NOAA Technical Memorandum NMFS-NWFSC-81

Status Review of Puget Sound Steelhead *(Oncorhynchus mykiss)*

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Executive Summary

In 1996 the National Marine Fisheries Service (NMFS) completed a status review of West Coast steelhead (anadromous *Oncorhynchus mykiss*) under the U.S. Endangered Species Act (Busby et al. 1996). That status review included steelhead from Puget Sound. At that time, a Biological Review Team (BRT) concluded the Puget Sound steelhead evolutionarily significant unit (ESU) was not at risk of extinction nor likely to become so in the foreseeable future. Nevertheless, the BRT expressed several concerns about the overall health of this ESU and about the status of certain stocks within the ESU. Recent trends in stock abundance were predominantly downward, although this may be due largely to recent climate conditions, and trends in the two largest stocks (Skagit and Snohomish rivers) had been upward. Prominent concerns the BRT had about this ESU included uncertainty about the abundance and status of summer run steelhead in Puget Sound and uncertainty about the extent of interaction between hatchery and wild steelhead. Hatchery steelhead production in the ESU was high, and the hatchery stocks were either from outside the ESU or highly domesticated. Nevertheless, these concerns were insufficient to support a BRT conclusion that risk of extinction was high.

On 13 September 2004 NMFS received a petition to list Puget Sound steelhead as endangered or threatened (Wright 2004). The petition described several factors that justify a reexamination of the extinction risk for the Puget Sound Steelhead ESU. These factors included: declines in steelhead abundances such that "not a single entire river basin, large or small … had a significant upward short-term trend," and that these declines have occurred under a harvest regime that prohibits the retention of wild (unmarked) adults by recreational anglers. The petition disputed the assertion by the Washington Department of Fish and Wildlife (WDFW) that winter run steelhead hatchery stocks were substantially spatially separated from natural winter run steelhead populations and cited studies of hatchery and wild steelhead interactions that substantiate the deleterious impact of hatchery fish on natural reproduction and sustainability. The conclusion of the petitioner was that these factors justify a determination that Puget Sound steelhead are in danger of extinction throughout all or a significant portion of its range or are likely to become so in the foreseeable future.

NMFS formed a Puget Sound steelhead BRT—consisting of scientists from the Northwest Fisheries Science Center, the Southwest Fisheries Science Center, the U.S. Forest Service, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey—and the team reviewed and evaluated scientific information compiled by NMFS staff from published literature and unpublished data. The BRT considered information presented at a public meeting in July 2005 in Seattle, Washington, and reviewed additional information submitted to the Endangered Species Act Administrative Record.

The BRT was charged with considering the following particular issues:

1. If the Puget Sound Steelhead ESU merits redelineation or refinement, describe the composition and geographic range of the redefined ESU. In your review … describe the relationship of rainbow trout (resident *O. mykiss*) populations to the defined ESU. … In addition, identify those hatchery programs propagating steelhead in the Puget Sound area that are part of the defined ESU.
2. Describe the level of extinction risk of the Puget Sound Steelhead ESU throughout all or a significant portion of its range. Describe the ESU's status with reference to its abundance, productivity, spatial structure, and diversity. In assessing the level of extinction risk faced by the ESU, include in your consideration, to the extent possible, the contribution of within-ESU resident rainbow trout populations and hatchery programs to the viability of the ESU.

After consideration of all the available scientific data, the BRT concluded the current configuration of the Puget Sound ESU is adequate and does not merit redelineation. The BRT concluded it was not possible at present to fully evaluate the contributions resident fish make to ESU viability. Nevertheless, based on the information available, a majority of BRT members concluded resident *O. mykiss*, in general, constitute a minor component of the Puget Sound ESU, and the contribution of resident fish to overall abundance and productivity of the ESU is likely to be small, due to relatively low numbers of resident fish and lack of evidence for resident populations that are demographically independent from anadromous populations in the same watersheds.

The BRT members believed the persistence of resident fish in the ESU below long-standing barriers is likely to reduce imminent risk of extinction, but that anadromy is necessary for the long-term persistence of the ESU. The presence of resident fish is likely to reduce long-term extinction risk only when this form maintains the ability to express the natural range of life history variation in this species, including anadromy. Even though resident populations might persist if anadromous fish are lost from a population, the contribution of resident populations depends on whether the genetic basis of anadromy is maintained in the resident form. This is not yet known for any Puget Sound *O. mykiss* population.

