estuarine floodplain had been converted to agricultural land use (Brown et al. 2005). The estuarine wetland area in 1998 was approximately 30 percent of the estimated area in 1880, mainly as a result of the diking of the Lummi River (Collins and Sheikh 2004). However, Brown et al. (2005) report that aerial photos from 1933 to 2005 indicate that the Bellingham Bay side of the estuary has expanded, mostly unimpeded by man, and developed into a diverse network of distributaries and blind channels, and now represents one of the most pristine estuaries in the Puget Sound. Habitat conditions on the Lummi Bay side of the estuary have not improved since the 1930s (Brown et al. 2005).

By the earlier 20th century, the lower mainstem Nooksack River had been shortened through meander cutoffs, while the upper mainstem river shifted from an anastomosing channel pattern to a braided channel (Smith 2002; Collins and Sheikh 2004). Dikes, bank armoring, and levees have converted nearly the entire mainstem Nooksack River to a single thread channel, resulting in a major loss of slough, side-channel, and off-channel habitats (Smith 2002). Downstream of Everson the entire length of the mainstem is leveed and/or armored, whereas only 20 percent of the mainstem is modified from Everson to the confluence of the North and South forks (WRIA 1 Salmon Recovery Board 2005). Further habitat losses resulted from extensive filling of floodplain wetlands adjacent to the mainstem. The levees, dikes, and bank armoring restrict channel migration and the development of complex in-river habitats, as well as off-channel habitats (WRIA 1 Salmon Recovery Board 2005). Cumulatively, floodplain impacts along the mainstem are believed to be among the greatest habitat limiting factors present downstream of the confluence of the North and South Forks (Smith 2002).

Floodplain impacts along the North Fork Nooksack River floodplain include: roads, dredging, channel straightening, and bank armoring (Smith 2002). Approximately 41-percent of the North Fork Nooksack River floodplain is constrained by bank hydro-modifications (WRIA 1 Salmon Recovery Board 2005). By the late-1930s, much of the South Fork Nooksack River had been straightened, the largest logjams had been removed, and many wetlands had been filled or otherwise lost; collectively this resulted in channel shortening and simplification, and loss of side-channel and off-channel habitats (Smith 2002). Approximately 61-percent of the lower mainstem South Fork is either diked or armored (WRIA 1

Salmon Recovery Board 2005). Dikes and bank armoring occur along 36-percent of the lower Middle Fork Nooksack River (WRIA 1 Salmon Recovery Board 2005).

Riparian forest cover has been substantially degraded within Nooksack River basin, reducing large woody debris recruitment and further simplifying channel habitat. Coe (2001) conducted an extensive inventory of riparian conditions which included 17,923 acres of riparian habitat in the mainstem and North, Middle, South Forks (Coe 2001, and following). Commercial forestry (36%) was the most common land use classification, followed by agriculture (22%), rural (15%), federal forest (15%), rural forest (7%), urban (3%), and federal park (2%). Coe (2001) found that near term large woody debris recruitment potential (LWDRP) varied by subbasin and overall was predominately low (50%). Moderate and high LWDRP were 19 and 31 percent by area, respectively. The mainstem subbasin had the highest proportion of land area classified as having low LWDRP at 76 percent, followed by the South Fork (41%), Middle Fork (34%), and North Fork (32%).

Other limiting factors identified within the Nooksack River basin include: channel instability, sediment load, habitat diversity, key habitat quantity, habitat connectivity, water withdrawals, stream flow, and water temperature (WRIA 1 Salmon Recovery Board 2005, and following).

Factors affecting channel stability are hypothesized to include: 1) increased magnitude and/or frequency of peak flows; 2) decreased flow resistance and in-channel sediment storage due to lack of large wood in the channel; 3) increased coarse sediment supply from mass wasting; 4) increased bank erosion due to loss of riparian vegetation that provides bank stability; and 5) hydro-modifications that restrict access of flood flows to the floodplain. Factors affecting channel stability are hypothesized to include: 1) increased fine sediment delivery due to mass wasting and surface erosion from managed forest lands; 2) increased bank erosion due to loss of riparian vegetation that provides bank stability; 3) disconnection of the channel from adjacent floodplain and wetlands, which can store fine sediments during overbank flows; and 4) loss of riparian vegetation that can trap fine sediment from upland runoff and overbank flows by slowing velocities and causing fine sediments to settle out.

Factors affecting loss of habitat diversity include: 1) loss of large in-channel wood; 2) disconnection of the channel from the floodplain due to channel incision or flood control; 3) simplification of bank condition through bank hardening; 4) loss of channel sinuosity through channelization; and 5) debris flows and frequent channel shifting. Factors affecting loss of key habitat include: 1) loss of in-channel wood, which forms and maintains pool habitats; 2) loss of floodplain habitat-forming processes due to channel incision or artificial confinement that disconnects the channel from its floodplain; 3) pool infilling through increased coarse sediment delivery; and 4) loss of mainstem habitat and edge habitat length due to channel straightening, meander cutoffs, and conversion to single-thread channels.

In-channel obstructions such as culverts, dams, tidegates, and floodgates can impede or block altogether access to upstream habitats. Complete barriers to fish passage affect the spatial distribution of spawning and rearing habitats. Whatcom County Public Works (Whatcom County Public Works 2006) describe a total of 1,673 sites having been assessed for fish passage; of these sites 837 had barriers to fish passage, blocking, at least partially, access to an estimated 650 miles of stream habitat. Smith (2002) includes the Middle Fork diversion as the highest priority barrier within Nooksack River basin.

Stillaguamish River Basin:

The Stillaguamish is the fifth largest river basin draining into Puget Sound (SIRC 2005). It drains the west slope of the Cascade Mountains and foothills and has a watershed area of approximately 684 sq. miles (1,772 km2) (Williams et al. 1975). The Stillaguamish River enters Puget Sound near Stanwood, through a complex delta system. The primary delta channel (Hat Slough) enters Port Susan, but the Old Stillaguamish River (distributary at RM 3.0) flows to the north and splits into two primary channels: South Pass (which enters Port Susan) and West Pass (which enters Skagit Bay). The watershed can be divided into three primary subbasins: lower mainstem Stillaguamish, South Fork Stillaguamish, and North Fork Stillaguamish (WCC 1999; SIRC 2005). The mainstem is formed by the confluence of the North and South Forks at RM 17.8, in the city of Arlington. The North and South Fork subbasins drain 284 and 254 square miles of the Stillaguamish River watershed, respectively (SIRC 2005).

The North Fork Stillaguamish emerges from a shallow canyon about 2 miles northwest of the city of Darrington and then turns west and flows 35 miles over a low-gradient valley to its confluence with the South Fork (Williams et al. 1975). The South Fork Stillaguamish originates in the vicinity of Lewis Peak and flows north for approximately 8 miles until its confluence with Coal Creek, where the river turns west and flows approximately 45 miles to its confluence with the North Fork. Elevations within the watershed range from sea level to 6,854 feet at Three Fingers Mountain (SIRC 2005). The three largest tributaries to the watershed include: Pilchuck Creek (76.2 sq. mi.; 11% by area), tributary to the mainstem; Deer Creek (66 sq. mi.; 9.6% by area), tributary to the North Fork; and Canyon Creek (63 sq. mi.; 9.2% by area), tributary to the South Fork (Williams et al. 1975; SIRC 2005; Myers et al. 2015). The Stillaguamish basin includes more than 3,112 miles of river, stream, and marine shore habitat (SIRC 2005); including more than 890 miles of anadromous stream habitat (WCC 1999 citing Pess et al., in press).

The Stillaguamish watershed is within the boundaries of Snohomish (73%) and Skagit (27%) counties, as well as the cities of Arlington, Stanwood, and Granite Falls (Washington State Conservation Commission 1999). Land use within the watershed is 76 percent forestry (includes federal, state, and private lands), 17 percent rural, 5 percent agriculture, and 2 percent urban (SIRC 2005). The Stillaguamish River watershed has extensive consumptive surface and ground water withdrawals which include the permitted consumptive use of 81.3 and 56.4 cubic feet per second of surface water and groundwater, respectively (Pelletier and Bilhimer 2004). Irrigation withdrawals represent the majority of consumptive surface water use within the basin (Pelletier and Bilhimer 2004). The human population within the Stillaguamish River watershed in 2005 was estimated to be 58,441, and population growth in Snohomish County is growing at an annual rate of 2.7 percent (SIRC 2005). Continued population growth will place increasing pressure on water use within the basin. In 2005, Washington State established the Stillaguamish Basin Water Management Rule (WAC 173-505) which established minimum instream flows for 32 stream and river segments throughout the basin.

As described above 76 percent of the watershed area land use is classified as forestry with 28, 21, and 51 percent under private, state, and federal ownerships, respectively (SIRC 2005). Less than 7 percent of Mt. Baker-Snoqualmie National Forest lands are designated for timber production (i.e., matrix land) (SIRC 2005). Extensive landslides and increased frequency and magnitude of high stream flows have been attributed to past forest practices within the basin (WCC 1999). An analysis of over 1,000 landslides within the basin revealed that 74 percent were associated with clearcuts and roads (SIRC 2005, citing Collins 1997). Forestry-related impacts on salmonid habitat have contributed, along with other land use impacts, to the decline of the historical salmonid habitat quality and productivity within the basin, thus effecting the existing populations of salmonids (SIRC 2005, and following). Many important river and stream habitats within the basin are on or near agricultural lands. Floodplain wetlands and riparian areas along the mainstem, North and South Forks, and larger tributaries have been converted to agricultural lands and are actively farmed. Significant portions of floodplain habitats throughout the basin have been cleared of native forests, diked, and drained for agricultural use. The conversion of existing forest and agricultural lands to rural residential and urban uses contributes to habitat degradation. Continued population growth and subsequent conversion of lands to more intensive uses will place increasing pressure on hydrologic and floodplain function, water quality, and habitat quality. Salmon and steelhead populations are facing increasing threats from land use development. The areas along mainstem rivers and along some lowland tributaries are most likely to be affected by growth and development pressures. When riverine lands are converted to residential and urban areas, forest cover and ecosystem processes are altered or lost.

Historically, a mixed forest consisting of deciduous and coniferous trees dominated the lower Stillaguamish River, however, between 1870 and 1910 most large conifers were cut down along the mainstem and lower South and North Forks (SIRC 2005). By the 1940s, most of the riparian areas within the basin had been logged. Factors for the decline of riparian function can be attributed to: forest removal, road and railroad construction, land use conversion, dike and revetment construction, grazing, and invasive plants (SIRC 2005). Historically, the Stillaguamish estuary consisted of a well-developed network of blind tidal channels that drained large areas of salt marsh wetland (Stillaguamish Natural Resources Department (SNRD 2005), citing Collins 1997, and following). The lower mainstem contained numerous, large, channel-spanning logjams and log rafts that maintained adjacent subsidiary sloughs. By the 1870s, most of the forest along the lower river had been cleared and this reduced the input of large woody debris and associated fish habitats. These lower river areas were largely converted to agricultural use and many of the salt marsh and blind tidal areas and most of the large logjams were eliminated. These lower river areas are critically important to salmon and steelhead, particularly as juvenile fish make the transition from fresh to saltwater. Prior to Euro-American settlement there were approximately 4,448 acres of salt marsh connected to the basin, by 1886, only one-third of the salt marsh remained. By 1968, only 15 percent of the original salt marsh remained with a similar loss of blind tidal channels. From 1968 to the 1990s, approximately 863 acres of newly accreted salt marsh were formed; however, this new habitat lacks a well-developed channel network, and is not of the same quality as the historical salt marsh that was destroyed.

Numerous limiting factors have been implicated as factors for decline, as well as factors that are currently limiting the productivity of salmonids within the basin. Currently, known or hypothesized limiting factors include: barriers to fish passage (e.g., culverts and tide gates), floodplain connectivity, riparian conditions, channel conditions, water quality, hydrology, and nearshore and estuarine habitat conditions (WCC 1999). Access to spawning and rearing habitat within the basin is affected by culverts, tide gates, the Cook Slough Weir, and the Granite Falls Fishway (WCC 1999). Three types of barriers exist throughout the basin - culverts, tide gates, and the Cook Slough Weir. All of these features can reduce, delay, or eliminate altogether access to rearing and spawning habitats. The Granite Falls Fishway provides access upstream of a natural barrier thereby providing access to anadromous fish which otherwise could not occupy habitats upstream of the falls. The final inventory and assessment of fish barriers in the Stillaguamish River basin is scheduled to be complete by late 2015.

Floodplain function has been altered throughout much of the basin; this is mainly attributable to the floodplain being disconnected from the river due to levees, dikes, and other flood control structures and bank modifications. Floodplain areas are important for salmon and steelhead survival, particularly when fish require shelter and refuge during higher flow periods. Other factors affecting floodplain function include: channelization and/or straightening, removal of snags, large wood debris (LWD), and gravel, constriction and simplification of stream and river channels from railroad and road construction (SIRC 2005). As described above riparian function has been affected by past land use throughout the basin. Currently, only 11 percent of riparian forests within the basin are "intact" and fully functional (WCC 1999).

Channel conditions have been affected by changes in location and abundance of LWD, pool habitat, sediment supply, channel morphology, and gravel mining (WCC 1999). The quantity and characteristics of in-channel LWD have been altered due to large-scale wood removal projects, the condition of riparian areas, and altered channel processes that affect wood recruitment. Loss of in-channel pool habitat is associated with the removal and reduction of LWD, increases in sediment supply, and increased peak flows (WCC 1999). Landslides associated with human land uses are the primary source of sediment in the watershed; 75 percent of the landslides are associated with logging roads and clearcuts and 98 percent of the sediment volume is associated with clearcuts and logging roads (WCC 1999).

Within the Stillaguamish River basin, the primary water quality problems for salmonids include: high stream temperatures, high levels of fine sediment in spawning gravels, low dissolved oxygen levels, and high total suspended sediments (WCC 1999). Nonpoint source pollution from agricultural practices, onsite sewage disposal, development and urban runoff, and forest practices are the leading causes affecting degraded water quality conditions (WCC 1999).

2.3.1 Fisheries

Hatchery-origin steelhead produced through the WDFW EWS programs are subject to incidental harvest in terminal area net fisheries in marine waters targeting other salmon species, directed harvest in terminal area freshwater net fisheries, and directed and incidental harvest in recreational fisheries in marine waters and freshwater (NMFS 2015a). Harvest of Dungeness, Nooksack, and Stillaguamish 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 Dungeness, Nooksack, or Stillaguamish river basins. However, the earliest returning natural-origin steelhead from these watersheds 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 in Puget Sound marine treaty and non-treaty commercial, ceremonial and subsistence, and recreational fisheries (i.e., 126 in treaty marine fisheries; 1 in non-treaty commercial fisheries; 198 in non-treaty recreational fisheries) (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 and ESA-listed hatchery origin steelhead. Overall, marine treaty and non-treaty fisheries have demonstrated a decrease in natural-origin steelhead harvest of 46% from 2008/2009 to 2013/2014 as compared to the previous 2001/2002 to 2006/2007 time period. There is no directed harvest of natural-origin winter steelhead in any fisheries within the action area. Non-Indian commercial fishing is closed to steelhead in all areas, although there is some incidental harvest mortality in salmon-directed fisheries. 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 EWS during the early winter months when natural-origin steelhead are at low abundance.

Long term time series data for escapement and harvest are lacking for all populations within the action area. Five Puget Sound watersheds have data sufficient to determine harvest rates (the Skagit, Snohomish, Green, Puyallup, and Nisqually watersheds). Analyses of these data indicate that the annual terminal (freshwater) harvest rate 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 means that harvest rates have been cut by more than half (from an average of 4.2 percent) since the fish were listed under the ESA (NMFS 2015a). At the time of listing, NMFS determined that the current harvest management strategy that had eliminated direct harvest of 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). Because of their earlier (summer-fall month) adult migration and spawn timing, Chinook salmon are absent from freshwater areas within the action area at the time when and in the locations where fisheries directed at EWS occur. Harvest impacts on ESA-listed Chinook salmon in EWS directed fisheries have therefore likely been negligible in recent years. In summary, and as mentioned in Section 1.3.2, NMFS analyzed the effects of all fisheries on ESA-listed salmon and steelhead in the Dungeness, Nooksack, and Stillaguamish basins in a biological opinion on Puget Sound fisheries for 2015-16, and concluded that fisheries harvest actions including those in the action area are 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 Dungeness River and Dungeness estuary, Jamestown S'Klallam tribal commercial and ceremonial and subsistence fisheries for primarily hatchery-origin salmon and steelhead occur seasonally contingent on the availability of fish surplus to escapement needs. WDFW-managed non-Indian commercial fisheries in the Dungeness estuary to target surplus returning coho salmon, and in odd-numbered years, pink salmon. Recreational fisheries for salmon and unlisted steelhead managed by WDFW occur in the Dungeness River and Dungeness estuary. Between 2000/2001 and 2012/2013, the total annual tribal and non-Indian fishery harvests of EWS in the Dungeness River portion of the analysis area averaged 14 and 49 fish, respectively (WDFW 2013a). Management measures, including time and area closures, are applied in all fisheries to minimize harvest impacts on natural-origin steelhead, and to ensure that encounters with late winter-returning natural-origin steelhead remain low. Tribal commercial, subsistence, and ceremonial fisheries targeting EWS in the Dungeness River action area are normally open for up to four-and-a-half days per week starting the second week in December through February in Area 6D (Dungeness Bay) and in the Dungeness River. Tribal regulations permit the use of nets and hook-and-line gear. Tribal fishing is excluded within a 1500-foot radius at the mouth of the Dungeness River as a measure to reduce impacts on milling/staging adult fish. The tribal hook-and-line subsistence fishery in the river is open from December through mid-March, under a daily bag limit of 2 fish. The recreational fishery in the Dungeness River is open from mid-October through January, from the mouth upstream to the Dungeness Forks Campground. Game fish regulations set a daily bag limit of two fish over 14 inches, composed of marked (hatchery origin) steelhead, sea run cutthroat, or resident trout. The Gray Wolf River is closed to recreational fishing from November through early June.

Within the Nooksack River basin portion of the action area, Lummi Nation and Nooksack tribal commercial and ceremonial and subsistence fisheries targeting mainly hatchery-origin salmon and steelhead occur seasonally in the Nooksack River and Bellingham Bay, contingent on the availability of fish surplus to escapement needs. WDFW-managed non-Indian commercial fisheries in terminal area marine waters only harvest surplus returning Chinook, coho, and chum salmon. Recreational fisheries for salmon and unlisted steelhead managed by WDFW occur in the Nooksack River. Between 2000/2001 and 2012/2013, the total annual tribal and non-Indian fishery harvests of EWS in the Nooksack River portion of the analysis area averaged 31 and 195 fish, respectively (WDFW 2013b). Management measures, including time and area closures, are applied in all fisheries to minimize incidental harvest impacts on natural-origin steelhead (including summer-run steelhead), and to ensure that encounters with late winter-returning natural-origin steelhead remain low. Lummi and Nooksack tribal commercial, subsistence, and ceremonial net fisheries targeting EWS in the Nooksack River basin are normally open from early December through mid-January (WDFW 2103b). The recreational fishery for EWS in the Nooksack River watershed is open from November through January each year, and through February 15 in the North Fork Nooksack River near Kendall Creek Hatchery. The EWS sport fishery is open within selected stream reaches with a bag limit of two marked hatchery origin steelhead over 20 inches.

In the Stillaguamish River basin portion of the action area, commercial and ceremonial and subsistence fisheries by the Stillaguamish Tribe and Tulalip Tribes are conducted each year in the river (Stillaguamish Tribe) and adjacent marine areas (both tribes) when fish surplus to escapement needs are available. Fisheries in these areas harvest Chinook, coho, and chum salmon, and in odd-numbered years, pink salmon. There are no WDFW-managed non-Indian commercial fisheries in the river or in the adjacent nearshore marine area, but surplus Chinook, coho, chum, and pink salmon may be harvested by the non-Indian fleet in more seaward marine areas. Recreational fisheries for salmon and unlisted steelhead managed by WDFW occur in the Stillaguamish River and adjacent marine areas.
Between 2000/2001 and 2012/2013, the total annual tribal and non-Indian fishery harvests of EWS in the Stillaguamish River portion of the analysis area averaged 12 and 572 fish, respectively (WDFW 2013c). Management measures, including time and area closures, are applied in all fisheries to minimize incidental harvest impacts on natural-origin steelhead, and to ensure that encounters with late winter-returning natural-origin steelhead remain low. There are no tribal steelhead-directed commercial fisheries in the Stillaguamish River, and tribal EWS harvests are restricted to marine areas (WDFW 2013c). The generic steelhead season is open from June 1, to January 31 or February 15, with two marked hatchery-origin steelhead over 20 inches allowed. All tribal harvest of summer steelhead occurs incidental to fisheries directed at Chinook, coho, and pink salmon. The tribes have chosen to take their

allocation of summer steelhead in the EWS fishery, pursuant to court orders. Tribal commercial, subsistence, and ceremonial net fisheries targeting EWS are normally open from early December through mid-January. The recreational fishery for EWS in the mainstem Stillaguamish River and its two forks is open from the first Saturday in June through January of each year, and through February 15 in the North Fork Stillaguamish River near the Whitehorse Ponds hatchery facility. The EWS sport fishery is open within selected stream reaches with a bag limit of two hatchery origin steelhead over 14 inches.

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 fish that stray into the action area from hatchery programs located outside the Dungeness, Nooksack, and Stillaguamish River basins. Past operation of steelhead and salmon hatchery programs in the three watersheds may have affected the viability of listed natural-origin steelhead and Chinook salmon natural populations. The types of potential hatchery-related effects are identified in Section 2.4.1. Since their inception, EWS hatchery programs are likely to have adversely affected the abundance, diversity, spatial structure, and productivity of the natural-origin steelhead populations in the watersheds where the EWS are produced.

Steelhead hatchery programs in Puget Sound were initiated beginning in the early 1900s. Beginning 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 Dungeness (Dungeness River Hatchery in 1995), Nooksack (Kendall Creek Hatchery beginning in 1998), and Stillaguamish (Whitehorse Ponds in 1964) river watersheds (WDFW 2014a; 2014b; 2014c). Advances in cultural techniques during the 1960s led to further development of the Chambers Creek (aka "Early Winter Steelhead [EWS]") hatchery-origin stock through broodstock selection and accelerated rearing practices (Crawford 1979), all for the purpose of producing fish for harvest. The earliest maturing adult steelhead were selected in order to produce fish that smolted at one year of age, rather than at age-2 or older (WDFW 2005a).

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[10] data) of a small group of steelhead populations that had been sampled in the 1970's and then again in the 1990's

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[10] 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.

(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[11]. 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.

Similar to past production of EWS, production and release of hatchery-origin early summer steelhead (ESS) of Skamania stock lineage into action area waters is likely to have adversely affected the abundance, diversity, spatial structure, and productivity of the natural-origin steelhead populations. ESS returns in Puget Sound, derived about 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 be available, upon their return from the ocean as adults, for harvest. ESS are thought to spawn somewhat earlier than summer steelhead from natural-origin 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 we consider that the genetic profile of the Chambers Creek EWS stock is too close to the other Puget Sound steelhead populations to be able to assess cumulative gene flow effects, more can be said in the case of releases of ESS because they originated in the Columbia Basin. This is discussed in greater detail in Section 2.4.2.

