Modeling Hatchery Influence: Estimates of Gene Flow and pHOS for Washington State Coastal Steelhead Hatchery Programs

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Abstract

There are currently fifteen harvest-oriented steelhead hatchery programs operated by the Washington Department of Fish and Wildlife along Washington's Pacific coast. Since 2010 these hatchery programs provide an average 15,000 steelhead for tribal and recreation harvest annually. However, hatchery steelhead also present ecological and genetic risks to wild steelhead populations. In 2008, WDFW adopted the Statewide Steelhead Management Plan (SSMP) to guide future management actions for both wild and hatchery steelhead. This plan provides a management framework, to balance the risks and benefits of hatchery steelhead by setting thresholds for allowable levels geneflow and the proportion of hatchery fish on the spawning grounds (pHOS). The plan also mandates the designation of Wild Steelhead Management Zones to protect select wild steelhead populations from future hatchery actions. The primary aim of this study was to assess the compliance of current WDFW operated hatchery steelhead programs along the Pacific coast with the standards set out in the SSMP and provide recommendations on measures achieve compliance with the SSMP. This was achieved by utilizing the Demographic Geneflow Model for segregated programs and the All-H-Analyzer for integrated programs. Where programs failed to meet the standards for geneflow and pHOS in the SSMP the models were used to scale release levels to meet the SSMP thresholds. A secondary aim was to identify WSMZ candidates along Washington's Pacific Coast. Our criteria excluded any populations with ongoing on-station hatchery production and indicated selected indicated that there must be at least one WSMZ per water resource inventory area (WRIAs 19 to 24), with the selected populations having a 6-year average of >300 spawners. Our findings identified nine potential WSMZs that fit these criteria. Based on the findings, the coastwide change in production is recommended to decrease by 262,000 smolts, although if program specific recommendations are implemented the decrease may not be as extreme.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

ACRONYMS

AHA	All H Analyzer
CRC	Catch Record Card (data)
DGM	Demographic Geneflow Model
DPS	Distinct Population Segment
ESS	Early Summer Steelhead
EWS	Early Winter Steelhead
FPP	Fish per Pound
H	Hatchery
HOB	Hatchery origin broodstock
HSRG	Hatchery Scientific Review Group
LWS	Late Winter Steelhead
MPG	Major Population Group
N	Natural
NOB	Natural origin broodstock
PHEC	Proportion of Hatchery Effective Contribution
pHOS	Proportion of hatchery origin spawners on the spawning grounds
PNI	Proportionate Natural Influence (pNOB/(pNOB+pHOS))
pNOB	Proportion of natural origin broodstock at the hatchery
SAR%	Smolt to adult survival rate
SSMP	Statewide Steelhead Management Plan
WRIA	Water Resource Inventory Area
WSMZ	Wild Steelhead Management Zone also known as a Wild Steelhead Genebank

DGM INPUT PARAMETERS

O_N	Proportion of natural fish that may spawn with hatchery strays
O_H	Proportion of hatchery strays that may spawn with natural fish
K_1	Fitness of an HxN mating relative to an NxN mating
K_2	Fitness of an HxH mating relative to an NxN mating
q	Proportion of natural spawners that are of hatchery origin

AHA INPUT PARAMETERS

$Prod_{Adult}$	The productivity of the adults spawning in the watershed
$Prod_{Smolt}$	The productivity of smolts migrating from the watershed
Cap_{Adult}	The number of natural origin adults that the habitat is able to sustain for viable spawning
Cap_{Smolt}	The number of smolts that the habitat is able to sustain
$Fecund_{NOR}$	Fecundity of natural origin females
$\%Fem_{NOR}$	% of natural origin spawners that are females
SAR_{obs}	Observed smolt to adult survival of natural origin fish
SAR_{pdo}	Survival variable based on the Pacific Decadal Oscillation
HR_{NOR}	Freshwater harvest rate of natural origin fish
HR_{HOR}	Freshwater harvest rate of hatchery origin fish
$S_{prespawn}$	Pre-spawn survival of hatchery broodstock
$Fecund_{HOR}$	Fecundity of hatchery origin broodstock
$\%Fem_{HOR}$	% of hatchery origin spawners that are females
$S_{egg\text{-}smolt}$	Egg to smolt survival of hatchery juveniles
$SAR_{yearling}$	Smolt to adult survival of hatchery origin fish
RRS_{HOS}	Relative reproductive success of hatchery origin fish
$\%Return_{Hatch}$	% of HORs that home back to the hatchery after fisheries
#Yearlings	Yearling releases
$Brood_{local}$	Natural origin broodstock used
$\%NOR_{max}$	Maximum % of the natural origin return used as broodstock

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WDFW Fish Program Policy Acknowledgement

As the Fish Program Director for the Washington Department of Fish and Wildlife (WDFW), I have reviewed an internal technical briefing document titled, "*Modeling Hatchery Influence: Estimates of Gene Flow and pHOS for Washington State Coastal Steelhead Hatchery Programs*" (hereafter termed "white paper"), authored by Gary Marston and Anja Huff from WDFW's Hatchery Evaluation and Assessment Team (HEAT). In the summer of 2021, the Fish Management team requested the modeling and analysis presented in the white paper to assess how steelhead hatchery programs on the Washington coast have performed relative to WDFW objectives adopted in 2008, as described in the Statewide Steelhead Management Plan (SSMP).

WDFW's Fish Program Policy team acknowledges and appreciates the modeling, analysis, and recommendations tailored to each coastal steelhead hatchery program presented in the white paper. This white paper provides a detailed methodological description of one of the tools the agency uses to evaluate hatchery programs and an application of these methods to Washington's coastal region. Additionally, it is important to consider other factors in the agency's decision-making process relative to managing hatchery programs, such as standing commitments with tribal co-managers, mitigation agreements, legal obligations, socio-economic considerations, and others. It is important to note that the white paper, while published and reviewed by qualified biologists and scientists within WDFW, has not been formally peer-reviewed by external scientists consistent with the rigorous standards of scientific journal publications.

I recognize that for many of the coastal steelhead hatchery programs reviewed in the white paper, results from modeling suggest a need for modifications to hatchery programs at some facilities such as reduced hatchery production. Reducing hatchery production represents one tool for meeting SSMP objectives. There are other approaches the Fish Program considers, such as improving trap efficiency and changes to release sites, as identified by the authors among other strategies. I believe there is more work to be done to identify a suite of tools and approaches to meet conservation objectives that balance the risks and benefits of hatchery steelhead.

In closing, I appreciate the excellent technical work of the authors to conduct a thorough technical assessment of coastal steelhead hatchery programs relative to the objectives of SSMP. This work will join a suite of tools including collaborative work with stakeholders, tribes, and other partners to support a balanced approach lead by sound science to managing coastal hatchery steelhead programs.

Sincerely,

Kelly Cunningham
WDFW Fish Program Director

INTRODUCTION

Steelhead hatcheries on Washington's coast generate important cultural, economic, and recreational opportunities for tribal and non-tribal anglers. Tribal and recreational harvest of hatchery steelhead from coastal programs has averaged over 15,000 per year since 2010. However, hatcheries also present ecological and genetic risks to wild steelhead populations. To reduce risks from hatchery releases, programs must be scaled to balance harvest opportunities with genetic and ecological impacts. The purpose of this paper is to approximate appropriate hatchery release scaling for each WDFW-operated hatchery program on the Washington coast based on management objectives outlined by the Statewide Steelhead Management Plan (SSMP) and the Hatchery Scientific Review Group (HSRG). Scaling recommendations aimed to meet management objectives are generated using the *Hoffman Demographic Geneflow Model (DGM)* (Hoffmann 2017) for segregated programs, and the All-H-Analyzer (AHA) model for integrated programs. This paper also provides additional recommendations for ways to reduce genetic interaction (i.e., gene flow) between hatchery and wild steelhead on a program-by-program basis.

The Washington Department of Fish and Wildlife (WDFW) currently operates or provides fish for fifteen harvest-oriented steelhead hatchery programs along Washington's Pacific coast: nine segregated and six integrated. Both program types are designed to reduce impacts on wild fish but take differing approaches. Integrated programs utilize natural origin returns in the broodstock to reduce genetic domestication and ensure that program fish are genetically similar to natural fish. Segregated programs, in contrast, only utilize hatchery spawners, which are purposefully separated temporally and spatially to reduce overlap between hatchery and natural origin adults.

To better understand the ecological and genetic impacts of hatcheries, the Hatchery Scientific Review Group (HSRG) reviewed of all Washington coastal steelhead programs in 2004. As a result, the HSRG recommended that WDFW reduce or eliminate backfilling from facilities outside the watershed, ensure that release locations for segregated steelhead have adequate acclimation and trapping facilities, and designate Wild Steelhead Management Zones (WSMZs). WSMZs are areas where fishing may still occur, but in which hatchery fish would no longer be planted. The HSRG also recommended that each population should be designated as either primary, contributing or stabilizing based on their importance to the conservation of the overall Distinct Population Segment (DPS). Under these designations, "primary" are biologically significant populations which are key to the conservation of the overall DPS; "contributing" populations are viable but less abundant than primary populations; and "stabilizing" are periphery populations that should maintain their current level of viability.

Within each of these groups, the HSRG set guidelines for integrated and segregated hatchery programs using the proportion of natural influence (PNI), defined as the amount of influence that the natural origin fish have on both the hatchery and natural populations, as well as the proportion of hatchery origin spawners (pHOS) as guidelines to manage hatchery impacts on natural populations. For primary populations, integrated programs should have a PNI of ≥0.67 and pHOS of ≤30% and segregated programs should have a pHOS of <5%. For contributing populations, integrated programs should have a PNI of >0.50 and pHOS ≤30%, and segregated programs should have a pHOS of <10%. Hatchery impacts for stabilizing populations should be maintained at the current conditions (HSRG 2004).

WDFW adopted the Statewide Steelhead Management Plan (SSMP) in 2008 to address the concerns and recommendations brought forth by the HSRG and provide a management framework for steelhead. The SSMP also mandates that at least one WSMZ should be established for each major population group (MPG) within each distinct population segment (DPS). Two non-listed DPSs are present on the Pacific coast, the Olympic Peninsula and Southwest Coast. However, MPGs have not been designated for these DPSs and as such we assumed the Water Resource Inventory Areas (WRIAs) would be representative of potential MPGs for the purposes of this paper.

The SSMP set a long-term goal of <2% gene flow from segregated harvest-oriented hatchery steelhead programs into natural origin populations. For integrated hatchery programs, the SSMP states that pHOS in streams should not exceed 30% and PNI should be set at 0.70 or higher (SSMP 2008). Regardless of the influence of hatchery steelhead, monitoring steelhead populations is challenging. Steelhead return during a prolonged period when flows are often high, and visibility is low. Furthermore, not all steelhead die after spawning, making traditional stock assessment tools such as carcass recoveries difficult. Based on these challenges, modeling provides an approach to assess the impacts of hatchery steelhead based on data that is available but must also account for fisheries management decisions.

Traditionally, hatchery fish from harvest programs have been produced with the expectation that fisheries will remove a majority of the returning fish prior to reaching the natural spawning grounds. In this way, fisheries play an important role in reducing potential genetic interactions between natural- and hatchery origin fish. However, when natural origin abundance declines below escapement thresholds, necessitating fisheries closures as a conservation measure, substantially more hatchery fish would be expected to reach the natural spawning grounds. If hatchery production has not been scaled to account for reduced natural origin abundance and potential fisheries closures, then there is a risk that the conservation benefit of the fisheries closure will be outweighed by the genetic impacts of the additional hatchery fish on the spawning grounds. Hatchery programs should develop an operating procedure and protocol by which production can be re-evaluated and scaled to meet conservation objectives during periods when no fisheries are expected to occur and low returns are expected based on forecasted escapement.

Hoffman Demographic Geneflow Model (DGM)

The *Hoffman Demographic Geneflow Model* (DGM) was developed in 2014 by Annette Hoffman to evaluate geneflow between segregated hatchery steelhead and natural origin steelhead in the Puget Sound. The DGM uses a geneflow equation that is described in the SSMP, and was updated in 2014 (Busack 2014). This equation utilizes the relative abundance of both hatchery- and natural origin fish on the spawning grounds, as well as their spatial and temporal overlap and the relative reproduction success of potential matings between hatchery-by-hatchery (HxH), hatchery-by-natural (HxN) and natural-by-natural (NxN) fish (Hoffmann 2017). To calculate gene flow, the DGM uses five basin input parameters. O_N, O_H, k_1, k_2 and q.

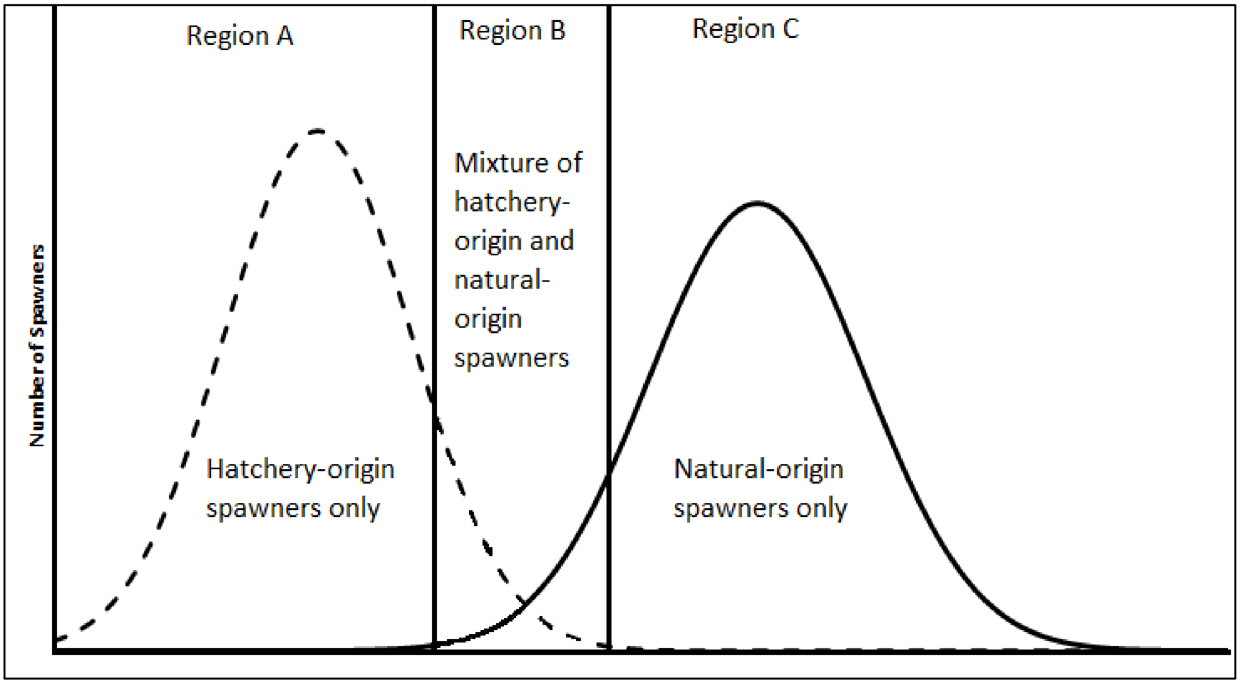

Figure 1. Schematic of temporal spawning overlap between segregated hatchery origin steelhead and natural origin winter steelhead. The shape, sizes, and placement of curves does not represent any real situation (reproduced from WDFW 2008). Region B is referred to as the overlap-period in this paper.

The proportion of natural origin steelhead spawning in Region B or the overlap period (**Figure 1**) is defined as O_N in the model, whereas the proportion of hatchery origin steelhead spawning in region B is defined as O_H. This model relies heavily on a spawning cutoff date of March 15, and uses redd timing standard deviation from this date to the last redd date to assume the proportion of natural origin redds prior to March 15. The mean hatchery spawn date is based on hatchery spawning events and dates of hatchery fish trapped. In the model k_1 is the relative fitness of HxH crosses and these values were drawn from empirical studies, with values of 0.02 to 0.13 for EWS and 0.09 to 0.18 for ESS (Hoffman 2017). In the model k_2 is the relative fitness of HxN crosses and these values assumed that HxN crosses would be twice as fit as HxH crosses relative to NxN crosses, with values of 0.54 for EWS HxN and 0.57 for ESS HxN (Hoffman 2017).

The parameter *q* in the model is the proportion of total natural spawners of hatchery origin and is estimated based on run reconstructions for each population of natural steelhead.

Hatchery origin spawners in the natural environment (HOS) were estimated from the return of hatchery origin fish to the hatchery expanded based on the assumed trapping efficiency at each hatchery. As actual trapping efficiency data is often lacking for steelhead, the HSRG typically used trapping efficiencies of 80% to 90% for programs with on-station release sites with adult collection facilities. Since the trapping efficiency has a large impact on the model results, 70% to 80% was used as a conservative estimate. However, evidence indicated that lower trapping efficiencies should be used for the Lake Aberdeen, North River and Naselle hatchery programs due to either outplanting or poor attraction flow. The model uses a six-year average for hatchery releases, and hatchery and natural origin escapement. This model does not typically include age structure data and instead assumes returns are age-3 at return to determine *q*. It also does not use catch data, but functions off the hatchery return rate and, as such, changes in the harvest rate downstream of the hatcheries would be expected to alter model outcomes. The geneflow output from the model is an average of four scenarios utilizing the two k_1 values at the two trapping efficiency levels. For more a more thorough description of the DGM and its parameters see Hoffman 2017. See **Appendix** for parameter details and sensitivity analysis.

Model Assumptions and Limitations

- Model uses the standard deviation after March 15 as the threshold date for natural spawners. This assumption is made due to an unknown number of hatchery origin redds in the spawning ground data. Alternate scenarios which account for the standard deviation across the entire observed spawning season were conducted for the Willapa Bay programs to show a "worst case" scenario for hatchery impacts.
- Model uses the average of two sets of assumed hatchery trap rate efficiencies, which were adjusted to represent the conditions at each hatchery. However, there is a significant amount of uncertainty around the trapping efficiency values at each facility.
- Natural origin steelhead may include both summer and winter steelhead, and the two run types cannot be assessed separately as escapement data is not available for natural origin summer run populations along Washington's Pacific coast.
- The model does not incorporate strays from or to other watersheds, but relies on hatchery returns, which may incorporate an unknown level of strays.
- Mean hatchery spawn timing is based on fish spawned in the hatchery as well as trapped fish not used in the broodstock and mortalities, with the assumption that mortalities and trapped fish not used in the broodstock would be ready to spawn immediately for winter steelhead and immediately after the first spawn date for summer steelhead.
- Model does not account for kelts and assumes all fish are first time spawners.
- The model assumes that the fitness of HxH EWS spawners in the wild is between 2% and 13% and that HxH ESS spawners in the wild is between 9% and 18%.

- The model assumes that EWS HxN spawners is 54% and ESS HxN spawners is 57% of the fitness of NxN spawners.
- The model does not include a spatial component and assumes that there is complete spatial overlap between hatchery origin and natural origin spawners on the spawning grounds.
- The model does not account for annual fluctuations in harvest rates when projecting geneflow.

All-H-Analyzer (AHA) Model

The All-H-Analyzer (AHA) Model is a Microsoft Excel®-based model that was developed by the HSRG to support the review of over 300 hatchery programs across the Pacific Northwest. AHA models the impacts of management decisions and hatchery effectiveness by projecting the average outcome of hatchery operations over 100 generations. This model uses hatchery and natural population data to provide estimates of pHOS, PNI, and predicted returns. Productivity data used by the model includes the SAR% (smolt to adult survival rate), recruits per spawner and adult and smolt capacity. However, reliable data for natural origin productivity and survival is lacking for most coastal populations, adding a higher degree of uncertainty into in AHA model results compared to those from the DGM. While we have a lower level of confidence in the individual natural origin productivity, capacity and survival data used, the values used resulted in natural origin abundance that was comparable to the six-year average abundance based on empirical data providing at least a moderate degree of confidence in the model outputs. We had a higher level of confidence in the harvest rates and hatchery data used in the model as these parameters were based on empirical data.

Data primarily came from the Hatchery Evaluation and Assessment Team (HEAT) Hatchery Performance Tables, utilizing catch record card (CRC) data for recreational harvest, tribal net data, and hatchery escapement and spawning data. These data were used to verify model inputs for hatchery fish, including SAR%, harvest rate, and trapping efficiencies. The AHA model uses the Ford equation (Ford 2002) to estimate relative fitness. For the coastal steelhead modeling, we utilized the 2020 version of AHA to assess current hatchery program sizes and evaluated scenarios that would fall within the guidelines in the SSMP. These outputs provide initial guidance for scaling hatchery releases and assessing the potential impacts of the programs on natural origin populations. For more details on the AHA Model see HSRG 2020. See also **Appendix Table 5** for parameter values and confidence.