In its review of Puget Sound artificial propagation programs, the BRT identified only two hatchery stocks that genetically represent native local populations (Hamma Hamma and Green rivers natural winter run). The remaining programs, which account for the vast majority of production, either are out-of-ESU-derived stocks or were within-ESU stocks that were substantially diverged from local populations. Intentional and inadvertent selection on life history in winter run steelhead has resulted in a domesticated strain with a highly modified average run and spawn timing. Such changes were generally considered by the BRT to have a detrimental effect on fitness in the wild. The BRT was also concerned that WDFW's focus on primarily collecting abundance information after the March 15 date WDFW uses to delineate hatchery and native winter run spawning does not appear to always provide an accurate estimate of the contribution of hatchery origin fish to natural production and could bias productivity estimates.

The BRT considered the major risk factors facing Puget Sound steelhead to be widespread declines in abundance and productivity for most natural steelhead populations in the ESU, including those in Skagit and Snohomish rivers, previously considered strongholds for steelhead in the ESU; the low abundance of several summer run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Continued releases of out-of-ESU hatchery fish from Skamania-derived summer run and Chambers Creek-derived winter run stocks were a major concern for diversity in the ESU.

The BRT observed most of the other populations in the ESU are small, especially those in Hood Canal and the Strait of Juan de Fuca. Declining trends in abundance have occurred despite widespread reductions in direct harvest of natural steelhead in this ESU since the mid-1990s. Natural run sizes (sum of harvest and escapement) for most populations show even more marked declining trends than indicated by escapements, indicating the substantially reduced harvest rates for natural fish since the early 1990s have not resulted in a rebound in steelhead production in Puget Sound. For many of the Puget Sound populations, the decline in adult recruits per spawner has been precipitous. In addition, the BRT was concerned about the status of the summer run populations of steelhead in the ESU. Populations of summer run steelhead occur throughout the Puget Sound ESU but are concentrated in the northern Puget Sound area, are generally small, and are characterized as isolated populations adapted to streams with distinct attributes.

Habitat utilization by steelhead has been most affected by reductions in habitat quality and by fragmentation. A number of large dams in Puget Sound basins have affected steelhead. In addition to eliminating accessibility to habitat, dams affect habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and the movement of large woody debris. Many of the lower reaches of rivers and their tributaries in Puget Sound have been dramatically altered by urban development. Urbanization and suburbanization have resulted in the loss of historical land cover in exchange for large areas of imperious surface (buildings, roads, parking lots, etc.).

The loss of wetland and riparian habitat has dramatically changed the hydrology of many urban streams, with increases in flood frequency and peak flow during storm events and decreases in groundwater-driven summer flows. Flood events result in gravel scour, bank erosion, and sediment deposition. Land development for agricultural purposes has also altered the historical land cover; however, because much of this development took place in river floodplains, there has been a direct impact on river morphology. River braiding and sinuosity have been reduced through the construction of dikes, hardening of banks with riprap, and channelizing the main stem. Constriction of rivers, especially during high flow events, increases likelihood of gravel scour and dislocation of rearing juveniles.

A majority of BRT members concluded the ESU is likely to be at elevated risk due to reduced complexity of spatial structure of its steelhead populations and, consequently, diminishing connectivity among them. Several members felt the declines in natural abundance for most populations, coupled with large numbers of anthropogenic barriers such as impassable culverts, sharply reduce opportunities for natural adfluvial movement and migration between steelhead aggregations in different watersheds. Although most BRT members believed resident *O. mykiss* below migration barriers in watersheds throughout the ESU may provide short-term buffers against demographic stochasticity in many of these populations, resident *O. mykiss* were considered to be a relatively minor component of these anadromous populations based on field surveys of juvenile fish in freshwater.