The river entry timing for EWS has been generally earlier than the majority of steelhead from natural populations, enabling some level of isolation and elective 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., the 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 species creating the redds and their origin (hatchery and natural), McMillan (2015a) reported that overlap was substantial in five tributaries within the Skagit River watershed. However, there is very little data to support this conclusion since only 6 natural-origin steelhead were observed during the five year period surveyed and only one natural-origin steelhead was

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

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 and that 50 to 67 percent of the early redds were constructed by hatchery origin steelhead; this equates to between 8.5 and 5.6 percent of all the natural-origin steelhead redds being constructed prior to March 15. It is important to understand that it is not very likely that this spawn timing is 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 indicate that the earliest natural-origin spawners are seen in middle Skagit tributaries such as Finney and Grandy creeks (Brett Barkdull, personal communication *in* Pflug et al. 2013). The data also show that redds/mile surveyed are higher from January through February than the first half of March, and further indicate that many of the early steelhead redds counted in McMillan (2015a; 2105b) were likely hatchery-origin steelhead. Furthermore, genetic analysis of unmarked adult steelhead in Finney Creek contained no hybrids and only one adult steelhead that was the progeny of two hatchery-origin fish (Warheit 2014a), and this is evidence that little 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), and responding to a request from NMFS for clarification regarding redd count data available for the Skagit River watershed (Tynan 2015), WDFW presented data from spawner redd count surveys conducted in the same Skagit River tributary locations and during the same time periods (WDFW 2015b). These data argue that McMillan (2015a) overestimates the number of steelhead redds, it estimated over three times as many redds as observed by WDFW personnel at the same times and in the same survey reaches, and they strongly suggest that available survey information, alone, is conflicting and certainly is inadequate upon which to base conclusions over the co-occurrence of EWS hatchery fish and natural-origin steelhead on the spawning grounds.

There are other data upon which to estimate the co-occurrence of hatchery and natural-origin steelhead on the spawning grounds, and these 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 (Figure 7) 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 (tributary to the Snohomish River) and only three redds (2.5% of the total 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 6.2 and 1.25 percent of redds were constructed prior to March 15 in the Nooksack and Stillaguamish rivers, respectively.

In the period leading-up to and since the ESA-listing of Puget Sound steelhead in 2007, there have been considerable changes in EWS hatchery production, all for the purpose of reducing adverse impacts on steelhead viability. Beginning in 1991, all juvenile fish released from EWS programs were marked with an adipose fin clip to allow for their differentiation from natural-origin steelhead in migration, spawning, and harvest areas. As indicated in the HGMPs under review (WDFW 2014a; 2014b; 2014c), further Puget Sound-wide measures were implemented beginning in the early 2000s. These measures included a 70% reduction in the number of EWS hatchery programs Puget Sound-wide (from 17 to 5) and a greater than 50% reduction in the number of EWS hatchery smolts released annually. For the Dungeness, Nooksack, and Whitehorse Ponds hatchery programs specifically, annual smolt release numbers have been reduced from 20,000 fish to 10,000 fish; 185,000 fish to 150,000 fish; and 140,000 to 130,000 fish respectively. Another measure implemented to reduce the risk of juvenile and adult steelhead interactions is a greater than 65% reduction in EWS smolt release locations, reducing the level of co-occurrence between hatchery and natural-origin fish, juvenile and adult fish alike. For example, annual off station transfers and releases of smolts from the Whitehorse Ponds Hatchery into Pilchuck Creek, a North Fork Stillaguamish River tributary, have been terminated. Similarly, annual transfers of EWS smolts from Kendall Creek Hatchery for release into Whatcom Creek and the Samish River have also been terminated. To reduce the risk of EWS adult straying into natural steelhead spawning areas, cross-basin smolt transfers (e.g., from Kendall Creek Hatchery to the Samish River), off-station smolt releases (e.g., Whitehorse Ponds Hatchery into Pilchuck Creek), and recycling of adult EWS captured at the hatcheries into natural migration areas have also been eliminated. EWS fry releases into anadromous waters have been terminated to reduce the likelihood of extended ecological interactions in freshwater resulting from hatchery fish rearing to smolt size in natural steelhead production areas. To reduce the likelihood of competition and predation, Puget Sound EWS programs apply volitional smolt release practices to have more smolts emigrate quickly downstream and fewer smolts residualize to potentially compete with natural-origin fish for food and space. Smolts that do not migrate after a three to six week period (depending on the program) are collected and planted into non-anadromous waters. To make EWS adults return earlier in the season than natural-origin steelhead, minimizing overlap in migration and spawning areas, EWS broodstock are collected no later than January 31st each year. To reduce straying risks, hatchery broodstock collection weirs are operated from January 31st through March 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 environmental baseline, hatcheries in Puget Sound 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 comprise 46% of all steelhead returns, annually, to Puget Sound tributaries, on average (Section 2.4.2.4).

In addition to the three EWS programs considered in this opinion, WDFW and three tribes operate 18 other individual hatchery salmon and steelhead programs in the action area (Table 10)[12]. There are ten other hatchery programs operating in the Nooksack River basin (WRIA 1), of which two are operated by WDFW and the Lummi Nation for stock conservation purposes, with the remainder implemented by WDFW (4 programs) and the Lummi Nation (four programs) to provide fish for harvest. All of the Nooksack River basin hatchery programs operate to offset natural-origin salmon and steelhead population reductions resulting from past and on-going land-use practices (SSPS 2005b). In the Stillaguamish River basin, WDFW operates two salmon and steelhead hatchery programs (one jointly with the Stillaguamish Tribe for conservation purposes and one for harvest augmentation), and the Stillaguamish Tribe operates four programs (two for stock conservation [one jointly with WDFW], and two for harvest augmentation). These hatchery programs operate in the Stillaguamish River basin to offset existing severe constraints on natural-origin fish production due to poor freshwater habitat conditions, and the programs would continue to operate until habitat is restored to a level that will increase productivity sufficiently to sustain viable natural- origin populations in the system (Stillaguamish Tribe 2007). WDFW, with some funding assistance from the Jamestown S'Klallam Tribe, operates three salmon hatchery programs in the Dungeness River basin. Two programs operate for conservation-directed supplementation purposes, and one program produces coho salmon, largely to provide fish for harvest. The Dungeness River hatchery programs are operated to conserve at-risk native salmon populations (Chinook and pink salmon) and partially mitigate for lost natural-origin fish production largely resulting from past and on-going loss and degradation of natural fish habitat, and impending climate change (WDFW 2013).

NMFS completed a consultation in 2002 under limit 5 of the ESA 4(d) rule regarding the effects of all Hood Canal and eastern Strait of Juan de Fuca region salmon and steelhead hatcheries on ESA-listed Hood Canal summer chum salmon (NMFS 2002a). NMFS determined that the hatchery programs, including those operating in the Dungeness River watershed to produce salmon and steelhead, would not jeopardize the listed summer chum salmon ESU or destroy or adversely modify the species' critical habitat.

The general effects of the programs described in Table 10 on ESA-listed Chinook salmon and steelhead likely include migration delay or blockage, and water quantity and quality effects on freshwater migration and rearing areas resulting from operation of facilities used to rear the hatchery fish; ecological effects, including resource competition, predation, and fish disease pathogen transfer

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[12] The other 18 individual hatchery programs in the action area will be evaluated for effects on listed salmon and steelhead through separate ESA 4(d) rule limit 6 evaluation and determination processes.

Table 10. Other salmon and steelhead hatchery programs operating in the action area watersheds, with species produced, program purpose, proposed annual juvenile fish release numbers, life stages, timings, and locations (data from WDFW, Lummi Nation, and Stillaguamish Tribe HGMPs)

Program	Purpose	Release Number (millions)	Life Stage	Release Timing	Release Location
Nooksack Basin					
Whatcom Creek Hatchery Pink	Education/Harvest	1.0	Fed fry	April	Bellingham Bay
Whatcom Creek Hatchery Chum	Education/Harvest	2.0	Fed fry	May	Bellingham Bay
Kendall Creek Hatchery NF Spring Chinook	Conservation 1/	0.75	Subyearling	May	NF Nooksack River
NF Nooksack River (Kendall Ck) Fall Chum	Harvest	1.0	Fed fry	April/May	NF Nooksack River
Skookum Creek Hatchery SF Spring Chinook	Conservation	1.0	Subyearling	May	SF Nooksack River
Samish River Hatchery Fall Chinook	Harvest	4.0	Subyearling	May-June	Samish River
Lummi Bay Hatchery Coho	Harvest	2.0	Yearling	May	Lummi Bay
Skookum Creek Hatchery Coho	Harvest	2.0	Yearling	May-June	SF Nooksack River
Lower Nooksack Fall Chinook	Harvest	2.0	Subyearling	May	Lummi Bay /Bertrand Ck.
Lummi Bay Hatchery Chum	Harvest	3.0	Fry	April/May	Lummi Bay
Stillaguamish Basin					
Stillaguamish Fall Chinook Natural Stock Restoration	Conservation	0.045	Subyearling	May	SF Stillaguamish R
Stillaguamish Summer Chinook Natural Stock Restoration	Conservation 1/	0.2	Subyearling	May	NF Stillaguamish R
Stillaguamish Late Coho	Harvest	0.054	Yearling	May-June	Stillaguamish River
Stillaguamish Fall Chum	Education/Harvest	0.25	Fry	April-May	Stillaguamish River
Whitehorse Ponds ESS	Harvest	0.07	Yearling	May	NF Stillaguamish R
Dungeness Basin					
Dungeness River Hatchery Spring Chinook	Conservation	0.15	Subyrlg/Yrlg	April-June	Dungeness River
Dungeness River Hatchery Coho	Harvest	0.5	Yearling	June	Dungeness River
Dungeness River Hatchery Fall Pink	Conservation	0.1	Fry	April	Dungeness River

1/ Programs have a conservation intent, but also produce marked fish as "Indicator Stocks" to identify US/Canada fishery impacts.

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 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 adverse effects on ESA-listed Chinook salmon and steelhead are therefore of critical importance. For example, the native-stock Chinook salmon hatchery programs operating for conservation purposes may both benefit target population viability, and pose risks to ESA-listed fish populations. Harvest-directed programs that rear fish in freshwater locations where no delineated Chinook salmon or steelhead populations are present (e.g., Whatcom Creek; Lummi Bay), with releases directly into saltwater, are expected to have unsubstantial or negligible effects.

Dungeness River Salmon Hatchery Programs

The specific effects of the salmon hatchery programs in the Dungeness River watershed portion of the action area (Table 10) on Puget Sound Chinook salmon and steelhead have been addressed through a separate ESA consultation completed in April, 2016 (NMFS 2016a). Through that consultation, NMFS determined that three hatchery-related factors were likely to adversely affect Dungeness Chinook salmon: Chinook salmon hatchery program effects on genetic diversity; spawning ground competition and redd superimposition effects from hatchery-origin pink salmon; and Dungeness River Hatchery water intake structure effects on Chinook salmon migration. NMFS also determined that one hatchery-related factor was likely to adversely affect Dungeness River steelhead: Dungeness River Hatchery water intake structure effects on steelhead migration. In implementing the three Dungeness River Hatchery salmon programs, the co-managers will apply best management practice risk reduction measures that are expected to adequately reduce genetic and ecological effects on the ESA-listed Dungeness Chinook salmon and Dungeness River steelhead natural populations. Risks associated with the Dungeness River Hatchery mainstem river water intake structure are being addressed by renovating the structure (WDFW 2014a). Canyon Creek, a tributary adjacent to Dungeness River Hatchery, has been blocked by a diversion dam, to enable the withdrawal of water for hatchery use. Water is withdrawn from Canyon Creek only when withdrawal of water from the main source in the Dungeness River becomes infeasible due to icing and high flows during the winter months when flows are at their highest. WDFW reports that there is not enough water flow in Canyon Creek to use the intake during the summer and fall months when flows in Canyon Creek are at their lowest (Ward 2013). Recently, the WDFW proposed to construct a fish ladder to allow fish passage past that diversion dam. Consultation on the effects of the construction of the fish ladder has occurred (NMFS 2013b), with the work expected to be completed by fall 2017. The presence of the fish ladder is expected to open up access to several miles of Canyon Creek, some of which might be suitable habitat for salmonid spawning and rearing. During flood events, flow conditions will be rapid and complex and the fish ladder may not meet NMFS (2011a) fish passage criteria. However, upon completion of the project, fish should be able to ascend the project and access upstream areas at least 90% of the time (NMFS 2013b; USCOE 2012). After reviewing the current status of the ESA-listed species, the environmental baseline within the action area, the effects of the proposed action, including effects that are likely to persist following expiration of the proposed action, and cumulative effects, NMFS determined that the three salmon programs are not likely to jeopardize the continued existence of the Puget Sound Chinook Salmon ESU and the Puget Sound Steelhead DPS, or to destroy or adversely modify designated critical habitat for the ESU and DPS (NMFS 2015b).

Nooksack River Salmon Hatchery Programs

No formal ESA consultation processes have as yet been completed to evaluate the past and potential recent effects of the Nooksack River watershed salmon hatchery programs identified in Table 10 on ESA-listed fish species. However, analyses presented in the NMFS Draft EIS for Puget Sound hatcheries can explain hatchery affects in the environmental baseline (NMFS 2014). Evaluation of the risks and benefits of nine Nooksack River hatchery programs identified in Table 10 were included in the Draft EIS. The Lummi Bay Chum program has just recently been proposed and was therefore not available at the time the DEIS was completed. From the DEIS, the Whatcom Creek Hatchery Pink, Whatcom Creek Hatchery Chum, and NF Nooksack River (Kendall Creek) Fall Chum programs have no adverse hatchery-related effects on ESA-listed fish. The programs produce non-listed species that do not interbreed with Chinook salmon or steelhead so there are no genetic effects. Because of their small size at release, and due to differences in migration behavior and diet preferences, pink and chum salmon fry pose negligible ecological risks to ESA-listed Chinook salmon and steelhead. None of the pink and chum salmon hatchery programs operate on streams where ESA-listed salmon and steelhead are present, so facility operation effects are not a risk factor. The Lummi Bay Chum salmon hatchery program has no adverse effects on ESA-listed salmon and steelhead. The Kendall Creek Hatchery North Fork Spring Chinook and Skookum Creek Hatchery South Fork Spring Chinook salmon hatchery programs operate for conservation purposes, and both produce ESA-listed hatchery-origin fish that benefit the viability status of the North Fork Nooksack and South Fork Nooksack natural populations, or at least reduce extinction risk of their associated natural populations in the short-term. There are still risks from these hatchery programs to diversity of the target Chinook salmon populations and abundance and productivity from 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 from predation effects on natural-origin juvenile Chinook salmon and steelhead in Nooksack River migration areas after the hatchery-origin Chinook salmon are released. Based on the biological status of these natural populations (see Section 2.2.2.1), benefits from the hatchery program reducing extinction risk outweigh the adverse effects they pose to population viability.

The Samish River Hatchery Fall Chinook salmon program operates for isolated harvest augmentation purposes in the Samish River watershed where no natural-origin independent Chinook salmon natural population exists according to the PSTRT (Ruckelshaus et al. 2006), although critical habitat for the species was designated in the watershed. ESA-listed steelhead are present in the Samish River watershed (Myers et al. 2015). The Samish River fall Chinook salmon hatchery program has likely adversely affected genetic diversity of ESA-listed Nooksack River Chinook salmon through straying and interbreeding with natural-origin fish. The hatchery program also is likely to adversely affect ESA-listed Chinook salmon by releasing juvenile fish that compete with natural-origin juveniles in the estuary and that prey on natural-origin juveniles in freshwater. ESA-listed steelhead juveniles may be adversely affected from predation by hatchery fall Chinook salmon juveniles after they are released into the Samish River. The Lummi Nation Fall Chinook salmon hatchery program operates for isolated harvest augmentation purposes using non-local stock. Chinook salmon produced by the Lummi Bay program are likely to have adversely affected the genetic diversity of ESA-listed Nooksack River Chinook salmon through straying and interbreeding. Fall Chinook salmon from the hatchery program are released as smolts directly into seawater, so ecological risks to ESA-listed fish species in freshwater are negligible. Hatchery Chinook salmon smolts released by the Lummi program may compete with ESA-listed Chinook salmon in the estuary. Coho salmon produced through the Lummi Nation's coho salmon hatchery programs (now described in two HGMPs) are not included in the Chinook salmon ESU and there are no genetic effects on listed fish species resulting from program implementation. Yearling coho released from Skookum Creek Hatchery into the South Fork Nooksack River pose predation risks to co-occurring juvenile Chinook salmon and steelhead. Coho produced by the Lummi Bay Hatchery program are released directly into seawater and pose no freshwater ecological risks to ESA-listed fish species. Because of the off channel location of Skookum Creek Hatchery, and the estuary location of Lummi Bay Hatchery, neither facility (i.e., facility effects) effects ESA-listed fish.

Stillaguamish River Salmon and Summer Steelhead Hatchery Programs

Similar to the salmon hatchery programs in the Nooksack River watershed, no formal ESA consultation processes have as yet been completed to show the effects of other Stillaguamish River watershed hatchery programs identified in Table 10 on ESA-listed fish species. However, analyses presented in the NMFS Draft EIS for Puget Sound hatcheries can explain hatchery affects in the environmental baseline (NMFS 2014) for the Stillaguamish River watershed. The South Fork Stillaguamish Natural Chinook Salmon Restoration and North Fork Stillaguamish Chinook Salmon Pacific Salmon Treaty (PST) Indicator Stock programs operate for conservation purposes, and both produce ESA-listed hatchery-origin fish that would benefit the viability status of the target North Fork Stillaguamish and South Fork Stillaguamish Chinook salmon natural populations. The hatchery programs forestall extinction of the natural populations at the cost of competition effects in freshwater and estuary areas and predation effects on co-occurring natural-origin juvenile Chinook salmon and steelhead. Neither program poses facility operation risks due to the absence of ESA-listed fish in the area where the hatchery operates (Brenner Creek) and the off-channel location of the release site for the North Fork Stillaguamish program (Whitehorse Springs Creek). The Stillaguamish Late Coho program produces non-listed coho salmon yearlings of native stock, and genetic effects to ESA-listed fish do not occur. Likely adverse effects from the yearling release hatchery program are predation on juvenile ESA-listed Chinook salmon and steelhead, and competition with co-occurring steelhead and Chinook salmon smolts after the smolts are released. The Stillaguamish Fall Chum program produces native Stillaguamish River chum fry for harvest augmentation purposes. Genetic effects on ESA-listed fish are not a risk factor. Because of their small size at release, and due to differences in migration behavior and diet preferences, the chum salmon fry pose negligible ecological effects to ESA-listed fish species. The hatchery chum fry facility does not pose substantial facility operational risks to any ESA-listed fish.

It is likely that the Whitehorse Ponds ESS program adversely affects ESA-listed natural-origin Chinook salmon and steelhead in the Stillaguamish River watershed through predation after the hatchery smolts are released. The level of adverse effect is unknown. 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 salmon and steelhead populations exist (Whitehorse Springs Creek). Adverse effects on genetic diversity are likely but the level of impact is unknown due to straying by returning adult hatchery-origin steelhead into natural spawning areas. Overlap in spawn timing between returning adult ESS originating from the Whitehorse Ponds program and natural-origin steelhead populations in the Stillaguamish River means there could be some level of gene flow into naturally producing steelhead populations, which would adversely affect their genetic integrity. Augmenting preliminary effects assignments made available in the Draft Hatchery EIS (NMFS 2014) is a recent analysis of genetic samples collected from hatchery and natural-origin steelhead adults and juveniles in Puget Sound region watersheds (including programs in the Stillaguamish and Nooksack River basins), Warheit (2014a) found that isolated winter-run and summer-run steelhead hatchery programs have affected the genetic structure of associated natural-origin steelhead populations to varying degrees. A higher level of gene flow (measured as "Proportion Effective Hatchery Contribution" or "PEHC") from hatchery-origin steelhead was found in the Stillaguamish River compared to the Nooksack River. No samples collected from summer-run steelhead under propagation at Whitehorse Ponds were included in the analysis. In the Stillaguamish watershed, Warheit (2014a) reported small to no hatchery influence (again, measured as PEHC) among aggregate samples of juvenile summer-run fish, but a large hatchery-origin summer-run influence in a collection of steelhead smolts analyzed. Analysis of the Stillaguamish River smolt sample indicated an average hatchery-origin summer-run steelhead PEHC of 18%, with a ninety percent confidence interval of 13% to 25% (Warheit 2014, Table 8). Of concern with regards to the Stillaguamish River watershed is that more detailed gene flow analysis, including analysis of samples from summer-run steelhead under propagation at Whitehorse Ponds, would indicate similar PEHC effects on extant, native summer-run steelhead populations.

The effects in the action area of hatchery programs outside of the Dungeness, Nooksack, and Stillaguamish River watersheds are likely unsubstantial for the following reasons. The closest Puget Sound region hatchery programs outside of the individual watershed components of the action area are in the Elwha River for the Dungeness River populations; the Skagit River for the Nooksack River populations; and the Snohomish River basin for the Stillaguamish River populations. Because of the geographic distance separating them, and considering life history strategies for salmon during their freshwater phase that sequester rearing and migrating fish to their natal streams, juvenile fish from these other watersheds 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 stray into the three action area watersheds has not been quantified, but it is unlikely that any 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 regional 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 risks associated with 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 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.

Salmon and steelhead habitat restoration and protection projects in the Puget Sound region, including within the three action area watersheds, have been funded and implemented through the PCSRF process. For the Dungeness River watershed, recent examples of habitat restoration and salmon recovery projects funded through the PCSRF that are improving conditions for ESA-listed Dungeness River Chinook salmon and steelhead include: construction of 14 engineered logjams in three remote upper Dungeness River and Gray Wolf River reaches in the Olympic National Forest where habitat was severely damaged by historical projects that removed large wood; improvement and stabilization of river banks on the lower Dungeness River by the North Olympic Salmon Coalition and Washington Conservation Corps through planting of trees and bushes along 75 acres of river bank, maintenance of existing plantings, and removal of invasive weeds on 112 acres of river channel; restoration of the mouth of the Dungeness River and its associated flood flats through development of approved plans to set back dikes on both sides of the river's lower channel, restoring habitat along 1.8 miles of its length; acquisition of land adjacent to the Dungeness River mouth and floodplain, encompassing essential habitat for salmon and steelhead rearing and migration; and replacement by the Clallam Conservation District of approximately 2.8 miles of open irrigation ditch in the Dungeness River watershed to conserve water withdrawn from surface and groundwater sources for irrigation purposes. In the Nooksack River watershed, recent examples of habitat restoration and salmon recovery projects funded through the PCSRF are: implementation of the South Fork Nooksack River Downstream of Hutchinson Phase 2a Restoration project, including construction of 8 engineered log jams and post-project replanting and invasive vegetation control; as the third phase of restoration in the reach, with 9 and 10 structures constructed in 2012 and 2014, respectively; acquisition 42.35 acres of river frontage and side-channel habitat on the North Fork Nooksack River; acquisition of 282 acres of riparian habitat along the last remaining natural meandering reaches of the South Fork Nooksack River; and acquisition of 168 acres of floodplain and associated uplands along the South Fork Nooksack River, that includes 235 acres of riparian forest in the project match to be perpetually protected as salmon habitat for a total of project size of 403 acres. Recent examples of habitat restoration and salmon recovery projects funded through the PCSRF in the Stillaguamish River are: installation of up to 6 engineered log jam structures in the North Fork Stillaguamish River in reaches identified as of high value for ESA-listed Chinook salmon productivity; installation of 5 additional log jams in the North Fork Stillaguamish near the town of Hazel, Washington; and acquisition and restoration of 14 acres of high value riparian habitat on the Stillaguamish River.