Model Assumptions and Limitations

- Natural origin watershed-specific productivity and capacity was not available. Instead, the model used values within the known range for steelhead that produced a natural origin return similar to the observed six-year average.
- The natural origin SAR% is currently unknown, as watershed-specific natural origin smolt outmigration data is lacking from coastal watershed. For the model we assumed that natural origin SAR% would be higher than the hatchery SAR% and used a set value of 4%.
- Model incorporates the Pacific Decadal Oscillation (PDO) as variability in the smolt to adult return rate (SAR).
- Model does not incorporate strays from other watersheds.
- Model does not account for kelts, and assumes all fish are first time spawners.
- Model does not incorporate extensive habitat parameters beyond adult capacity, smolt capacity and smolts per adult produced, and assumes complete spatial and temporal overlap between hatchery- and natural origin fish.
- Escapement data used for the model relies on the March 15 spawner cutoff date as a means to determine whether spawners are hatchery- or natural origin. However, because fish from integrated programs spawn at a similar time as natural origin fish, the March 15 cutoff cannot be expected to separate hatchery origin and natural origin spawners. It is therefore unlikely that spawners before March 15 are primarily of hatchery origin. Due to this overlap, escapement numbers used in modeling integrated programs likely include significant numbers of hatchery origin spawners and can be expected to be biased high.
- The model was set so that no more than 30% of the natural origin returns will be used as broodstock.
- The relative reproductive success of hatchery origin spawners was assumed to be 80%.
- Six-year average harvest rates were estimated from run reconstruction data on recreational and tribal harvest, hatchery escapement and SAR%.
- Fecundity was based on a six-year average of fish used in broodstock. Where available, NOB and HOB fecundity were calculated separately. Where NOR specific data was not available, we used the fecundity for the overall integrated broodstock as a surrogate.
- The percent of both natural- and hatchery origin females was assumed to be 50%.
- In hatchery survival data for both broodstock and juveniles were based on a six-year average of data collected at WDFW hatcheries.

Wild Steelhead Management Zones (WSMZs)

This report provides recommendations for the selection of Wild Steelhead Management Zones (WSMZs) within the Olympic Peninsula and Southwest Washington Distinct Population Segments (DPSs), as mandated in the Statewide Steelhead Management Plan (SSMP). Currently the only WSMZ on Washington's Pacific coast is in the Sol Duc River (**Table 2**). The SSMP calls for at least one WSMZ per Major Population Group (MPG) in each DPS, however, MPGs have not been established in these DPSs. As a result, for the purpose of this analysis, we assumed that at least one WSMZ should be established within each of the five Water Resource Inventory Areas (WRIAs) located in the study area.

The SSMP indicates that WSMZs should be located in areas with sufficiently abundant and productive wild steelhead populations should be self-sustaining into the future. Accordingly, we only considered areas that contain populations with relatively stable abundance trends and a six-year average of >300 spawners as potential WSMZs. Populations over the minimum abundance threshold were further categorized as small (300-499), medium (500-999) or large (>1000). Areas lacking wild steelhead abundance data were not considered. Other factors that guided our recommendations included the amount of hatchery influence, usefulness of given locations as control streams for research, and designation as wild only management zones for other salmonid species. In terms of hatchery influence, we excluded all watersheds that currently contain on-station hatchery releases. On the other hand, streams with off-station releases were considered. In some cases, establishing WSMZs around robust natural populations may necessitate discontinuing on-station production. Those decisions should be based on the status of natural populations and the success of hatchery programs in meeting their fisheries goals. Regardless of the recommendations made in this report, WDFW should work with tribal co-managers and fisheries stakeholders to ensure that the selection of WSMZs align with fishery and conservation goals.

RESULTS AND RECOMMENDATIONS

Strait of Juan de Fuca Hatchery Programs

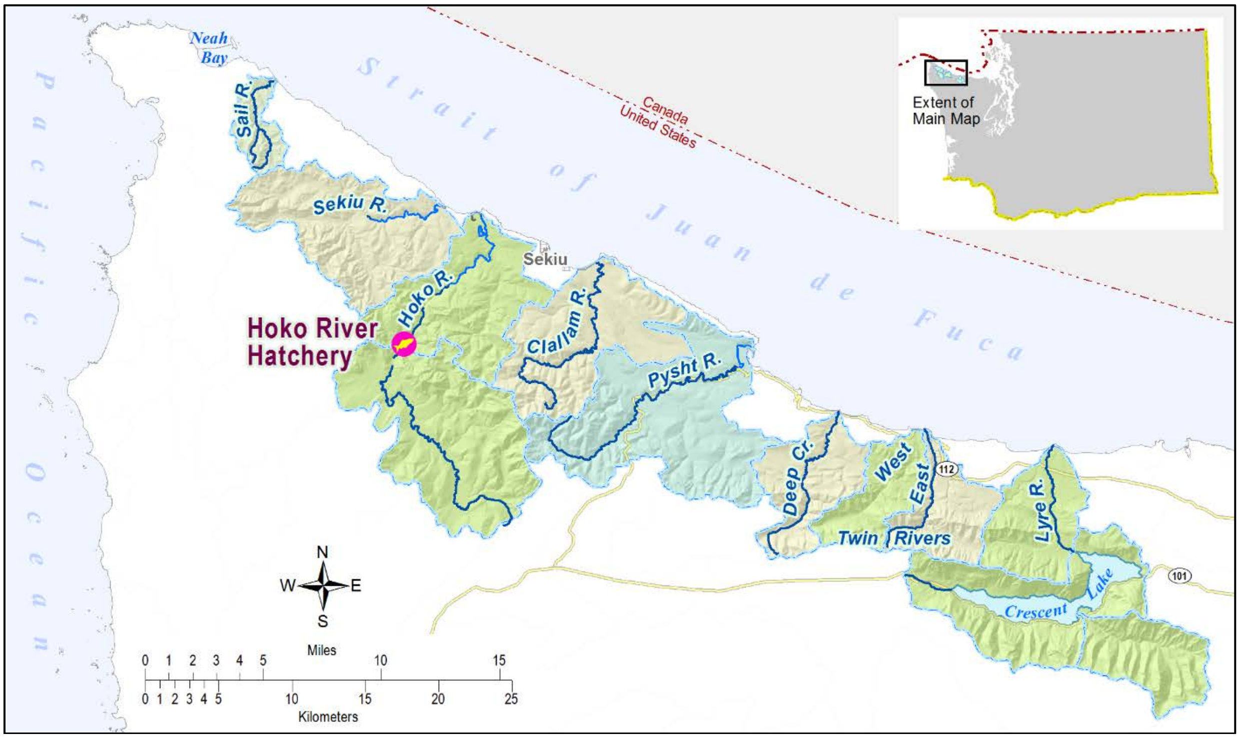

Figure 2. West Strait of Juan de Fuca watersheds, hatcheries, and release locations.

There are two active segregated hatchery steelhead programs in operation on the Strait of Juan de Fuca west of the Elwha River. These programs include the Makah Tribe's Hoko River Hatchery and an outplant on the Sekiu River (**Figure 2**). In the past, WDFW operated outplanting programs on the Clallam, Pysht and Lyre rivers with fish from Bogachiel Hatchery but discontinued these releases in 2008. Two smaller outplants also occur on the Makah Reservation at Agency and Village Creeks, and the Makah Tribe previously outplanted fish into the Sail River as well.

The Hoko River Hatchery and Sekiu River outplants are operated by the Makah Tribe and these programs were not evaluated here. However, as these programs release fish into co-managed waterways, WDFW should work with the Makah Tribe to model impacts from these programs to ensure that they are properly sized. There are currently no data regarding the Sekiu River natural origin population and given the current hatchery program in that watershed, WDFW should prioritize evaluating the abundance of the natural population to allow future assessment of hatchery and fishery impacts. There are currently no WSMZs designated on the western Strait of Juan de Fuca; see **Table 1** for possible candidates.

Table 1. Wild Steelhead Management Zone (WSMZ) recommendations and selection criteria for the Strait of Juan de Fuca (WRIA 19).

Population	Status	Criteria
Lyre River Winter Steelhead	Not Considered	No data.
Salt Creek /Independents Winter Steelhead	Not Considered	Below the 300-spawner threshold, with a six-year average of 70 spawners. Long -term decline, but relatively stable since 2008.
Pysht River/Independent Straits Tributaries Winter Steelhead	Candidate for WRIA 19	Small population with a six-year average of 392 spawners. Stable to slightly increasing population trend. Intensively monitored watershed in the East/ West Twin Rivers. Historically there were outplants of EWS into the Pysht River, but no plants have occurred since 2008.
Clallam Winter Steelhead	Not Considered	Below the 300-spawner threshold, with six-year average of 130 spawners. Long-term decline but stable since 2003. Historic EWS outplants until 2008.
Hoko River Winter Steelhead	Not Considered	Small population with a six-year average of 381 spawners. Long-term decline, but relatively stable since 2005. Makah Tribe has an on-station release at Hoko Falls Hatchery.
Sekiu River Winter Steelhead	Not Considered	No data. Current outplant from Makah Tribe's Hoko Falls Hatchery.
Sail River Winter Steelhead	Not Considered	No data. Historic outplants from Makah Tribe's Hoko Falls Hatchery.

North Olympic Peninsula Hatchery Programs

Figure 3. North Olympic Peninsula watersheds, hatcheries, and release locations.

There are four segregated hatchery steelhead programs in operation on the north Olympic Peninsula coastal watersheds. These programs include the federally-operated Makah National Fish Hatchery on the Tsoo-yess (Sooes) River (**Figure 3**), the WDFW-operated Bogachiel early winter and summer steelhead programs in the Quillayute watershed, and the Chalaat Creek Hatchery early winter steelhead program operated by the Hoh Tribe in the lower Hoh River watershed (**Figure 4**). For this review we evaluated the WDFW-operated programs but did not evaluate the Makah NFH or Chalaat Creek programs. There was also an integrated steelhead program until 2021 with releases in the Bogachiel and most recently Calawah rivers that is evaluated in this report. A WSMZ was established in the Sol Duc River in 2012; see **Table 2** for additional candidates.

Table 2. Wild Steelhead Management Zone (WSMZ) recommendations and selection criteria for the Strait of Juan de Fuca (WRIA 20).

Population	Status	Criteria
Tsoo-Yess/Waatch Winter Steelhead	Not Considered	No data. Current on-station releases at Makah National Fish Hatchery.
Ozette River Winter Steelhead	Not Considered	No data.
Dickey River Winter Steelhead	Candidate for WRIA 20	Small population with a six-year average of 374 spawners. Relatively stable, with slightly decreasing trend. Very limited hatchery influence, with the only plants occurring in 1973 in WF Dickey and 1998 in Dickey Lake.
Sol Duc River Winter/ Summer Steelhead	Current WSMZ for WRIA 20.	Not Applicable.
Calawah River Winter/ Summer Steelhead	Not Considered	Large winter population with a six-year average of 2,626 spawners. No data on summer population. Slightly increasing population trend. Current on-station hatchery releases from Calawah Ponds.
Bogachiel River Winter/ Summer Steelhead	Not Considered	Large with population with a six-year average of 1,156 spawners. No data on summer population. Long-term decline. Current on-station release from Bogachiel Hatchery.
Goodman Creek Winter Steelhead	Not Considered	Below the 300-spawner threshold with six-year average of 99 spawners. Long-term decline but stable since 2003. Historic EWS outplants until 2008.
Mosquito Creek Winter Steelhead	Not Considered	No data. Received one outplant of EWS in 1996.
Hoh River Winter/ Summer Steelhead	Not Considered	Large population with six-year average of 2,582 spawners. No data on summer population. Long-term decline. Current Hoh Tribe on-station EWS releases from Chalaat Creek Hatchery.

Quillayute River: Bogachiel Hatchery and Calawah Ponds

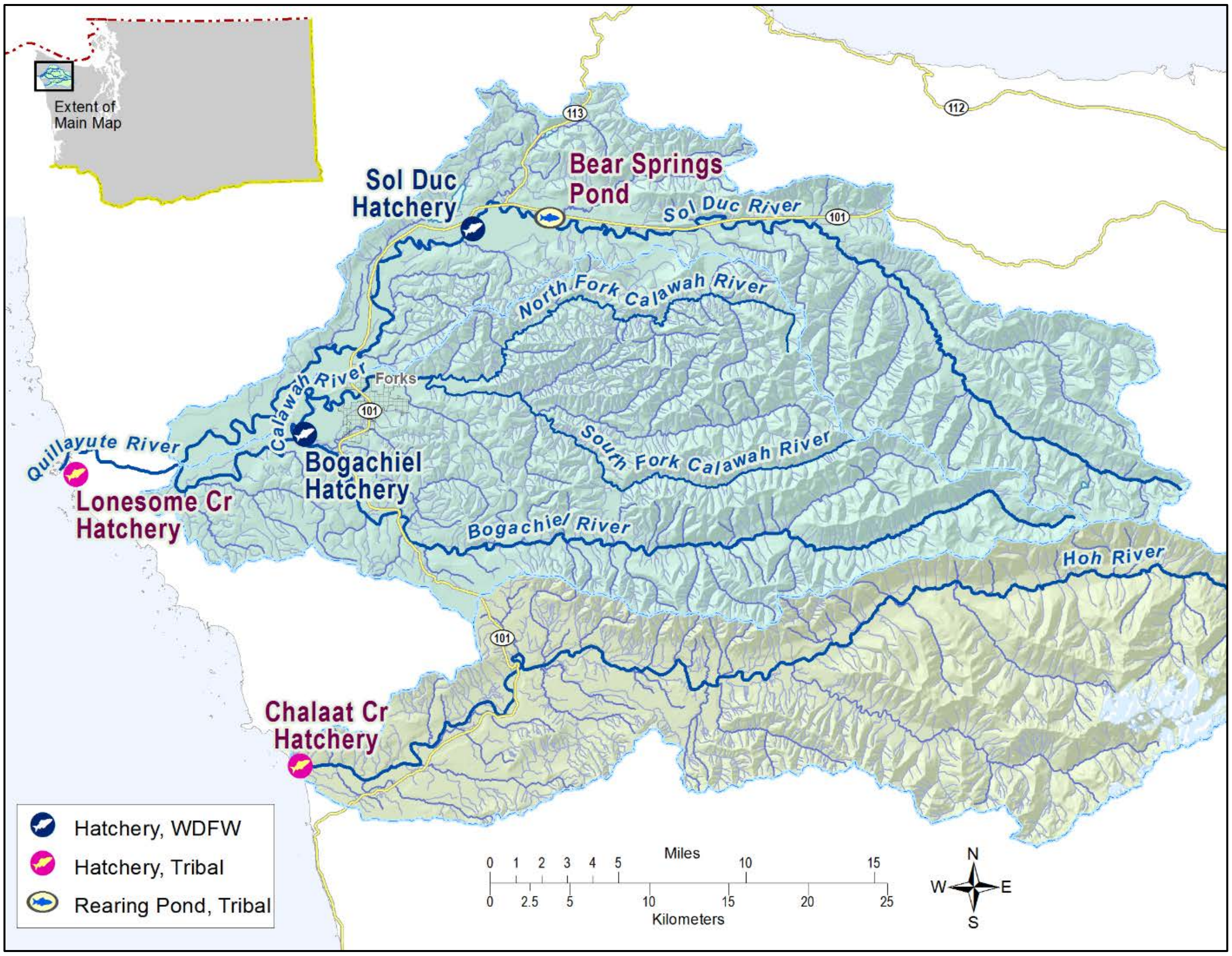

Figure 4. Quillayute and Hoh watershed hatcheries and release locations.

The Bogachiel Hatchery is located on the Bogachiel River at RM 8.4, at its confluence with the Calawah River (**Figure 5**). Calawah Ponds is located on the Calawah River at RMs 0.8 and 0.5 for the North and South Ponds, respectively. Two segregated steelhead programs are operated out of these facilities: an early winter, and a summer steelhead program. The Bogachiel Hatchery has good attraction flow into the hatchery trap and all modeling assumes that the Bogachiel Hatchery has a trapping efficiency of 70-80%. Bogachiel hatchery staff currently operate two trapping sites: one at the main pond at Bogachiel Hatchery and one at the North Pond on the Calawah River. The trapping facilities at Bogachiel hatchery are currently open from October 1 to March 15, while the trapping facilities at the Calawah Ponds is open from July 1 to March 15. These traps are operated continuously through the trapping season. The facility recently reared fish for a late winter integrated steelhead program, which was also modeled for comparative purposes.

Natural origin Steelhead

We used a combined redd count dataset from 1996 to 2017 for the Calawah and Bogachiel Rivers to evaluate the impacts on the natural populations for the DGM. This was due to the location of Bogachiel Hatchery at the confluence with the Calawah River and the releases from Calawah Ponds, as well as the genetic similarity between steelhead in the two watersheds. We did not look at impacts into the Sol Duc or Dickey watersheds as there are no releases into either watershed and stray rates from the Bogachiel programs are currently unknown. Spawning ground surveys on the Bogachiel and Calawah rivers are conducted by WDFW, the Quileute Tribe and Olympic National Park staff throughout the entire spawning period. The mean spawn date for the natural origin population is April 22 (SD = 27.6 days), with an assumed 8.43% of natural origin fish spawning before March 15 (**Figure 5**), resulting in 3.96% of the natural origin steelhead spawning in the overlap period(**Figure 1**) with hatchery fish based on a gamma distribution (**Figure 6**). The six-year average (return years 2013/2014 to 2018/2019) of natural origin escapement was combined for Bogachiel and Calawah populations, data was corrected for natural origin fish spawning prior to March 15 is 4,181.

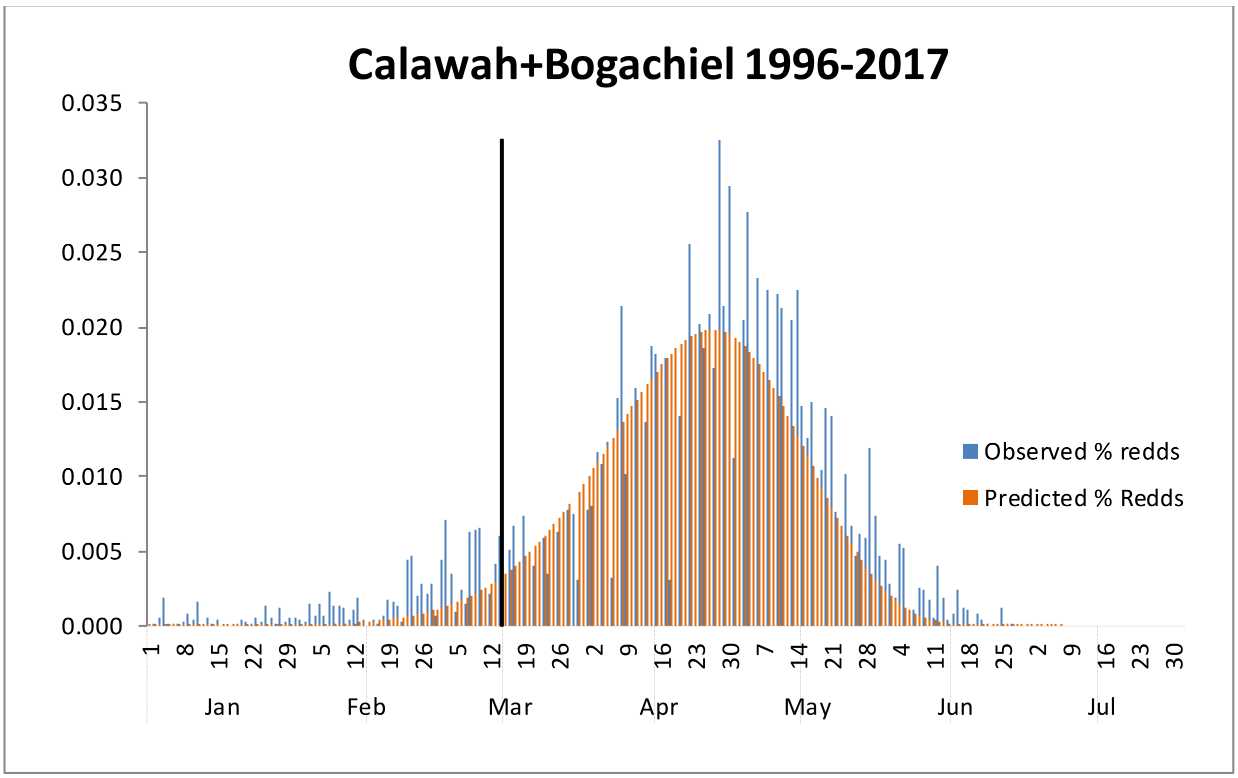

Figure 5. Bogachiel and Calawah River natural origin steelhead spawner distribution and gamma fit. O_n = 4.0%. The black bar indicates the March 15 hatchery-wild spawner cut-off date.