Reduced harvest levels and recent changes in management of natural steelhead, the recent onset of recovery efforts in Puget Sound and Hood Canal for Chinook salmon (*O. tshawytscha*) and summer run chum salmon (*O. keta*) prompted by the listing of those ESUs, and reduced off-site plantings of hatchery steelhead were all considered as recent actions that could positively affect Puget Sound steelhead. However, the continued releases of out-of-ESU hatchery summer run and winter run steelhead throughout the region, reductions in steelhead escapement goals to help support harvest opportunities in several systems, evidence for diminishing marine survival rates, a recent increase in the Pacific Decadal Oscillation Index reflecting a general change in climate in the region toward warmer and drier conditions, increases in pinniped populations in Puget Sound, degradation of water quality in Hood Canal and southern Puget Sound, and continued land development and urbanization with associated impacts on freshwater habitat are all likely to increase risk to this ESU.

After considering all these factors, the BRT concluded steelhead in the Puget Sound ESU are likely to become at risk of extinction throughout all or a significant portion of their range in the foreseeable future, but are not currently in danger of extinction. This conclusion reflected the collective scientific opinion of an overwhelming majority of the BRT members.

Acknowledgments

The status review for Puget Sound steelhead was conducted by a team of 13 scientists from the Northwest Fisheries Science Center (NWFSC), Southwest Fisheries Science Center, U.S. Fish and Wildlife Service, U.S. Forest Service, and U.S. Geological Survey. This biological review team relied on comments and informational reports submitted by the public and by state, tribal, and federal agencies. The authors acknowledge the efforts of all who contributed to this record, especially staff from the Washington Department of Fish and Wildlife (WDFW), Northwest Indian Fisheries Commission (NWIFC), Western Washington Treaty Indian Tribes, Washington Trout (WT), and the Wild Salmon Center (WSC).

Numerous individual fishery scientists and managers provided information that aided in preparation of this document and deserve special thanks. We particularly wish to thank Bob Gibbons and Bob Leland of WDFW, Bill McMillan and Nick Gayeski of WT, Bob Hayman of the Skagit River System Cooperative, Will Beattie of NWIFC, and John McMillan of WSC for updated information, data, opinions, and advice. We are grateful to Paul McElhany of NWFSC for his review of the risk analyses. We also wish to thank four anonymous scientists whose peer review of this document provided added clarity.

Abbreviations and Acronyms

BRT	Biological Review Team
CCWS	Chambers Creek winter run steelhead
DPS	distinct population segment
ESA	Endangered Species Act of 1973
ESU	evolutionarily significant unit
FEMAT	Forest Ecosystem Management Assessment Team
FSH	fall run steelhead
HSRG	Hatchery Scientific Review Group
ISAB	Independent Scientific Advisory Board
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
ONRC	Oregon Natural Resources Council
PDO	Pacific Decadal Oscillation
PVA	population viability analysis
R/S	recruits per spawner
RKM	river kilometer
RM	river mile
RSRP	Recovery Science Review Panel
SAR	smolt-to-adult return
SaSI	Salmonid Stock Inventory
SASSI	Salmon and Steelhead Stock Inventory
SSH	summer run steelhead
SSHAG	Salmon Steelhead Hatchery Assessment Group
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population
WDF	Washington Department of Fisheries
WDFG	Washington Department of Fisheries and Game
WDFW	Washington Department of Fish and Wildlife
WDG	Washington Department of Game
WSC	Wild Salmon Center
WSH	winter run steelhead
WT	Washington Trout (renamed Wild Fish Conservancy in 2007)

Introduction

The U.S. Endangered Species Act (ESA) of 1973 is intended to conserve threatened and endangered species in their native habitats. The ESA defines a "species" to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." According to National Marine Fisheries Service (NMFS) policy (56 FR 58612), a salmon population or group of populations is considered a "distinct population segment" and hence a "species" under the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component of the evolutionary legacy of the species.

The term evolutionary legacy is used in the sense of inheritance, that is, something received from the past and carried forward into the future. The evolutionary legacy of a species is the genetic variability that is a product of past evolutionary events and represents the reservoir upon which future evolutionary potential depends. Conservation of these genetic resources should help to ensure the dynamic process of evolution will not be unduly constrained in the future.