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 Puget Sound Salmon Recovery Plan 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

Dungeness, Nooksack, and Stillaguamish River watersheds. 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.

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).

Generally speaking, effects range from beneficial to negative for programs that use local fish[13] for hatchery broodstock and from negligible to negative when a program does not use local fish for broodstock[14]. 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) supporting hatchery program implementation,
(6) the operation, maintenance, and construction of hatchery facilities (i.e., facility effects), and
(7) fisheries that would not exist but for the hatchery production.

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 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

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[13] 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.

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

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 2011b).

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, which is basically 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.

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_b (Fiumera et al. 2004; Busack and Knudsen 2007). An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman and Laikre 1991; Ryman et al. 1995), 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; 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 (Grant 1997; Quinn 1997; Jonsson et al. 2003; Goodman 2005), 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 16). 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 (Saisa et al. 2003; Blankenship et al. 2007). 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 (Reisenbichler and McIntyre 1977; Leider et al. 1990; McLean et al. 2004; 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 (Lynch and O'Hely 2001; Ford 2002), 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.

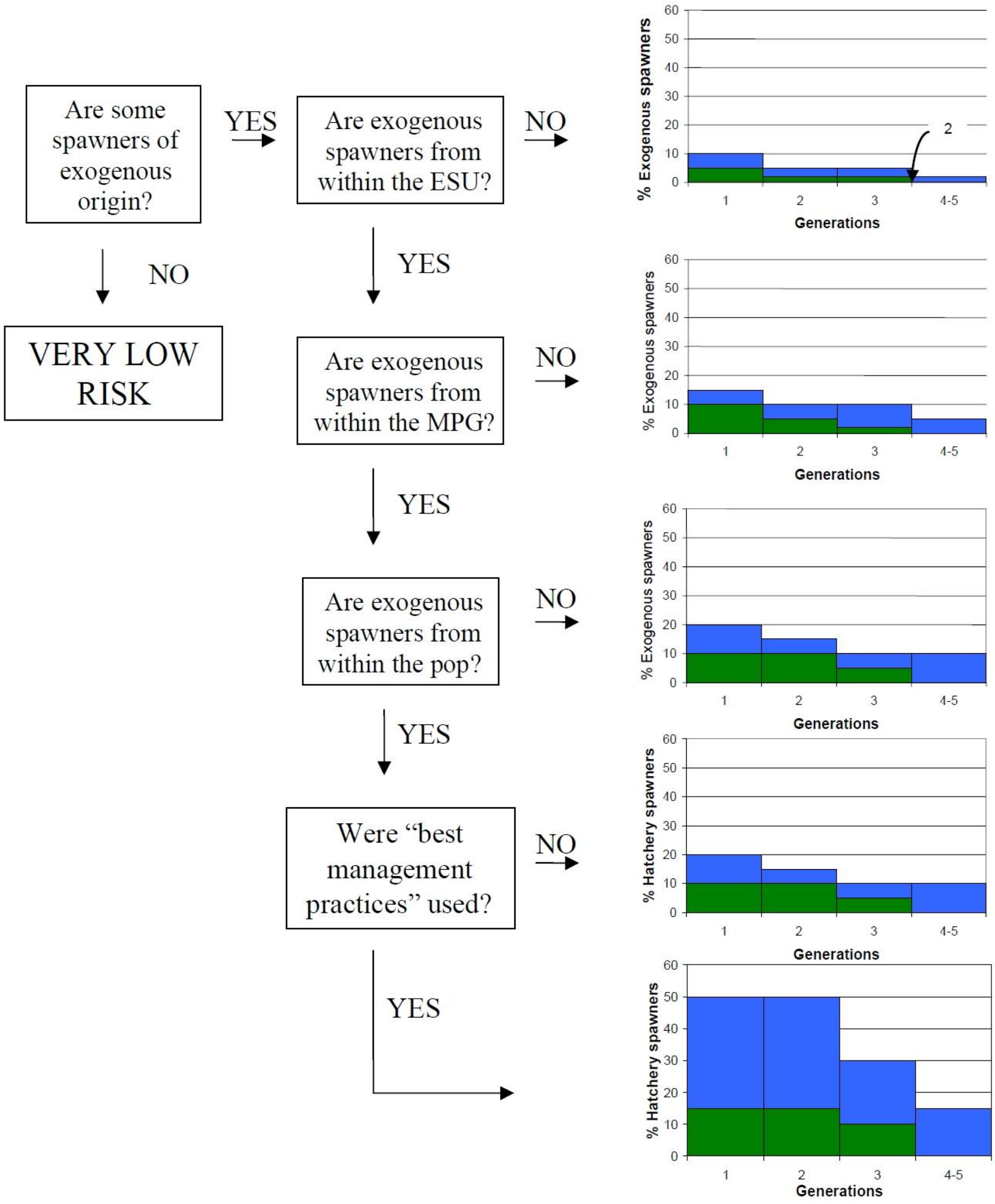

Figure 16. ICTRT (2007) risk criteria associated with spawner composition for viability assessment of exogenous spawners on maintaining natural patterns of gene flow. Green (darkest) areas indicate low risk combinations of duration and proportion of spawners, blue (intermediate areas indicate moderate risk areas and white areas and areas outside the graphed range indicate high risk. Exogenous fish are considered to be all fish of 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 fall and summer Chinook salmon and chum salmon 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; Theriault et al. 2011; Ford et al. 2012; Hess et al. 2012). 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[15]. The Interior Columbia Technical Recovery Team (ICTRT) developed guidelines based on the proportion of spawners in the wild consisting of hatchery-origin fish (pHOS) (Figure 16).

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)[16]. 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

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[15] 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.

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

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. 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

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

where $pHOS_{eff}$ 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

$$pHOS_{eff} = RRS * pHOS_{census}$$

where $pHOS_{census}$ 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 modelling is provided by a simple analysis of the expected proportions of mating types. Figure 17 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[17]. 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

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

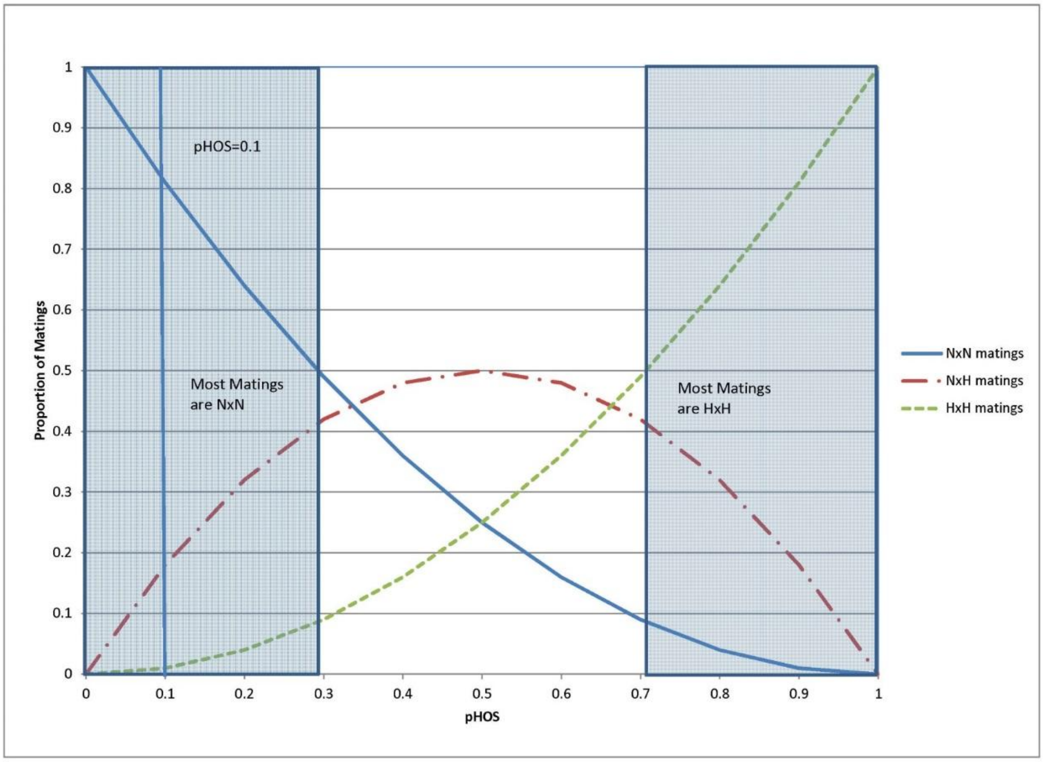

Figure 17. Relative proportions of types of matings as a function of proportion of hatchery-origin fish on the spawning grounds (pHOS) (NxN – natural-origin x natural-origin; NxH – natural-origin x hatchery; HXH – hatchery x hatchery).

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 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.

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; Ward and Slaney 1988; Hartman and Scrivener 1990; Johnston et al. 1990; Quinn and Peterson 1996; Bradford et al. 2000; Bell 2001; Brakensiek 2002; Ward and Slaney 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 2012b). 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.* 1992).
- 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,[18] 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.

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[18] "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.

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

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 salmon fry, thereby reducing the likelihood for interaction between the hatchery and naturally produced fish.
- Operating hatchery programs and releases to minimize the potential for residualism.

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 four risk factors that are likely to have adverse 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; 3) hatchery research, monitoring and evaluation; and 4) operation, maintenance and construction of hatchery facilities. For all other risk factors, the Proposed Actions would have either a negligible effect, or effects are not 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 Dungeness, Nooksack, and Stillaguamish 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 are more than moderately diverged from any native steelhead population, and not part of the Puget Sound Steelhead DPS. All steelhead adults collected for broodstock are from the extant, non-listed, early winter hatchery steelhead stock localized to each hatchery site. All broodstock voluntarily enter off-channel hatchery traps during a time (December through March) 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;** **Effects on Population Viability (C): Negligible effect;** **Marine-derived Nutrients (D): Negligible effect.** A: Steelhead produced through the three WDFW hatchery programs may have negative effects on the genetic diversity and fitness of associated listed steelhead populations. The magnitude of negative

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		effects depends on 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 of 2% into these particular steelhead natural populations are unsubstantial, and indicative of very low, and unsubstantial associated genetic risks. For the three proposed programs, two credible and independent analytical approaches indicate that gene flow (measured either as PEHC or *Gene_Flow*) *will* be under 2% with sufficient confidence in all natural-origin steelhead populations affected by the three programs. The hatchery programs would be managed to minimize unintended natural spawning by hatchery-origin steelhead, and to continue to limit gene flow from the hatchery populations to the naturally spawning listed populations. Extensive monitoring and evaluation actions would be implemented to determine the abundance of naturally spawning steelhead by origin and their spatial distribution. Levels of gene flow between EWS and natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish river basins must be monitored (Anderson et al., 2014) to estimate gene flow levels and validate whether the programs remain below the 2% gene flow level which NMFS believes poses low, unsubstantial genetic risk to the affected natural steelhead populations. B: The very latest returning hatchery-origin steelhead adults from the hatchery program may spawn in the same areas where Dungeness, Nooksack, and Stillaguamish basin populations of natural-origin steelhead spawn, potentially leading to adverse spawning ground competition and redd superimposition effects. However, the 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. 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 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.

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		Puget Sound Chinook: **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. There would be no genetic diversity or other effects on natural populations of Chinook salmon in the Dungeness, Nooksack, and Stillaguamish rivers. The species is not propagated as part of the proposed actions, and there would therefore be no adult hatchery Chinook salmon produced that would stray into natural spawning areas. The much later spawn timing for steelhead relative to Chinook salmon makes adult fish interactions and substantial competitive or redd superimposition effects in listed Chinook salmon spawning areas unlikely. The proposed steelhead programs would have negligible effects on 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 would 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 and proposed for EWS rearing and release would limit any adverse ecological interaction effects (competition and predation) on ESA-listed natural-origin fish populations while promoting high juvenile fish to adult return survival rates consistent with meeting proposed program harvest augmentation objectives. All EWS would be marked externally for easy identification 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 three 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

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		State" (WDFW and WWTIT 1998, updated 2006). Protocols described in the policy and applied through the programs would help 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 would be released in healthy condition. For these reasons, the risk of fish disease pathogen transfer and amplification associated with steelhead production through the programs would be unsubstantial. *Competition* – Substantial adverse resource competition effects on natural-origin ESA-listed fish associated with EWS yearling releases are unlikely because of size differences and resulting prey preferences between 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 are much larger in size than co-occurring juvenile Chinook salmon and steelhead parr and the two groups would likely have different diet preferences. Yearling hatchery steelhead released into the rivers during 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 produced by the programs would 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). Through this practice, the duration of any interactions between EWS smolts and natural-origin fish would 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 HGMPs that are designed to reduce the potential for competition between ESA-listed natural-origin juvenile fish and hatchery-origin juvenile steelhead. Results from juvenile outmigrant monitoring in watershed areas downstream of the hatchery release sites would be used to validate that EWS hatchery smolts (mass marked with an adipose fin clip as an identifier) disperse from freshwater areas rapidly. Alternate hatchery steelhead release timings or other mitigation measures would be developed in response to deviations from expected freshwater exodus timings. *Predation* –The hatchery-origin steelhead released from the three WDFW hatchery facilities are likely to have a substantial spatial and temporal overlap with juvenile ESA-listed Chinook salmon that are vulnerable to predation. Yearling hatchery fish are released relatively high in the North Fork Nooksack and North Fork Stillaguamish river subbasins, and mid-basin within the Dungeness River watershed: Kendall Creek (RM 0.25, tributary to the North Fork Nooksack River at RM 45.8), and Whitehorse Ponds (RM 1.5, tributary to the North Fork Stillaguamish RM 28.0, tributary to Stillaguamish at RM 17.8), and Dungeness River (RM 10.5). All hatchery smolts are released into these watershed areas during periods when emigrating Chinook salmon fry and parr are present. Yearling steelhead are not likely to

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		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 yearlings would 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 large size of these fish make predation by hatchery smolts unlikely. The proposed EWS programs would reduce the 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, minimizing the duration of interaction with ESA-listed fish in freshwater and lower river estuarine areas, and reducing opportunities for predation. Results from juvenile outmigrant monitoring in watershed areas downstream of the hatchery release sites would be used to validate that EWS hatchery smolts (mass marked with an adipose fin clip and easily identifiable) disperse from freshwater areas rapidly. Alternate hatchery steelhead release timings or other mitigation measures would be developed in response to deviations from expected freshwater exodus timings.
Hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, estuary, and ocean	Negligible	**Puget Sound Chinook salmon and Puget Sound steelhead - 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 amplification and 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 ESA-listed natural-origin salmonid populations and to determine the performance of the programs in producing adult steelhead for harvest as mitigation for lost natural-origin steelhead production in the action area basins. Monitoring and evaluation actions that would 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 would be monitored to determine the status of the natural- and hatchery-origin salmon total return and escapement abundances. In addition to regular foot surveys to census salmon 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 would be collected through monitoring trap counts at program hatcheries. Adult steelhead return abundance, timing, sex ratio, mark status, disposition, holding mortality, and fish health

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		condition data would be collected at all hatchery facilities to monitor the effects of the programs. Juvenile fish outmigrant data collected by the WDFW and tribes through annual operation of downstream-migrant traps in the mainstem Dungeness, Nooksack, and Stillaguamish rivers would 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 would provide sources of tissue samples that would be analyzed to determine gene flow levels between EWS and associated natural-origin populations. The effects of these RM&E actions on the viability of ESA-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. There are three existing water intakes on Dungeness River and one on Canyon Creek supplying Dungeness River Hatchery that do not meet the latest NMFS "Anadromous Salmonid Passage Facility Design" criteria (WDFW 2014a; NMFS 2011c). The secondary water intake for Dungeness River Hatchery on Canyon Creek is adjacent to a small dam that completely blocks access to upstream salmonid spawning habitat. WDFW is in the process of correcting fish passage problems at the location of the Dungeness River and Canyon Creek structures, with plans to complete work by fall 2020, and fall 2017, respectively. The current three structures used to withdraw water from the Dungeness River will be reduced to one structure, which will be passable to upstream and downstream migrating fish (WDFW 2014a). On Canyon Creek, by fall 2017, a fish ladder will be constructed in the dam that impounds water for periodic (winter only) use by the hatchery so that the structure is passable to migrating fish (WDFW 2014a: Andy Carlson, WDFW, pers. comm., April 24, 2015). Through a separate NMFS ESA consultation (NMFS 2013b), effects of the construction of the fish ladder to allow unimpeded upstream and downstream passage for salmon, steelhead, and bull trout were found not likely to adversely affect ESA-listed salmon and steelhead. NMFS's approval of the ladder construction as designed will allow the hatchery water intake structure on Canyon Creek to be brought into compliance with NMFS fish passage criteria (NMFS 2011c). WDFW plans to upgrade fish screens at Hurd Creek Hatchery to ensure compliance with NMFS fish passage criteria by summer 2017. A recent on-site evaluation of the Hurd Creek Hatchery surface water intake screen by WDFW presents information indicating adverse effects on any migrating salmonids are unlikely (WDFW 2015b). Screening at the Kendall Creek and Whitehorse Ponds hatchery facilities do not meet the latest NMFS Anadromous Salmonid Passage Facility Design Criteria (NMFS 2011c). However, the facilities are screened and effects on ESA-listed fish are negligible, as none of the streams on which the hatcheries are located are utilized by ESA-listed listed steelhead and Chinook salmon. At the maximum permitted levels for diverting streamflow and during

Factors	Range in Potential Effects for This Factor	Analysis of Effects for Each Factor
		summer and fall low-flow periods, high proportions of the flow in the Dungeness River, Canyon Creek, Hurd Creek, Kendall Creek, and Whitehorse Springs would be diverted to support the three 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, hatchery water requirements fluctuate seasonally. The highest needs for flows at the hatchery correspond with periods when natural stream flows from rainfall and/or snowmelt are highest. Hatchery water withdrawal needs for fish rearing are lowest in the late summer months when river 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 Dungeness River, Kendall Creek, and Whitehorse Ponds facilities is monitored, treated, and then discharged back into the river or creek from which it came in accordance with current NPDES permits that limit effects on downstream aquatic life. Monthly and annual fish production at the McKinnon Rearing Ponds is relatively small and under the 20,000 pounds per year fish production criteria set by WDOE as the limit for concern regarding hatchery effluent discharge effects. 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.
Fisheries	Beneficial to negative effect	**Puget Sound Chinook salmon and Puget Sound steelhead – Not Applicable** 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 in the Nooksack, Stillaguamish, and Dungeness rivers 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 three basins is discussed in the Environmental Baseline. Similar fisheries and effects are expected going forward.

2.4.2.1 Broodstock collection - Negligible Effect –

Steelhead collected for use as hatchery broodstock are adult EWS hatchery-origin fish returning to Dungeness River Hatchery, Kendall Creek Hatchery and North Fork Nooksack River, and Whitehorse Ponds Hatchery. There are no broodstock collected that are part of the Puget Sound Steelhead DPS. All winter steelhead collected for broodstock are from the extant, non-listed, EWS hatchery stock. The proposed WDFW hatchery programs are not operated for conservation purposes, and would function to produce EWS for fishing. All broodstock voluntarily enter off-channel hatchery traps during a time period (December through March) when other listed species are not typically present. The hatchery traps would remain open for the entire duration of the hatchery steelhead adult return period as a measure to remove all EWS returning to the release sites (EWS recruiting to the traps after January 31 would not be used as broodstock and would not be returned to the river). 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 salmon 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 (Dungeness population: mid-August through mid-October; North Fork Nooksack population: late-July through September; South Fork Nooksack population: mid-August through September; North Fork Stillaguamish population: late-August through mid-October; South Fork Stillaguamish population: mid-September through October), ESA-listed Chinook salmon are unlikely to be encountered, handled, 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

Negative Effect- Genetic Diversity:

The hatchery programs under consideration in the Nooksack (WDFW 2014b), Stillaguamish (WDFW 2014c), and Dungeness (WDFW 2014a) 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 produced by the programs (identified by early return timing and presence of an adipose fin clip mark) as 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 spawn under sub-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 pose adverse genetic effects to natural populations. In this section, we analyze the effects of gene flow. As explained in Section 2.4.1, 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

Effects 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[19]. 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

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[19] 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.

from a small number of hatchery-origin parents (Ryman et al. 1995). We do not expect this to be the case with the five proposed 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[20] are essentially identical in the hatchery and natural steelhead populations (Warheit 2014a). In general, we expect the effects posed by the Proposed Action to within-population diversity to be negligible.

However, a concern that has often been raised in connection with these isolated steelhead hatchery 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 18 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).

Assuming random mating[21], 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:

$\frac{pHOS*O_N*O_H}{pHOS*O_H+(1-pHOS)*O_N}$ (1) , 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. Based on extrapolations from spawning ground observations and return times of hatchery fish to the hatcheries (Hoffmann 2014), the proportion of the natural-origin spawners involved in HxN[22] matings is expected to be very low under the proposed action, at most 0.6% (Table 13). Thus, under the assumption that the reproductive output of a natural-origin fish mating with

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[20] 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.

[21] 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 complex and fact non-random (Seamons et al. 2004), 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 modeling are robust to the typical deviations from random mating found in nature. This is, therefore, a more conservative assumption than what is likely to occur.

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

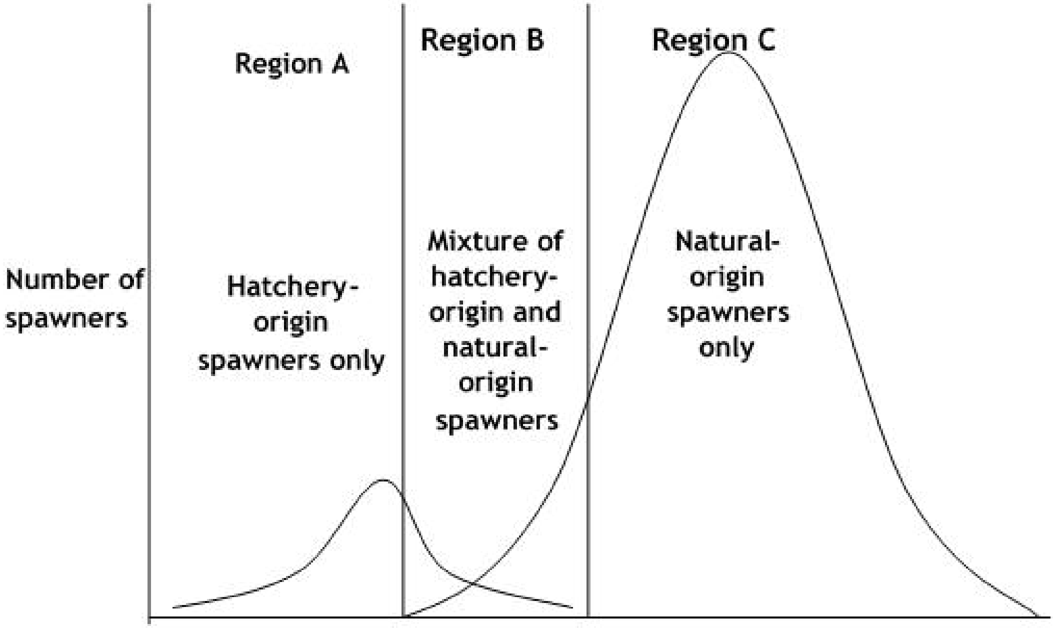

Figure 18. Schematic of temporal spawning overlap between early winter hatchery steelhead and natural-origin winter steelhead. Shape, sizes and placement of curves is conceptual and is not meant to represent any specific situation (Scott and Gill 2008, Fig. 4-7)

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).