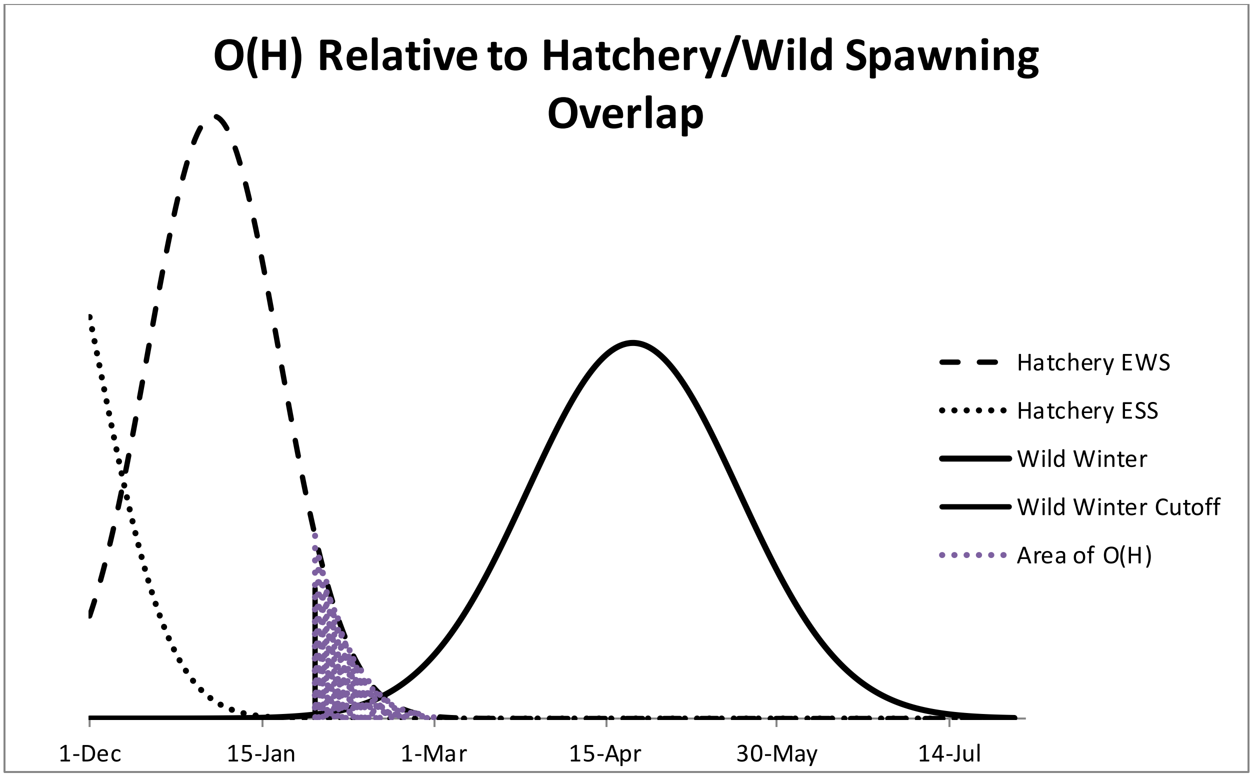

Figure 6. The temporal distribution of hatchery origin and natural origin spawners in the Bogachiel and Calawah rivers the majority ESS spawning typically is completed by January 9, the majority of EWS spawning typically is completed by February 23 and wild spawning commences after January 29.

Late Winter Steelhead

The late winter steelhead program was an integrated program intended to increase the abundance of steelhead during the early component of the natural steelhead run. The program was first initiated out of the Snider Creek rearing ponds on the Sol Duc River in 1986 but was moved to the Bogachiel River in 2013 when the Sol Duc River was designated as a WSMZ. Fish for the program were collected via hook and line by Olympic Peninsula Guides Association guides and their clients and were spawned at Bogachiel Hatchery. Juveniles were outplanted into the Bogachiel River from 2013 to 2019, with the program transitioning to releasing fish into the Calawah River from 2020 to 2021 before it was discontinued due to a shared interest in prioritizing the early timed program and concern for wild populations by Olympic Peninsula Guides Association, the Quileute Tribe, and multiple conservation organizations. This program was evaluated using the AHA model, with the release sized at 30,000 yearling smolts, spawned from 100% natural origin parents.

Table 3. Bogachiel Hatchery steelhead programs, projected pHOS and PNI from the AHA model and geneflow from the DGM.

Program	LWS Program	EWS Program	ESS Program	pHOS (PNI)[1] /Geneflow[2]			
				LWS	EWS	ESS	Total GF
Max. EWS	30,000	69,500	30,000	11.12% (0.90)	0.72%	0.53%	1.26%
Max. ESS	30,000	63,000	32,500	11.12% (0.90)	0.66%	0.58%	1.24%

1/ The Late Winter (LWS) program values were derived from the AHA model and display % pHOS and the PNI for the population.

2/ Early Winter (EWS) and Early Summer (ESS) values were derived from the DGM and display percent geneflow into the natural population.

Early Winter Steelhead

The Bogachiel early winter steelhead was established in 1967 using a mix of Chambers Creek and native stocks (Marston 2014). Program fish are released at approximately 6.0 fpp in April, with 150,000 released on-station at Bogachiel Hatchery and 50,000 released from Calawah Ponds. The average release from the program for the past six years (release years 2012 to 2017) was 176,014 smolts. However, release levels from 2016 to 2019 may not have been accurately accounted for due to issues with the fish counters at the facility, which may add some error into the model results. The hatchery return rate for the early winter steelhead program after fisheries and including strays to the spawning grounds was estimated to be 1.62% and 1.85% at a trapping efficiency of 80% and 70%, respectively. During this same period the overall SAR% was 5.39%, with 2,043 and 1,099 fish caught in recreational and tribal fisheries, respectively. Of recovered fish, 57.7% are caught in fisheries and 42.3% return to the hatchery. The mean spawn date for program fish at Bogachiel Hatchery is January 2 (SD = 17.2 days) with 6.0% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 6**).

Summer Steelhead

The Bogachiel summer steelhead program is a segregated hatchery program released on-station at Calawah Ponds. Summer steelhead for this program originated with stock from Skamania Hatchery in 1977. The Bogachiel summer steelhead are released on-station at Calawah Ponds at 6.0 fpp in April. The average release from the program for the past six years (release years 2012 to 2017) was 35,310 smolts. However, due to issues with the fish counters at the facility from 2016 to 2019, release levels may not have been accurately accounted for, which may add some error into the model results. The hatchery return rate after fisheries and including strays to the spawning grounds was estimated to be 2.04% and 2.33%, at trapping efficiency of 80% and 70%, respectively. During this same period, overall SAR% was 2.45%, with 272 caught in recreational fisheries. Of the recovered fish, 41.1% are caught in fisheries and 58.9% return to the hatchery. The mean spawn date for program fish is November 16 (SD = 18.2 days), less than 1% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 6**).

Table 4. Bogachiel Hatchery steelhead programs, projected geneflow and recreational harvest.

Program	EWS Program	ESS Program	Geneflow			Potential Rec. Harvest[1]	
			EWS	ESS	Total	EWS	ESS
Current	150,000	30,000	1.51%	0.53%	2.04%	1,773	208
Max. EWS	145,000	30,000	1.46%	0.53%	1.99%	1,714	208
No Fisheries Current[2]	150,000	30,000	3.35%	1.09%	4.44%	---	---
No Fisheries[2]	35,000	30,000	0.87%	1.09%	1.96%	---	---

[1] Based on a six-year average from return year 2014-2019.

[2] Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations

The model suggests that up to a total of 175,000 segregated summer and winter steelhead combined could be released. In contrast, modeling suggests that up to 30,000 integrated late winter steelhead and 95,500 segregated steelhead would also meet conservation goals.

Southern Olympic Peninsula Hatchery Programs

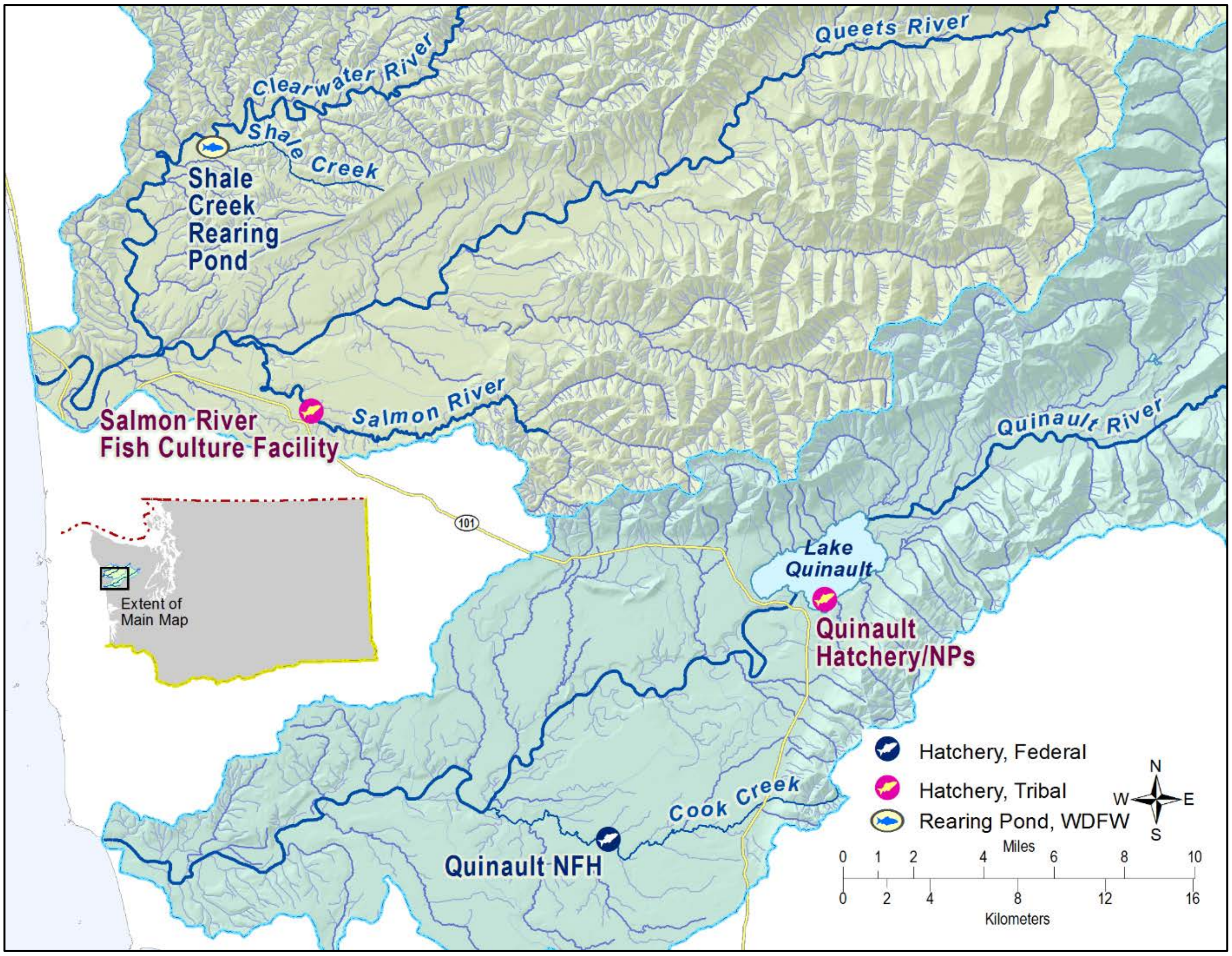

Figure 7. South Olympic Peninsula (Queets and Quinault watershed) hatchery and release locations.

There are three tribal- or federally operated hatchery steelhead programs in the Queets and Quinault watersheds. These include the segregated Quinault National Fish Hatchery at Cook Creek, the integrated Lake Quinault Net Pens, and the integrated Salmon River Fish Culture Facility (**Figure 7**). WDFW should work with the tribal comanagers, where possible, to ensure that these programs are properly sized to minimize adverse impacts to natural origin populations. Currently there are no WSMZs designated in this area; see **Table 5** for possible candidates.

Table 5. Wild Steelhead Management Zone (WSMZ) recommendations and selection criteria for the Strait of Juan de Fuca (WRIA 21).

Population	Status	Criteria
Queets River Winter/ Summer Steelhead	Not Considered	Large population with six-year average of 2,030 spawners. No data on summer population. Long-term decline. Current Quinault Tribe on-station EWS releases from Salmon River Hatchery.
Clearwater River Winter/ Summer Steelhead	Candidate for WRIA 21	Large population with a six-year average of 1,408 spawners. Long-term decline, but relatively stable trend since 1994. No data on summer population. Very limited hatchery influence with <1,000 smolts released in 1981 and 1983.
Raft River Winter Steelhead	Not Considered	No data. Received outplants of hatchery steelhead until 2008.
Quinault River Summer Steelhead	Not Considered	No data.
Lower Quinault Winter Steelhead	Not Considered	Large population with a six-year average of 1,258 spawners. Significant long-term decline. Hatchery programs from Quinault National Fish Hatchery and the Lake Quinault Net Pens.
Upper Quinault River Winter Steelhead	Candidate for WRIA 21	Large population with a six-year average of 1,473 spawners. Slight long-term increasing population trend. No current hatchery releases but straying from Lake Quinault net pens may be a concern.
Moclips River Winter Steelhead	Not Considered	No data since 2000. The 1995-2000 average spawner abundance was 311 fish, with a slightly increasing trend. Received outplants of hatchery steelhead until 2007.
Copalis River Winter Steelhead	Not Considered	No data. Only a single hatchery release in 1985.

Grays Harbor Hatchery Programs

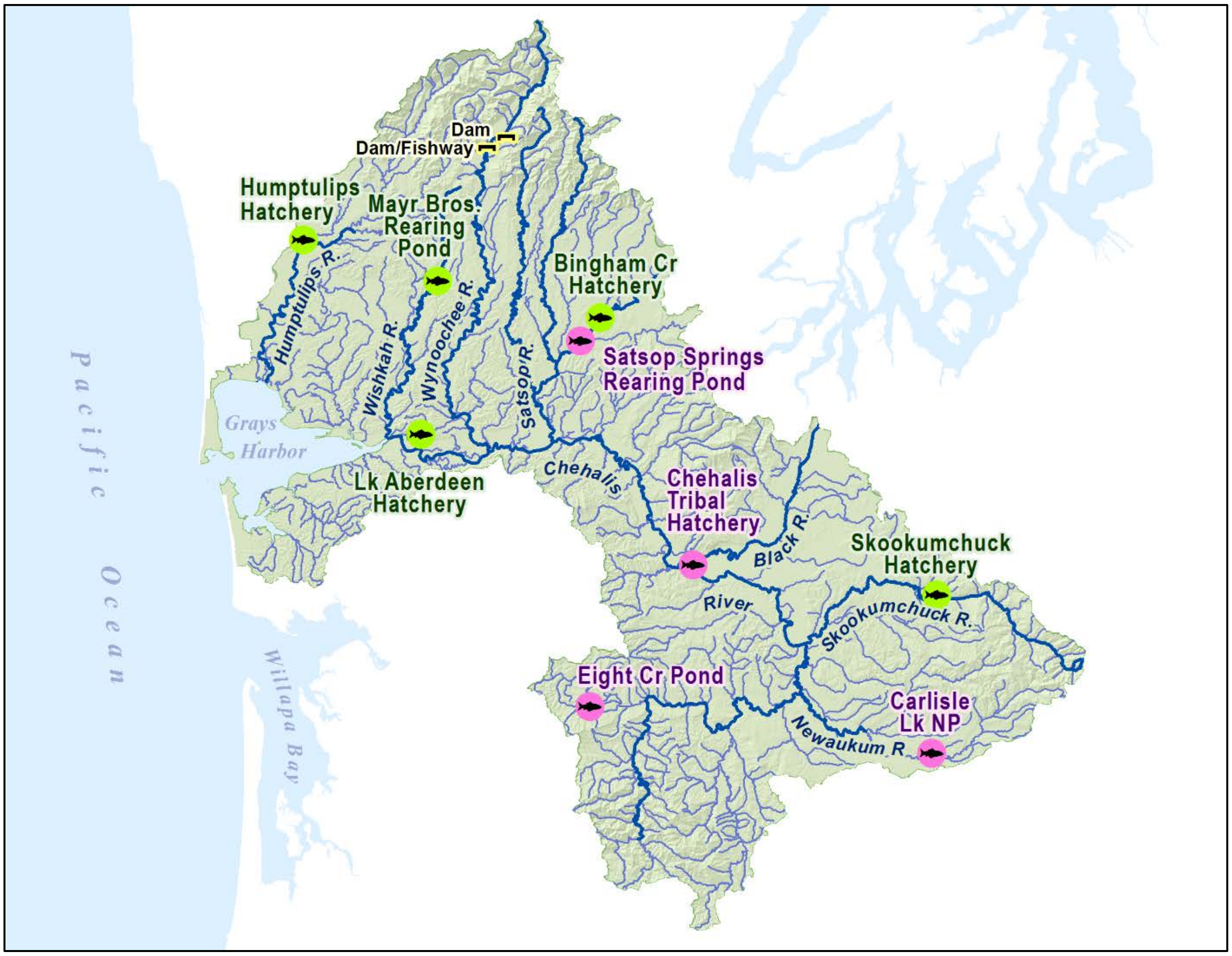

Figure 8. Grays Harbor watersheds, hatcheries, and release locations.

There are four segregated hatchery steelhead programs and five integrated hatchery steelhead programs in operation in the Grays Harbor/Chehalis River watershed. The segregated programs include the WDFW-operated Humptulips Hatchery segregated early winter steelhead and summer steelhead programs, an early winter steelhead program released at Mayr Bros. Hatchery on the Wishkah River, and the Lake Aberdeen Wynoochee River summer steelhead program released into the Wynoochee River (**Figure 8**). The integrated programs include the Lake Aberdeen/Wynoochee River late winter steelhead, Bingham Creek late winter steelhead, Skookumchuck late winter steelhead, Onalaska FFA Carlisle Lake late winter steelhead, and Eight Creek late winter steelhead program. There are currently no WSMZs established in the Grays Harbor/ Chehalis basin; see **Table 6** for possible candidates.

Table 6. Wild Steelhead Management Zone (WSMZ) recommendations and selection criteria for the Strait of Juan de Fuca (WRIAs 22-23).

Population	Status	Criteria
Humptulips River Winter/ Summer Steelhead	Not Considered	Large population with a six-year average of 1,709 spawners. Significant long-term decline. No data on summer population. Current on-station releases from Humptulips Hatchery.
Hoquiam River Winter Steelhead	Candidate for WRIA 22	Small population with a six-year average of 309 spawners. The population has been experiencing a long-term decline but is relatively stable since 1997. There where historically outplants of EWS in the drainage, but no hatchery plants have occurred since 2006.
Wishkah River Winter Steelhead	Candidate for WRIA 22	Small population with six-year average of 360 spawners, long-term decline, with slower decline since 1994, no hatchery plants between 1995 and 2019. Currently has EWS releases from Humptulips Hatchery.
South Bay Winter Steelhead	Not Considered	No data. John River received EWS outplants until 2007 and the Elk River received EWS outplants until 2006.
Wynoochee River Winter Steelhead	Not Considered	Large population with a six-year average of 1,393 spawners. Long-term decline. Dam on the upper watershed. Current off-station releases from Lake Aberdeen Hatchery.
Satsop River Winter Steelhead	Not Considered	Large population with a six-year average of 2,108 spawners. Long-term decline. Current on-station hatchery program at Bingham Creek. The WF Satsop should be considered as a candidate to serve as a control stream for research with the Bingham Creek late winter steelhead program. It is not a separate population, however, so not in consideration for the WRIA 22 WSMZ designation.
Skookumchuck/ Newaukum River Winter Steelhead	Not Considered	Large population with a six-year average of 1,125 spawners. Stable population trend. Current on-station hatchery program at Skookumchuck Hatchery and off station release at Carlisle Lake on the Newaukum River.
Chehalis River Winter / Summer Steelhead	Candidate for WRIA 23	Large population with a six-year average of 2,190 of spawners. The population is experiencing a slight long-term decline but has been relatively stable. No data on summer population. Some hatchery influence from current Eight Creek integrated late winter steelhead program.

Humptulips River: Humptulips Hatchery

The Humptulips Hatchery is located on Stevens Creek at RM 0.2, a tributary to the Humptulips at RM 22.5. Two segregated steelhead programs are released out of the facility: an early winter, and a summer steelhead program. Additionally, the facility currently provides juveniles for the Wishkah River early winter steelhead program. The Humptulips Hatchery has good attraction flow into the hatchery trap and modeling assumed that Humptulips Hatchery has a trapping efficiency of 70-80%. Trap facilities at the hatchery are open from the fall until after several weeks with no recruitment to the trap, typically in February.

Natural origin Steelhead

Spawning ground surveys on the Humptulips River are conducted by the Quinault Tribe, with limited supplemental surveys by WDFW. We used combined redd timing data from 1996 to 2020. The mean spawn date for the natural origin population is April 28 (SD = 15.9 days), with an assumed 0.3% of natural origin fish spawning before March 15 (**Figure 9**), resulting in 0.33% of the natural origin steelhead spawning in the overlap period with hatchery fish based on a gamma distribution (**Figure 10**). Unlike other populations modeled in this paper, the Humptulips only has very limited supplemental spawning ground surveys conducted prior to March 15, which results in significantly more uncertainty in the model results due to a potential underestimation of the proportion of natural origin fish spawning before March 15. This likely adds an artificial separation in the overlap period between natural- and hatchery origin steelhead that is unlikely to fully represent what is occurring in the environment. The six-year average (return years 2013/2014 to 2018/2019) natural origin escapement, corrected for fish spawning prior to March 15, is 1,709, slightly above the escapement goal of 1,600.