The NMFS policy identifies a number of types of evidence that should be considered in species determination. For each of the two criteria (reproductive isolation and evolutionary legacy), the NMFS policy advocates a holistic approach that considers all types of available information as well as their strengths and limitations. Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue in different population units. Important types of information to consider include natural rates of straying and recolonization, evaluations of the efficacy of natural barriers, and measurements of genetic differences between populations. Data from protein electrophoresis or DNA analyses can be particularly useful for this criterion because they reflect levels of gene flow that have occurred over evolutionary time scales.

The key question with respect to the second criterion is, if the population became extinct, would this represent a significant loss to the ecological or genetic diversity of the species? Again, a variety of types of information should be considered. Phenotypic and life history traits such as size, fecundity, migration patterns, and age and time of spawning may reflect local adaptations of evolutionary importance, but interpretation of these traits is complicated by their sensitivity to environmental conditions. Data from protein electrophoresis or DNA analyses provide valuable insight into the process of genetic differentiation among populations but offer little direct information regarding the extent of adaptive genetic differences. Habitat differences suggest the possibility for local adaptations but do not prove such adaptations exist.

The identification of an ESU is a prerequisite to evaluation of the risk of extinction for that ESU. The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by an ESU. Important considerations include 1) absolute numbers of fish and their spatial and temporal distribution, 2) current abundance in relation to historical abundance and carrying capacity of the habitat, 3) trends in abundance based on indices such as dam or redd counts or on estimates of recruit-to-spawner ratios, 4) natural and human influenced factors that cause variability in survival and abundance, 5) possible threats to genetic integrity (e.g., selective fisheries and interactions between hatchery and natural fish), and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the ESU.

Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations. The BRT used a risk matrix method to quantify risks in different categories within each ESU. This method is a modification of the risk assessment used in the original Busby et al. (1996) coast wide steelhead (anadromous *Oncorhynchus mykiss*) status review, but is designed to reflect the four major population viability criteria identified in the NMFS viable salmonid populations (VSPs) document (McElhany et al. 2000): abundance, growth rate/productivity, spatial structure, and diversity. These criteria are being used as a framework for ESA recovery planning for salmon and steelhead. Tabulating mean risk scores for each element allowed the BRT to identify the most important concerns for each ESU and to compare relative risk across ESUs and species. The BRT considered these data and other information in making its overall risk assessments. The BRT had access to NMFS final policy on how to consider hatchery fish in ESA viability assessments (NMFS 2005). Following this policy, the BRT explicitly considered both the negative and positive effects of existing hatchery programs on the overall viability of the ESU.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status after taking into consideration conservation measures that are proposed or are in place. In this review, we do not evaluate likely or possible effects of conservation measures. Therefore, we do not make recommendations as to whether identified ESUs should be listed as threatened or endangered species, because that determination requires evaluation of factors not considered by us. Rather, we have drawn scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue (recognizing, of course, that natural demographic and environmental variability is an inherent feature of "present conditions"). Conservation measures will be taken into account by the NMFS Northwest Regional Office in making its listing recommendations.

If it is determined that a listing or listings is warranted, NMFS is required by law (1973 ESA Sec. 4(a)(1)) to identify one or more of the following factors responsible for the species' threatened or endangered status: 1) destruction or modification of habitat, 2) over utilization by humans, 3) disease or predation, 4) inadequacy of existing regulatory mechanisms, or 5) other natural or human factors. This status review does not formally address factors for decline, except insofar as they provide information about the degree of risk faced by the species in the future.

Puget Sound Steelhead

Previous Determinations

NMFS received two petitions to list populations of steelhead in the Puget Sound region as threatened or endangered species under the ESA. The ESA stipulates that, if a petition is found to present substantial information that a listing may be warranted, NMFS must conduct a status review and issue a determination on its findings within one year. Washington Trout (WT, renamed Wild Fish Conservancy in 2007) (1993) petitioned NMFS on 21 September 1993 for ESA listing of Washington's Deer Creek summer run steelhead. NMFS determined Deer Creek summer run steelhead did not, itself, constitute an ESU (NMFS 1994). On 16 February 1994 the Oregon Natural Resources Council (ONRC) and 15 co-petitioners asked NMFS to list all steelhead in Washington (including Puget Sound), Idaho, Oregon, and California as threatened or endangered under the ESA (ONRC et al. 1994). The petitioners identified 178 stocks of steelhead of special concern and included information on stock origin, stock status, and factors affecting their abundance.