Metric/Data	Population		
	Nooksack	**Stillaguamish**	**Dungeness**
O_N	6.21	1.25	4.33
O_H	8.38	18.41	16.88
Proposed Action pHOS	5.5	5.1	3.8
Expected proportion of natural-origin fish mating with hatchery-origin fish	0.45	0.55	0.58

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 1%. This loss would be expected to occur repeatedly, but the effects would not be 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.

All parameters used in this demonstration model are subject to uncertainty, as will be discussed below. We present a simple evaluation of the effects of this uncertainty in Figure 19, which shows the proportion of natural-origin fish participating in HxN matings as a function of pHOS and overlap. For simplicity, in this simple analysis we assume that O_N and O_H are equal, which is a much higher level of overlap than has been observed (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.

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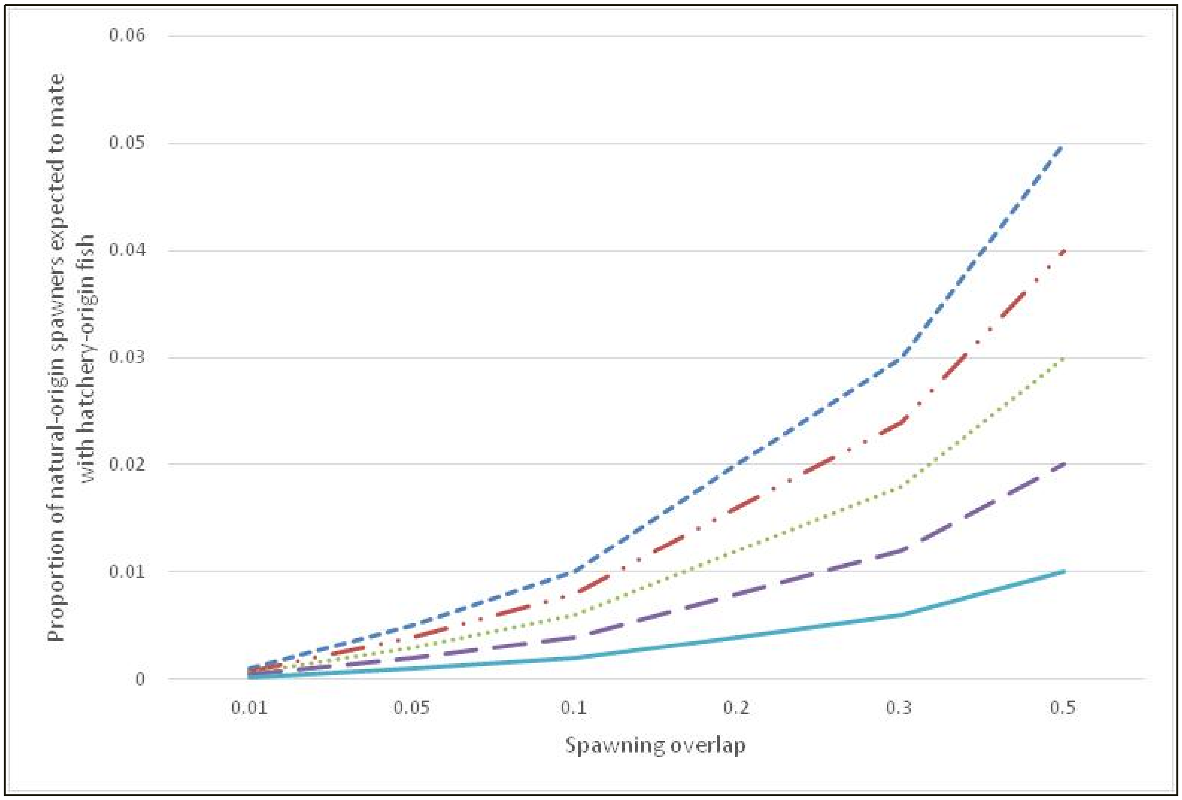

Figure 19. Proportion of natural-origin fish expected to be involved in HxN matings as a function of pHOS, and proportion of spawners in overlap zone. For simplicity we have assumed that the overlap is the same for natural-origin and hatchery-origin fish; e.g., for the 0.05 level, O_N=O_H=0.05. Isopleths represent pHOS=0.1 (small dashes), 0.08 (dots and dashes), 0.06 (dots), 0.04 (large dashes), and 0.02 (solid).

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, 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. Residual males accounted for less than 1% of the observed mating attempts, and were observed 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 programs in the Proposed Action are not known. A recent meta-analysis of steelhead 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) before fish cultural methods were developed to control precocious maturation, currently 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
This additional analysis of possible effective size reduction reinforces our original conclusion, of the proposed action having a negligible effect on 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 hatchery fish and the steelhead natural populations considered in this Proposed Action. In fact, the EWS are considered so diverged genetically from natural populations of 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, but also earlier spawning time (Crawford 1979). Of all the salmon and steelhead hatchery populations used on the West Coast, NMFS considers EWS the most altered by artificial selection. NMFS has often expressed 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. Under conditions of no selection and no genetic drift, the best existing management guidance for avoiding out breeding effects remains 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) has suggested that perhaps 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". Indeed, any natural spawning by fish from these broodstocks may be considered unacceptable because of the potential genetic impacts on natural populations" (HSRG 2004, Appendix B). WDFW used the Ford (2002) model to evaluate the hatchery-influenced selection risk of early winter isolated steelhead hatchery 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 2008). 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 about 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 the 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 (2008) 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., Chilcote et al. 1986; Araki et al. 2007), 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 traits 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 opinion, with those that are less domesticated. A modeling effort by Baskett and Waples (2013) demonstrated that the effects of hatchery 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 our 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[23], with selection occurring only at reproduction[24] 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[25]. 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: the total number of spawners, pHOS, and overlap of hatchery and natural 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[26] and 10σ for strong and weak selection, respectively[27], and distances between the two optima ranging from approximately 3σ to 15σ. We used approximately the 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 θw 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

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

[24] 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.

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

[26] σ is the phenotypic standard deviation.

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

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 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[28]in the initial set of runs in Figure 20. 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[29]. 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 proposed programs (see below), it was at most under 1.5%. 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.

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 20 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.

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[28] 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

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

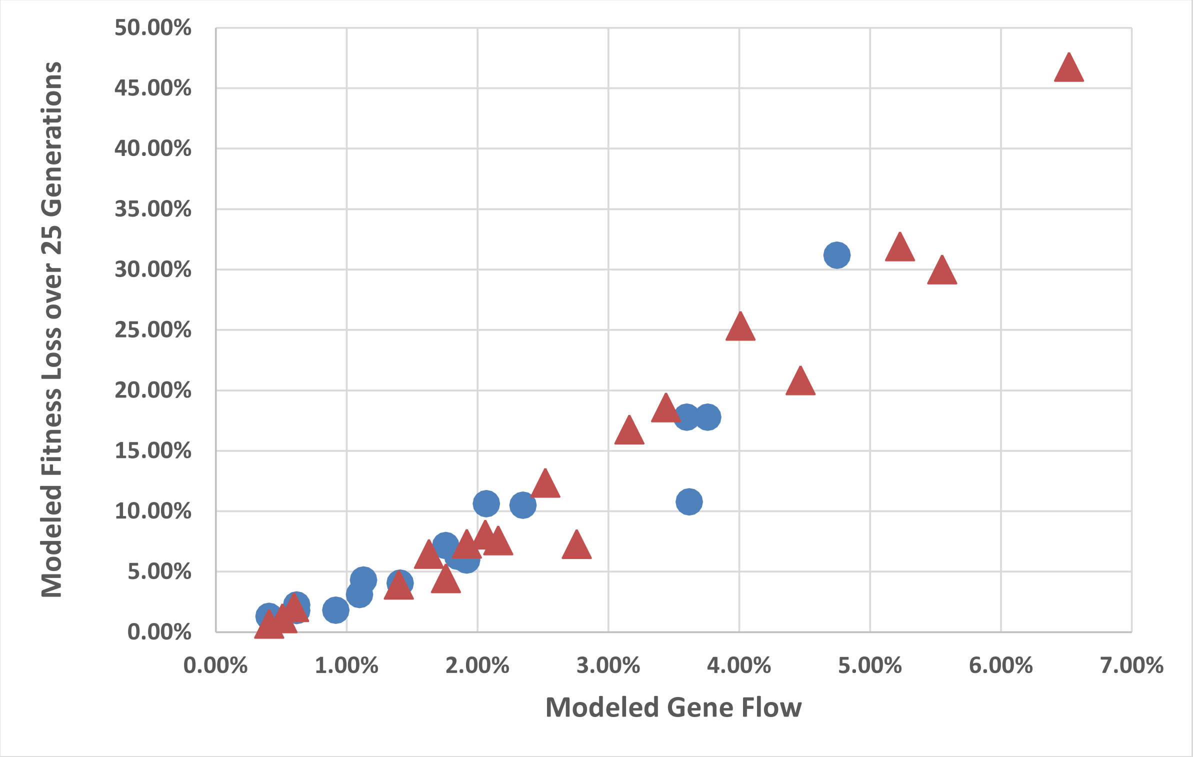

Figure 20. EWS Sim results: percent fitness loss over 25 generations as a function of gene flow. Circles and triangles denote data points from scenarios in which modeled spawning overlap is 20% or 40%, respectively.

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 they 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 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 fitnesses of approximately 85% or more of 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; 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 population (HSRG 2014, Table 3-2)[30]. 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 do 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 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 programs with respect to EWS Sim results is to consider 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 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 general viability criteria have been developed for the DPS, requiring that a specified proportion of populations in each MPG within the DPS reach viable status, no detailed plans have as yet been developed designating which populations must reach viable status. This also argues for a conservative approach to acceptable fitness loss. 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.

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[30] 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.

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; 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, NMFS believes that a 15% long-term fitness loss is insufficiently conservative for the proposed EWS programs. At this time, considering the state of scientific knowledge (including uncertainties inherent in the modeling above), the acceptable modeled 25-generation fitness loss for these populations should generally not exceed 10%. This level of maximum fitness loss 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 referred to in many NMFS documents and elsewhere 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 as a potential "vector" for gene flow is illustrated by the observation that these fish (i.e., the progeny of HxH matings) 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[31] 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 2008).

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

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[31] 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/

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 possibly 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[32]. 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 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 River winter steelhead. Skagit River winter steelhead are included in the Puget Sound steelhead DPS. 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 wild 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

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

Structure-based assignment proportions, based on the assignment error from analysis of the simulated populations.

NMFS Northwest Fisheries Science Center (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 et al. 2015). 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 made 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 the best scientific method available at this time.

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 Nooksack and Stillaguamish steelhead populations

WDFW has applied the Warheit method to the Nooksack and Stillaguamish steelhead natural populations, as well as several other Puget Sound steelhead populations, but has not yet applied it to the Dungeness population because of lack of genetic data. Table 14 reports *PEHC* information provided by WDFW (2015a) on these steelhead natural populations, along with sampling details[33]. We have labeled these values "recent past" because they are based on samples collected between 1995 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[34].

Table 14. *PEHC* estimates and confidence intervals, and projected PEHC estimates from EWS hatchery programs and sampling details for the Nooksack and Stillaguamish steelhead populations (WDFW 2015a). No *PEHC* estimates are available for the Dungeness Basin. The Stillaguamish sample was not 100% winter steelhead (see text). All values presented as percentages.

Basin	**Listed Population**	**Sample size and details**	**Recent Past *PEHC* and 90% CI**	**Projected *PEHC* under Proposed Action**
Nooksack	Nooksack (W)	246 (2009-2013 adults and juveniles)	1(0-4)	1
	SF Nooksack (S)	66 (2010-2011 adults)	0(0-7)	0
Stillaguamish	Stillaguamish (W)	86 (2006 smolt trap samples)	0 (0-7)	0
	Deer Cr. (S)	157 (1995+2013 juveniles, few 2012-2013 adults)	0 (0-3)	0
	Canyon Cr. (S)	96 (2013 juveniles)	0 (0-5)	0

Before beginning general discussion of the results in Table 14, some discussion of the Stillaguamish winter steelhead sample is warranted. Warheit (2014a) noted that the Stillaguamish was the most poorly represented system in his analysis. The sample marked in the table as Stillaguamish (W) was a sample of out-migrating smolts at a lower basin smolt trap that undoubtedly collects fish from multiple natural steelhead populations. Assuming that the collection could easily be predominantly winter steelhead smolts, upon NMFS request Dr. Warheit used *Structure* to determine the run-time composition of the sample. Of the fish in the sample that were assignable, 86%-94% assigned to winter steelhead (Warheit 2016). Based on the new information from Dr. Warheit, we decided to include data from this sample for estimating *PEHC* in Stillaguamish winter steelhead, part of best available scientific information, even though WDFW did not proffer it as such. WDFW has not provided an updated confidence interval for

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

[34] 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).

PEHC based on this sample, but because the updated intervals that have been provided tend to be somewhat larger than those originally provided in Warheit (2014a), we assume an updated confidence interval would be wider that that reported in Table 14. WDFW also did not provide a projected PEHC value, but based on their method, the projected value would have been 0%. However, as discussed below, this sample also yielded a PEHC estimate for influence from early summer steelhead (ESS) programs of 18% (Warheit 2014a), which seems to conflict with the classification results described above. Given the fact that the sample is a smolt-trap sample and is a decade old, the *PEHC* estimate for EWS effects should be viewed cautiously.

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 stipulated levels. Here we consider whether the monitoring plan in the Proposed Action (Anderson et al. 2014) is capable of doing that. The plan includes sampling in several Puget Sound basins. Table 15 presents genetic sampling details for the Nooksack, Stillaguamish, and Dungeness Basins.

Table 15. Genetic sampling plans for Nooksack, Stillaguamish, and Dungeness steelhead (Anderson et al. 2014).

Basin	**Sample site**	**Life stage**	**N**	**Population(s) sampled**
Nooksack	Mainstem Nooksack R.	Smolts	≤ 100 annually	Nooksack (W) and (S)
	SF Nooksack R.	Adults	≤ 50 every third year	SF Nooksack (S)
Stillaguamish	Mainstem Stillaguamish R.	Smolts	≤ 100 annually	Stillaguamish (W), Canyon Cr. (S), Deer Cr. (S)
	Deer Cr.	Adults	≤ 50 every third year	Deer Cr. (S)
Dungeness	Mainstem Dungeness R.	Smolts	≤ 100 annually	Dungeness (S/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 that there is no link between sample size and analytical power. In the Dungeness River, for example, is a sample of 100 smolts 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 be collected in a season at the various locations. This is especially an issue with the Nooksack and Stillaguamish 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.

We also note that there is no directed sampling of the Canyon Creek summer steelhead natural population. Summer steelhead are at low abundance levels in the Stillaguamish basin, with no available escapement estimates, but intrinsic potential estimates of capacity for Deer Creek may be ten times higher than that for Canyon Creek. Canyon Creek fish can be expected to be sampled at low rates at the smolt trap, but at this point sampling this population effectively seems very difficult. In the monitoring plan, WDFW has chosen to sample the Deer Creek population intensively to represent Stillaguamish summer steelhead. This is not really a deficiency, but the monitoring plan should deal with this issue in more detail.

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 in Figure 17. The method assumes random mating within mating region, and uses estimates of the proportion of spawners that are of hatchery origin (pHOS[35]), the proportion of hatchery-origin and natural-origin spawners in region B, and the 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 seems to us 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, including the Nooksack and Stillaguamish 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 State, steelhead spawning surveys are ordinarily not done 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 early winter hatchery steelhead, including a range for HxH matings. The parameter most susceptible to error is pHOS, which was estimated from spawning ground surveys and from hatchery-origin fish returning to the hatchery. The total number of fish returning to the hatchery was assumed to be 70-80% of the total escapement to the watershed. This assumption of 20-30% of the hatchery-origin escapement remaining in the river to spawn was considered to be conservative in comparison to earlier estimates by the HSRG of 10-20% (Hoffmann 2014). The Dungeness population was also analyzed by the Scott-Gill method in the HGMP (WDFW 2014a), but using slightly differing assumptions about proportion of hatchery-origin escapement remaining in the river, and RRS.

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 populations in the Nooksack, Stillaguamish, Dungeness, Basins computed with the same assumed values for RRS (0.13 for HxH matings and 0.54 for HxN), and for pHOS as proportion of hatchery-origin escapement (30%) (Hoffmann 2015a; 2015b). No Scott-Gill analysis was possible for the summer steelhead populations potentially affected by the Proposed Action, because these populations are not monitored (WDFW 2014b), 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*

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

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.

Table 16. *DGF* values generated from the Scott-Gill equation for the Nooksack, Stillaguamish, and Dungeness winter steelhead populations (revised from Hoffmann 2015a; Hoffmann 2015b). All values are expressed as percentages. For recent past pHOS and *DGF*, means are reported with maxima in parentheses. Proposed action pHOS values were 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. Recent past pHOS and DGF values assume the 30% stray rate and higher of the assumed RRS values.

	Population		
Metric/Data	**Nooksack**	**Stillaguamish**	**Dungeness**
Escapement years	2010-2015	2002-15, except 2007	2010-2015, except 2012
O_N	6.21	1.25	4.33
O_H	8.38	18.41	16.88
Recent past pHOS	3.1 (8.4)	4.8 (17.5)	1.8 (4.2)
Recent past *Gene_Flow*	0.37 (1.46)	0.61 (3.07)	0.27 (0.96)
Proposed Action pHOS	3.0-5.0	3.0-5.1	1.8-3.0
Proposed Action *Gene_Flow*	0.46 (0.19-.84)	0.54 (0.27-0.92)	0.36 (0.18-0.74)

Comparison of projected *DGF* values with the recent past values can be misleading. The recent past values are the mean and maximum reflecting what actually happened, using worst case assumptions (30% "stray rate, and higher RRS values), and including releases that were reduced compared to the proposed program size. The projected values assume the programs will operate at full size, and the means are based on the four combinations of RRS and "stray" rate values. Therefore, the fact that the recent past means are in most cases close to, but slightly lower than the projected values is to be expected. Possibly a better comparison is the recent past maxima with projected maxima; in all cases the projected values are considerably lower.

The Scott-Gill results indicate that under the proposed action, gene flow into the natural steelhead winter populations in the Nooksack and Stillaguamish Basins, and the summer/winter population in the Dungeness Basin has been under 2% in the past, and projected to be under 1% in the future. These results are consistent with the *PEHC* analysis.

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 perform a comprehensive sensitivity analysis, but did a brief exploration of the effect of varying spawner 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. This was a general rather than a basin- or population-specific analysis. Average parameter values for overlap, pHOS, and RRS[36] over all the Puget Sound steelhead populations were analyzed in the document to arrive at an average *DGF*. Each parameter average was then varied individually up and down 50% (Table 17) to determine the effect on that average *DGF* estimate (Figure 21). 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 needs to be done 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 average. 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 variability/uncertainty than others.

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 is frequently cited in discussions of effects from naturally spawning returning EWS, particularly the failure of assumptions about spawning overlap and resulting high proportions 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 to Puget Sound EWS programs. 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. 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

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

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

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 HH matings)	0.07	0.11	0.04
K2 (RRS of HN, NH matings)	0.54	0.81	0.27
On Station pHOS (q)	5.05%	7.58%	2.53%

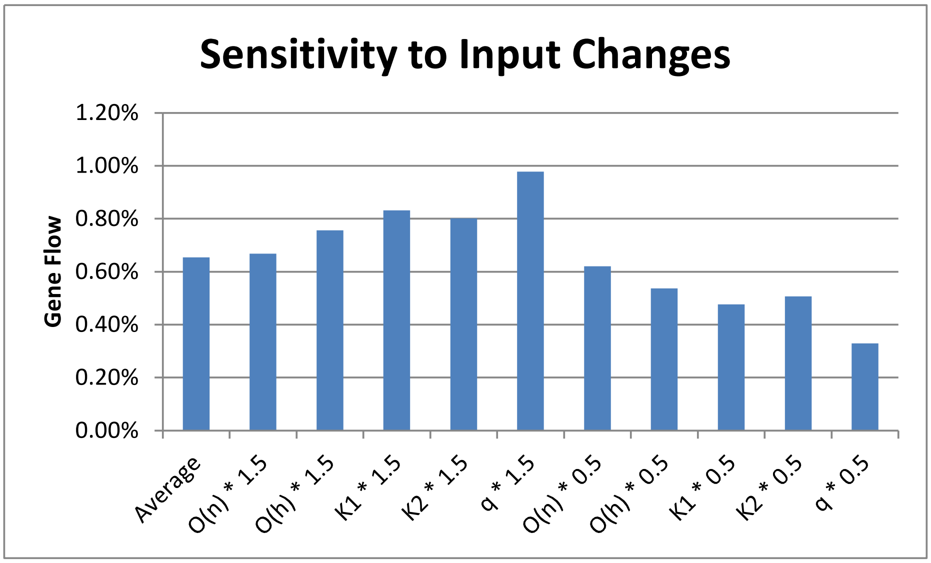

Figure 21. *DGF* values when varying each Scott-Gill parameter in isolation by a 50% increase and a 50% decrease over the input value averaged over all watersheds and all cases. (from Fig. 11 in Hoffmann 2014).

overlap in Forks Creek does not appear to be different from the values used in the Scott-Gill modelling (Hoffmann 2015a; 2015b). Because there is no evidence for overlap in 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 Nooksack and Stillaguamish rivers? The most likely explanations are higher pHOS and higher spawner overlap than would be expected in Puget Sound rivers. Unpublished data indicate that pHOS in Forks Creek is 15%, far higher than in the streams in the proposed action (Table 16), so more hybrids would be expected than in lower pHOS systems. The spawner overlap argument is based on size of the system and hatchery location. Hatchery fish were 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 natural steelhead population's introgression with EWS in the basin encompassing Forks Creek, therefore any population scale effects are conjecture. The proposed programs operate as isolated hatchery 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. Forks Creek also passed excessive numbers of hatchery-origin steelhead onto the spawning grounds, allowing interaction with the earliest natural-origin steelhead spawners

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 of genetic diversity impacts from the proposed action

Table 18 presents the *PEHC* and *DGF* values for the Nooksack, Stillaguamish, and Dungeness steelhead populations together for easy comparison. 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 additional sensitivity analysis, along with validation through 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 five proposed programs, two credible and independent approaches indicate that gene flow, measured either as *PEHC* or *DGF* should be well under 2% in natural steelhead populations affected by the Nooksack, Stillaguamish, and Dungeness EWS hatchery programs. And although we have concerns about the precision of the genetically based results, and concerns about both precision and bias of the demographically based results, we conclude that there would have to have been 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.

Table 18. Summary of analyses of gene flow from early winter hatchery steelhead into ESA-listed Nooksack, Stillaguamish, and Dungeness steelhead natural populations. (Data from Table 14 and Table 16). All values are expressed as percentages.

Basin	**Listed Population**	***PEHC (%)***		***DGF (%)***
Nooksack	Nooksack (W)	1 (0-4)	1	0.46 (0.19-0.84)
	SF Nooksack (S)	0 (0-7)	0	-
Stillaguamish	Stillaguamish (W)	0 (0-7)	0	0.54 (0.27-0.92)
	Deer Cr. (S)	0 (0-3)	0	-
	Canyon Cr. (S)	0 (0-5)	0	-
Dungeness	Dungeness (S/W)	-	NA	0.45 (0.23-0.74)

One final issue that must be addressed is the potential impact through gene flow from early summer steelhead (ESS) hatchery programs in North Puget Sound. These 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. *PEHC* estimates are available for the impacts of ESS programs in the Nooksack and Stillaguamish and are presented in Table 19. The Nooksack populations were included just for the sake of completeness; no ESS are released in the Nooksack Basin, so no gene flow is expected. There is an ESS program that releases fish in the Stillaguamish, however.