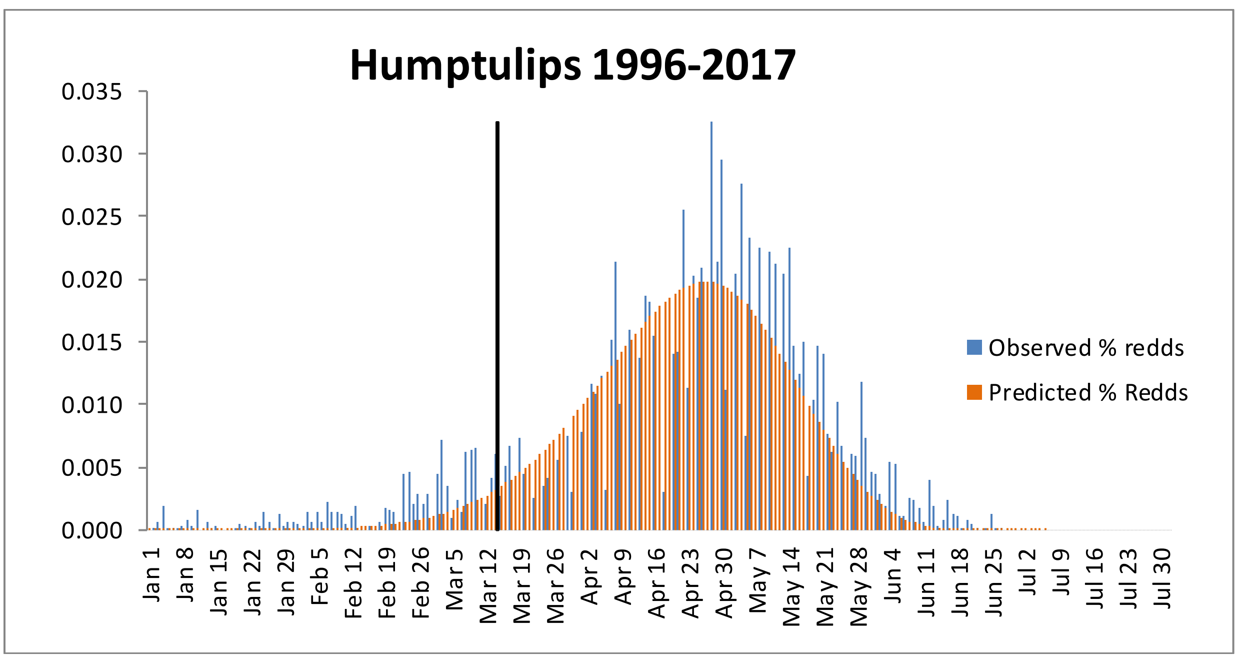

Figure 9. Humptulips River natural origin steelhead spawner distribution and gamma fit. O_n = 0.3%. The black bar indicates the March 15 hatchery-wild spawner cut-off date.

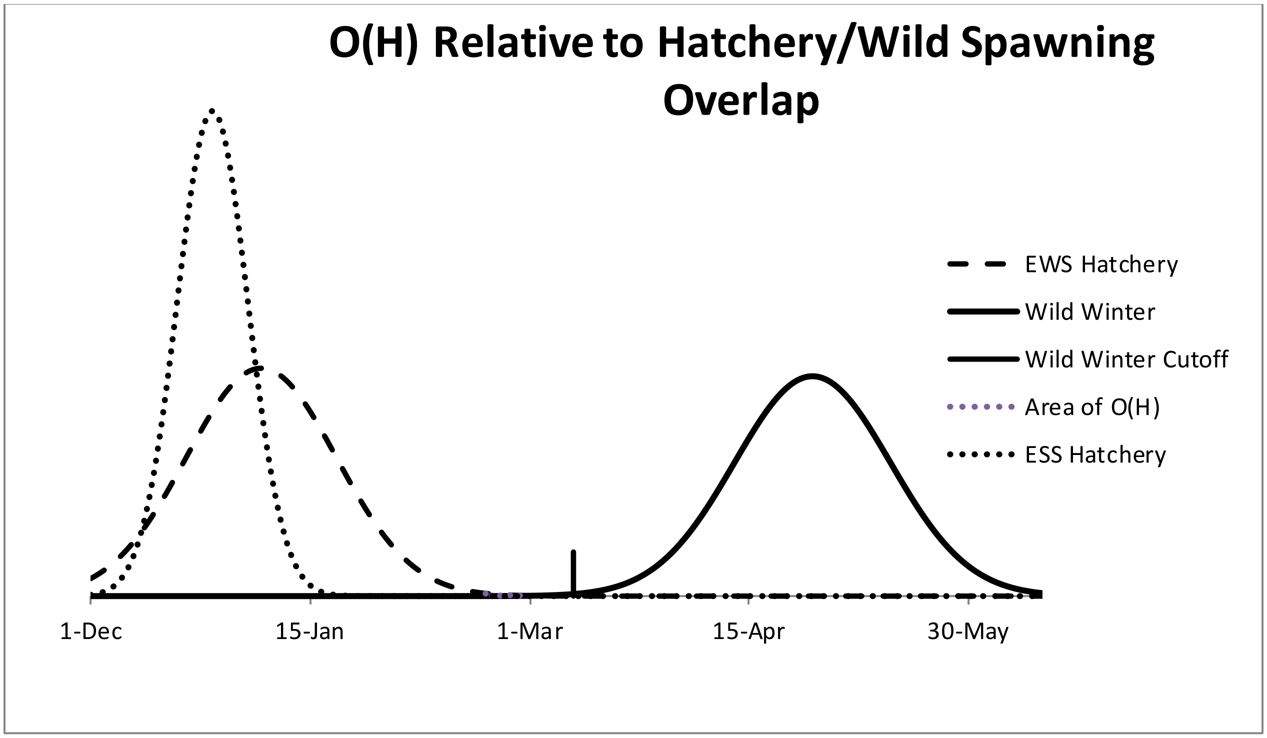

Figure 10. The temporal distribution of hatchery origin and natural origin spawners in the Humptulips River the majority ESS spawning typically is completed by January 17, the majority of EWS spawning typically is completed by February 20 and wild spawning commences after March 11.

Early Winter Steelhead

The Humptulips early winter steelhead was established with early returning naturally spawning steelhead in the 1980s. They were believed to be the result of outplants from Lake Quinault and Bogachiel hatcheries, which is thought to be a mix of coastal and Chambers Creek-derived stocks (Marston 2014). Juveniles are released on-station at 6.0 fpp in May. The average release from the program for the past six years (release years 2012 to 2017) was 130,479 smolts. The hatchery return rate after fisheries for the early winter steelhead program, including strays to the spawning grounds, was estimated to be 0.84% and 0.96%, at a trapping efficiency of 80 % and 70%, respectively. During this same period overall SAR% was 1.83%, with and 1,025 and 495 fish caught in recreational and tribal fisheries, respectively. Of the recovered fish, 63.0% are caught in fisheries and 37.0% return to the hatchery. The mean spawn date for program fish at Humptulips Hatchery is January 5 (SD = 15.4 days) with less than 1% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 10**).

Summer Steelhead

The Humptulips summer steelhead program is a segregated hatchery program released on-station at Humptulips Hatchery, at 6.0 fpp in May. The program was initiated in 1981 with summer steelhead from Skamania Hatchery, with the on-station program established in 1995 using summer steelhead from Lake Aberdeen Hatchery. The average release from the program for the past six years (release years 2012 to 2017) was 32,032 smolts hatchery return rate for the summer steelhead program after fisheries and including strays to the spawning grounds was estimated to be 0.88% and 1.01% at a trapping efficiency of 80% and 70%, respectively. During this same period overall SAR% was 1.62%, with and 294 caught in recreational fisheries. Of the recovered fish 57.7% are caught in fisheries and 42.3% return to the hatchery. The mean spawn date for program fish is December 26 (SD = 7.3 days), less than 1% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 10**).

Table 7. Humptulips Hatchery steelhead programs, projected geneflow derived from the DGM and recreational harvest.

Program	EWS Program	ESS Program	Geneflow			Potential Rec. Harvest/1	
			EWS	ESS	Total	EWS	ESS
Current	125,000	30,000	1.22%	0.56%	1.79%	987	280
Max. EWS	145,000	30,000	1.42%	0.56%	1.98%	1,145	280
Max. ESS	125,000	40,000	1.22%	0.75%	1.98%	987	374
Suggested Program	120,000	30,000	1.18%	0.56%	1.74%	947	280
Current Program, No Fisheries	125,000	30,000	3.23%	1.28%	4.51%	---	---
No Fisheries Max EWS /2	40,000	20,000	1.07%	0.86%	1.93%	---	---

/1 Based on a six-year average from return year 2014-2019.

/2 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations

While the model suggests that up to 175,000 ESS and EWS steelhead could be released from Humptulips Hatchery while remaining below 2% geneflow, it is likely that the March 15 spawner cut-off deadline assumption has been violated. This violation is due to spawning ground surveys only being conducted after March 15. Based on the higher level of uncertainty around the geneflow estimates for these programs, we suggest only running the programs to 1.75% geneflow to provide a buffer in the case that the model is underestimating the geneflow impacts. This would result in a release number of 150,000 combined ESS and EWS steelhead. If there is a desire by WDFW to increase the program beyond this, we recommend that spawning ground surveys should be expanded into a pre-March 15 timeframe to achieve a better understanding of the overlap between hatchery and natural origin steelhead spawning. In addition, WDFW should evaluate the trapping efficiency at Humptulips Hatchery; while the hatchery does not have an active rack, steelhead appear to have a high fidelity back to the facility. Also, the hatchery should keep the trap open and ensure it is regularly checked through at least March 15 to ensure that any late returning hatchery fish are removed from the system.

Wishkah River: Mayr Bros. Hatchery

The Wishkah River early winter steelhead program was initiated in release year 2021 with juveniles originating from Humptulips Hatchery. Juveniles are transported to the Mayr Bros. Hatchery, located at RM 26.9, and released at 7 fpp. in May. As the Wishkah early winter steelhead program is new and lacks any data for program adult returns to the Mayr Bros. Hatchery, data from the Humptulips early winter steelhead program was used as a surrogate (see Humptulips *Early Winter Steelhead* program for inputs). The Mayr Bros. Hatchery has good attraction flow into the hatchery trap and has a weir at the river pumphouse with a brail and hoist that allows fish to be trapped, based on this a trapping efficiency of 70-80% was used. The trapping facilities at the hatchery are open from the fall until no fish are trapped or observed.

Natural origin Steelhead

The six-year average (return years 2014/2015 to 2019/2020) natural origin escapement, corrected for fish spawning prior to March 15 is 471, slightly above the escapement goal of 412. The modeling for the Wishkah River used Humptulips River redd timing data as a surrogate, as the watersheds are adjacent. However, Wishkah River-specific redd data was not available in time for this review and will be used in future modeling (see Humptulips *Natural origin Steelhead* program for inputs).

Table 8. Wishkah Hatchery early winter steelhead program, projected geneflow derived from the DGM and recreational harvest.

Program	Smolt Release	Projected Geneflow	Potential Harvest/1
Current Program	15,000	0.70%	194
Maximum Program	43,000	1.97%	556
No Fisheries/2	15,000	1.88%	---

/1 Assumes similar survival and fisheries contribution to the Humptulips early winter program.

/2 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations:

Maintain the program at a 15,000 smolt release until adult returns are established and the program can be reevaluated using data from the Wishkah River program. Ensure that program performance, survival and contribution to fisheries warrants releases into the basin. Once hatchery return data from the Wishkah River program is available, ensure that the program is sized at or below a 2% geneflow impact and continue regular monitoring. If there is a desire to increase the program, we recommend establishing on-station production to drive local adaption in the hatchery release group. Additionally, the hatchery should keep the trap open and ensure it is regularly checked through at least March 15 to ensure that any late returning hatchery fish are removed from the system.

Wynoochee River: Lake Aberdeen Hatchery

The Lake Aberdeen Hatchery is located at RM 0.8 on Van Winkle Creek and provides segregated summer steelhead and integrated late winter steelhead for release in the Wynoochee River. Releases into the Wynoochee River occur at five locations ranging from RM 5 to RM 51. Both programs provide mitigation for the construction of Wynoochee Dam, located at RM 51, which blocked migration to the Upper Wynoochee River.

There are two trapping sites for the Lake Aberdeen programs: one on Van Winkle Creek and one in the Wynoochee River at RM 51. The Van Winkle trap opens during the first rains of the fall or when there are fish observed in the creek and remains operational until late April. Tacoma Public Utilities operates the Wynoochee River trap from the time fish are observed and closes in May after no fish are trapped or observed.

Natural origin Steelhead

Spawning ground surveys in the Wynoochee River are conducted by WDFW and the model utilized combined redd timing data from 1996 to 2020. The mean spawn date for the natural origin population is April 20 (SD = 23.6 days), with an assumed 6.3% of natural origin fish spawning before March 15 (**Figure 11**), resulting in 4.3 % of the natural origin steelhead spawning in the overlap period with hatchery fish based on a gamma distribution (**Figure 12**). The six-year average (return years 2013/2014 to 2018/2019) natural origin escapement, corrected for fish spawning prior to March 15, is 1,393 and the unadjusted escapement of 1,305 are both slightly above the escapement goal of 1,260.

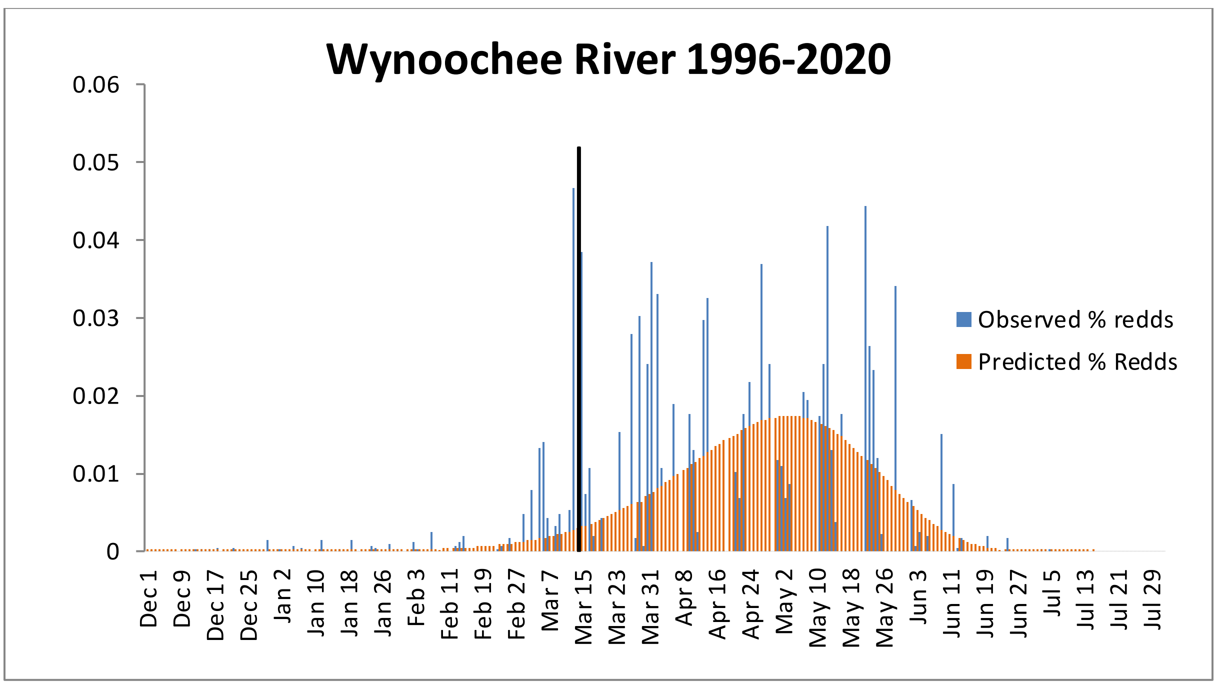

Figure 11. Wynoochee River natural origin steelhead spawner distribution and gamma fit. O_n = 4.3%. The black bar indicates the March 15 hatchery-wild spawner cut-off date.

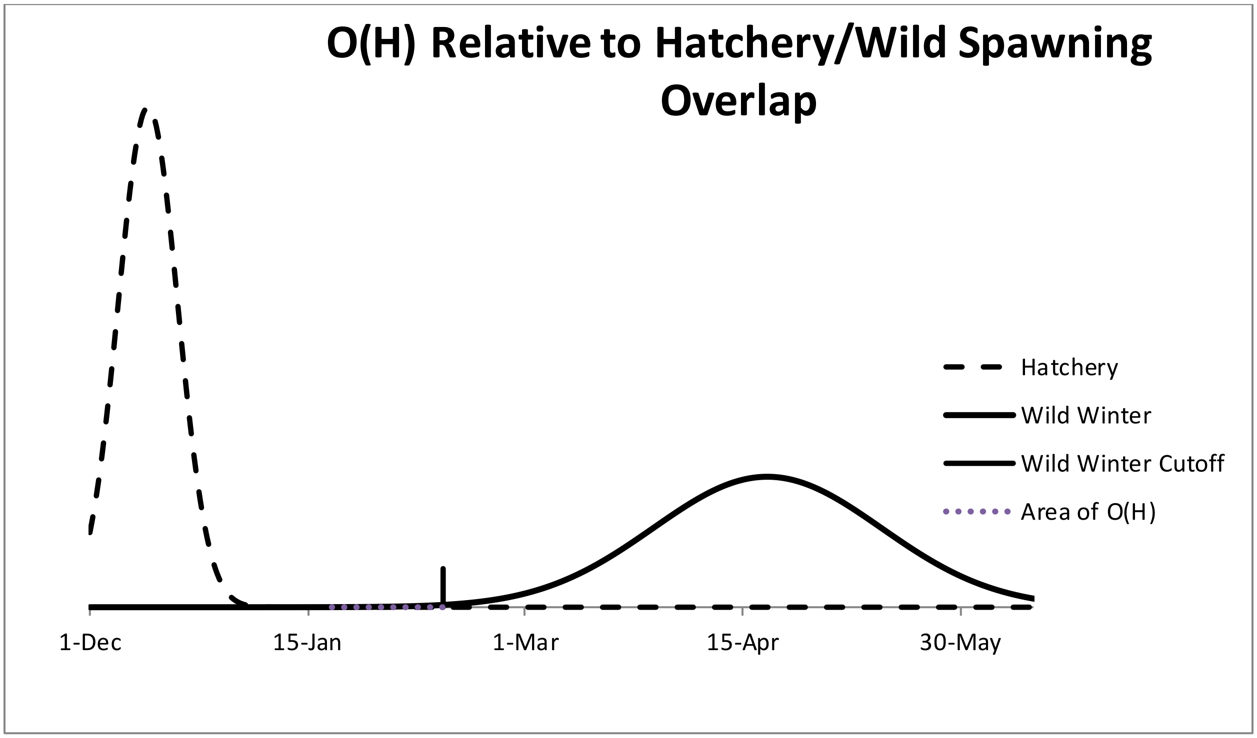

Figure 12. The temporal distribution of hatchery origin ESS and natural origin spawners in the Wynoochee River the majority ESS spawning typically is completed by January 1 and wild spawning commences after February 12.

Late Winter Steelhead

The late winter steelhead program was established in 1978 and is derived from natural origin fish collected in the Wynoochee River. A small number of late winter steelhead are passed upstream above Wynoochee Dam each year to provide a fishery above Lake Wynoochee and to supplement the upper Wynoochee River. The only location in the Wynoochee River with trapping available is at the Wynoochee Dam trap at RM 51. Some fish also recruit back to the trap at Lake Aberdeen Hatchery. However, overall trapping efficiency for program fish is low (20% to 30%). The pNOB level in the model was set at 30%, but the collection of natural origin fish is often limited. The six-year release averaged 162,000 smolts with an estimated pHOS of 35.1%, indicating a need for reduction of the current program.

Summer Steelhead

The summer steelhead program is derived from segregated Skamania stock and is currently self-sustaining with returns to Lake Aberdeen Hatchery and the trap at Wynoochee Dam. Summer steelhead are currently released at 5.0 fpp in May at five sites ranging from RM 5 to RM 51. The only location in the Wynoochee River with trapping available is at the Wynoochee Dam trap at RM 51. Some fish that stray and recruit back to the trap at Lake Aberdeen, but overall trapping efficiency for program fish is low and was assumed to be 20% to 30%. The average release from the program for the past six years (release years 2012 to 2017) was

61,845 smolts; hatchery return rate after fisheries and including strays to the spawning grounds for the summer steelhead program was estimated to be 1.85% at a 30% trapping efficiency, and 2.77% at a 20% trapping efficiency. During this same period overall SAR% was 3.11%, with and 1,531 caught in recreational fisheries. Of the recovered fish, 82.8% are caught in fisheries and 17.2% return to the hatchery. The mean spawn date for program fish is December 11 (SD = 6.2 days), less than 1% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 12**).

Table 9. Lake Aberdeen Hatchery Steelhead Programs, projected pHOS and PNI (LWS) from the AHA model, geneflow (ESS) from the DGM, and recreational harvest.