In 1994 NMFS convened a BRT to determine if the 178 stocks of steelhead listed in the ONRC et al. petition constituted one or more distinct species as defined by the ESA. Based on an analysis of environmental characteristics (geologic, geographic, and ecological) and steelhead biological characteristics (genetic, life history, and morphometric), the BRT identified 15 ESUs for steelhead in Washington, Idaho, Oregon, and California (Busby et al. 1996). A Puget Sound ESU was identified that included steelhead spawning in rivers from the Elwha River to the Nooksack River (Figure 1). The Puget Sound Steelhead ESU was characterized by Busby et al. (1996) as follows:

> Puget Sound—This coastal steelhead ESU occupies river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington. Included are river basins as far west as the Elwha River and as far north as the Nooksack River.
>
> No recent genetic comparisons have been made of steelhead populations from Washington and British Columbia, but samples from the Nooksack River differ from other Puget Sound populations, and this may reflect a genetic transition zone or discontinuity in northern Puget Sound. In life history traits, there appears to be a sharp transition between steelhead populations from Washington, which smolt primarily at age 2, and those in British Columbia, which most commonly smolt at age 3. This pattern holds for comparisons across the Strait of Juan de Fuca as well as for comparisons of Puget Sound and Strait of Georgia populations. At the present time, therefore, evidence suggests the northern boundary for this ESU coincides approximately with the U.S.-Canada border.