Table 19 *PEHC* estimates for EWS and ESS hatchery programs in the Nooksack and Stillaguamish Basins (Warheit 2014a; WDFW 2015a; Unsworth 2016).

Basin	**Listed Population**	**PEHC and 90% CI from EWS programs**	**Projected *PEHC* from EWS programs**	**PEHC and 90% CI from ESS programs**
Nooksack	Nooksack (W)	1(0-4)	1	0 (0-2)
	SF Nooksack (S)	0(0-7)	0	0 (0-7)
Stillaguamish	Stillaguamish (W)	0 (0-7)	0	18 (13-25)
	Deer Cr. (S)	0 (0-3)	0	0 (0-5)
	Canyon Cr. (S)	0 (0-5)	0	0 (0-5)

In the Stillaguamish Basin, estimates for the ESS program are 0% for both summer steelhead natural populations, but 18% for the winter steelhead natural population. It is curious that the gene flow estimate from summer steelhead releases would be so much larger in a winter steelhead population than in summer steelhead populations. Gene flow would be expected to be higher in the populations with a life history more similar to the hatchery fish than in populations with the dissimilar life history. Another concern about the 18% *PEHC* estimate is that it is based on the same mixed smolt sample that was discussed above with respect to PEHC from EWS programs. Because of the age of the sample and its mixed composition, we have little confidence that it reflects current gene flow from ESS hatchery fish. It is logical to expect that whatever the past gene flow levels have been, current gene flow levels are likely to be considerably reduced due to the complete cessation of tributary-level hatchery outplants of steelhead throughout Puget Sound.

Upon NMFS request, WDFW estimated *DGF* from the Whitehorse ESS program into the Stillaguamish winter steelhead natural population (Hoffmann 2016; Scott 2016; WDFW 2016). DGF averaged 0.5%, and ranged from 0.35% to 0.72% (recent past and projected) over the four assumed stray rate-RRS combinations (as in Table 16), casting further doubt on the 18% *PEHC* estimate. Securing and analyzing new genetic data for the Stillaguamish Basin for purposes of estimating PEHC from both EWS and ESS needs to be a high priority for WDFW for continued operation of these programs (Section 2.8.4), but at this point it seems unlikely that gene flow from the EWS and ESS programs combined, pose significant risk to Stillaguamish steelhead natural populations.

NMFS concludes that the proposed action does not appear, at this time, to pose significant risk through gene flow or other genetic effects to the survival or recovery of ESA-listed steelhead natural populations in the Nooksack, Stillaguamish, and Dungeness Basins. However, NMFS also feels that this conclusion must be validated as indicated above by; 1) further development of the Warheit method to answer concerns raised in the NWFSC review and in this analysis, 2) further development of the genetic monitoring plan, and 3) 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.

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. This is because steelhead and Chinook salmon have different temporal and spatial natural spawning preferences, because EWS, generally speaking, spawn before (i.e., earlier than) natural-origin steelhead, and because few EWS escape to spawn naturally in the first place.

The first hatchery egg takes over the last 10 years have averaged December 29, December 30, and December 31 for the Kendall, Dungeness, and Whitehorse programs, respectively (WDFW, unpublished weekly in-season hatchery escapement reports from 2004-2015, and following). The earliest first egg take during this 10-year period took place on December 17, December 21, and December 22 for the Dungeness, Kendall, and Whitehorse programs, respectively. The latest first egg take took place January 20, January 14, and January 11 for the Dungeness, Whitehorse, and Kendall programs, respectively. Older (2000-2004) weekly WDFW in-season hatchery escapement reports indicate last egg takes and fish captures typically occurred from early-February to early-March. Hoffman (2014) determined that during the most recent years when hatchery traps were operated well into the month of March, that 8.4 and 18.4 percent of the total hatchery-origin steelhead returns entered Kendall Creek Hatchery and Whitehorse Ponds Hatchery after January 26, respectively. EWS spawn timing was therefore assumed to occur from late-December through early-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, reflecting the proportion of the total return removed by fisheries, has averaged 65 to 70 percent in the three action area basins. The number (harvest and hatchery escapement) of EWS returning to action area watersheds is not large, averaging 85, 356, and 777 adults over the last twelve years in the Dungeness, Nooksack, and Stillaguamish basins, respectively (WDFW 2014a; 2014b; 2014c). 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 85, 777, and 785 in the Dungeness, Stillaguamish, and Nooksack basins, respectively. Thus given the approximately 65% exploitation rate on EWS, the potential numbers of EWS returning to the hatcheries or terminal areas would be approximately 30, 271, and 275 for the Dungeness, Stillaguamish, and Nooksack basins, respectively. Recent year (2001-2013) annual hatchery rack escapement data provided in the HGMPs (WDFW 2014a; 2014b; 2014c) indicate that most unharvested fish remaining in total annual returns would home to their hatchery release sites, where weirs and traps are operated for the entire EWS adult return period to remove them from the natural environment to reduce straying.

Chinook salmon spawning takes place much earlier than any potential spawning by steelhead, including stray EWS. The earliest returning Chinook salmon spawn from late-July through September (North Fork Nooksack population) and the latest returning Chinook salmon spawn from mid-September through October (South Fork Stillaguamish population [Table 20]). The earliest and latest Chinook salmon spawning therefore is complete two to three months prior to the initiation of EWS spawning. In addition, Chinook salmon redds are typically constructed in larger substrate (i.e., different locations) than the substrates preferred by steelhead; although there is some overlap in substrate size utilized by two species (Kondolf and Wolman 1993). The anticipated low 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 very unlikely.

EWS straying into natural spawning areas 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 populations (Table 20), and their primary spawning habitats are thought to be isolated by cascades and waterfalls that are likely unpassable during higher winter streamflows (WDFW and WWITT 1994, Mauldin et al. 2002, Myers 2014). Hoffman (2014) estimated that only 6.2 and 1.3 percent of all natural-origin winter-run steelhead spawning occurred prior to March 15, in the Nooksack and Stillaguamish basins, respectively. As discussed above, the large proportion of the total annual EWS adult returns removed through harvest and escapement to the hatcheries decreases the number of hatchery fish available for straying into natural steelhead spawning areas. While spatial overlap likely exists between stray hatchery-origin steelhead and natural-origin steelhead, temporal separation between EWS and natural steelhead spawners, and the likely low number of steelhead remaining in the rivers after harvest and escapement to the hatcheries, decreases the likelihood of substantial competition for spawning sites and makes redd superimposition unlikely.

Negligible Effect- Effects on Population Viability:

EWS are produced for fisheries harvest augmentation purposes, and are managed to be isolated from the ESA-listed steelhead populations in the Dungeness, Nooksack, and Stillaguamish rivers. 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 stocks non-native status in the watersheds where they are released, the program may have negative effects on natural steelhead genetic diversity (see "Genetic Diversity" discussion 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).

Negligible effect – Marine-derived Nutrients:

ESA-listed Chinook salmon and steelhead in the Dungeness, Nooksack, and Stillaguamish basins would 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 would contribute nutrients that increase productivity in action area basins, providing food resources for naturally produced Chinook salmon and steelhead (WDFW 2014a; 2014b; 2014c). Diminished numbers of salmonids returning to spawn in most Puget Sound watersheds have resulted in nutrient deficiencies compared to historical conditions, affecting salmon and steelhead productivity potential. 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.

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

Species (Population)	Terminal Area/River Entry Timing	Spawn Timing	Spawning Locations
Chinook			
Dungeness	May - August	mid-August - - mid-October	Dungeness and Gray Wolf rivers
North Fork Nooksack	February - July	late-July - Sept	North Fork, Middle Fork, and large tributaries
South Fork Nooksack	March - August	mid-August - September	South Fork and large tributaries
North Fork Stillaguamish	June - August	late-August - mid-October	North Fork and large tributaries
South Fork Stillaguamish	August - September	mid-September - October	Mainstem Stillaguamish, South Fork Stillaguamish, and large tributaries
Steelhead			
Dungeness	November - early-June	March- June	Dungeness and Gray Wolf Rivers, tributaries
Nooksack	November - October	February - June	Mainstem, North Fork, Middle Fork, South Fork, tributaries
South Fork Nooksack	April - October	February - April	South Fork above RM 25.0, tributaries
Stillaguamish	November - April	March - June	Mainstem, North Fork, and South Fork Stillaguamish, tributaries
Deer Creek	July - mid-October	March - May	Deer Creek upstream of RM 5.1
Canyon Creek	June - Oct	February - April	Canyon Creek upstream of RM 1.2

Data sources: Williams et al. 1975, WDFW and WWITT 1994, Myers et al. 1998, Haring 1999, WCC 1999, Mauldin et al. 2002, Stillaguamish Tribe 2007, WRIA 1 Salmon Recovery Board 2005, Hard et al. 2007, PSIT and WDFW 2013; 2014, Myers et al. 2015; WRIA 1, 5, 18 WDFW spawning ground database, accessed January 2015 (updated through 2012).

For example, diminished adult salmon and steelhead returns to the Dungeness River have resulted in nutrient deficiencies compared to historic conditions, and the productivity potential of salmon and steelhead has been degraded as a result. Adult salmon and steelhead spawning escapements have significantly declined to a fraction of their historic abundance, raising concerns about a lack of marine-derived nutrients returning back to the system in the form of salmon carcasses (Haring 1999). The Nooksack and Stillaguamish river basins are similarly starved of marine-derived nutrients historically provided by abundant adult salmon and steelhead returns. Natural spawning by stray hatchery-origin steelhead that results in in-river mortality and hatchery carcass seeding that would be implemented for a portion of annual adult returns through the WDFW hatchery steelhead programs (WDFW 2014a; 2014b; 2014c), would benefit marine derived nutrient deposition in the action area basins. However, the carcass biomass contributed by the hatchery programs would not be substantial compared with marine-derived nutrient input afforded by carcasses from naturally-spawning, natural-origin salmon and steelhead, which comprise the majority of the spawners at current depressed total abundance levels for the species.

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 would be implemented to address fish health are described in each of the three WDFW steelhead HGMPs. Fish health protection and maintenance measures, and hatchery sanitation procedures would 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 plan. Proposed fish health monitoring and evaluation measures are also described in those HGMP sections.

The hatchery programs would 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 would 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 would provide fish health management support and diagnostic fish health services. Following is a summary of fish health management procedures that would be applied during operation of the EWS hatchery programs (from WDFW 2014a; WDFW 2014b; and WDFW 2014c).

Minimally invasive fish health maintenance procedures would 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 would be routinely observed by hatchery staff, and non-lethal sampling would 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 would be removed from holding ponds and examined. If necropsy is warranted, the carcass would 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 would 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 would be would 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 would 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 would reduce the likelihood of disease transmission from program hatchery steelhead to naturally produced fish. When implemented, those practices would 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 three 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 would be associated with HGMP implementation appear to be adequately addressed and minimized.

Negligible effect to Negative 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 ESA-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 Dungeness River Hatchery is located at RM 10.5; the Kendall Creek Hatchery is located at RM 0.25 on Kendall Creek, tributary to the N.F. Nooksack River at RM 45.8; and Whitehorse Ponds Hatchery is located at RM 1.5 on Whitehorse Springs Creek, tributary to the North Fork Stillaguamish River at RM 28, which is a tributary to the Stillaguamish River at RM 17.8. EWS hatchery smolts must travel a minimum 10.5, 46.1, and 47.3 miles from their respective release sites in freshwater to reach an estuary and then 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). The relative sizes of EWS hatchery 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.

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

Species/Origin	***Life Stage***	***Individual Size (mm FL avg. and range)***	***Occurrence or Release Timing***
Chinook salmon (wild)	Fry	*39 (33-79)*	*Mid February-April*
Chinook salmon (wild)	Parr-Subyrlg.	*78 (43-120)*	*May-July*
Chinook salmon (wild)	Yearling	*120 (92-154)*	*late March-May*
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*
Steelhead (hatchery)	Smolt	*198-210*	*late-April-early-June*

-- Natural-origin Chinook salmon data from Volkhardt et al. 2006; Topping et al. 2008a (fry and parr data for the Dungeness River), Beamer et al. 2005 (yearling data), and WDFW juvenile out-migrant trapping reports (general fish size range and timing data from Seiler et al. 2000; 2003; 2004; Volkhardt et al. 2006; Kinsel et al. 2007).

- Natural-origin steelhead individual size data and occurrence estimates from Shapovalov and Taft (1954) and WDFW juvenile out-migrant trapping reports (Volkhardt et al. 2006; Kinsel et al. 2007).

- Hatchery-origin EWS smolt size at release and release timing ranges from WDFW 2014a; 2014b; 2014c.

Adverse resource competition effects on natural-origin ESA-listed steelhead and Chinook salmon 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 ESA-listed steelhead smolts from EWS hatchery 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 Kendall Creek and Whitehorse Ponds programs, and planned for the Dungeness Hatchery program, is volitional release of EWS hatchery smolts. EWS smolts would be volitionally released from hatchery rearing ponds - and non-migrating fish would be culled - to minimize hatchery fish residualization in freshwater. 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. 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 and reduced co-occurrence and interactions with natural-origin salmon and steelhead 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 number of residual steelhead, thereby reducing risks of associated negative ecological interactions between hatchery steelhead and natural-origin 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 than in years when the smolts were force released. These findings support implementation of volitional release practices for the EWS hatchery programs for the purposes of meeting ecological risk reduction and adult EWS production objectives of the HGMPs. Although Dungeness River Hatchery EWS would be forced released, juvenile out-migrant trapping data for the Dungeness River indicate that most (greater than 90%) of the hatchery fish leave freshwater for the estuary in under 14 days (Topping et al. 2006, Topping and Kishimoto 2008, Topping et al. 2008). The lower watershed release location (RM 10.5) and rapid seaward emigration of newly released steelhead indicate that the duration of interaction between EWS hatchery smolts and natural-origin fish, and the risk of predation, would be unsubstantial.

Included with volitional release practices applied by hatchery operators to promote rapid downstream migration are slot limit size at release criteria for EWS hatchery 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 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. Over 70% of steelhead under 180 mm TL were not detected at downstream sites, while approximately 85% of smolts over 180 mm TL were detected. This information suggests that release of juvenile steelhead less than 180 mm TL will contribute to residualism, and the ideal release size may be larger than 220 mm TL. Under the proposed EWS hatchery programs, the target average smolt size at release for yearling fish produced each year would 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, 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 of the population to pond edges, inflow, and outflow areas. When these conditions were observed after May 1st, rearing pond end-screens would be removed to provide the opportunity for migration-ready steelhead smolts ready to exit downstream. Steelhead that do not volitionally migrate out of the rearing vessel 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, would substantially reduce the likelihood for creation of residuals that could potentially compete with natural steelhead and Chinook salmon juveniles.

Although measures are applied to limit the duration of any interactions, there would likely be some level of overlap during the three to five week (21 to 35 days) outmigration period required for most volitionally released hatchery steelhead in the Nooksack and Stillaguamish river watersheds to exit freshwater, and the maximum one to two week (7 to 14 days) outmigration period for Dungeness River Hatchery forced released hatchery steelhead (Volkhardt et al. 2006; Topping et al. 2008a; 2008b). Although it is reasonable to assume that most (90%) of the newly released EWS smolts would have exited the rivers after three weeks (21 days), there is clear temporal and spatial overlap with out-migrating 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 all action area basins.

Beamer (2013) examined the effects of EWS production on natural Skagit River basin steelhead populations 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 impacting natural steelhead population potentially as a result of competition for food and space among hatchery and wild juveniles. In a similar correlative analyses of Skagit River EWS production and natural steelhead productivity trends, Pflug et al. (2013) concluded that their analysis indicated that EWS smolt releases have had a negative impact on natural steelhead population growth rates, hypothesized to be in part as a result of ecological interactions, potentially including EWS competition and predator attraction in river areas were EWS and wild 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 wild steelhead productivity.

Although these Skagit River studies demonstrated statistical correlation between EWS release numbers and wild steelhead productivity, the actual cause of wild steelhead productivity trends remains in question. It is possible that low productivity of wild 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 annual number of wild 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 that were not incorporated in modelling through the Skagit River studies that may have affected wild steelhead productivity. For example, Moore et al. (2015) showed that Skagit River-origin hatchery steelhead survived at the same or higher rate from release point to river mouth than wild 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 migration. 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 observed survival levels (Moore et al. 2015). Skagit River wild 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 wild 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 wild 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 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 22).

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

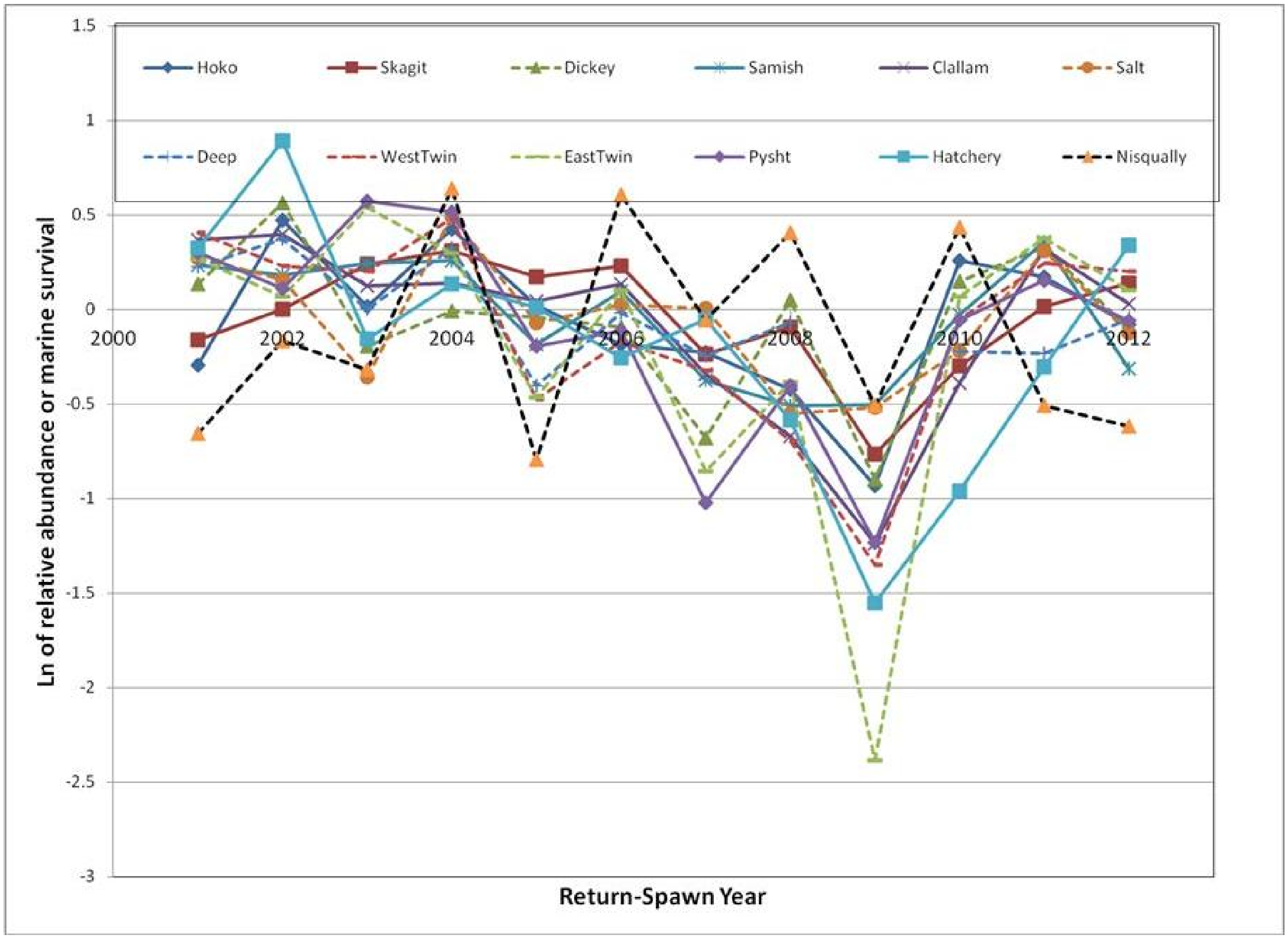

Figure 22. Comparative abundance or marine survival levels (SAR - smolt to adult return estimates) for natural steelhead populations in watersheds where hatchery steelhead are or were released (solid lines) and in watersheds lacking hatchery steelhead production (dashed lines). Included for comparison 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).

To reduce potential competition risks, the co-managers have proposed management practices designed 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 hatchery steelhead juveniles produced by the programs in the action area watersheds would be released on-station at sizes, and with appearances, and behaviors, indicating their status as seawater-ready smolts as a measure to foster rapid emigration seaward. This measure would reduce the duration of interaction with natural-origin steelhead during 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; WDFW 2014b; WDFW 2014c) to ensure the fish are at size that will promote downstream migration. The hatchery EWS smolt populations would be released at a uniform size closely adhering to the 5 to 6 fpp minimum to reduce the risk of residualism.
- All hatchery-origin steelhead smolts produced by Kendall Creek Hatchery and Whitehorse Ponds Hatchery would be volitionally released from hatchery rearing ponds to minimize residualization, and associated competition risks to natural fish. The plans 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 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). 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 of the population to pond edges, inflow, and outflow areas. When these conditions were observed after May 1st, rearing pond end-screens would 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 would be removed (culled) and planted into landlocked lakes to enhance recreational fishing opportunities.
- On-station release of smolts-only from Dungeness River Hatchery would confine any effects on natural steelhead to the lowest portion of the watershed (below RM 10.5), and for a duration of less 2 weeks before the EWS smolts exit freshwater after migrating the relatively short distance to seawater.
- Hatchery-origin and natural-origin steelhead juvenile emigration timing and co-occurrence and abundance would be monitored each year through operation of WDFW and tribal juvenile out-migrant trapping programs to evaluate whether hatchery smolt release timings pose substantial risks of harmful ecological interactions with ESA-listed natural-origin steelhead. Monitoring will provide estimates of EWS hatchery steelhead outmigration timing and freshwater residualism. Based on monitoring results, alternate EWS smolt release timings or other mitigation measures would be developed as necessary to minimize such interactions.

For the above reasons, for the three programs reviewed in this opinion, EWS hatchery smolt competition effects on listed natural-origin salmon and steelhead in freshwater are likely short in duration, and unsubstantial. Monitoring is required to verify this expectation. 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 determine whether EWS smolts are rapidly exiting freshwater areas as expected, will help ensure that competition risks are adequately minimized.

Negligible effect to Negative effect: Predation

Predation on naturally produced salmon and steelhead attributable to direct consumption or to 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) 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. 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 hatchery 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 Dungeness River Hatchery, Kendall Creek Hatchery, and Whitehorse Ponds Hatchery EWS smolt releases are the Dungeness mid-watershed release location (RM 10.5), the Kendall Creek upper-watershed release location (Kendall Creek RM 0.25, tributary to the North Fork Nooksack RM 45.8), and North Fork Stillaguamish upper-watershed release location (Whitehorse Springs RM 1.5, tributary to the North Fork Stillaguamish River RM 28, tributary to the Stillaguamish River RM 17.8). Risk is further indicated by the large individual fish size of EWS hatchery smolts relative to the size of natural-origin juvenile Chinook salmon that they would encounter (Table 21).