Program	LWS Program	ESS Program	pHOS (PNI)/ Geneflow		Potential HOR Harvest[/3]	
			LWS[/1]	ESS[/2]	LWS	ESS
Current	170,000	60,000	36.37% (0.45)	9.12%	3,649	1,543
Maximum LWS Only	55,000	None	13.02% (0.70)	---	1,181	---
Maximum ESS Only	None	12,000	---	1.99%	---	309
Current Program, No fisheries[/4]	170,000	60,000	67.78% (0.31)	34.86%	---	---
No Fisheries [/4]	12,000	None	12.08% (0.71)	---	---	---

[/1] The Late Winter (LWS) program values were derived from the AHA model and display % pHOS and PNI for the population.

[/2] Early Summer (ESS) values were derived from the DGM and display % geneflow into the natural population.

[/3] Based on AHA model projections and a six-year average from return year 2014-2019.

[/4] Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds. The "No Fisheries" scenarios show what the hatchery influence could be at the current release levels, program levels that adhere to recommended pHOS thresholds

Recommendations

Current pHOS and geneflow levels in the Wynoochee River exceed the thresholds set in the SSMP even with the current high harvest rate. The current recommended production to achieve the standards in the SSMP would be to eliminate the summer steelhead program and reduce the late winter steelhead program to 55,000 smolts. Given the challenges of maintaining a high enough PNI, additional effort to obtain natural origin broodstock should be pursued.

While modeling suggests the need for substantial reductions in hatchery production, the primary limiting factor associated with the Wynoochee River hatchery steelhead programs is the poor trapping efficiency due to outplanting steelhead throughout the basin. If the trapping efficiency of the programs can be improved to 70% to 80%, then modeling suggests that 60,000 summer steelhead and 155,000 late winter steelhead could be released while still meeting the standards of the SSMP (**Table 10**). To address the poor trapping efficiency, outplanting of both summer and late winter steelhead should be eliminated in the Wynoochee River. Instead, we suggest that fish should only be released at Wynoochee Dam, unless other trapping and acclimation sites can be established in the basin. WDFW should explore acclimating the steelhead in net pens in Lake Wynoochee to increase homing back to their release location.

While research comparing acclimated steelhead releases with direct release outplants have had mixed results, several studies indicate that acclimation can result in lower stray rates as well as improved survival (Whitesel et al. 1994, Clarke et al. 2010). After these actions are taken, the return rate of hatchery fish should be evaluated for a minimum of three years of adult returns to ensure that the program is properly sized.

Table 10. Lake Aberdeen Hatchery Steelhead Programs with improved trapping efficiency, projected pHOS and PNI (LWS) from the AHA model, geneflow (ESS) from the DGM, and recreational harvest.

Program	LWS Program	ESS Program	pHOS (PNI)/ Geneflow		Potential HOR Harvest/3	
			LWS/1	ESS/2	LWS	ESS
Improve Trapping Efficiency/4	155,000	60,000	12.69% (0.70)	1.08%	3,327	1,543
No fisheries + Improved Trapping Efficiency/4, /5	38,000	11,000	12.77% (0.70)	1.11%	---	---

/1 The Late Winter (LWS) program values were derived from the AHA model and display % pHOS and the PNI for the population.

/2 Early Summer (ESS) values were derived from the DGM and display % geneflow into the natural population.

/3 Based on AHA model projections and a six-year average from return year 2014-2019.

/4 Assumes improved acclimation and discontinuation of outplanting, resulting in a trapping efficiency of between 70% and 80% for DGM and 75% for AHA.

/5 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Satsop River: Bingham Creek Hatchery

Bingham Creek Hatchery was built in 1948 and is located at RM 17.5 on the East Fork Satsop River, at the confluence with Bingham Creek. The facility is owned and operated by WDFW and is partially funded through Skookumchuck mitigation. The Bingham Creek integrated late winter steelhead program was founded in 1998 with natural origin steelhead collected from February to early April via hook and line in the Satsop River and at the Bingham Creek trap, which is a full rack across the stream.

Natural origin Steelhead

Spawning ground surveys in the Satsop River are conducted by WDFW. The six-year average (return years 2014/2015 to 2019/2020) natural origin escapement is 2,108, well below the escapement goal of 2,800.

Late Winter Steelhead

Late winter steelhead are released on-site at Bingham Creek Hatchery in April at 5.0 to 8.0 fpp. Previously, 100,000 fingerlings were outplanted into the East Fork Satsop, but this program was discontinued. The six-year release has averaged 73,000 smolts with an estimated pHOS of 6.84% and PNI of 0.76.

Table 11. Bingham Creek Hatchery late winter steelhead program, projected pHOS, PNI and recreational harvest derived from the AHA model.

Program	Smolt Release	Projected pHOS and PNI	Potential HOR Harvest/1
Current Program	55,000	5.08% (0.81)	912
Maximum Program	100,000	9.37% (0.70)	1,659
Current Program, No Fisheries	55,000	16.29% (0.57)	---
No Fisheries/2	32,000	9.37% (0.70)	---

/1 Based on AHA model projections and a six-year average from return year 2014-2019.

/2 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations

The Bingham Creek late winter steelhead program has the potential to expand to a 100,000 smolt release. However, we do not advise increasing production at this time, given that the Satsop River natural steelhead population has been well below its escapement goal in recent years. If production is increased when the escapement goal has consistently met, pNOB should be maintained at a high level to ensure that PNI is at least 0.70. Any increase in pNOB should be sized against the natural origin abundance and set at no more than 30% of the natural origin spawners being taken for broodstock. Given the barrier at the Bingham Creek trap, this facility would make an excellent location for researching the effectiveness of integrated steelhead programs. However, as fish may jump the dam during high water events and attraction flow at the facility has been limited, this may necessitate facility improvements.

Skookumchuck River: Skookumchuck Hatchery

Skookumchuck Hatchery is located at RM 22.0 on the Skookumchuck River, just downstream of Skookumchuck Dam. The program was established in 1973 with natural origin Skookumchuck steelhead and provides mitigation for lost fish production resulting from dam construction. Trapping for broodstock occurs at the base of Skookumchuck Dam from February to early April, with fish volunteering to the trap. In addition to on-station releases, the hatchery also provides fish for two co-operative (co-op) enhancement programs, at Carlisle Lake on the Newaukum River and on Eight Creek, a tributary to the upper Chehalis River.

Natural origin Steelhead

Spawning ground surveys in the Skookumchuck River are conducted by WDFW. The Skookumchuck and Newaukum rivers are currently managed as a single population with a combined escapement goal. The six-year average (return years 2014/2015 to 2019/2020) natural origin escapement to the two watersheds is 1,029, slightly below the escapement goal of 1,429.

Late Winter Steelhead

The current Skookumchuck Hatchery program provides the majority of hatchery steelhead for the upper Chehalis basin. Fish from the program are integrated with natural origin fish in the Skookumchuck River and are raised on-station until September, when approximately 90,000 juveniles are transferred at approximately 40 fpp to a rearing pond at the dam. These are released in May at roughly 6 fpp. Releases over the last six-years averaged 159,042 smolts, with an estimated pHOS of 37.56%. The program has since shifted to a smaller size to reduce the potential impacts on natural origin returns. The six-year average harvest of hatchery steelhead from this program was 2,800 to both tribal and recreational fisheries.

Table 12. Skookumchuck Hatchery late winter steelhead program, projected pHOS, PNI and recreational harvest derived from the AHA model.

Program	Smolt Release	Projected pHOS and PNI	Potential HOR Harvest/1
Current Program	75,000	19.94% (0.60)	1,369
Maximum program	48,000	12.85% (0.70)	876
Current Program, No Fisheries/2	75,000	31.35% (0.49)	---
No Fisheries/2	28,000	12.73% (0.70)	---

/1 Based on AHA model projections and a six-year average from return year 2014-2019.

/2 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations

Modeling indicates a maximum program size of 48,000 smolts should be released out of Skookumchuck Hatchery. The program is meeting pHOS thresholds at the current size but has not been able to obtain enough natural origin broodstock in recent years. We recommend maintaining the program at 75,000 smolts and working to improve the number of natural origin fish utilized in the broodstock to keep pNOB around 30%. If insufficient NORs are available from the trap at the dam, other collection methods should be pursued. If the program is unable to obtain additional pNOB, then it should be reduced to 48,000 smolts to ensure that the PNI goal is met.

Newaukum River: Onalaska FFA

The Onalaska FFA late winter steelhead program is an educational co-op program supported by Skookumchuck Hatchery. Historically, there was also a late winter steelhead program released at Noel Cole Ponds on the Newaukum River, but it was discontinued in 2007. There has been little trapping in the past, but the program now operates a trap in Gheer Creek that is removed in May.

Natural origin Steelhead

Spawning ground surveys in the Newaukum River are conducted by WDFW. The Skookumchuck and Newaukum rivers are currently managed as a single population with a combined escapement goal. The six-year average (return years 2014/2015 to 2019/2020) natural origin escapement to the two watersheds is 1,029, slightly below the escapement goal of 1,429.

Late Winter Steelhead

The current Onalaska FFA program receives 40,000 late winter steelhead eyed eggs from Skookumchuck Hatchery in March. The fish are reared until they reach tanks capacity in the hatchery and are then transferred to a net pen on Carlisle Lake (between December and January). Around 25,000-30,000 smolts are released into Carlisle Lake/Gheer Creek in April at 5-8 fpp, with a 100% adipose fin-clip rate (FBD 2021). The outlet of Carlisle Lake is through a drainage pipe at an earthen dam, and the drop likely results in high mortality; the six-year average adult return is 30 fish to both recreational and tribal fisheries. The FFA also operates a trap just below the outlet of Carlisle Lake to collect returning steelhead. The six-year release averaged 32,000 smolts with a pHOS of 0.63%.

Table 13. Onalaska FFA Hatchery late winter steelhead program, projected pHOS, PNI and recreational harvest.

Program	Smolt Release	Projected pHOS and PNI	Potential HOR Harvest/1
Current Program	30,000	0.58% (0.99)	30
SAR Improved to 1.5%	30,000	5.05% (0.85)	258
Current Program, No Fisheries/2	30,000	2.14% (0.94)	---

/1 Based on AHA model projections and a six-year average from return year 2014-2019.

/2 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations

The Onalaska FFA late winter steelhead program has high educational value for the students at Onalaska High School. However, the program has experienced extremely low survival and minimal contribution to fisheries when compared to other hatchery programs in the Chehalis watershed. Historically, survival was much higher out of the Nole Cole Pond release group, and it appears that the outlet of Carlisle Lake is the source of high mortality.

We recommend maintaining the program at its current size and continue to release fish below the outlet of Carlisle Lake to improve survival. The Onalaska FFA should also continue to ensure that the trap is operated throughout the steelhead return period. If survival remains low out of Carlisle Lake, consider exploring reinitiating releasing a portion fish at Nole Cole Ponds, as it might improve overall survival in addition to providing ADA-accessible and special needs fishing opportunity.

Upper Chehalis River: Eight Creek Acclimation Ponds

The Eight Creek steelhead program is released from an earthen pond made from a repurposed beaver pond. The outflow enters Eight Creek (RM 5), tributary to Elk Creek, ten miles west of Doty WA, where it joins the Chehalis River. The pond is managed by the Upper Chehalis Fishery Enhancement Association with partial funding from the Aquatic Lands Enhancement Account for feed and mass marking.

Natural origin Steelhead

Spawning ground surveys on the Upper Chehalis are conducted by WDFW. The six-year average (return years 2013/2014 to 2018/2019) natural origin escapement is 2,198, below the escapement goal of 2,700.

Late Winter Steelhead:

The fish are transferred to the acclimation pond between 10 to 13 fpp. Smolts are voluntarily released in April at 5 to 10 fpp by pulling the restrictive screens from a section of creek. This release location does not have any trapping facilities. The six-year release averaged 27,500 smolts with an estimated pHOS of 8.44%.

Table 14. Eight Creek late winter steelhead program outplants, projected pHOS, PNI and recreational harvest.

Program	Smolt Release	Projected pHOS and PNI	Potential HOR Harvest[/1]
Current Program	32,000	9.81% (0.75)	352
Max Program	42,000	12.83% (0.70)	462
Current program, No Fisheries[/2]	32,000	17.07% (0.64)	---
No Fisheries[/2]	24,000	12.94% (0.70)	---

[/1] Based on AHA model projections and a six-year average from return year 2014-2019.

[/2] Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations

While the model projects that the program could be increased while still maintaining the standards of the SSMP, the upper Chehalis River has failed to meet its escapement objective in recent years, and we recommend maintaining this program at its current size. If WDFW determines that the hatchery and natural origin fisheries and conservation goals are not being achieved, then this program should be discontinued.

Willapa Bay Hatchery Programs

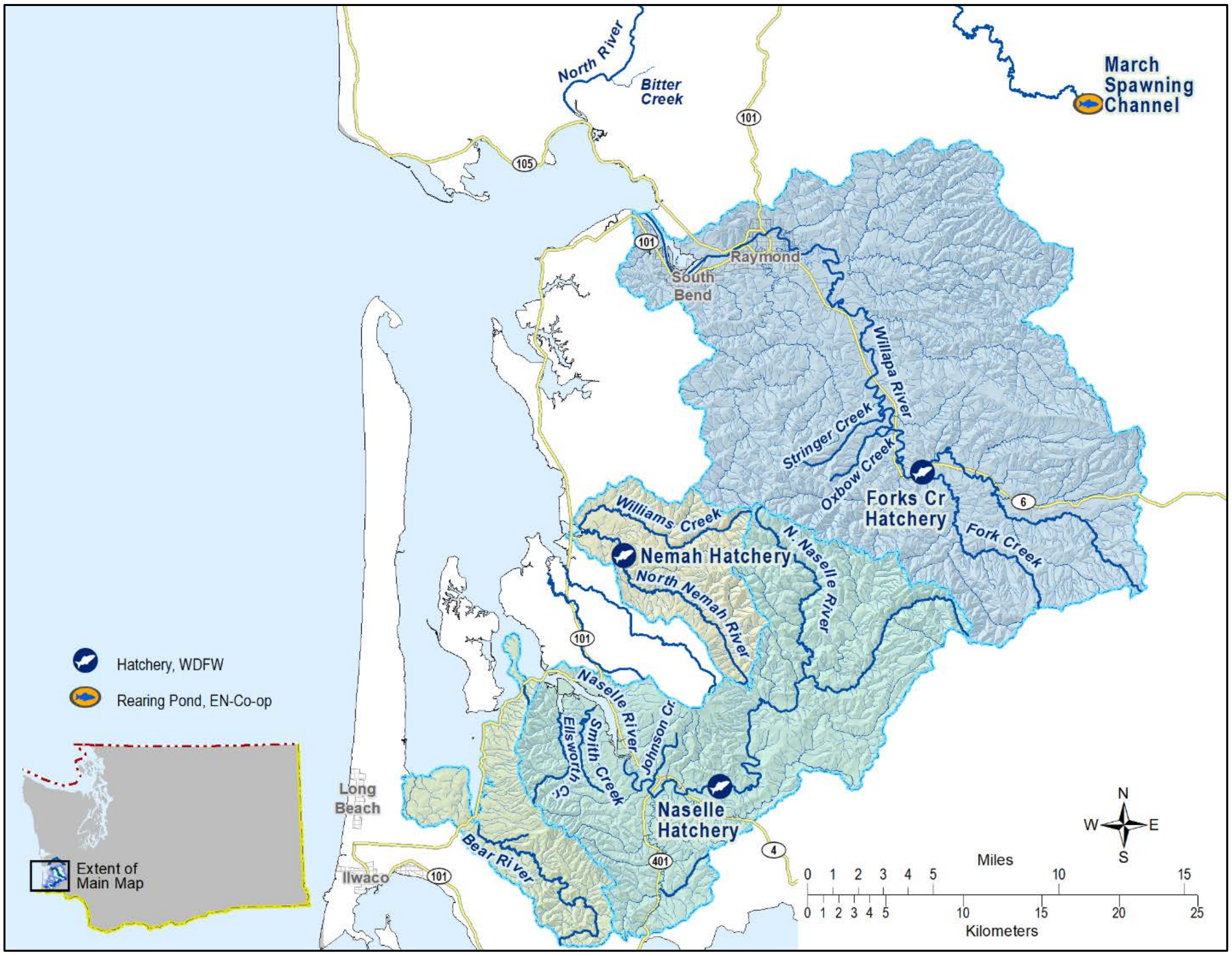

Figure 13. A map of Willapa Bay hatchery facilities.

There are three segregated hatchery steelhead programs in operation in Willapa Bay watersheds. These programs include the WDFW-operated Forks Creek early winter steelhead, Naselle Hatchery early winter steelhead, and a co-op outplant of early winter steelhead from Forks Creek Hatchery into the North River by RFEG 10 Willapa Bay. There are currently no WSMZs established in Willapa Bay; see **Table 15** for possible candidates.

Table 15. Wild Steelhead Management Zone (WSMZ) recommendations and selection criteria for the Strait of Juan de Fuca (WRIA 24).

Population	Status	Criteria
North River/Smith Creek Winter Steelhead	Candidate for WRIA 24	Medium population with a six-year average of 571 spawners. The population has been experiencing a slight long-term decline, but relatively stable population has been increasing since 2003. The North River is currently designated as a wild Chinook management zone and is being considered as one for candidate for Coho and Chum Salmon. High level of hatchery influence from outplanting for EWS from Forks Creek Hatchery.
Willapa River Winter Steehead	Not Considered	Medium population with a six-year average of 884 spawners. The population has been experiencing a slight long-term decline but has been increasing since 2005. Current EWS releases from Forks Creek Hatchery.
Palix River Winter Steelhead	Not Considered	Below the 300-spawner threshold with a six-year average of 148 spawners. Long-term increasing trend. No hatchery release.
Nemah River Winter Steelhead	Candidate for WRIA 24	Small population with a six-year average 495 of spawners. The population has experienced a slight long-term decline but has been increasing since 2005. relatively stable population. Historic hatchery plants until 2009 and one plant in 2015. Would serve as an excellent control stream for future hatchery research.
Naselle River Winter Steelhead	Not Considered	Medium population with a six-year average of 942 spawners. The population has been experiencing a slight long-term decline but has been relatively stable since 2005. There is a current on-station release from Naselle Hatchery. The Naselle EWS program has the lowest survival of the Pacific Coast segregated programs if the survival cannot be improved and the program does not meet its fisheries goals, WDFW should consider discontinuing it and designating the Naselle River as a WSMZ.
Bear River Winter Steelhead	Not Considered	Below the 300-spawner threshold with a six-year average of 202 spawners. Long-term decreasing trend but increasing since 2005. No hatchery releases

North River Outplants

The North River early winter steelhead program has been planted consistently since 2001 with fish originating from Forks Creek Hatchery. Historically, juveniles are transported at 5.0 fpp to the Fred March Ponds spawning channel at RM 56.5, where they were released in May. This release location lacked any trapping facilities and releases at the site were discontinued after release year 2014 and transitioned to direct outplants with no acclimation facilities.

Natural origin Steelhead

Spawning ground surveys on the North River are conducted by WDFW throughout the entire spawning period, and the model included redd data primarily from tributaries to the North River from 1999-2020. The mean spawn date for the natural origin population is April 2 (SD = 14.4 days), with an assumed 10.4% of natural origin fish spawning before March 15 (**Figure 14**), resulting in 4.01% of the natural origin steelhead spawning in the overlap period with hatchery fish based on a gamma distribution (**Figure 15**). Scenario 2 used the standard deviation across the entire spawning period (SD = 24.3 days), resulting in an assumed 22.8% of natural origin fish spawning before March 15 and 19.4% of the natural origin fish spawning in the overlap period with hatchery fish (**Figure 16**). The six-year average (return years 2013/2014 to 2018/2019) natural origin escapement, corrected for fish spawning prior to March 15 is 548, well below the escapement goal of 1,453.

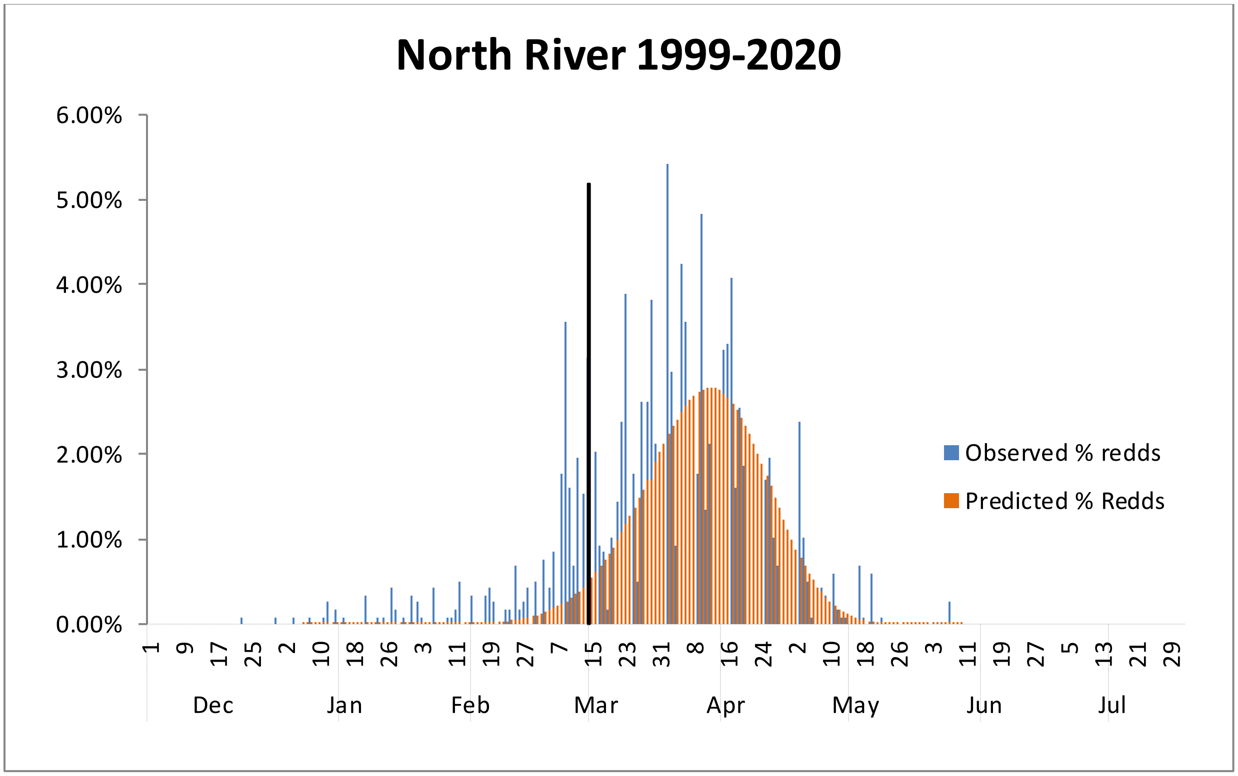

Figure 14. North River natural origin steelhead spawner distribution and gamma fit. O_n = 4.0%. The black bar indicates the March 15 hatchery-wild spawner cut-off date.

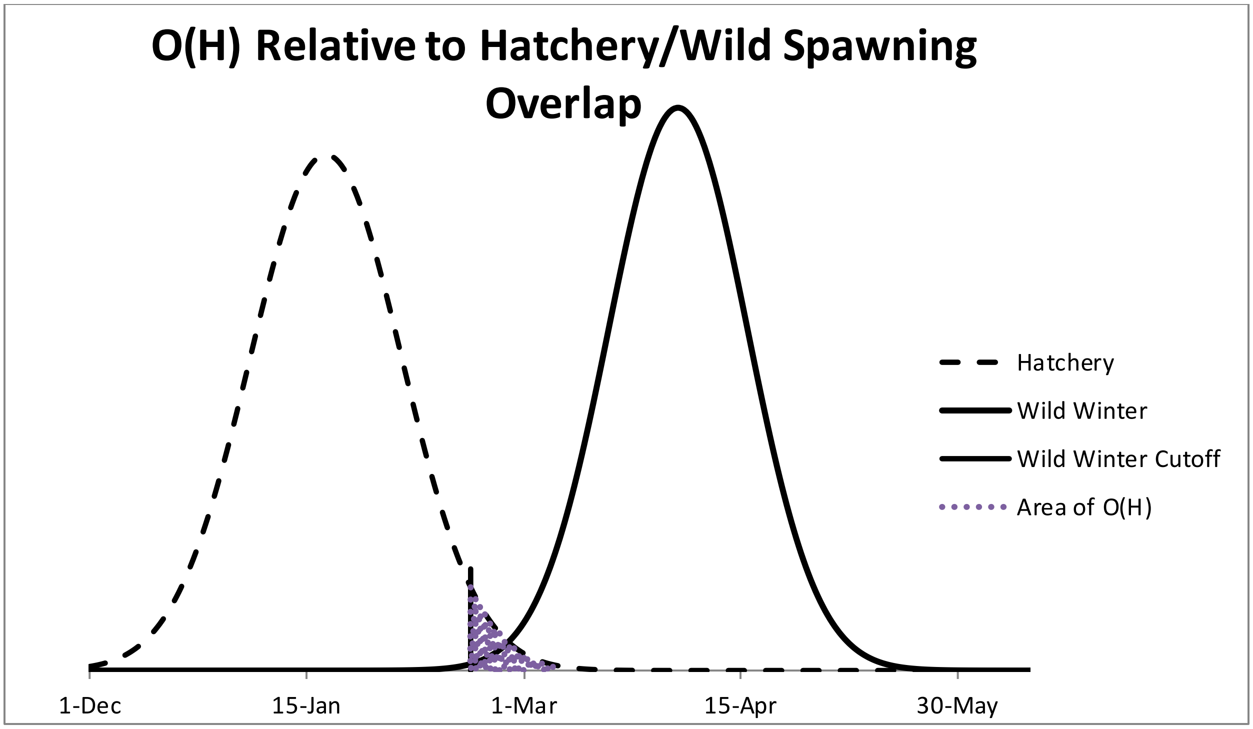

Figure 15. Scenario 1: The temporal distribution of hatchery origin and natural origin spawners in the North River with the period of overlap from February 18 to March 7 using the standard deviation of observed redds after March 15.

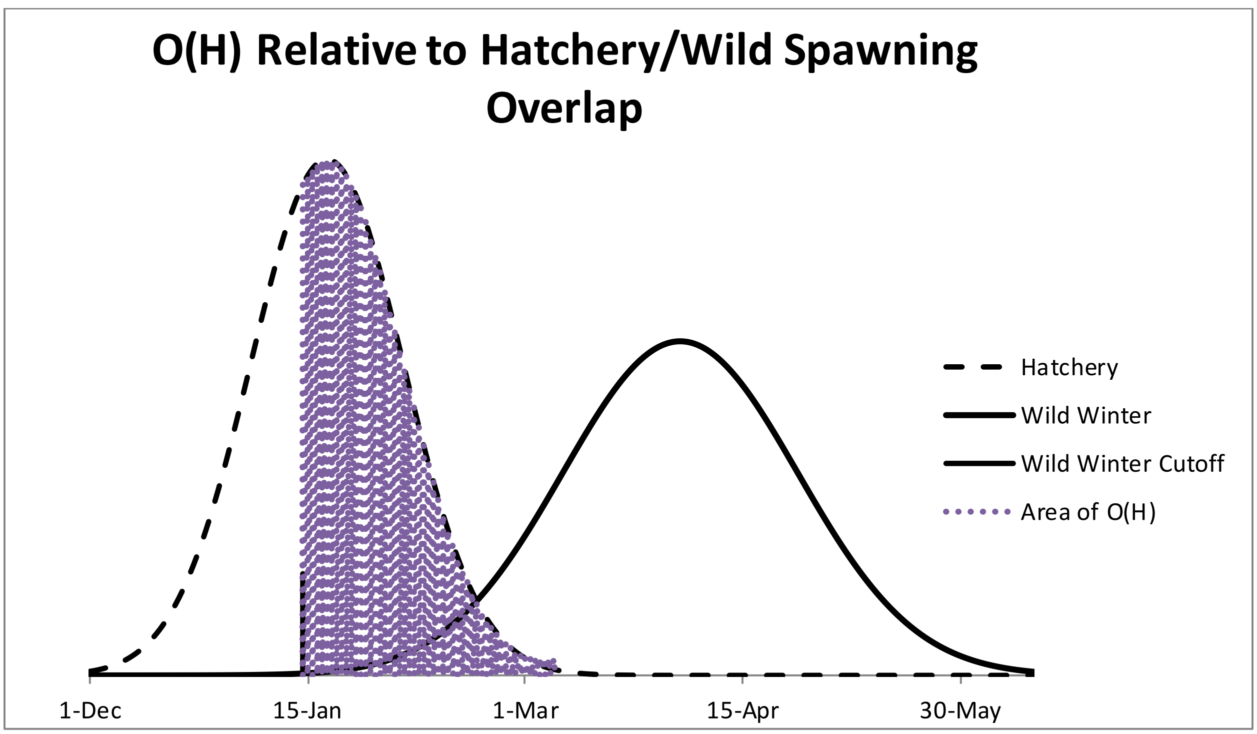

Figure 16. Scenario 2: The temporal distribution of hatchery origin and natural origin spawners in the North River with the period of overlap from January 14 to March 7 using the standard deviation of observed redds across the entire observed spawning period.

Early Winter Steelhead:

Hatchery spawn timing used for the DGM was based on Forks Creek Hatchery early winter steelhead and indicated a mean spawn date of January 19 (SD = 15.7 days) with 1.4% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 15**). The more conservative approach of using the standard deviation across the entire spawning period, results in 37.8% of the hatchery fish spawning in the overlap period with natural origin fish (**Figure 16**). The North River early winter steelhead program lacks any trapping data, so recreational harvest data was used as a surrogate to evaluate the program. The program return rate based on recreational harvest and strays to the spawning grounds was estimated to be 2.13% at a 10% trapping efficiency and 2.43% at a 5% trapping efficiency and it was assumed that the trapping efficiency would range between 5% to 10% based on stray rates back to Forks Creek Hatchery.

Table 16. North River early winter steelhead program, projected geneflow and recreational harvest.

Program	Smolt Release	Geneflow	Potential Rec. Harvest/1
Current Program Scenario 1/2	10,000	20.2%	229
Current Program Scenario 2/3	10,000	23.8%	229
Maximum Program/2	650	1.91%	15
Trapping Efficiency 70%-80%/2	25,000	1.79%	573

/1 Based on a six-year average from return year 2014-2019.

/2 Based on standard deviation naturally spawned redds after March 15.

/3 Based on standard deviation around natural spawned redds across the entire observed spawning period.

Recommendations:

The six-year average natural origin steelhead escapement in the North River is well below the escapement goal, and the DGM indicates that geneflow from the current release (20.2%) significantly exceeds the 2% geneflow threshold. Additionally, the more conservative modeling approach in Scenario 2 indicates results in a geneflow of 23.8% (**Figure 11**). The SSMP stipulates that where risks are inconsistent with watershed goals, juveniles should only be released from locations where returning adults can be trapped (SSMP 2008). Acclimation and trapping facilities should be developed if hatchery plants are to be continued in the North River. However, we recommend discontinuing this program, given that current geneflow levels greatly exceed the thresholds in the SSMP.

Willapa River: Forks Creek Hatchery

The Forks Creek Hatchery is located at RM 0.5 on Fork Creek, tributary to the Willapa River at RM 30.5. An early winter steelhead program was founded at Forks Creek Hatchery in 1994, with steelhead from Chambers Creek, Bogachiel and Lake Aberdeen hatcheries. There are currently two releases in the basin: an on-station release of 45,000 smolts at 5.0 fpp in May, and an outplant of 10,000 smolts released at 5.5 fpp in May at Stringer Creek. The trap on Forks Creek is a full barrier to upstream migration and is open from September through April. Based on the good attraction flow at the trap, it was assumed that the trapping efficiency was between 70% and 80%.

Natural origin Steelhead

Spawning ground surveys on the Willapa River are conducted by WDFW throughout the entire spawning period, and the model included redd data from 1999-2020. The mean spawn date for the natural origin population is April 7 (SD = 19.0 days), with an assumed 11.27% of natural origin fish spawning before March 15 (**Figure 17**), resulting in 5.35% of the natural origin steelhead spawning in the overlap period with hatchery fish based on a gamma distribution (**Figure 18**). Scenario 2 used the standard deviation across the entire spawning period (SD = 29.5 days), resulting in an assumed 21.8% of natural origin fish spawning before March 15 and 18.4% of the natural origin fish spawning in the overlap period with hatchery fish (**Figure 19**). The six-year average (return years 2013/2014 to 2018/2019) natural origin escapement, corrected for fish spawning prior to March 15 is 884, well below the escapement goal of 1,230.

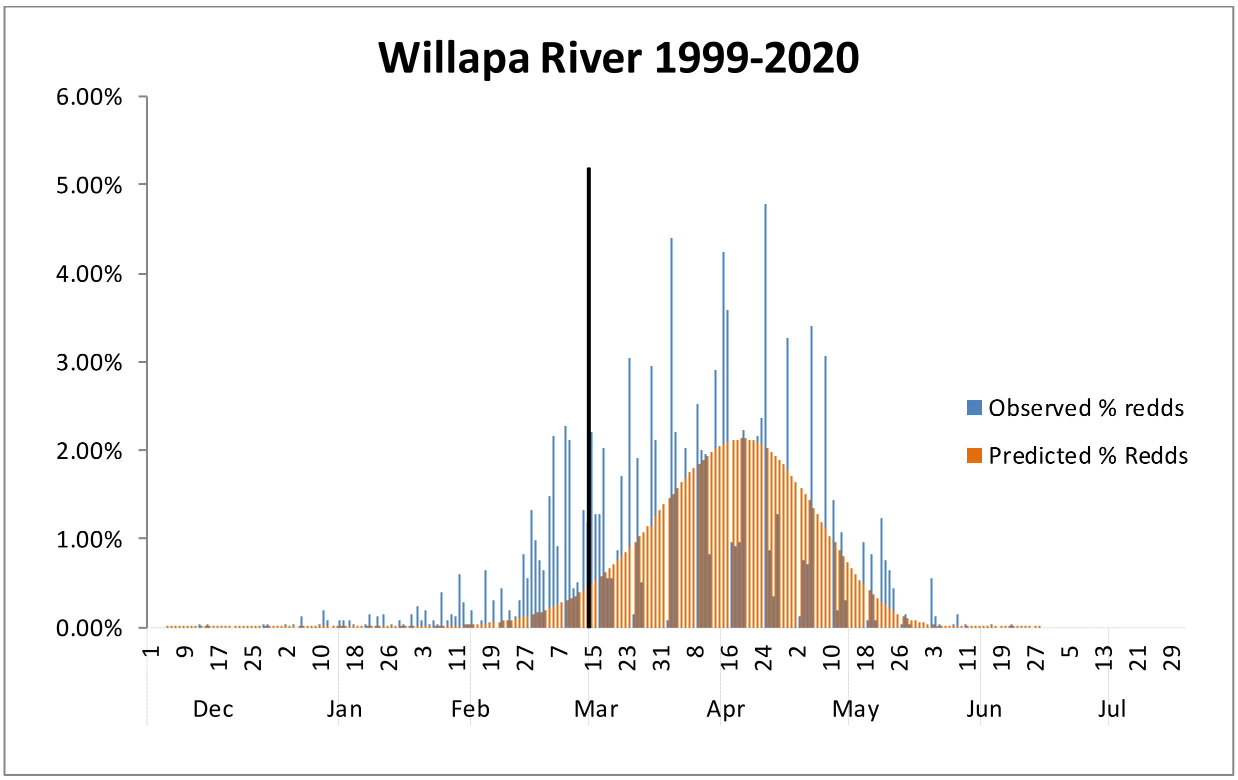

Figure 17. Willapa River natural origin steelhead spawner distribution and gamma fit. O_n = 5.3%. The black bar indicates the March 15 hatchery-wild spawner cut-off date.

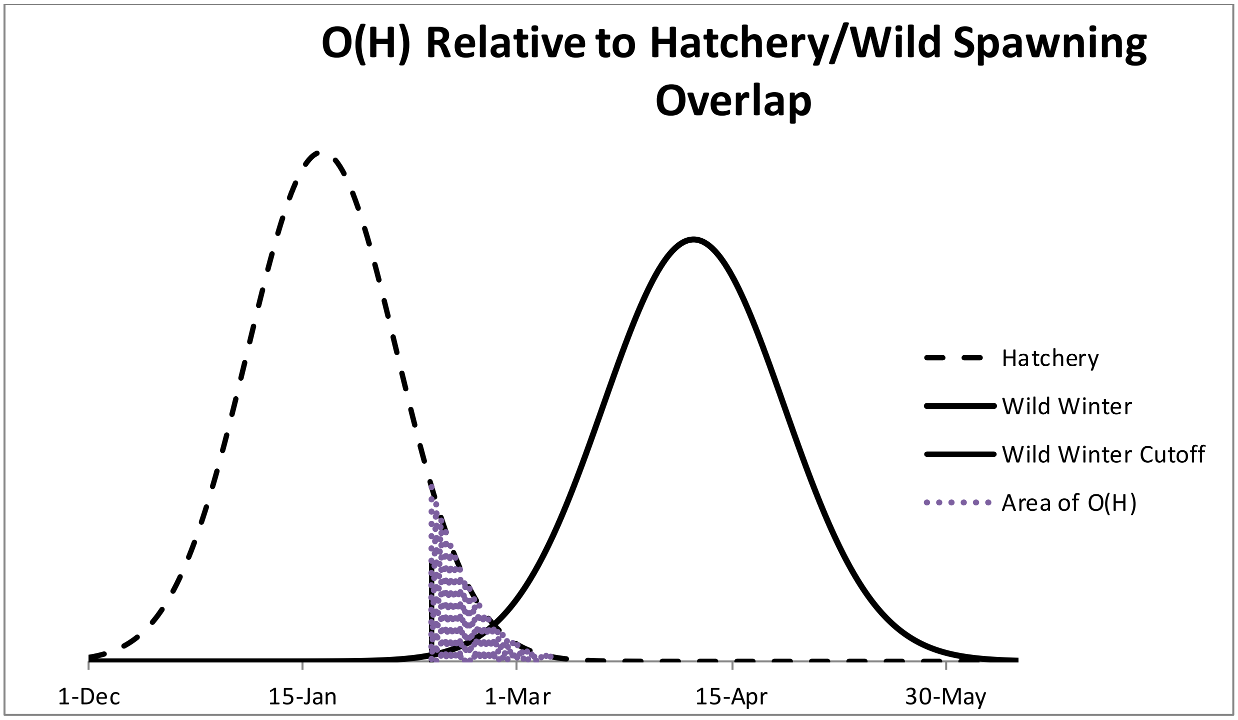

Figure 18. Scenario 1: The temporal distribution of hatchery origin and natural origin spawners in the Willapa River with the period of overlap from February 9 to March 7 using the standard deviation of observed redds after March 15.

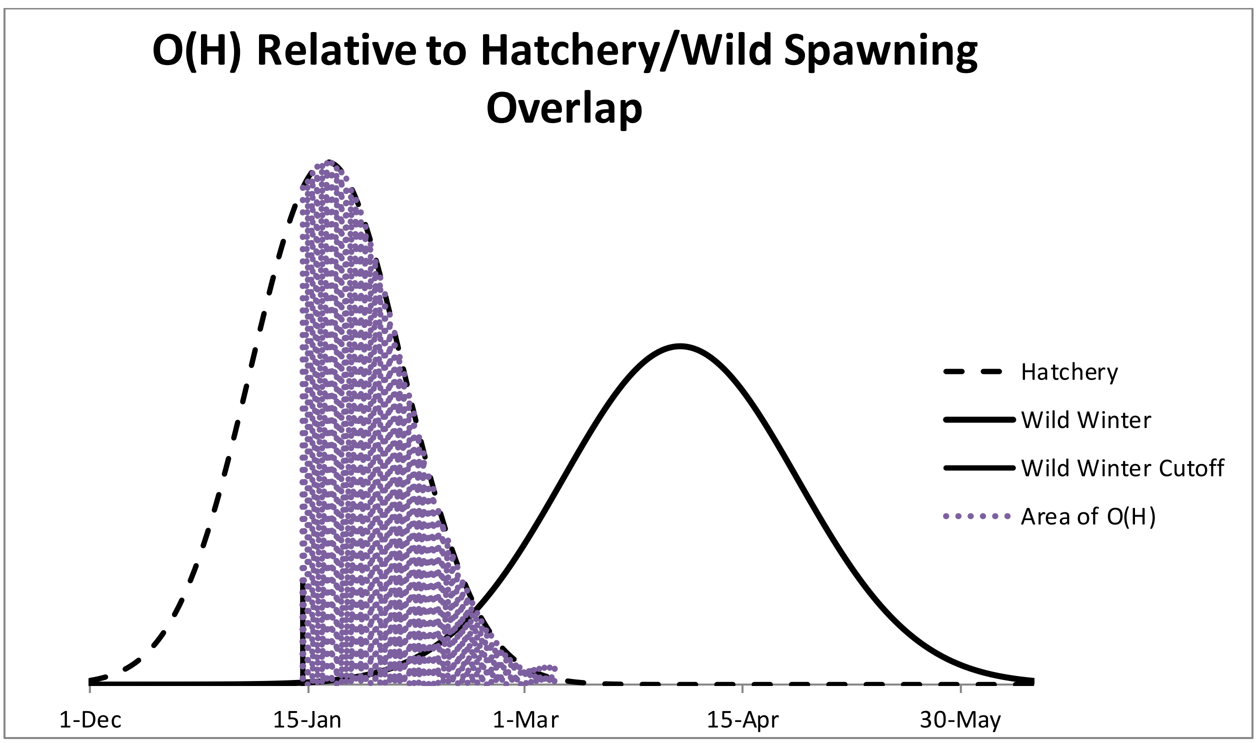

Figure 19. Scenario 2: The temporal distribution of hatchery origin and natural origin spawners in the Willapa River with the period of overlap from January 4 to March 7 using the standard deviation across the entire spawning period.