Yearling EWS hatchery fish would 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 (upper river) portions of the watersheds, and are present as yearling parr in migration reaches used by the hatchery yearlings months after the yearlings would be released (Section 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, would 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 10-year average size of EWS yearlings released from the Dungeness River Hatchery was 204 mm fl, with an average release date of May 23. During the last week of May, the period when the hatchery smolts would be released, Dungeness Chinook salmon juveniles have been shown to average 67 mm (fl) (range 46-90 mm fl) (size range data from Volkhardt et al. 2006; Topping et al. 2008a; 2008b). Dungeness River natural-origin juvenile Chinook salmon observed in late-May to mid-June average 71.2 mm fl (range 46-103 mm). 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 juvenile Chinook salmon in the Dungeness River is too large to be preyed upon, and that only the smallest juvenile Chinook present would potentially be vulnerable as prey to newly released EWS hatchery fish.

For several weeks in May, EWS hatchery yearlings released from Kendall Creek Hatchery would be of large enough average size (10 year average size at release of 205 mm fl) to prey on juvenile natural-origin Chinook salmon that average 64 mm (fl) (size range data from LNRD 2012; 2013). The average release date for EWS from Kendall Creek Hatchery is May 8. From late-May to mid-June, Nooksack River natural-origin juvenile Chinook salmon average 69.4 mm fl and are too large to be preyed upon by EWS hatchery fish. Only the smallest juvenile Chinook salmon present would potentially be vulnerable as prey to EWS.

EWS hatchery smolts released from Whitehorse Ponds Hatchery would be of large enough average size (10 year average size at release of 198 mm fl) to prey on juvenile natural-origin Chinook salmon that average 62 mm (fl) (size range data from Griffith and Scofield 2012; Scofield and Griffith 2012; 2013). The average release date for EWS from Whitehorse Ponds Hatchery is May 13 (WDFW 2014c). From late-May to mid-June, Stillaguamish River natural-origin juvenile Chinook salmon average 65 mm fl and would be vulnerable as prey to EWS hatchery fish.

Because EWS hatchery 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 rely to any substantial extent on fish as prey. 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 their prey, in 2010, being fish, primarily pink salmon. 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 none of the yearling Chinook salmon sampled for stomach contents at WDFW's 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 WDFW's 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, some number of the EWS smolts released from the hatcheries do 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) may 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. It is expected that monitoring of stream reaches downstream of hatchery release points will occur 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 would be seawater-ready smolts, propagated using methods to ensure that the fish are of uniform, large size that would ensure the fish 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 in the Dungeness River (Volkhardt et al. 2006; Topping et al. 2008a; 2008b) indicates that newly released Dungeness River Hatchery yearling steelhead migrate downstream rapidly, with the majority passing the trapping location in less than two weeks. In 2005, 89 percent of the hatchery steelhead were estimated to have passed the trap site on the way to the ocean within one week (7 days) of release (Volkhardt et al. 2006). In 2006, estimates were that 66 and 100 percent of the hatchery smolts passed the trap location within five and twelve days of release, respectively (Topping et al. 2008a). In 2008, the number was 100 percent within 16 days of release (Topping et al. 2008b). Downstream smolt trapping data in the Stillaguamish River (Stillaguamish Tribe, 2015, unpublished trap data for 2011-2014, and following) indicates that the vast majority of EWS released from Whitehorse Ponds migrate downstream rapidly and pass the trapping location in less than two weeks. In 2011, 99 percent of the EWS hatchery fish collected were captured within 14 days of the last hatchery release. In 2012, 97 percent were captured within 15 days of last hatchery release, in 2013, 100 percent were captured within 10 days of last the hatchery release, and in 2014, 98 percent were captured within 7 days of the last hatchery release. 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 scientific 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 proposed WDFW EWS hatchery programs would reduce temporal and spatial overlap and the potential for predation on listed juvenile salmon and steelhead through application of the following measures:

- All hatchery steelhead juveniles produced by the programs in the action area watersheds would be released on-station at sizes, and with appearances, and behaviors, indicating their status as seawater-ready smolts as a measure to foster rapid emigration seaward. This measure would reduce the duration of interaction with natural-origin steelhead during a life stage vulnerable to competition for food or space.
- All EWS smolts would be released no earlier than mid-April, and concentrated in May, immediately after a freshet (when possible), to foster rapid seaward emigration.
- All juvenile EWS released from Kendall Creek Hatchery and Whitehorse Ponds Hatchery would be released volitionally, as migration-ready smolts that have been shown through juvenile out-migrant trapping studies to move downstream rapidly to the estuary where they would disperse seaward. On-station release of smolts-only from Dungeness River Hatchery would confine any effects on natural steelhead to the lowest portion of the watershed before the EWS smolts exit freshwater after migrating the relatively short distance to seawater. Based on juvenile out-migrant trapping data, almost all of the EWS smolts produced by the three programs would exit freshwater areas downstream of the hatchery release sites within three weeks (21 days) of their release date. These best management release practices will minimize the potential for hatchery steelhead residualization that may exacerbate predation effects. Any non-migrating steelhead that remain in rearing ponds for

more than a few days after the hatchery screens are removed would be prevented from entering the natural environment, and instead planted into landlocked lakes to provide recreational fishing opportunities.

- Juvenile out-migrant monitoring (permitted for ESA-listed fish takes through separate ESA consultations) would continue in the Dungeness, Nooksack, and Stillaguamish watersheds to verify that hatchery fish move quickly to the ocean and that residual rates are low, and determine annual salmonid size and timing by fish origin, and to identify spatial and temporal overlap among natural- and hatchery-origin juvenile out-migrant aggregations.
- If natural-origin smolt outmigration timing, determined by downstream juvenile migrant monitoring in the mainstem rivers, suggests that proposed release timings for yearling steelhead from the hatcheries would result in predation effects that are greater that the effects considered in the opinion, alternate release timings or other mitigation measures will be developed and implemented to effectively reduce such interactions.

In summary, although there would 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 may be piscivorous, NMFS does not expect that predation by newly released EWS smolts would pose a substantial risk to 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 propose to include numerous measures to prevent significant spatial and temporal overlap between EWS smolts and Chinook salmon juveniles. Juvenile outmigrant trapping data indicating that EWS smolts migrate out of the river basins quickly and that a very low number residualize in freshwater. While a small amount of take through predation cannot be discounted, the number of Chinook salmon juveniles expected to be consumed by EWS hatchery 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 EWS hatchery-origin smolts to compete with and prey on natural-origin Chinook salmon and steelhead in estuarine and marine waters has been considered in this consultation. 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), 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-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 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 the importance or significance of the early marine life stage 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. EWS production could exacerbate density-dependent effects during years of low ocean productivity. However, there are no studies that demonstrate, or even suggest the magnitude of EWS smolt release numbers into Puget Sound that might be associated with adverse changes in 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 all the steelhead production in Puget Sound, can effect natural-origin salmon survival and productivity in the Northeast Pacific Ocean (Ruggerone et al. 2011; Ruggerone et al. 2010), the degree of impact or 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 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 preference for the middle offshore 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. 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 natural-origin Skagit River steelhead 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 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 (2002a) concluded that predation by hatchery-origin fish on juvenile natural-origin fish in marine waters 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, and 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 the size of the 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 the Puget Sound, depending on whether a very conservative estimate (6% Chinook in diet) or reasoned assumptions (20% Chinook in diet in May and June 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 is 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 and are most concentrated. Subyearling Chinook salmon tend to use nearshore 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 for different species makes sense from an evolutionary and survival perspective and it naturally reduces the likelihood that hatchery-origin steelhead would pose a pose substantial competition risks to subyearling Chinook salmon in marine waters.

The proposed EWS smolt release hatchery programs would 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 outside of the basin. The maximum total number of EWS smolts that would be released from the hatchery programs is 290,000 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% of the estimated 9.0 million natural-origin juvenile Chinook salmon entering Puget Sound each year. EWS smolts would 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 the hatchery released fish transited through the Strait of Georgia towards the Pacific Ocean. Studies in Puget Sound indicate that only 13 percent to 70 percent of 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), and that is even before they reach Puget Sound.

The number of adult fish produced by the proposed hatchery actions would also represent an unsubstantial 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 Dungeness River winter-run hatchery-origin steelhead was 88 fish, or 0.24 percent of the total Puget Sound run size of the species for the entire region. Over the same period, the average total annual return of Nooksack River and Stillaguamish winter-run hatchery-origin steelhead was 412 and 860 fish, or 1.14 and 2.37 percent of the Puget Sound run size of the species for the entire region, respectively. These percentages are expected to decline further because EWS hatchery production has been reduced and because natural-origin steelhead are expected to increase in abundance as habitat remediation and other recovery efforts proceed.

Table 22. Average total adult returns of Dungeness, Nooksack, and Stillaguamish 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
Dungeness Steelhead	88[1/]	36,223[4/]	0.24%
Nooksack Steelhead	412[2/]		1.14%
Stillaguamish Steelhead	860[3/]		2.37%

1/ Estimated total terminal area adult return of winter-run hatchery-origin Dungeness River steelhead from WDFW 2014a; assumes a post-harvest 30% stray rate applied to hatchery escapement.
2/ Estimated total terminal area adult return of winter-run hatchery-origin Nooksack River steelhead from WDFW 2014b; assumes a post-harvest 30% stray rate applied to hatchery escapement.
3/ Estimated to-al terminal area adult return of winter-run hatchery-origin Stillaguamish River steelhead from WDFW 2014c; assumes a post-harvest 30% stray rate applied to hatchery escapement. .
4/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 2014d; WDFW 2014e; WDFW 2014f; Myers et al. 2015; Hard et al. 2015; Pflug 2013; WDFW and Long Live the Kings 2012; Scott and Gill 2008; WDFW 2005a; 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 effects of Dungeness, Nooksack, and Stillaguamish basin EWS hatchery-origin juvenile and adult 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 effects-related research, monitoring, and evaluation (RM&E) (see Section 2.4.1.5). The programs include RM&E to monitor and verify performance and effects of the EWS hatchery actions, and to inform future decisions regarding how the hatchery program can make adjustments that further reduce risks to ESA-listed action area Chinook salmon and steelhead.

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 three HGMPs include RM&E actions designed to verify performance of the programs in meeting their fisheries harvest augmentation and ESA-listed fish protection and effects objectives. Specific RM&E actions for the three HGMPs are described in section 1.10 and section 11.0 of each HGMP. 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 steelhead and Chinook salmon natural populations. In particular, the co-managers will monitor interactions between juvenile hatchery- and natural-origin salmonids in freshwater and marine areas within the region to evaluate and manage program ecological effects. They will also collect tissue samples from juvenile and adult steelhead in each watershed to verify and limit gene flow effects of the EWS hatchery programs on associated natural populations (Anderson et al. 2014), and validate low (less than 2%) gene flow levels for the programs.

An adult steelhead monitoring program (spawning ground surveys) will be conducted annually to verify origin, abundance, and spatial structure of steelhead escaping to natural spawning areas and to hatchery facilities (WDFW 2014a; 2014b; 2014c). In addition, within the Dungeness River system adult genetic samples will be collected and analyzed to compare the number of hybrid and hatchery-ancestry fish observed from smolt sampling (Anderson 2014, and following). Within the Nooksack River watershed, genetic sampling of adults will occur as available. Within the Stillaguamish River watershed, adult genetic sampling will be conducted in the Deer Creek subbasin on a rotating basis 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 ESA-listed adult steelhead would generally be confined to visual observations of spawning fish during spawning ground surveys that may lead to avoidance behavior and temporary displacement of ESA-listed fish from preferred areas until surveyors move through a stream reach. Steelhead carcasses would be removed from the water, and sampled for biological data and tissues (for DNA analyses) before being returned to the recovery location. These activities would have only very minor, temporary effects on ESA-listed steelhead and any effects will be greatly offset by the importance and usefulness of RM&E data and analysis to steelhead management and recovery. 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 three HGMPs affecting juvenile salmonids are described in section 1.10 and section 11.0 of each HGMP (WDFW 2014a; 2014b; 2014c). Although the results of these juvenile fish RM&E actions would be used to guide implementation of the proposed steelhead hatchery programs, juvenile salmonid sampling occurring outside of the hatchery locations have been previously authorized through a separate ESA consultation process (NMFS 2009; NMFS 2015b). This information is vital to understanding steelhead dynamics and status and to informing decisions on how to recover them. 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 program ecological effects. Continued juvenile out-migrant trapping by WDFW and by the Jamestown S'Klallam, Lummi and Stillaguamish tribes is planned using rotary screw traps and a channel spanning panel weir (Matriotti Creek only) in the Dungeness River and Matriotti Creek, the Nooksack River, and the Stillaguamish River, 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-listed natural-origin coho, chum, and pink salmon. Smolt traps positioned downstream from single or multiple steelhead populations will obtain a mixed sample at trapping sites (Anderson 2014, and following). In cases of multiple populations (e.g., Stillaguamish River trap site), 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 will implement a ten-year monitoring plan and sample up to 100 unmarked juvenile steelhead annually from the Dungeness, Nooksack, and Stillaguamish river smolt traps. Under the separate ESA authorization provided for the juvenile and adult steelhead and salmon RM&E activities described in the HGMPs , completion and distribution of annual reports describing approved listed fish sampling actions and results are required (NMFS 2009; 2015b).

Other effects of the proposed hatchery steelhead programs on ESA-listed salmon and steelhead populations would also be monitored and considered with other habitat- and harvest-related effects. These actions would help determine whether the programs were harming juvenile and adult Chinook salmon or steelhead as a result of operation of the hatcheries, 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 would 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:

Dungeness River Hatchery
The majority of the water supply systems used for EWS rearing in the proposed programs are designed and operated such that groundwater extraction and surface water withdrawals are not expected to reduce survival, spatial distribution, and productivity of natural-origin Dungeness River Chinook salmon and steelhead. However, the hatchery water intake structures on the Dungeness River and Canyon Creek supplying Dungeness River Hatchery, and on Hurd Creek for the Hurd Creek Hatchery, do not meet the latest NMFS intake screening or fish passage criteria (WDFW 2014a) and below we discuss the effects of these facilities on ESA-listed salmon and steelhead.

The Canyon Creek water intake is adjacent to a small dam that completely blocks anadromous fish access to upstream spawning habitat. Although included as designated critical habitat for steelhead, the creek is not part of designated critical habitat for Chinook salmon (70 FR 52630, September 2, 2005).

As described in Section 2.3.2, above, WDFW is in the process of constructing an approved fish ladder, a project for which NMFS issued a biological opinion in 2013 (NMFS 2013b). The construction will bring the structure into compliance with NMFS (2011c) fish passage criteria by fall 2017. The intent during ladder construction is to operate the existing ladder for successful fish passage and that means a minimum flow of 22 cubic feet per second (cfs) will be provided in the fishway. This level of flow will provide sufficient conditions in the fish ladder and in the reach downstream of the dam to allow fish passage (NMFS 2013b).

WDFW is bringing water intake structures on the Dungeness River into compliance with the latest NMFS fish passage criteria. The current three structures used to withdraw water from the mainstem Dungeness River will be consolidated into one structure, which will remain passable to upstream and downstream migrating fish (WDFW 2014a). Work on the mainstem water intake is planned for completion by fall 2020. Until that construction is complete, the Dungeness Hatchery mainstem structures are expected to pose unsubstantial fish passage risks to migrating juvenile and adult salmon. This is not about providing fish passage it is about improving upon existing fish passage. Although out of compliance with current NMFS (2011c) fish passage criteria, no fish passage problems or fish mortality events have been observed during operation of the water intakes. Screening on the current water intakes on the Dungeness River mainstem does not meet current NMFS screening requirements (NMFS 2011c), but does meet NMFS previous screening criteria (NMFS 2008a), and NMFS (2011c) states that such screening is adequately protective of listed Chinook salmon and steelhead from impingement and entrainment effects until the structures are renovated, at which time they must meet the latest NMFS (NMFS 2011c). WDFW will ensure that screening on the new water intake is in compliance with the latest NMFS criteria when construction is completed by fall 2020.

As noted in Section 1.3.1.5, the Dungeness River Hatchery uses surface water exclusively, currently withdrawn through the water intakes on the mainstem Dungeness River, in addition to the water intake on Canyon Creek. Dungeness River Hatchery may withdraw up to 40 cfs of surface water from the Dungeness River and up to 8.5 cfs from Canyon Creek. Assuming hatchery water withdrawals at the maximum permitted levels 10 percent of the water in the river could be withdrawn during median flows 406 cfs) (Table 23). Up to 100 percent of the water in Canyon Creek could theoretically be diverted into the hatchery for discharge into the Dungeness River at the hatchery outfall, assuming maximum hatchery water withdrawal levels at the annual median flow. As noted above, minimum flow criteria were developed in connection with a NMFS consultation on the construction of the Canyon Creek fish ladder and water intake, to provide fish passage in Canyon Creek (NMFS 2013b).

While water intake screens at Hurd Creek Hatchery currently do not comply with the latest NMFS criteria (NMFS 2011c), a recent specific on-site evaluation of the Hurd Creek Hatchery surface water intake screen indicates adverse effects on any migrating salmonids are unlikely (WDFW 2015b). The intake is a horizontal inclined screen that is positioned at the bottom of a pond created in a Hurd Creek side-channel that is away from creek areas where downstream-migrating salmon and steelhead would be present. Rather than operating the intake by directing water flow over (and through) the screen, water is instead backwatered over the screen by the placement of stop logs at the downstream end of the screen. WDFW indicates that because the intake is positioned and operated in an off-channel pond, it is unlikely that the intake screen would contact or cause impingement by natural-origin salmon or steelhead. The Hurd Creek Hatchery facility uses a combination of groundwater withdrawn from five wells, and surface water withdrawn from Hurd Creek for fish rearing and as an emergency back-up source. Under its State

Table 23. Water source and use by Dungeness River salmon hatchery facilities.

Hatchery Facility	Surface Water Use Max (cfs) [1]	Surface Water Source	Ground-water Use Min/Max (cfs)	Daily Average Surface Water Flow (min/mean/max) (cfs) [2]	Maximum Percentage of Total Surface Water Withdrawn for Hatchery Program (%) [4]	Effluent Discharge Location	NPDES Permit Number
Dungeness River Hatchery	40	Dungeness R.	0	114 / 406 / 3,890	35 / 10 / 1	Dungeness River RM 10.5	WAG 13-1037
	8.5	Canyon Creek	0	2 / 8 / 25	100 / 100 / 34		
Hurd Creek Hatchery	1.4	Hurd Creek	0.9 – 4.5	2 / 5/ 7	70	Hurd Creek RM 0.5	NA [3]
Gray Wolf Acclimation Pond	1.0	Gray Wolf R.	0	/ 189 /	0.5	Gray Wolf River RM 1.0	NA [3]
Upper Dungeness Acclimation Ponds	1.0	Dungeness R.	0	/ 358 /	0.3	Dungeness River RM 15.8	NA [3]

[1] Maximum allowable surface water withdrawal for hatchery use under Washington State water withdrawal permits #S2-06221 and #S2-21709 for Dungeness River and #S2-00568 for Canyon Creek. Hurd Creek Hatchery retains groundwater permit # G2-24026 (WDOE 2012b).

[2] October through September 5-year (2010-2014) mean, minimum, and maximum flow data for the lower Dungeness River from USGS Dungeness River Stream Flow Monitoring Station #12048000 just downstream of Dungeness River Hatchery near RM 10.5, accessible at: http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12048000&PARAmeter_cd=00060,00065. Additional source of flow data is EDPU (2005) available at: http://www.clallam.net/environment/elwhadungenesswria.html. Flows presented for the Gray Wolf River and upper Dungeness River are the estimated incremental average annual flows from EDPU (2005). The Dungeness River Management Team recommended minimum instream flows for the lower Dungeness River at seasonal flow levels recommended by the Dungeness Instream Flow Group (EDPU 2005; Hiss 1993): November through March: 575 cfs; April through July: 475 cfs; and August through October: 180 cfs. These minimum flows are not based on seasonal, historical Dungeness River flows, but represent flows required to maintain optimal potential fish habitat area (EDPU 2005).

[3] A NPDES Permit is not required for hatchery facilities producing less than 20,000 pounds of fish each year.

[4] Maximum percentage withdrawals derived assuming hatchery use of available surface water up to water maximum permitted surface water withdrawal levels. Actual surface water percentages withdrawn for use in the hatcheries as applied to minimum and mean surface water flows are much lower.

water right permit, Hurd Creek Hatchery may withdraw up to 1.4 cfs from Hurd Creek. Under a worst case scenario (in the unlikely event that the maximum permitted amount was diverted during the lowest natural flow conditions, see below), up to 70 percent of the water in the Hurd Creek could be withdrawn to rear Chinook and fall-run pink salmon in the hatchery. Although unlikely to occur because use of surface water at the full permitted amount is not necessary for fish rearing during the annual low flow period, withdrawal of this proportion of the total flow in the creek would likely affect the ability of adult fish to migrate upstream. WDFW plans to upgrade fish screens at Hurd Creek Hatchery to ensure compliance with NMFS fish passage criteria by summer 2017.

The two Dungeness River basin hatchery facilities have current surface water right permits issued by WDOE authorizing water withdrawals up to the amounts identified as maximums in their permits.

Withdrawal of surface and groundwater for use in the Dungeness River Hatchery EWS hatchery program would have no substantial effect on ESA-listed fish in the watershed. All water used by the hatcheries, minus any loss by evaporation, would be returned to the watercourses near the points of withdrawal. Fish biomass in the hatcheries 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 flows in river and tributary sources reach annual maximums. We do not expect water withdrawal for use at the hatcheries to result in take of ESA-listed salmonids through dewatering of any stream reaches.

Fish rearing at Dungeness River Hatchery is implemented consistent with NPDES permit number WAG 13-1037 issued by WDOE (Table 23). Under its NPDES permit, the hatchery operates an off-line settling pond and artificial wetland to remove effluent before the water is released back into the Dungeness River (WDFW 2014a). Although under the 20,000 pounds per year fish production criteria set by WDOE for needing a permit, WDFW has still constructed a two-bay pollution abatement pond to treat water prior to its release into Hurd Creek.

Structures and measures proposed for adult steelhead broodstock collection would not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. Steelhead broodstock would be collected as volunteers to Dungeness River Hatchery. The facility is removed from ESA-listed Chinook salmon and steelhead migration and rearing areas, and there would be no effects resulting from operation of broodstock collection actions at the hatchery.

Kendall Creek Hatchery

Effects to ESA-listed Chinook salmon and steelhead from in-water structures and associated screening for the Kendall Creek Hatchery EWS program are negligible. The screens at this facility have been identified for replacement but are a lower priority than at other hatcheries because ESA-listed fish do not utilize habitat upstream of the rack on Kendall Creek (WDFW 2014b). Other structures at this hatchery include two weirs for collecting returning salmon and hatchery adult steelhead for use as hatchery broodstock. The lower weir directs all returning adults into a holding pond, and the upper weir restricts further movement upstream into the hatchery. Current hatchery operational protocols require immediate upstream passage of all adult natural-origin coho salmon and cutthroat trout, and downstream release of all bull trout, that encounter the weirs (K. Clark, unpublished WDFW data, pers. comm., February 18, 2015, and following). Any natural-origin steelhead and Chinook and pink salmon that encounter the weirs are returned to the North Fork Nooksack River. Flows in Kendall Creek are typically quite low during the Chinook and pink salmon migration and spawning seasons making the stream unsuitable for migration and spawning. Flows during the steelhead spawning period are adequate for migration and spawning, however, steelhead do not appear to utilize Kendall Creek for spawning upstream of the hatchery rack. WDFW hatchery records indicate that during the last 10 years, no natural-origin steelhead have entered the hatchery trap.