Early Winter Steelhead:

The mean spawn date for program fish at Forks Creek Hatchery is January 19 (SD = 15.7 days), with 5.1% of hatchery fish spawning in the overlap period with natural origin fish (**Figure 18**). The more conservative approach of using the standard deviation across the entire spawning period results in 64.7% of the hatchery fish spawning in the overlap period with natural origin fish (**Figure 19**). The six-year average hatchery return rate for the early winter steelhead program, after fisheries and including strays to the spawning grounds, was estimated to be 1.76% and 2.01%, at a trapping efficiency of 80% and 70%, respectively. Currently only 40% of the returning fish are caught in recreational fisheries, while the other 60% escape fisheries and return to the hatchery trap.

Table 17. Forks Creek Hatchery early winter Steelhead program, projected geneflow derived from the DGM and recreational harvest.

Program	Smolt Release	Geneflow	Potential Rec. Harvest/1
Current Program Scenario 1/2	45,000	2.23%	337
Current Program Scenario 2/3	45,000	5.13%	337
Maximum Program Scenario 1/2	40,000	2.00%	300
Maximum Program Scenario 2/3	13,000	1.97%	97
No Fisheries/4	23,000	1.94%	---

/1 Based on a six-year average from return year 2014-2019.

/2 Based on standard deviation naturally spawned redds after March 15.

/3 Based on standard deviation around natural spawned redds across the entire observed spawning period.

/4 Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations:

We recommend discontinuing the Stringer Creek release and moving all production on-station. The Forks Creek release should be reduced to a maximum of 40,000 smolts and reevaluated regularly to ensure that it is properly sized. As the hatchery fish at Forks Creek return later, compared with both Bogachiel and Humptulips hatcheries, efforts should be made to move the spawn timing of this stock earlier and continue to ensure that hatchery fish are trapped throughout the season. Additionally, the natural origin spawn timing data indicates that there are a significant number of redds prior to March 15, and we recommend evaluating the use of the March 15 cutoff date in Willapa Bay. While Scenario 2 represents a worst-case scenario and likely includes hatchery spawners, it suggests a much lower maximum release size of 13,000 smolts and highlights the importance of reevaluating the March 15 cutoff date.

Due to the high recruitment to the hatchery and recent low sport catch of hatchery steelhead, we also suggest that a pilot study to evaluate recycling of hatchery fish is considered. A recycling program should only use fish that return prior to December 31, and all fish should be marked with Floy tags to ensure they are identifiable, with an angler reward system to encourage floy tag reporting. Fish should only be recycled a single time and WDFW should explore an incentive system to encourage anglers to report the catch of any recycled fish during the pilot study period. An alternative to a recycling program would be to explore splitting Forks Creek releases into two separate programs, with an integrated late winter steelhead program and a segregated early winter steelhead program. This would allow harvest opportunity to spread throughout the season, which would increase opportunity, but would also result in further impacts on the natural population and would also require additional modeling. Beyond direct hatchery actions, WDFW should explore opportunities to increase access to this fishery, allowing anglers better opportunities to harvest hatchery fish.

Naselle River: Naselle Hatchery

The Naselle Hatchery is located at RM 15.6 on the Naselle River and currently has an early winter steelhead program that was established with Chambers Creek stock-derived steelhead from Forks Creek Hatchery. The trap at Naselle Hatchery is open from August 1 until there has been two weeks with no recruitment, typically in March. The current attraction flow is limited, and therefore the trapping efficiency was assumed to be 50-60%. Naselle Hatchery is currently undergoing a significant rebuild, which is also expected to improve the trapping efficiency at the facility.

Natural origin Steelhead:

Spawning ground surveys on the Naselle River are conducted by WDFW throughout the entire spawning period, and the model included redd data from 1999-2020. The mean spawn date for the natural origin population is April 1 (SD = 18.0 days), with an assumed 17.18% of natural origin fish spawning before March 15 (Figure 20), resulting in 4.09% of the natural origin steelhead spawning in the overlap period with hatchery fish based on a gamma distribution (**Figure 21**). Scenario 2 used the standard deviation across the entire spawning period (SD = 33.8 days), resulting in an assumed 30.7% of natural origin fish spawning before March 15 and 24.0% of the natural origin fish spawning in the overlap period with hatchery fish (**Figure 22**). The six-year average (return years 2013/2014 to 2018/2019) natural origin escapement, corrected for fish spawning prior to March 15 is 942, slightly above the escapement goal of 831.

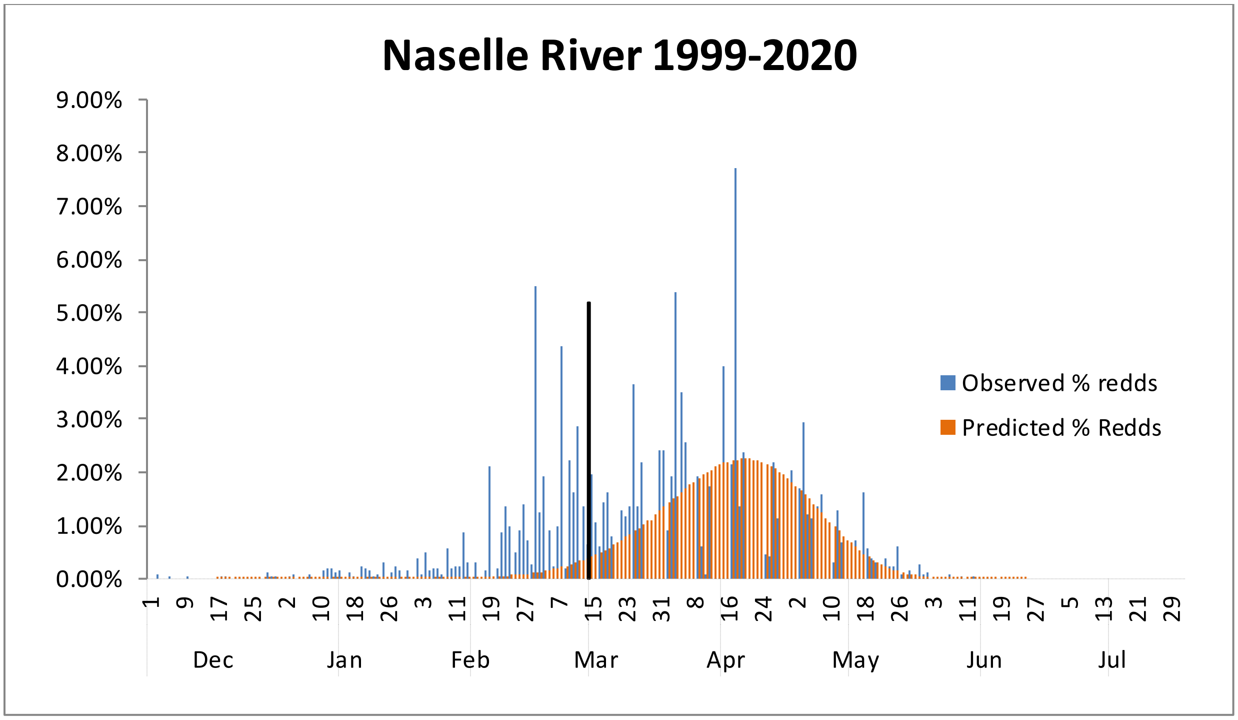

Figure 20. Naselle River natural origin steelhead spawner distribution and gamma fit. O_n = 4.1%. The black bar indicates the March 15 hatchery-wild spawner cut-off date.

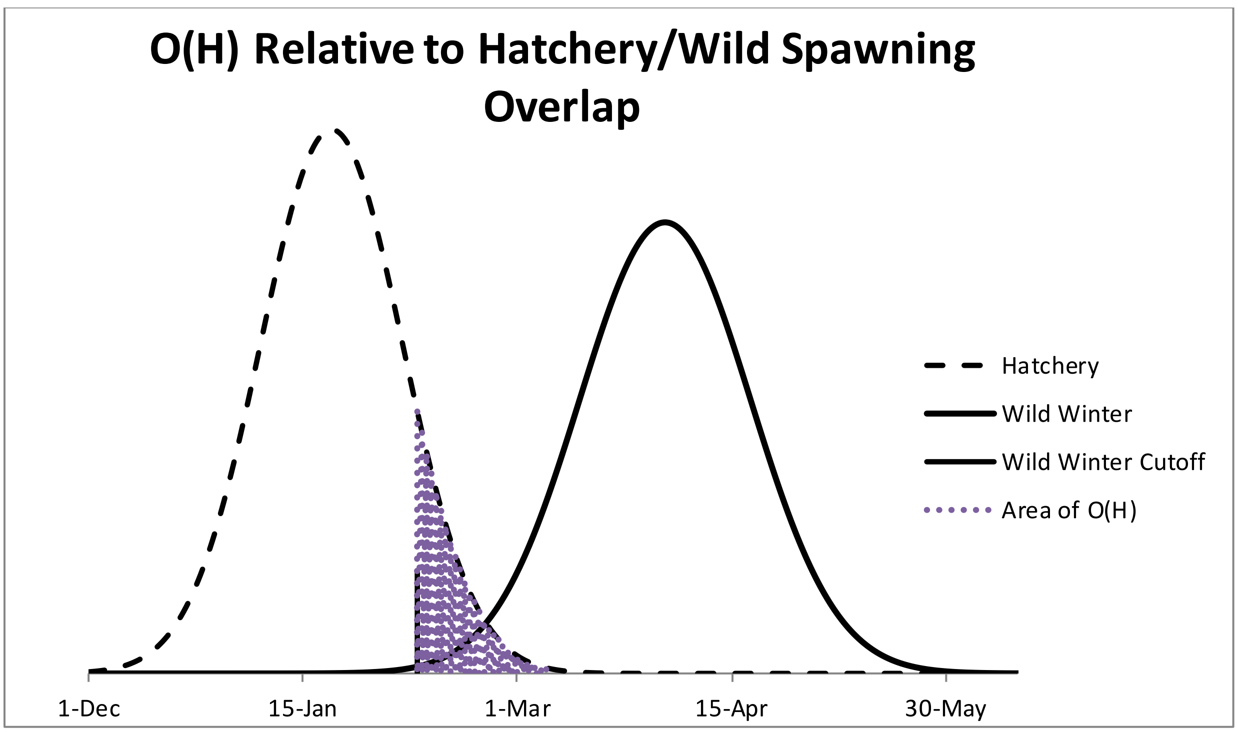

Figure 21. Scenario 1: The temporal distribution of hatchery origin and natural origin spawners in the Naselle River with the period of overlap from February 6 to March 7 using the standard deviation of observed redds after March 15.

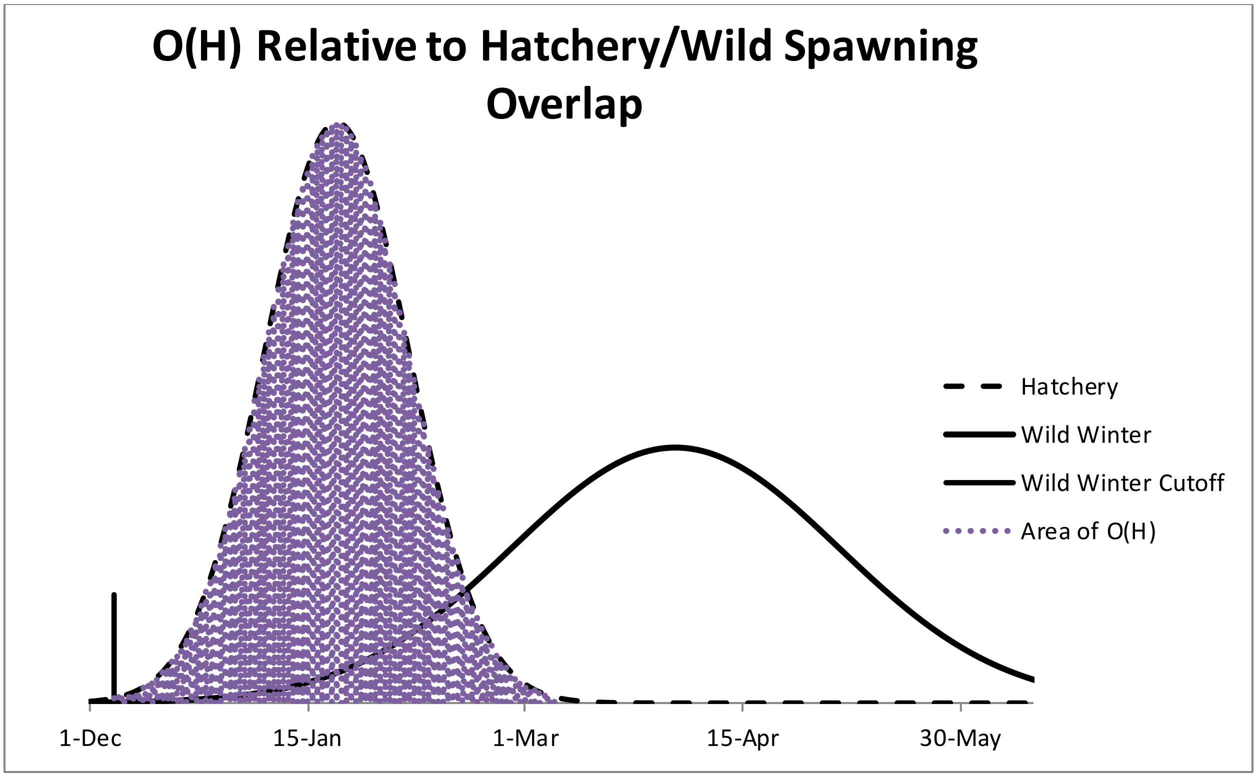

Figure 22. Scenario 2: The temporal distribution of hatchery origin and natural origin spawners in the Willapa River with the period of overlap from December 6 to March 7 using the standard deviation across the entire spawning period.

Early winter Steelhead:

All smolts at Naselle Hatchery are released on-station in May at 5.5 fpp at Naselle Hatchery, with an extensive history of backfilling from Forks Creek Hatchery. The mean spawn date for program fish at Naselle Hatchery is January 21 (SD = 18.0 days) with 8.53% of hatchery fish spawning in the overlap period with wild fish (**Figure 21**). The more conservative approach in Scenario 2 using the standard deviation across the entire spawning period, results in 96.6% of the hatchery fish spawning in the overlap period with natural origin fish (**Figure 22**). The six-year average hatchery return rate for the early winter steelhead program after fisheries and including strays to the spawning grounds was estimated to be 0.68% and 0.78% at a trapping efficiency of 60% and 50%, respectively. The program has averaged 346 fish harvested annually over the past six years, with 44.8% of the collected returns caught in fisheries.

Table 18. Naselle Hatchery early winter Steelhead program, projected geneflow and recreational harvest.

Program	Smolt Release	Geneflow	Potential Rec. Harvest[/1]
Current Program Scenario 1[/2]	75,000	3.38%	297
Current Program Scenario 2[/3]	75,000	4.51%	297
Maximum Program Scenario 1[/2]	40,000	1.94%	178
Maximum Program Scenario 2[/3]	27,000	1.99%	120
Trapping Efficiency 70%-80%[/2], [/4]	100,000	1.97%	445
No Fisheries[/2], [/5]	22,000	1.95%	---

[/1] Based on a six-year average from return year 2014-2019.

[/2] Based on standard deviation naturally spawned redds after March 15.

[/3] Based on standard deviation around natural spawned redds across the entire observed spawning period.

[/4] Likely over estimated as increased trapping efficiency is likely to increase the hatchery return rate, which is likely biased low currently, resulting in a higher geneflow rate.

[/5] Assumes that all current catch would return as hatchery escapement or strays to the spawning grounds.

Recommendations:

The Naselle Hatchery early winter steelhead program should be reduced to maximum of 40,000 smolts to meet the standards in the SSMP. The more conservative Scenario 2 suggest a release of 27,000 but represents a worst-case scenario as it includes an unknown amount of hatchery spawners. The natural origin spawn timing data indicates that there are a significant number of redds prior to March 15, and we recommend reevaluating the March 15 cutoff date in Willapa Bay. Once the hatchery rebuild is completed, we recommend at least three years of the program evaluation to determine the effects on the hatchery return rate and hatchery trap efficiency. After this period, the program should be reevaluated to determine if it is properly sized. The model currently suggests that a program of up to 100,000 smolts could be released at a 70% to 80% trapping efficiency. However, this is likely artificially inflated due to the poor hatchery return rate at Naselle Hatchery. The Naselle Hatchery EWS has the lowest post release survival rate of any of the Coastal segregated EWS programs. The cause of this poor survival should be investigated, and efforts should be made to improve the survival of hatchery fish at this facility. If the survival cannot be improved and the program is unable to achieve its fisheries goals, WDFW should consider discontinuing the program. Once the facility rebuild is completed, we recommend ensuring that the broodstock at Naselle Hatchery is self-sustaining and does not rely on backfill from other facilities. Additionally, as with Forks Creek, hatchery fish at Naselle return later when compared to both Bogachiel and Humptulips hatcheries, and an effort should be made to move this stock to an earlier spawn timing and to continue to ensure that hatchery fish are trapped throughout the season.

CONCLUSIONS

The modeling conducted here is the first attempt to assess the genetic impacts of hatchery steelhead production on natural populations along Washington's Pacific coast. The results represent the recommended maximum program sizes for each of the hatchery program that were evaluated. Current modeling indicates that hatchery release goals at many of the facilities along the Washington Coast should be adjusted to align with the SSMP. Based on the findings, the overall coastwide change in production is expected to be a decrease of 262,000 (**Table 19**). The majority of the production decreases are associated with the release of Lake Aberdeen summer and late winter steelhead into the Wynoochee River. These programs would need to reduce their combined release goal by 175,000 smolts to meet the SSMP guidelines. Despite this, these release levels do not consider potential changes to the programs' release and acclimation strategies, which could allow for substantially higher release levels (**Table 19**). Modeling also indicates that the Naselle early winter steelhead program will need to decrease by 35,000 smolts to meet the SSMP. However, infrastructure changes at the facility are expected to greatly improve the trapping efficiency, which has the potential to reduce hatchery straying onto the spawning grounds and allow for high production levels. Several integrated programs were modeled to allow higher production levels while remaining within the thresholds in the SSMP. While higher production levels could be possible, integrations rates at these facilities have been inconsistent and the natural populations impacted by these programs are currently not meeting their escapement objectives, and as such we do not suggest increasing production at this time.

During this analysis, we were challenged with data limitations associated with some of the key parameters used in both the AHA and DGM. These limitations increase the level of uncertainty around the model results and WDFW should seek to validate the following parameter values with moderate to high levels of uncertainly, such as data regarding the natural origin SAR%, watershed productivity and capacity values. Validation would greatly improve the level of confidence in the model results for future AHA modeling. For the DGM, a thorough assessment of the trapping efficiency at each facility and an evaluation of the validity of the March 15 hatchery- and natural origin spawner cutoff date would lead to a higher degree of confidence in the model results as well as a better understanding of hatchery stray rates into neighboring watersheds. While the DGM and AHA model do address genetic risks, they do not directly assess such ecological risks as predation, competition and disease, and additional modeling would be needed to estimate the impacts of these factors. In the future, an assessment of all ecological risks using the Predation, Competition and Disease Risk Model (PCD Risk) should be conducted.

Table 19. Summary of Current hatchery program sizes and recommended program sizes based on modeling.

Program	Current Release Goal	Recommended Maximum Release Goal/1	Maximum Modeled Release with Program/ Population Improvements/2
Bogachiel EWS	150,000	145,000	145,000
Bogachiel ESS	30,000	30,000	30,000
Humptulips EWS	125,000	120,000	145,000
Humptulips ESS	30,000	30,000	30,000
Wishkah ESS	15,000	15,000	43,000
Lake Aberdeen LWS/1	170,000	55,000	155,000
Lake Aberdeen ESS/1	60,000	0	60,000
Bingham Creek LWS	55,000	55,000	100,000
Skookumchuck LWS	75,000	48,000	48,000
Newaukum LWS	30,000	30,000	30,000
Eight Creek LWS	32,000	32,000	42,000
North River EWS	10,000	0	0
Forks Creek EWS	45,000	40,000	40,000
Naselle EWS/1	75,000	40,000	100,000
Total	**902,000**	**640,000**	**968,000**

/1 Recommended maximum release levels based on DGM and AHA modeling

/2 Releases have the potential to increase beyond their current recommended levels if improvements in monitoring, natural population abundance, program release structure or if infrastructure changes are made to improve the hatchery trapping efficiencies.

As described above, appropriate levels of hatchery releases are directly linked with abundance of wild steelhead. When wild steelhead populations decline, the number of adult hatchery steelhead in the natural environment should also be reduced. To achieve this, WDFW should adopt a clear, proactive adaptive management framework to link the management of hatchery production and fisheries with the current status of natural steelhead populations along Washington's Pacific coast. The development of this approach is beyond the scope of this paper but should include goals for managing hatchery production during periods of low natural origin returns that necessitate stronger fisheries regulations or closures. Metrics on diversity, viability, long-term and short-term escapement goals that consider both the historical watershed capacity as well as the current capacity based on shifting habitat structure and stability should be among the considerations when determining management goals for production and conservation. Additionally, an adaptive management framework should set critical thresholds for natural origin populations and hatchery responses to actions such as fisheries closures that would necessitate significant reductions, transitions to conservation programs, or the discontinuation of hatchery production.