Both surface and well water are used for EWS production at the hatchery. The surface water supply is limited by low flows because Kendall Creek can have little to no flow during the summer months. Surface water rights are formalized through trust water right permits G1-1056c, G1-2361c, and S1-00317. From December through March of each year, up to 50,000 Kendall Creek Hatchery EWS are transported to McKinnon Rearing Ponds. The McKinnon facility is supplied exclusively by surface water. The gravity water intake screens at the McKinnon Rearing Ponds meet the current federal fish passage criteria (NMFS 2011c). Surface water rights are formalized through trust water right permit number S1-27351.

The majority of the water supply systems used for EWS rearing are designed and operated such that groundwater extraction and surface water diversion do not reduce survival, spatial distribution, and productivity of natural-origin Nooksack River Chinook salmon and steelhead. As noted in Section 1.3.1.5, Kendall Creek Hatchery facility uses surface and groundwater, currently withdrawn through one water intake on Kendall Creek, and five wells. Kendall Creek Hatchery may withdraw up to 23.8 cfs of surface water from Kendall Creek and up to 27.2 cfs from the five wells. Stream flow gauging on Kendall Creek is limited to a three-year period from water year 1948 through 1950; during this period, average monthly stream flow averaged 28.2 cfs. The highest flows occurred from February through May, averaging 55 cfs. Intermediate flows occurred in December, January, and June, averaging 29.2 cfs. The lowest flows occurred from July through November, averaging 6.3 cfs. The maximum cfs in their permit represents up to 100, 82, and 43 percent of the mean monthly flows in Kendall Creek during the low, intermediate, and high flow months respectively. The estimated hatchery water withdrawal proportion of the total flows during the low flow period is a worst case estimate that is unlikely to be realized. Like Kendall Creek flow, surface water withdrawal needs for the hatchery program also 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.

The McKinnon Rearing Ponds uses gravity fed surface water from a stream locally known as "Peat Bog Creek" (WRIA 01.0352). Up to 2 cfs of surface water may be diverted into the rearing ponds. No stream flow data are available for this water source. Monitoring and measurement of water usage are reported in monthly NPDES reports to WDOE.

Withdrawal of surface and groundwater for use in the Kendall Creek Hatchery EWS program would have no substantial effect on ESA-listed fish. All water used by the hatchery facilities would be returned to the watercourses near the points of withdrawal. Fish biomass in the hatchery, 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 flows in North Fork Nooksack River (to which Kendall Creek is a tributary) reach annual maximums. We do not expect water withdrawal for use at the hatchery to result in take of ESA-listed salmonids.

Fish rearing at Kendall Creek Hatchery is implemented consistent with NPDES permit number WAG 13-3007 issued by WDOE. Under its NPDES permit, Kendall Creek Hatchery operates a water cleaning treatment system to remove pollutants before effluent is discharged back into natural waters (WDFW 2014b). The McKinnon Rearing Ponds are relatively small and under the 20,000 pounds per year fish production criteria requiring a permit by WDOE. The outflow from the ponds consists of a settling box and approximately 100 yards of heavily vegetated stream channel that returns directly into Peat Bog Creek (not far above the confluence with the Middle Fork Nooksack River).

Structures and measures proposed for adult steelhead broodstock collection would not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. All EWS used as hatchery broodstock would be collected as volunteers to Kendall Creek Hatchery. The facility is removed from ESA-listed Chinook salmon and steelhead migration and rearing areas, and there would be no effects resulting from operation of broodstock collection actions at the hatchery.

Whitehorse Ponds Hatchery

Effects to ESA-listed Chinook salmon and steelhead from in-water structures and associated screening for the Whitehorse Ponds Hatchery EWS program are negligible. ESA-listed fish do not utilize Whitehorse Spring Creek, or habitat upstream of the water intake structure (WDFW 2014c), so there would be no hatchery facility-related effects. Both surface and well water are used by the hatchery for EWS production. The surface water supply at the hatchery is limited by seasonal flows and range from 0.2 cfs during the summer low flows to 6.2 cfs during high flows (spring). Surface and well water rights are formalized through trust water right permits S1-00825 and G1-28153p, respectively (WDFW 2014c). During low flow periods, well water can be used to supplement surface water for fish rearing at a flow rate of approximately 1.1 cfs.

Fish rearing at the Whitehorse Ponds facility is implemented consistent with NPDES permit number WAG 13-3008 issued by WDOE. Under its NPDES permit, Whitehorse Ponds Hatchery operates a water cleaning treatment system to remove pollutants before effluent is discharged back into natural waters (WDFW 2014c). Structures and measures proposed for adult steelhead broodstock collection would not substantially affect migration or spatial distribution of natural-origin juvenile and adult Chinook salmon and steelhead. All EWS used as hatchery broodstock would be collected as volunteers to Whitehorse Ponds. The facility is removed from ESA-listed Chinook salmon and steelhead migration and rearing areas, and there would be no effects resulting from operation of broodstock collection actions at the hatchery.

2.4.2.7 Fisheries

EWS hatchery fish are produced for harvest only and steelhead fisheries in the Nooksack, Dungeness, and Stillaguamish rivers 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 for steelhead and Chinook salmon were considered through this consultation, and NMFS found that operation of the hatchery programs would have a negligible effect on shared PCEs for these ESA-listed salmonid species 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 three EWS hatchery programs have not led to: 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 proposed 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 river and tributary channels, and do not affect designated critical habitat for ESA-listed steelhead and Chinook salmon. The only effects of proposed hatchery operation actions on PCEs for steelhead and Chinook salmon would result from water withdrawals (water quantity), effluent discharge (water quality), and migration delay, migration blockage, or fish injury occurring at hatchery water intake structures.

We do not expect adverse effects on critical habitat associated with the fish ladder at the Canyon Creek diversion dam – in fact, the HGMP requires a functional fish ladder and this will restore anadromous fish access to several miles of potential habitat. Regarding water withdrawal effects, water needs for the hatchery are at their lowest when instream-flows are at their lowest, during the summer and fall months, and measureable effects on critical habitat for steelhead in Canyon Creek are therefore highly unlikely.

WDFW plans to upgrade fish screens at Hurd Creek Hatchery to ensure compliance with NMFS fish passage and screening criteria by summer 2017. For the reasons provided by WDFW in the agency’s evaluation and findings regarding the current water intake and screening structure (Section 2.4.2.6; WDFW 2015b), risks of entrainment and mortality to ESA-listed Chinook salmon and steelhead are unlikely to be substantial. The location of the Hurd Creek Hatchery surface water intake in an area removed from stream reaches where Chinook salmon and steelhead adults and juveniles would migrate, and the horizontal design of the intake that draws water from the bottom of a created off-channel pond, lessen the risk of listed fish injury and mortality. The water intake and screening are expected to be adequately protective of listed fish over the two year period until the structure is renovated to be in compliance with the latest NMFS criteria.

Hatchery water intake structures and associated screening at the other EWS hatcheries would be operated so that the steelhead and Chinook salmon PCE for unobstructed freshwater migration corridors is not substantially affected. All water intakes would be operated to protect ESA-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 proposed for retrofitting on set schedules to meet those criteria (where listed fish are present).

Proposed surface water withdrawals for rearing EWS for the Dungeness River Hatchery, Kendall Creek Hatchery and Whitehorse Ponds programs 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 programs would 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 would 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, and water withdrawn for hatchery use is non-consumptive, 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 that have a very low risk of being realized, because the amount of water needed at a particular time for diversion from surface waters or extracted by wells is dictated by the number and life-stage of embryos or fish on hand at the hatchery. Like natural flows, hatchery water needs fluctuate seasonally, with the highest hatchery water withdrawal needs occurring in the spring months when surface water flows are highest, because that is when fish are at their largest size (as smolts) and need high rearing flows for fish health maintenance. Hatchery water withdrawal levels are lowest in the summer and early fall months when surface water flows are at their lowest, because hatchery biomass (young of the year fry and parr) is at seasonal lows, and commensurate rearing water needs are low.

Hatchery effluent released into receiving waters after use for EWS rearing is not expected to affect water quality to the detriment of freshwater spawning, rearing, and migration corridor PCEs for steelhead and Chinook salmon. Consistent with NPDES effluent discharge permit requirements developed by EPA and the WDOE for upland fish hatcheries, water used for fish production of EWS at the hatcheries would be adequately treated prior to discharge into downstream areas to ensure that federal and state water quality standards for receiving waters are met and that downstream aquatic life, including listed salmon and steelhead, are protected. The hatcheries have current NPDES permits that require monitoring, measurement, and monthly reporting to WDOE of water use, chemical use, and effluent discharge levels (WDFW 2014a; WDFW 2014b; WDFW 2014c).

Following NPDES permit requirements, the following water quality parameters, selected by EPA and WDOE as important for determining hatchery-related water quality effects, are monitored at the EWS hatcheries:

- Total suspended solids - 1 to 2 times per month on composite effluent, maximum effluent and influent samples.
- Settleable solids - 1 to 2 times per week through effluent and influent sampling.
- In-hatchery water temperature - daily maximum and minimum readings.

Consistent with the NPDES permits issued for the programs, all water used for fish rearing is released into off-line settling ponds and (for Dungeness River Hatchery) an artificial wetland where settleable solids and nutrients from fish feces and uneaten food are removed before the water is discharged back into receiving waters.

Fish production at satellite hatchery ponds used for the Dungeness River Hatchery and Kendall Creek Hatchery programs are below annual levels for which NPDES permits are required, and for which effects on water quality and fish are of concern. The satellite ponds produce low annual levels of fish poundage, well under the 20,000 pounds per year trigger for NPDES permit. Annual fish production under 20,000 pounds per year typically produces effluent amounts that exert no more than local and transitory impacts on ESA-listed salmonids, assuming adequate mixing and dilution occur.

For these reasons, the proposed hatchery programs are not expected to pose substantial risks to designated critical habitat through water quality impairment to downstream aquatic life, including ESA-listed salmon and steelhead. No hatchery maintenance activities are expected to adversely modify designated critical habitat for these listed fish species.

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 regional 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 (SSPS 2005c)) and Volume II of the plan (SSPS 2005a SSPS 2005b; and SSPS 2005c) describe, in detail, the on-going and proposed state, tribal, and local government actions that are targeted to reduce known threats to ESA-listed salmon in the Dungeness, Nooksack and Stillaguamish river watersheds. A recovery plan for Puget Sound steelhead has yet to be developed, but 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 ESA-listed species. State, tribal, and local governments have developed plans and initiatives to benefit listed species (SSPS 2005c) 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 expect the activities identified in the baseline to continue at similar magnitudes and intensities as in the recent past. On-going State, tribal, and local government salmon restoration and recovery actions implemented through the Shared Strategy Plan (SSPS 2005c) and through other plans and initiatives (e.g., Hood Canal Coordinating Council's Summer Chum Salmon Plan (HCCC 2007) will 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., SSPS 2005). But the actions must actually be funded and in the process of implementation (most are not) and sustained in a comprehensive manner before NMFS can consider them "reasonably certain to occur" 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 steelhead DPS and Puget Sound Chinook salmon ESU, including natural populations in the Dungeness, Nooksack, and Stillaguamish river basins. Following the fish restoration strategies described in the Shared Strategy Plan (SSPS 2005c), the individual watershed volumes of the Shared Strategy Plan (SSPS 2005a; SSPS 2005b; SSPS 2005c), 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, marine shorelines, and Puget Sound; instream flow protection and enhancement; and reduction of forest practice and farming impacts on salmon habitat. Specific actions to recover ESA-listed salmon and steelhead in Puget Sound watersheds, including the Dungeness River, Nooksack River, and Stillaguamish River watersheds (recent examples in Section 2.3.3), 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. Also, the effects of such activities are sometimes difficult to demonstrate in the near-term, as benefits may take varying periods of time to show an effect. To the extent that the effects of these protection and restoration actions improve the likelihood of survival and recovery of the ESA-listed species, such effects will be reflected in the species' status and abundance. Consideration of protection and restoration actions is included in the following integration and synthesis of 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 (Section 2.3) and the cumulative effects (Section 2.5), taking into account the status of the species and critical habitat (section 2.2), to formulate the agency's opinion as to whether the Proposed Action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species 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 appreciably 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 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 and analysis of the proposed EWS hatchery 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 negligible to negative (see Table 12). Of the effects categories evaluated, three hatchery–related factors – gene flow to natural steelhead populations resulting from natural spawning by hatchery-origin steelhead and affecting steelhead population genetic diversity; hatchery-origin yearling steelhead competition with natural-origin steelhead juveniles affecting steelhead population abundance; and, Dungeness River 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 Dungeness, Nooksack, and Stillaguamish river watersheds (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 three EWS hatchery programs is identified as having negative effects on Puget Sound steelhead population diversity. 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 Nooksack and Stillaguamish river watersheds (Warheit 2014a), and application of a demographic-based method for steelhead in the Dungeness, Nooksack, and Stillaguamish rivers (Scott and Gill 2008; Hoffmann 2014; WDFW 2014a; WDFW 2014b; WDFW 2014c). Based on NMFS's consideration of the present level of empirical and theoretical information currently available on the subject, gene flow levels of 2% into natural-origin Puget Sound steelhead populations will pose only minor genetic risk resulting in reduced fitness. For the three proposed EWS hatchery programs, these two credible and independent analytical approaches indicate that gene flow (measured either as *PEHC* or Gene Flow) resulting from implementation of each program should be under the 2% level with sufficient confidence in all affected natural-origin steelhead populations (Table 19).

To reduce effects to genetic diversity, as part of the proposed EWS hatchery program actions, measures would 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; 2014c). These measures would include: use of only localized EWS broodstock that spawn prior to February 1st to promote homing fidelity to each hatchery release site, and encourage temporal separation between natural origin steelhead and EWS; fully acclimating hatchery smolts to the hatchery release sites, with no off-station planting, to enhance returning adult fish homing fidelity; operating weirs and traps at the hatcheries for the full duration of the EWS adult return period to attract fish back to hatchery facilities where they originated and maximize removal from the natural environment of adult fish escaping to the watersheds, and prohibiting any steelhead recycling (i.e., returning adult hatchery steelhead to the river to increase harvest opportunity). Extensive monitoring and evaluation actions would be implemented to verify 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-origin populations in the Dungeness, Nooksack, and Stillaguamish river basins would be monitored (Anderson, 2014) to verify that the hatchery programs are meeting the requirement to remain below 2% gene flow.

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.

The ESS hatchery programs are similarly part of the environmental baseline. Although there is considerable uncertainty about ESS gene flow levels that should be remedied as soon as possible with a new sample for genetic analysis, it is possible that this program poses no more genetic risk to natural winter-run steelhead than the Whitehorse Ponds EWS program included in the proposed action. PEHC and Projected PEHC estimates for the Whitehorse Ponds EWS program are "0" for all natural steelhead populations affected by the program (Section 2.4.2.2). Because best available science-based estimates indicate that gene flow associated with the EWS program is already very low, application of any additional measures to reduce risks associated with the Stillaguamish River ESS program by adjusting the Whitehorse Ponds EWS program would result in negligible changes in genetic risks imparted by the basin's hatchery steelhead programs.

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 fitness is likely low, consistent with analyses and findings described in Section 2.4.2.2, and considering risk minimization actions included as part of the Proposed Action, any fitness loss effects are likely to be very minor. To ensure that genetic effects remain minor and at levels estimated for the proposed programs, NMFS believes the following actions should be implemented: 1) further development of the Warheit (2014a) method to address concerns stated in the NWFSC review and in the analysis in this document, 2) further development 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 our interest in the further development of the Warheit methodology and in increasing our confidence in 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 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 hatchery smolts is likely to have negative effects on listed natural-origin steelhead abundance and productivity in those portions of the action area where the hatchery-origin and natural-origin fish commingle (Section 2.4.2.3). Adverse resource competition effects on natural-origin ESA-listed steelhead fry and parr associated with hatchery EWS smolt releases are unlikely because of substantial size and hence prey differences (SIWG 1984) between the EWS 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 associated with WDFW hatchery EWS 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. Because all EWS juveniles would be released as migrating, seawater-ready smolts as a measure to foster rapid emigration seaward, competition and any resulting effects on natural-origin fish is expected to be extremely limited. The practice of releasing only actively migrating smolts, that would exit freshwater rapidly, would reduce the duration of interaction with natural-origin steelhead that may be vulnerable to competition for food or space. Smolt out-migration studies in the Dungeness and Stillaguamish rivers indicate that most EWS emigrate rapidly downstream after their release (Volkhardt et al. 2006; Topping et al. 2008a; 2008b; Stillaguamish Tribe, 2015, unpublished trap data for 2011-2014), and exit the river to seawater where they disperse into expansive marine areas where competition risks become negligible.

For these reasons, and consistent with analyses findings described in Section 2.4.2.32.4.1.4, the magnitude of effects to ESA-listed steelhead abundance and productivity from competition with juvenile EWS is likely to be very low, and the proposed actions are unlikely to pose substantial risks to the viability of the listed natural steelhead populations in the action area, or impede the recovery of the ESA-listed Puget Sound steelhead DPS. To verify this low competition risk assessment, hatchery-origin and natural-origin steelhead smolt emigration timing and abundance would 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 would 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 and maintenance activities associated with implementation of the Dungeness River Hatchery EWS program are likely to affect ESA-listed steelhead abundance, but only temporarily and only to a limited degree. Similar activities at Kendall Creek Hatchery and Whitehorse Ponds are not expected to pose substantial risks to listed steelhead (Section 2.4.2.6). The water intake and associated screens used for the Dungeness River program 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 (WDFW 2014a; NMFS 2011c). WDFW is in the process of updating their facilities at the Dungeness River and Canyon Creek water intake structures, with plans to complete work by fall 2020 and fall 2017, respectively. The current three structures used to withdraw water from the Dungeness River will be consolidated to one structure, which will be passable to upstream and downstream migrating fish (WDFW 2014a). When renovated, the Dungeness River mainstem structure is not likely pose substantial fish passage effects to migrating juvenile and adult steelhead. Although out of compliance with current NMFS (2011c) fish passage criteria, no fish passage problems or fish mortality events have been observed during operation of the mainstem water intakes. The current water intakes on the Dungeness River mainstem meet NMFS previous screening criteria (NMFS 2008a), and NMFS (2011c) states that such screening is adequately protective of listed steelhead from impingement and entrainment effects until the structures are renovated, at which time they must meet current NMFS screening criteria (NMFS 2011c). WDFW will ensure that screening on the new water intake is in compliance with the latest NMFS criteria when construction is completed.

With regards to the Canyon Creek water intake, by fall 2017, a fish ladder will be constructed in the dam that impounds water for periodic (winter only) use by the hatchery, so that the structure is passable to migrating fish (WDFW 2014a: A. Carlson, WDFW, pers. comm., April 24, 2015). Through a separate NMFS ESA consultation (NMFS 2013b), effects of the construction of the fish ladder to allow unimpeded upstream and downstream passage for salmon, steelhead, and bull trout were found not likely to adversely affect ESA-listed salmon and steelhead. The ladder construction was designed so that the hatchery water intake structure on Canyon Creek will be brought into compliance with NMFS fish passage criteria (NMFS 2011c). It was also completed earlier so that remediation of the ladder could be accelerated and fish passage improved as soon as possible. Until remediation is complete, the structure will continue to negatively effects steelhead passage, but not at a level that affects viability. Construction of the ladder will provide access to additional upstream habitat for steelhead in Canyon Creek. 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 ESA-listed steelhead will be reduced to an inconsequential level.

By the summer of 2017, fish screens at Hurd Creek Hatchery will be updated to ensure compliance with NMFS fish passage criteria. Until that time and for the reasons provided by WDFW in the agency's evaluation and findings regarding the current water intake and screening structure (Section 2.4.2.6; WDFW 2015b), effects from entrainment and mortality are not likely to affect the viability status of the Dungeness River steelhead natural population. The location of the Hurd Creek Hatchery surface water intake in an area removed from creek reaches where steelhead adults and juveniles would migrate, and the horizontal design of the intake that draws water from the bottom of a created off-channel pond, substantially reduce the level of injury and mortality to ESA-listed fishes. The water intake and screening are expected to be adequately protective of listed fish over the approximately one-year period (2016-fall 2017) until the structure is renovated to be in compliance with the latest NMFS criteria.

Withdrawal of surface water at maximum permitted levels for fish rearing 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 for the reasons previously discussed (Sections 2.4.2.6 and 2.4.2.8). As dictated by fish biomass at the hatchery rearing locations, required water withdrawal amounts would reach 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 Dungeness River, Canyon Creek, and Hurd 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 the analyses of effects described in Sections 2.4.2.6 and 2.4.2.8, the magnitude of adverse effects on ESA-listed steelhead abundance, spatial structure, and productivity associated with hatchery operation and maintenance actions is likely very low;, and on-going monitoring would make possible an adaptive management response if conditions warrant. 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 Skamania); declining diversity in the DPS, including the uncertain, but weak 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 and 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 DPS diversity (NWFSC 2015), but it also noted that there have been substantial improvements in the programs including the termination of several EWS hatchery programs, reduced smolt releases, ceasing off-station smolt releases altogether, termination of "recycling" adults trapped at the hatcheries downstream to enhance sport fisheries, and maintaining traps open for the entire duration of the EWS adult period to remove as many hatchery fish from the rivers as possible. All of these risk minimization measures have been applied to the EWS programs reviewed in this opinion, as well as the two EWS programs analyzed in NMFS (2016b). While also considering gene flow estimates that suggest that the influence of hatchery EWS in several natural populations is 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 ESA-listed DPS and the potential 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 a negative effect on natural steelhead populations that are part of the Puget Sound steelhead DPS. As discussed above, some low, negative effects to ESA-listed steelhead natural populations 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 a negligible effect 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 proposed action is likely to adversely affect ESA-listed steelhead but it will not appreciably reduce the likelihood of ESA-listed steelhead 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 negligible to negative (see Table 12). Of the effects categories evaluated, two hatchery–related factors - hatchery EWS predation on ESA-listed juvenile Chinook salmon population abundance; and Dungeness River Hatchery facility water intake structure and screening effects on Chinook salmon population abundance and spatial structure - were assigned as having negative effects on listed Chinook salmon in the Dungeness, Nooksack, and Stillaguamish river action area watersheds (see Sections 2.4.2.3 and 2.4.2.6).

Predation Effects **(Section** 2.4.2.3)
To reduce predation effects on juvenile Chinook salmon in freshwater, all yearling steelhead released from the three WDFW hatcheries would be seawater-ready smolts, propagated using methods to ensure that the fish are of uniform, large size that would ensure the fish are physiologically ready to emigrate downstream, and not residualize in freshwater (Section 2.4.2.3). The proposed EWS hatchery programs would also reduce temporal and spatial overlap and the potential for predation on rearing or migrating ESA-listed juvenile Chinook salmon by releasing yearling EWS from May through early-June, after the majority of juvenile Chinook salmon have migrated seaward (Table 20). Volitional releases of steelhead smolts at Kendall Creek Hatchery and Whitehorse Ponds Hatchery should 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 have substantial negative effects on the viability of the listed natural Chinook salmon populations, or impede recovery of the listed Puget Sound Chinook salmon ESU. On-going monitoring would make management responses possible if conditions warrant. To verify this low predation risk assessment, juvenile out-migrant monitoring will continue in the watersheds 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 would be revised if juvenile out-migrant monitoring in the Dungeness, Nooksack, and Stillaguamish rivers suggests that release timings for yearling EWS results in substantial predation on vulnerably sized, 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 and maintenance activities is likely to have negative effects on ESA-listed Chinook salmon of the same types and at the same magnitudes as described above for steelhead. Hatchery operation and maintenance activities associated with implementation of the Dungeness River Hatchery EWS program is likely to reduce Chinook salmon abundance. The same activities at Kendall Creek Hatchery and Whitehorse Ponds are expected to pose negligible effects to ESA-listed Chinook salmon, because natural populations of the species are absent in the tributaries where the two hatcheries operate (Section 2.4.2.6). Although the hatchery water intake screens on the Dungeness River and Canyon 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 (WDFW 2014a). WDFW is in the process of updating fish passage and/or screening facilities at the locations of the Dungeness River and Canyon Creek water intake structures, with plans to complete work by fall 2020 and fall 2017, respectively. The current three structures used to withdraw water from the Dungeness River will be consolidated to one structure, which will be passable to upstream and downstream migrating fish (WDFW 2014a). When renovated, the Dungeness River mainstem structure will provide improved conditions for migrating juvenile and adult Chinook salmon. Although out of compliance with the latest NMFS (2011c) fish passage criteria, no Chinook salmon passage problems or fish mortality events have been observed during operation of the mainstem water intakes. The current water intakes on the Dungeness River mainstem meet NMFS previous screening criteria (NMFS 2008a), and NMFS (2011c) states that such screening is adequately protective of listed steelhead from impingement and entrainment effects until the structures are due for renovation, at which time they must meet the latest NMFS screening criteria (NMFS 2011c). WDFW will ensure that screening on the new water intake is in compliance with the latest NMFS criteria when construction is completed.

With regards to the Canyon Creek water intake, by fall 2017, a fish ladder will be constructed in the dam that impounds water for periodic (winter only) use by the hatchery, so that the structure is passable to migrating Chinook salmon (WDFW 2014a: A. Carlson, WDFW, pers. comm., April 24, 2015). Through a separate NMFS ESA consultation (NMFS 2013b), effects of the construction of the fish ladder to allow unimpeded upstream and downstream passage for salmon, steelhead, and bull trout were found not likely to adversely affect ESA-listed salmon and steelhead. The ladder construction was designed so that the hatchery water intake structure on Canyon Creek will be brought into compliance with NMFS fish passage criteria (NMFS 2011c). Currently, although the creek is not part of designated critical habitat for the species, the structure impedes Chinook salmon passage. Construction of the ladder will provide access to additional upstream habitat for Chinook salmon in Canyon Creek. 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 ESA-listed Chinook salmon will have been addressed.

WDFW plans to upgrade fish screens at Hurd Creek Hatchery to ensure compliance with NMFS fish passage criteria by the summer of 2017. For the reasons provided by WDFW in the agency's evaluation and findings regarding the current water intake and screening structure (Section 2.4.2.6; WDFW 2015b), risks of entrainment and mortality of ESA-listed Chinook salmon are not likely to affect the viability status of the Dungeness Chinook salmon natural population. The location of the Hurd Creek Hatchery surface water intake, in an area removed from creek reaches where Chinook salmon adults and juveniles would migrate, and the horizontal design of the intake that draws water from the bottom of a created off-channel pond, substantially reduce the risk of substantial listed Chinook salmon injury and mortality. The existing water intake and screening structures will provide some protection to ESA-listed fish during the approximately one-year interim period (2016- fall 2017) until the structure is renovated to be in compliance with the latest NMFS criteria.

Withdrawal of surface water at maximum permitted levels for fish rearing would decrease the quantity of water available for Chinook salmon migration and rearing, resulting in negative effects. However, negative effects on Chinook salmon viability are unlikely, because, for the reasons described in Sections 2.4.2.6 and 2.4.2.8, 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 (). As dictated by fish biomass at the hatchery rearing locations, required water withdrawal amounts would reach 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 Dungeness River, Canyon Creek, and Hurd 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 the analyses and findings described in Sections 2.4.2.6 and 2.4.2.8, the magnitude of effects on ESA-listed Chinook salmon abundance, spatial structure, and productivity associated with hatchery operation and maintenance actions is likely to be low; and the proposed actions are unlikely to pose more than very minor effects to listed Chinook salmon, and on-going monitoring would make possible management responses if conditions warrant. 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 State Conservation Commission's (WSCC) WRIA 18 Limiting Factors Analysis (Haring 1999), the WSCC's WRIA 1 Limiting Factors Analysis (Smith 2002), and the WCC's WRIA 5 Limiting Factors Analysis (WSCC 1999) identified primary limiting factors and threats to Chinook salmon populations in the Dungeness, Nooksack, and Stillaguamish river basins. These limiting factors and threats, summarized in the individual watershed volumes of the Shared Strategy Plan (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 salmonids; 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 was not identified as a limiting factor or threat, and would not affect any of these factors or threats in any way.

This analysis has considered limiting factors identified for the ESA-listed Puget Sound Chinook salmon ESU, and the likely 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 2.3.1), the effects of past hatchery operations (Section 2.3.2), and habitat protection and restoration projects implemented to benefit ESU 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 salmon 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 EWS 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 guidance. 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 ESU.

2.6.3 Critical Habitat

Designated critical habitat for ESA-listed Puget Sound steelhead and Puget Sound Chinook salmon is described in Sections 2.2.1.2 and 2.2.2.2 of this opinion, respectively. In reviewing the proposed action and evaluating its effects, NMFS has determined that the proposed action will not degrade habitat designated as critical for listed fish spawning, rearing, juvenile migration, and adult migration purposes.

The mainstem water intake structures used by Dungeness River Hatchery on the mainstem Dungeness River and in Hurd Creek Hatchery as currently designed do not pose substantial risks to critical habitat associated with upstream and downstream anadromous fish access. Screening at both sites is in compliance with NMFS (2005) and NMFS (2006) screening criteria, and water intakes used are in the process of being replaced or renovated so that they will be in compliance with the latest NMFS fish passage and screening criteria (NMFS 2011c). For the interim period, the intake structures at the two locations are expected to pose only low and unsubstantial negative effects to Chinook salmon and steelhead critical habitat in the action area (Section 2.4.2.6). Under current conditions, the water intake structure on Canyon Creek adversely affects anadromous fish access to critical habitat for steelhead (the creek is not designated critical habitat for Chinook salmon). As reviewed and approved through a separate NMFS ESA consultation (NMFS 2013b), WDFW will, by fall 2017, construct a ladder in the dam on Canyon Creek that impounds water for periodic (winter only) use by the hatchery so that the structure is more efficient at passing migrating fish. Through that separate NMFS ESA consultation, effects of the construction of the fish ladder to allow unimpeded upstream and downstream passage for salmon, steelhead, and bull trout were found not likely to adversely affect critical habitat for steelhead. NMFS's approval of the ladder construction is designed so that the hatchery water intake structure on Canyon Creek will be brought into compliance with the latest NMFS fish passage criteria (NMFS 2011c), and will thereby no longer affect designated critical habitat for steelhead.

Withdrawal of surface water at maximum permitted levels for fish rearing would reduce the quantity of water available for salmon and steelhead migration and rearing between the hatchery water intake and water discharge points, leading to adverse effects on designated critical habitat. However, this situation, diverting the maximum permitted levels of flow and adverse effects to designated critical habitat, is 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. Fish biomass at the EWS 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 flows in watersheds 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 and steelhead in the action area that may lead to substantial effects is therefore highly unlikely.

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 Dungeness River water intake structures are proposed. The proposed action includes strict criteria for withdrawing and discharging water used for fish rearing. In summary, the proposed action is expected to have minor effects on a very limited portion of the critical habitat designated for Puget Sound steelhead and Puget Sound Chinook. Because the effects are minor, and will impact only a small portion of designated critical habitat, the proposed action is not expected to affect the ability of critical habitat to serve its intended conservation role for the species.

2.6.4 Climate Change

Steelhead and Chinook salmon populations in the Dungeness, Nooksack, and Stillaguamish river basins may 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 Olympic and Cascade Mountains would be expected to reduce spring and summer flows, impairing water quantity and water quality in primary fish rearing habitat located in the mainstem Dungeness and Gray Wolf rivers, Nooksack River (including the North, South, and Middle Forks), and the Stillaguamish River (including the North and South Forks). Predicted increases in rain-on-snow events would 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 ESA-listed fish species. Additional access to spawning and rearing habitat in Canyon Creek in the Dungeness River watershed provided through construction of a fish ladder may also provide a small buffer to climate effects by increasing spawning and rearing capacity.

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.[37] 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 five factors applicable to the proposed EWS hatchery program actions. 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 Dungeness River Hatchery facility 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 Dungeness River Hatchery facility water intake structure and screening effects on natural-origin Chinook salmon survival and migration.

Take by Genetic Effects

Implementation of the EWS hatchery programs is expected to result in gene flow, and adverse effects on steelhead population diversity and fitness, resulting from natural spawning by hatchery fish straying into natural-origin, native steelhead production areas in the Dungeness, Nooksack, and Stillaguamish river watersheds. 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 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

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[37] 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.

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]), with a coefficient of variation of less than 50%. The 2% level corresponds to a modeled fitness loss over 25 generations of approximately 10%.

Analysis of the three programs in the proposed action indicates that all three will be under the 2% level. Compliance with this take limit will be based on an aggressive monitoring effort: a four consecutive-year span over which gene flow must be maintained below 2% with a sufficient degree of confidence is appropriate in this instance. This time span 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 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 Dungeness, Nooksack, and Stillaguamish river basins 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 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 Dungeness, Nooksack, and Stillaguamish river basins 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 Effects of Water Intake Structures

The existing Dungeness River Hatchery water intake structures on the Dungeness River mainstem and Canyon Creek are likely to take ESA-listed Chinook salmon and 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 watershed. The mainstem intakes present risks of entrainment for juvenile fish in no more than a total of 4 square meters of migration and rearing area adjacent to the intakes, where intake water velocities may be high enough to cause fish to be drawn from the river into the intake screens. Following completion of the planned construction activities described above, the area affected by the intake structures is not expected to change, but compliance with current NMFS criteria would be expected to 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 Canyon Creek currently impedes upstream access to approximately 1.6 miles of potential fish habitat, where only some of the area upstream is suitable habitat for salmonid spawning and rearing (NMFS 2013b). When the fish ladder construction is completed, ESA-listed fish could pass above the current impediment, and therefore be exposed to the water intake structure. The risk of entrainment of juvenile fish would also be 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 Canyon Creek into the intake screens. Because Canyon Creek contains a relatively small amount of spawning and rearing habitat for Chinook salmon and steelhead as a proportion of total basin habitat, only a small proportion of the listed fish populations in the Dungeness River would be exposed to this effect. With renovation of the Canyon Creek water intake structure as described above, the area affected by the intake structure will not change, but compliance with current NMFS criteria will reduce the amount of take in that area, because the intake screening would 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 jeopardize the Puget Sound Chinook salmon ESU or the Puget Sound steelhead DPS, or result 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 Dungeness River Hatchery, Kendall Creek Hatchery, and Whitehorse Ponds 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 smolt releases do not pose competition threats to juvenile natural-origin steelhead in the Dungeness, Nooksack, and Stillaguamish river watersheds at levels greater than those described and evaluated for the proposed actions in this opinion.

4. Ensure that EWS smolt releases do not pose predation threats to juvenile natural-origin Chinook salmon in the Dungeness, Nooksack, and Stillaguamish river watersheds at levels greater than those described and evaluated for the proposed actions in this opinion.

5. Ensure that screening used for Dungeness River Hatchery operations is renovated so that all screening associated with program implementation complies with NMFS 2011 "Anadromous Salmonid Passage Facility Design" criteria by fall 2020.

6. 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.

7. Implement the hatchery programs as described in the three steelhead HGMPs and monitor their operation.

8. 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 Dungeness, Nooksack, and Stillaguamish river watersheds to the extent feasible, based on natural conditions. These data will be collected for the purpose of validating 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 Dungeness, Nooksack, and Stillaguamish river watersheds.
1c. For four consecutive years 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 between naturally spawning EWS and the associated natural-origin steelhead populations in the Dungeness, Nooksack, and Stillaguamish river watersheds.
1d. For four consecutive years beginning with the 2020 smolt outmigration, annually report estimates of *PEHC* for naturally spawning steelhead populations in the Dungeness, Nooksack, and Stillaguamish river watersheds. *PEHC* estimates may be based on smolt sampling, adult sampling, or a combination of the two. The four-year average (2020-2023) for *PEHC* shall not exceed 2%.
1e. 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 signature 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 signature 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 signature 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 signature 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. The plan will be implemented in the first calendar year following its review and approval by NMFS.
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 signature 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 steelhead, proportion of hatchery returnees remaining in the river to spawn, temporal and spatial overlap of hatchery-origin and natural-origin spawners, incidence 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 WDFW and 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 Dungeness, Nooksack, and Stillaguamish rivers.
3c. Submit any revisions of individual fish release size and timing protocols described in the three 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 WDFW and 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 Dungeness, Nooksack, and Stillaguamish 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 all water intake structures and screening used by the Dungeness River Hatchery EWS program by fall 2020.
5b. 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.
5c. Ensure that new water intake structures and associated screening at Dungeness 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 downstream 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, 5b, 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, 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 three 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 three hatchery steelhead programs in the Dungeness, Nooksack, and Stillaguamish river basins, 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 Dungeness River from RM 0.0 to the upstream extent of anadromous fish access at RM 18.7; the Gray Wolf River from its confluence with the Dungeness River at RM 15.8 to the upstream extent of anadromous fish access; Hurd Creek from its confluence with the Dungeness River at RM 2.7 to the upstream extent of anadromous fish access; Canyon Creek from its confluence with the Dungeness River at RM 10.8 to the upstream extent of anadromous fish access; and Dungeness Bay (see Figure 1, above). The Nooksack River basin from RM 0.0 to the upstream extent of anadromous fish access in the North, Middle, and South fork river watersheds; Kendall Creek from its confluence with the North Fork Nooksack River at RM 45.8 to RM 0.1; and Bellingham Bay (Figure 2). The Stillaguamish River from RM 0.0 to the upstream extent of anadromous fish access in the North Fork and South Fork Stillaguamish river basins; and Port Susan (Figure 3).

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 Dungeness, Nooksack, and Stillaguamish rivers 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 action area basins; ecological interactions and genetic effects in Chinook, coho, and pink salmon spawning areas in the watersheds; and ecological effects in rearing areas for the species in the basins, 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 Dungeness River Hatchery that have affected fish migration will occur by fall

2020, and 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 Dungeness River downstream from RM 10.5, in the North Fork Nooksack and Nooksack rivers downstream of RM 45.8, and in the South Fork Stillaguamish and Stillaguamish rivers downstream of RM 28 and 17.8, respectively.

The release of yearling steelhead through programs at Dungeness River, Kendall Creek, and Whitehorse Ponds 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. Although the steelhead smolts would be released form the hatcheries after the identified pink salmon fry migration period in the Nooksack and Dungeness River watersheds, no pink salmon emigration data are available for the Stillaguamish River. The small size of the pink salmon fry makes the species vulnerable to hatchery steelhead smolt predation if the species interact in Stillaguamish River areas downstream of the hatchery fish release site. An elevated risk for predation effects on Chinook salmon EFH for hatchery steelhead yearling releases is assigned based on the middle (Dungeness River RM 10.5) and upper watershed release locations (Kendall Creek 46.1 miles upstream of Bellingham Bay and Whitehorse Ponds 47.3 miles upstream of Port Susan), 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 Whitehorse Ponds hatchery steelhead releases is possible based on the unknown pink salmon fry emigration timing for the Stillaguamish River, the upper watershed release location (Whitehorse Ponds 47.3 miles upstream of Port Susan), 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 Dungeness and Nooksack 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 program in the lower Dungeness, Nooksack, and Stillaguamish rivers through this consultation, and two other ESA consultations (NMFS 2009: NMFS 2015b). 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 Dungeness River Hatchery water intake structures in the Dungeness River and Canyon Creek 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 Dungeness River watershed affected by the intake structures have not been estimated. Effects associated with the intakes in the Dungeness River 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 Canyon 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 2013. Funds were appropriated in 2012 to renovate the intakes to meet current NMFS fish passage and screening requirements (WDFW 2014a), with construction scheduled to be completed by the fall 2017 (NMFS 2013b).

Effects from the Kendall Creek water intake structure are unlikely. The intake structure and adult trapping structure currently blocks access for migrating salmon to upstream EFH. However, current hatchery operation protocols call for upstream passage of all adult natural-origin coho salmon encountered at the structure (K. Clark, unpublished WDFW data, pers. comm., February 18. 2015, and following). The creek is not a natural spawning area used by natural-origin Chinook and pink salmon. Stream flows are typically quite low during the Chinook and pink salmon migration and spawning seasons, making the stream unsuitable for spawning. During the last 10 years, no pink salmon have entered the hatchery trap. Any stray natural-origin Chinook and pink salmon encountered during hatchery trapping operations are returned unharmed to the North Fork Nooksack River.

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 2013b), the co-managers will comply with NMFS Anadromous Salmonid Passage Facility Design criteria (NMFS 2011c) for all water intake structures supplying Dungeness River Hatchery by fall 2020. Although posing no adverse effects on salmon or steelhead migration, the Hurd Creek Hatchery surface water intake screens are scheduled for renovation in summer, 2017. The hatchery program operators will also monitor and report annually hatchery facility compliance with NMFS fish passage criteria, and will survey migration conditions in the bypass reaches between the Dungeness River Hatchery water intake structures on the Dungeness River and Canyon Creek, and report any blockages or delays observed in juvenile or adult salmon upstream and downstream migration.

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 2014c) 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 Dungeness, Nooksack, and Stillaguamish river basins.

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 Jamestown S'Klallam, Lummi, Nooksack, Stillaguamish, and 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 Dungeness, Nooksack, and Stillaguamish river basins, 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.

5 REFERENCES

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Appendix 1 - Overview of the EWS Sim Model

Craig Busack PhD., February 24, 2016

1. Single-generation version

EWS Sim was developed specifically to gain insights into the potential fitness effects on a single population of natural-origin steelhead of EWS spawning with them in the wild. The model, programmed in R, is largely based on the Ford model Ford (2002), simulating deterministic phenotypic change in a natural population at an arbitrary trait subject to stabilizing Gaussian selection relative to an optimal value. EWS Sim uses the same key parameters as the Ford model: heritability (h^2), selection strength (ω), hatchery and natural trait optima (θ_H and θ_W , respectively), and phenotypic variance (σ^2). We denoted hatchery and natural fraction of spawners as *pHOS* and 1-*pHOS*, respectively. The EWS Sim departs from the Ford model in three important respects:

1) It simulates selection at reproduction
2) It simulates the partial assortative mating scheme hypothesized for reproductive interactions between EWS (H) and natural-origin (N) fish (temporal zones where only NxN or HxH matings and a zone where NxN, HxN, and HxH are possible. In this respect it is similar to the model of Baskett and Waples (2013).
3) It is individual-based, both to be able to simulate mating dynamics more adequately, and to avoid assumptions of normality.

These differences required the introduction of four additional parameters: total number of spawners (*N*), proportion of H fish spawning distribution that overlaps spawning distribution of n fish (o_H), and vice versa (o_N), and the mean number of adult progeny produced by a high-fitness mating (*prog_ave*).

A model run consists of a user specified number of iterations, each involving the following steps:

1. Generation of parents:
    a. Total of n parents generated (1-*pHOS*)**n* are natural-origin (N), and *pHOS*n* are hatchery-origin (H).
    b. Equal numbers of males and females of each type (H or N).
    c. Each parental fish is identifiable by index number.
    d. For each fish, the additive component of the phenotype is randomly sampled from a Gaussian distribution with mean Θ_N or Θ_H, as appropriate, and standard deviation $\sqrt{h^2\sigma^2}$ (additive standard deviation).
    e. For each parental fish, the environmental component of the phenotype is randomly sampled from a Gaussian distribution with mean 0, and standard deviation $\sqrt{(1-h^2)\sigma^2}$.
    f. For each parental fish, the phenotype is the sum of the additive and environmental components.

   g. For each parental fish fitness is calculated as $\exp(-0.5 * \frac{(x-\theta_W)^2}{\omega^2})$, as in Ford (2002), where x is the phenotypic value and ω is a specified multiple of σ.

2. Mating structure:
   a. Total of *n*/2 matings are simulated, in three groups: N only, mixed N and H, and H only.
   b. Based on overlap and *pHOS* values, numbers of matings are calculated for each group
   c. Equal numbers of males and females are assigned to each group, and in-group, sex ratios of types are 1:1.
   d. For each mating, one male and one female are randomly chosen within the group, with replacement. Thus, an individual fish can participate in more than one mating.
3. Progeny generation:
   a. Number of offspring produced by each mating is determined by mean fitness of parents and parameter *prog_ave*; high-fitness pairs produce the max number, low produce none.
   b. *prog_ave* is usually set to 2.5, which results in the number of progeny being produced equaling the number of parents when there is not fitness difference between hatchery and natural-origin parents.
   c. The number of progeny produced by a mating is a random sample from a Poisson distribution with a mean equal to the product of mean parental fitness and *prog_ave* is rounded to the nearest whole number. This use of Poisson sampling resulted in the variance of family size being approximately equal to the mean family size.
   d. For each progeny fish the additive component of the phenotype is the mean of the parental additive values plus a random Gaussian (0, $\sqrt{(h^2\sigma^2/2)}$) deviate (Dupont-Nivet et al. 2006). The addition of the deviate simulates Mendelian sampling; functionally it keeps the additive variance from contracting.
   e. For each progeny fish, the environmental component of phenotype is generated as for the parental fish.
   f. Phenotype and fitness value for each progeny fish is generated as for parents
   g. For each progeny fish, index numbers of its parents are recorded, as well as its ancestry (0, 1, or 2 H parents).
4. Collection of results
   a. For each iteration number of progeny fish produced, *PEHC*, relative reproductive success (*RRS*), and differences between mean progeny and parental phenotypes and fitnesses are computed. The values are stored for each iteration.

   b. *PEHC* is computed as per Warheit (2014a, equation 3), by examining the progeny matrix and tabulating the proportions of progeny that resulted from NxH and HxH matings. Because all the progeny are available for inspection, *PEHC* is a "true" value and not an estimate.
   c. *RRS* is also computed by examination of the progeny matrix. Because the parents of each progeny fish are listed, it is straightforward to count the number of progeny produced by each parent. *RRS* is the mean progeny/parent for H fish divided by the corresponding value for n fish. Because all the progeny are available for inspection, *RRS* is a "true' value and not an estimate.

5. Summary- after completion of all iterations, means and other summary statistics are computed over all iterations

2. Multiple-generation version

Mechanics are the same as for single-generation version, but process is repeated a user-specified number of generations within each iteration, and tracking of variables is restricted to fitness and phenotype.

1. The natural-origin parents for the next generation are created by randomly sampling without replacement (1-*pHOS*)**n* fish from the previous generation's progeny. This obviously requires production of at least (1-*pHOS*)**n* progeny. Because fitness reductions could allow the number of progeny fish to fall below this value under strong selection scenarios. When this occurred, *prog_ave* was adjusted upward the minimal amount needed to eliminate the problem.
2. Hatchery-origin parents are generated each generation as in the single-generation version.
3. Each generation the progeny mean phenotype, and mean progeny fitness divided by mean parental fitness are calculated and stored, resulting in a time series for each iteration of the specified number of generations for mean phenotypic change and mean fitness retention.
4. After completion of all iterations, generational mean phenotype and fitness retention values are calculated over all iterations.

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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*