We are not recommending that any of WDFWs current hatchery programs on the coast transition to conservation programs at this time, if steelhead populations continue to decline this may become necessary in the future. However, many of Washington's conservation hatchery programs have not resulted in positive responses in natural steelhead populations. As a result, alternative approaches to conservation hatchery programs, such as those developed under the Hood Canal Steelhead Supplementation Program (Berejikian and Van Doornik 2018), should be developed according to the best available science. Regardless, clear program goals and a robust monitoring framework should be established before considering transitioning programs to focus on conservation, to ensure that those goals are achieved. Improving our scientific understanding of our how hatchery steelhead interact with natural origin populations and continued modeling is crucial to the development and implementation of an adaptive management framework for coastal steelhead fisheries and associated hatchery production.

Modeling efforts like this one should be conducted regularly, as steelhead survival has been highly variable in recent years and populations are currently experiencing declines across the coast. Regular modeling will ensure that hatchery releases are properly scaled to reduce overarching impacts on natural origin populations and allow for adaptive management of not only the hatchery releases but of harvest and conservation goals. Instead of the set release targets, WDFW should consider utilizing regular modeling and monitoring to scale hatchery production levels to account for shifts in natural abundance and hatchery return rates. Increased monitoring, improved data sets for watershed level survival and capacity, and a re-evaluation of release goals will make it possible to find a balance between harvest and conservation objectives. Ensuring that hatchery programs do not exceed the thresholds for genetic risk laid out in the SSMP will continue to be important in a changing climate with shifting ocean conditions and fluctuating natural origin returns. As such, ensuring that hatchery impacts are properly managed and do not impede natural origin populations will be crucial to ensuring that sustainable fisheries for both hatchery and natural origin fish can be enjoyed by future generations in Washington State.

Overarching Recommendations

- Work with anglers and other stakeholders to develop a coastwide portfolio of hatchery programs and WSMZs that meet fisheries goals while aligning with the SSMP.
- Develop a clear adaptive management framework for managing hatchery programs and fisheries based on the status of natural origin steelhead populations.
- Establish at least one WSMZ for each MPG along the Washington's Pacific coast. WSMZ recommendation tables in each section provide potential designation options identified from this analysis.
- Assess the status, spawn timing and spatial distribution of natural origin summer run steelhead populations, so that future modeling can take the status of these populations into account.
- Reevaluate the March 15 hatchery origin/natural origin spawner cutoff date to assess the validity of this assumption.
- Design alternative methods from the March 15 spawner cutoff date to differentiate hatchery and natural origin spawners, especially in watersheds where integrated

steelhead are released. Where integrated fish are released there should be no significant difference in the hatchery- and natural origin spawn timing and, as such, WDFW should develop new methodologies to account for the abundance of hatchery origin steelhead on the spawning grounds.

- Ensure that river-specific genetic baselines are established and that genetic samples are collected on a regular basis for all watersheds where hatchery fish are released to validate modeling results and determine the PHEC.

Hatchery and Fishery Specific Recommendations

- Discontinue outplanting for segregated programs without trapping or acclimation facilities.
- Where outplanting occurs for integrated programs, reduce number of planting sites for a single hatchery program within the watershed to increase homing and site fidelity. This will help, not only for targeted fisheries, but conservation goals by reducing straying and spawning ground swamping.
- Develop clear adult production goals for each hatchery program, including targets for SAR%, catch in fisheries, and needs for broodstock. These goals should be included in the Hatchery Management Plans for each program.
    - Programs should aim to maintain or improve their SAR% in comparison with the coastal average for the same run type. For programs with low SAR%, evaluate the causes for the lower survival.
    - Harvest goals should be set to ensure that hatchery programs are providing meaningful harvest and maintaining high harvest rates on hatchery fish.
- Consider discontinuing programs that do not consistently meet their adult production goals.
- Do not exceed 30% mining of natural populations for integration programs. Ensure that natural populations tied to integrated hatchery programs achieve demographic replacement for natural origin fish used as broodstock, so that natural populations do not decline due to broodstock collection practices.
- Use volitional release strategies for hatchery smolts; non-migrating juveniles should be planted into lakes that do not have access to anadromous waters.
- Consider using mandatory retention of hatchery fish caught in recreational fisheries as a tool to remove hatchery fish, especially during years of low natural origin returns.
- Prioritize studies to compare the performance of integrated hatchery steelhead programs compared to segregated hatchery steelhead programs, specifically comparing each hatchery type to a control stream with no hatchery planting to determine the short-term and long-term impacts on natural populations, as well as to compare the risks and benefits of each program type.
- Pursue research on relative reproductive success to validate literature values used in the models

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APPENDIX

Appendix Table 1. DGM Parameters for recommended maximum Quillayute segregated hatchery steelhead program sizes. Colors denote confidence levels in the parameter values (Green = High), (Yellow = Moderate), (Red = Low).

Natural:	Bogachiel + Calawah Wild				Bogachiel Wild			
Hatchery:	Bogachiel Summer				Bogachiel EWS			
Parameter	Case 3 Stray Rate = 0.20		Case 6 Stray Rate = 0.30		Case 3 Stray Rate = 0.20		Case 6 Stray Rate = 0.30	
	K_1 = 0.09	K_1 = 0.18	K_1 = 0.09	K_1 = 0.18	K_1 = 0.02	K_1 = 0.13	K_1 = 0.02	K_1 = 0.13
Spawners prior to Mar 15[/1]	0.0843	0.0843	0.0843	0.0843	0.0843	0.0843	0.0843	0.0843
O_N[/1]	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396
O_H[/2]	2.06E-05	2.06E-05	2.06E-05	2.06E-05	0.0599	0.0599	0.0599	0.0599
K_1[/3]	0.0900	0.1800	0.0900	0.1800	0.0200	0.1300	0.0200	0.1300
K_2[/4]	0.5675	0.5675	0.5675	0.5675	0.5400	0.5400	0.5400	0.5400
Homing Rate[/5]	0.8000	0.8000	0.7000	0.7000	0.8000	0.8000	0.7000	0.7000
Stray Contribution Rate[/5]	0.0041	0.0041	0.0070	0.0070	0.0032	0.0032	0.0056	0.0056
Hatchery Spawning Ground Strays[/4]	122	122	210	210	470	470	805	805
Natural Spawners[/7]	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829
Adj. Natural Spawners[/4]	4,181	4,181	4,181	4,181	4,181	4,181	4,181	4,181
q[/4]	0.0284	0.0284	0.0478	0.0478	0.1010	0.1010	0.1615	0.1615
Projected DGF[/8]	0.26%	0.52%	0.45%	0.89%	0.52%	1.67%	0.85%	2.80%
Program DGF[/8]	0.53%				1.46%			
Model Release Size	30,000				145,000			

[/1] Data source WDFW Spawning Ground Survey Database (SGS) and Quillayute Tribal Data.

[/2] Data source WDFW Hatchery Escapement Database.

[/3] Based on values from Araki et al. 2008 for EWS and HSRG for ESS.

[/4] Calculated values.

[/5] Data source calculated with six-year average of hatchery releases and hatchery escapement.

[/6] Estimated value.

[/7] Data source WDFW SaSI Database.

[/8] DGF results for each scenario and average geneflow for each program.

Appendix Table 2. DGM Parameters for recommended maximum Grays Harbor/ Chehalis River segregated hatchery steelhead program sizes. Colors denote confidence levels in the parameter values (Green = High), (Yellow = Moderate), (Red = Low).

Natural Stock:	Humptulips Wild												Wynoochee Wild			
Hatchery Stock:	Humptulips Summer				Humptulips EW								Lake Aberdeen Summer			
Parameter	Case 3 Stray Rate = 0.20		Case 6 Stray Rate = 0.30		Case 3 Stray Rate = 0.20		Case 6 Stray Rate = 0.30		Case 3 Stray Rate = 0.20		Case 6 Stray Rate = 0.30		Case 3 Stray Rate = 0.70		Case 6 Stray Rate = 0.80	
	K_1= 0.09	K_1= 0.18	K_1= 0.09	K_1= 0.18	K_1= 0.02	K_1= 0.13	K_1= 0.02	K_1= 0.13	K_1= 0.02	K_1= 0.13	K_1= 0.02	K_1= 0.13	K_1= 0.09	K_1= 0.18	K_1= 0.09	K_1= 0.18
Spawners prior to Mar 15/1	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0630	0.0630	0.0630	0.0630
O_N/1	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0434	0.0434	0.0434	0.0434
O_H/2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K_1/3	0.0900	0.1800	0.0900	0.1800	0.0200	0.1300	0.0200	0.1300	0.0200	0.1300	0.0200	0.1300	0.0900	0.1800	0.0900	0.1800
K_2/4	0.5675	0.5675	0.5675	0.5675	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5675	0.5675	0.5675	0.5675
Homing Rate/5	0.8000	0.8000	0.7000	0.7000	0.8000	0.8000	0.7000	0.7000	0.8000	0.8000	0.7000	0.7000	0.3000	0.3000	0.2000	0.2000
Stray Contribution Rate/5	0.0018	0.0018	0.0030	0.0030	0.0017	0.0017	0.0029	0.0029	0.0017	0.0017	0.0029	0.0029	0.0129	0.0129	0.0222	0.0222
Hatchery Spawning Ground Strays/4	53	53	91	91	201	201	345	345	25	25	43	43	155	155	266	266
Natural Spawners/7	1,704	1,704	1,704	1,704	1,704	1,704	1,704	1,704	360	360	360	360	1,305	1,305	1,305	1,305
Adj. Natural Spawners/4	1,709	1,709	1,709	1,709	1,709	1,709	1,709	1,709	361	361	361	361	1,393	1,393	1,393	1,393
q/4	0.0301	0.0301	0.0505	0.0505	0.1054	0.1054	0.1681	0.1681	0.0652	0.0652	0.1068	0.1068	0.1002	0.1002	0.1604	0.1604
Projected DGF/8	0.28%	0.55%	0.48%	0.95%	0.24%	1.51%	0.40%	2.56%	0.14%	0.90%	0.24%	1.53%	0.99%	1.97%	1.69%	3.32%
Program DGF/8	0.56%				1.18%				0.70%				1.99%			
Model Release Size	650				40,000				40,000				12,000			

/1 Data source WDFW Spawning Ground Survey Database (SGS).

/2 Data source WDFW Hatchery Escapement Database.

/3 Based on values from Araki et al. 2008.

/4 Calculated values.

/5 Data source calculated with six-year average of hatchery releases and hatchery escapement.

/6 Estimated value.

/7 Data source WDFW SaSI Database.

/8 DGF results for each scenario and average geneflow for each program.

Appendix Table 3. DGM Parameters for recommended maximum Willapa Bay segregated hatchery steelhead program sizes. Colors denote confidence levels in the parameter values (Green = High), (Yellow = Moderate), (Red = Low).

Natural Stock:	North River Wild				Willapa River Wild				Naselle River Wild			
Hatchery Stock:	Forks Creek EWS								Naselle EWS			
Parameter	Stray Rate = 0.20		Stray Rate = 0.30		Stray Rate = 0.20		Stray Rate = 0.30		Stray Rate = 0.40		Stray Rate = 0.50	
	K_1 = 0.02	K_1 = 0.13	K_1 = 0.02	3_1 = 0.18	K_1 = 0.02	K_1 = 0.13	K_1 = 0.02	K_1 = 0.13	K_1 = 0.02	K_1 = 0.13	K_1 = 0.02	K_1 = 0.13
Spawners prior to Mar15/1	0.1042	0.1042	0.1042	0.1042	0.1127	0.1127	0.1127	0.1127	0.1718	0.1718	0.1718	0.1718
O_N/1	0.0401	0.0401	0.0401	0.0401	0.0535	0.0535	0.0535	0.0535	0.0409	0.0409	0.0409	0.0409
O_H/2	0.0141	0.0141	0.0141	0.0141	0.0511	0.0511	0.0511	0.0511	0.0854	0.0854	0.0854	0.0854
K_1/3	0.0200	0.1300	0.0200	0.1300	0.0200	0.1300	0.0200	0.1300	0.0200	0.1300	0.0200	0.1300
K_2/4	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400	0.5400
Homing Rate/5	0.1000	0.1000	0.0500	0.0500	0.8000	0.8000	0.7000	0.7000	0.6000	0.6000	0.5000	0.5000
Stray Contribution Rate/5	0.1533	0.1533	0.3237	0.3237	0.0035	0.0035	0.0060	0.0060	0.0036	0.0036	0.0054	0.0054
Hatchery Spawning Ground Strays/4	100	100	210	210	141	141	241	241	145	145	217	217
Natural Spawners/7	571	571	571	571	784	784	784	784	780	780	780	780
Adj. Natural Spawners/4	637	637	637	637	884	884	884	884	942	942	942	942
q/4	0.1353	0.1353	0.2483	0.2483	0.1374	0.1374	0.2145	0.2145	0.1333	0.1333	0.1874	0.1874
Projected DGF/8	0.42%	2.08%	0.87%	4.28%	0.68%	2.31%	1.12%	3.87%	0.82%	2.36%	1.15%	3.44%
Program DGF/8	1.91%				2.00%				1.94%			
Model Release Size	650				40,000				40,000			

/1 Data source WDFW Spawning Ground Survey Database (SGS).

/2 Data source WDFW Hatchery Escapement Database.

/3 Based on values from Araki et al.

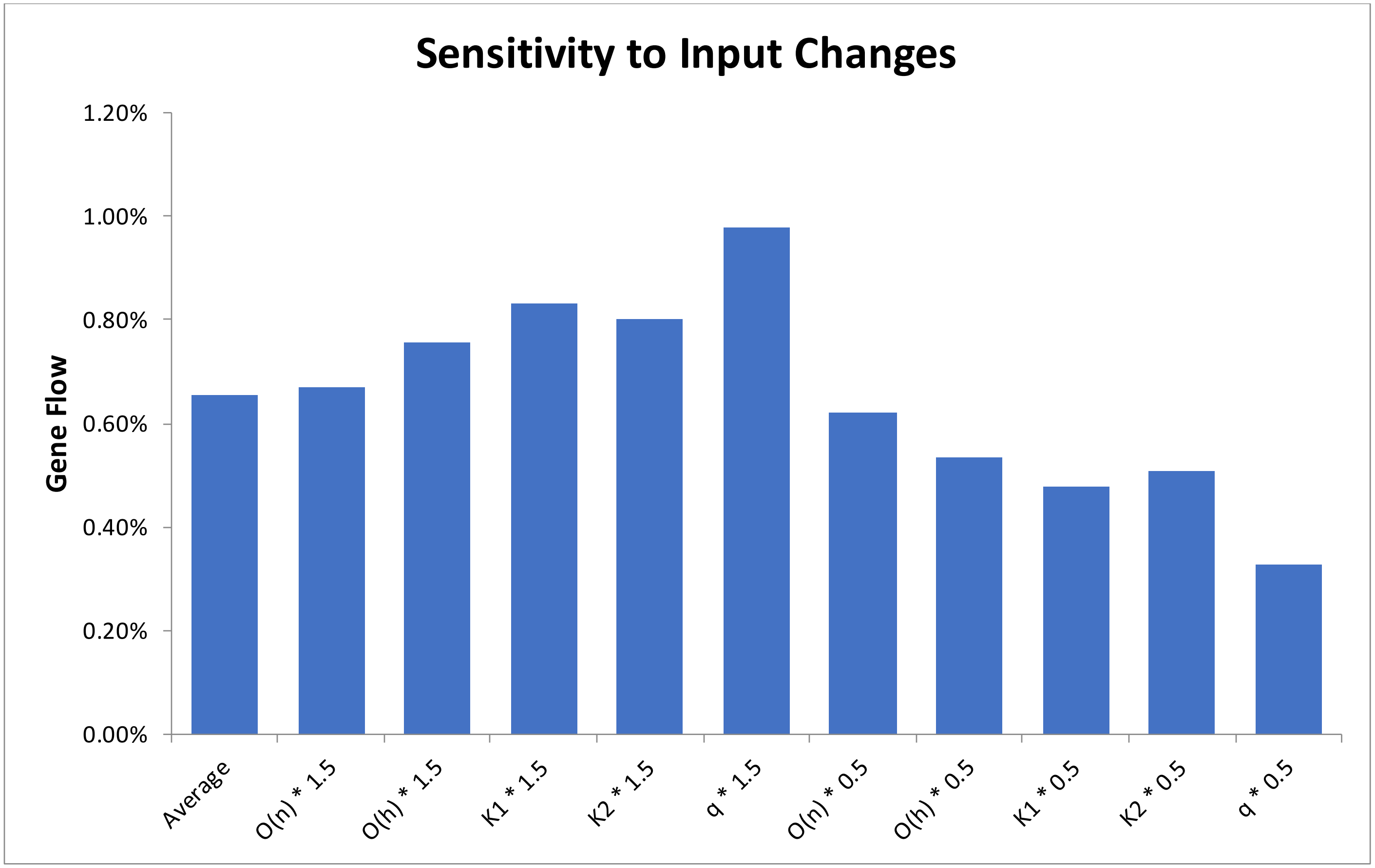
/4 Calculated values.

/5 Data source calculated with six-year average of hatchery releases and hatchery escapement.

/6 Estimated value.

/7 Data source WDFW SaSI Database.

/8 DGF results for each scenario and average geneflow for each program.



Appendix Figure 1. Sensitivity analysis for the key parameters in the DGM.

Appendix Table 4. Mean spawn dates and associated standard deviations for natural winter populations and segregated hatchery programs on the North Olympic Peninsula.

Facility/ Population	Population	Mean Spawning Date	Mean Spawning Day Number/[1] (day)	Standard Deviation (day)	Natural/Hatchery Cutoff Date/[2]
Bogachiel/ Calawah River	Natural Winter	April 22	143	27.6	January 29
Bogachiel	EWS	January 2	33	17.2	February 23
Bogachiel	ESS	November 16	-15	18.2	January 9
Humptulips River	Natural Winter	April 28	149	15.9	March 11
Wynoochee River	Natural Winter	April 20	141	23.6	February 12
Humptulips	EWS	January 5	36	15.4	February 20
Humptulips	ESS	December 26	26	7.3	January 17
Lake Aberdeen	ESS	December 11	11	6.2	January 1
North River	Natural Winter	April 2	123	15.7	February 18
Willapa River	Natural Winter	April 7	128	19.0	February 9
Naselle River	Natural Winter	April 1	122	18.0	February 6
Forks Creek	EWS	January 19	50	15.7	March 7
Naselle	EWS	January 21	52	18.0	March 7

/[1]December 1 is Day Number 1.

/[2] The Cutoff Date is the date corresponding to the mean Day Number minus three standard deviations for natural populations (Region C boundary) and the mean Day Number plus three standard deviations for the hatchery programs (Region A boundary).

Appendix Table 5. AHA Model parameters for recommended maximum coastal integrated hatchery steelhead programs release sizes. Colors denote confidence levels in the parameter values (Green = High), (Yellow = Moderate), (Red = Low).

Late Winter Steelhead Program						
Parameters	**Bogachiel**	**Lake Aberdeen**	**Bingham Creek**	**Skookumchuck**	**Newaukum**	**Eight Creek**
$Prod_{Adult}$/1	3.25	2.5	3.5	2.5	2.5	3.0
$Prod_{Smolt}$/1	81	63	88	63	63	75
Cap_{Adult}/1	8,500	2,475	3,400	2,300	2,300	4,000
Cap_{Smolt}/1	212,500	61,875	85,000	57,500	57,500	100,000
$Fecund_{NOR}$/2	3,913	3,833	3,911	3,980	3,980	3,980
$\%Fem_{NOR}$/1	50%	50%	50%	50%	50%	50%
SAR_{obs}/1	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
SAR_{PDO}	PDO	PDO	PDO	PDO	PDO	PDO
HR_{NOR}/3	25%	8.5%	8.5%	12.7%	12.7%	12.7%
HR_{HOR}/3	45%	80%	72%	54%	56%	54%
$S_{prespawn}$/2	80%	90%	99%	99%	99%	99%
$Fecund_{HOR}$/2	3,193	3,833	3,874	3,980	3,980	3,980
$\%Fem_{HOR}$/2	50%	50%	50%	50%	50%	50%
$S_{egg\text{-}smolt}$/2	85%	81%	90%	95%	85%	95%
$SAR_{yearling}$/4	3.00%	2.6%	2.3%	3.3%	0.40%	2.0%
RRS_{HOS}/5	100%	80%	80%	80%	80%	80%
$\%Hatch_{return}$/1	0%	25%	60%	75%	10%	5%
#Yearlings	30,000	55,000	55,000	48,000	30,000	32,000
$Brood_{local}$	23	39	35	26	18	17
$\%NOR_{max}$	30%	30%	30%	30%	30%	30%

Note: Watershed Productivity and Capacity for Skookumchuck Hatchery and Newaukum had combined spawning ground return numbers and escapement goals, reducing our confidence in these parameters.

/1 Estimated values.

/2 Data source WDFW Hatchery Data.

/3 Data source WDFW Biologist Run Reconstruction data, CRC Data and Tribal Net data.

/4 Data source WDFW Hatchery Release Database, WDFW Hatchery Escapement Database, CRC data, tribal net data.

/5 Data source HSRG.