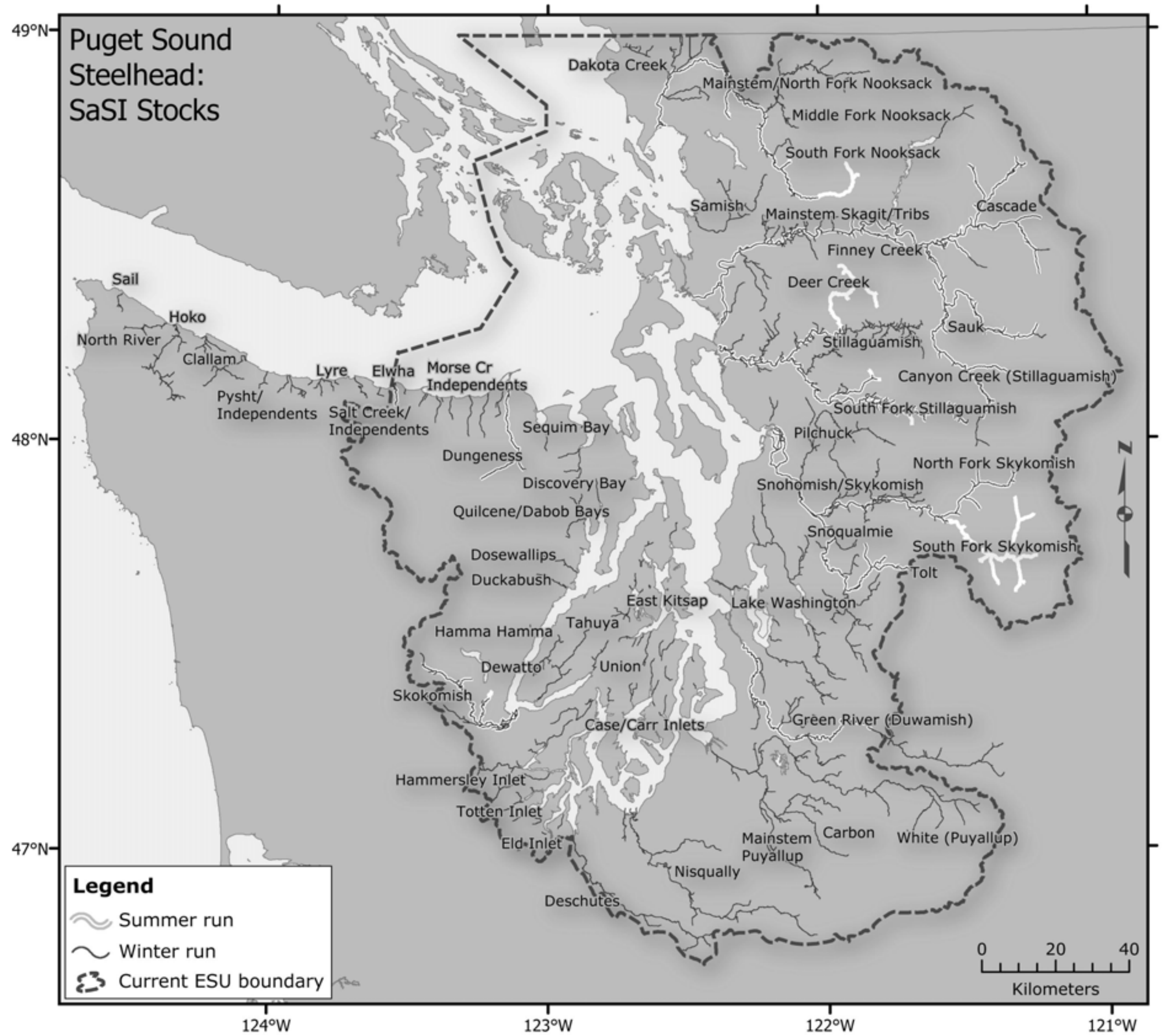

Figure 1. Map of the Puget Sound steelhead ESU, denoting the major summer and winter run populations identified by SaSI (2002). Map by Jeremy Davies, NWFSC.

Recent genetic data provided by the Washington Department of Fish and Wildlife (WDFW) show samples from the Puget Sound area generally form a coherent group, distinct from populations elsewhere in Washington. There is also evidence for some genetic differentiation between populations from northern and southern Puget Sound, but the BRT did not consider that ecological or life history differences were sufficient to warrant subdividing this ESU. Chromosomal studies show that steelhead from the Puget Sound area have a distinctive karyotype not found in other regions.

The Puget Sound region is in the rain shadow of the Olympic Mountains and, therefore, is drier than the Olympic Peninsula; most of the Puget Sound region averages less than 160 cm of precipitation annually, while most areas of the Olympic Peninsula exceed 240 cm (Jackson 1993). Climate and river hydrology change west of the Elwha River (see Weitkamp et al. 1995). The rivers in Puget Sound generally have high relief in the headwaters and extensive alluvial floodplains in the lowlands. Geology and topography are dominated by the effects of the Cordilleran Ice Sheet as evidenced by glacial deposits and the regional geomorphology.

Puget Sound's fjord-like structure may affect steelhead migration patterns; for example, some populations of coho (*O. kisutch*) and Chinook salmon (*O. tshawytscha*), at least historically, remained within Puget Sound and did not migrate to the Pacific Ocean itself (Wright 1968, Williams et al. 1975, Healey 1980). Even when Puget Sound steelhead migrate to the high seas, they may spend considerable time as juveniles or adults in the protected marine environment of Puget Sound, a feature not readily accessible to steelhead from other ESUs.

Most of the life history information for this ESU is from winter run fish. Apart from the difference with Canadian populations noted above, life history attributes of steelhead within this ESU (migration and spawn timing, smolt age, ocean age, and total age at first spawning) appear to be similar to those of other West Coast steelhead. Ocean age for Puget Sound summer steelhead varies among populations; for example, summer steelhead in Deer Creek (North Fork Stillaguamish River basin) are predominately age-1-ocean, while those in the Tolt River (Snoqualmie River basin) are most commonly age-3-ocean (Washington Department of Fisheries [WDF] et al. 1993).

The Puget Sound ESU includes two stocks that have attracted considerable public attention recently: Deer Creek summer steelhead (North Fork Stillaguamish River Basin) and Lake Washington winter steelhead. Deer Creek summer steelhead were petitioned for listing under the ESA (Washington Trout 1993), but NMFS determined that this population did not by itself represent an ESU (NMFS 1994). Adult Lake Washington winter steelhead have experienced a high rate of predation by California sea lions (*Zalophus californianus*) below the fish ladder at Hiram M. Chittenden Locks (also known as the Ballard Locks), the artificial outlet of Lake Washington. Deer Creek summer steelhead and Lake Washington winter steelhead were 2 of the 178 stocks identified in the West Coast steelhead petition (ONRC et al. 1994).

This ESU is primarily composed of winter steelhead but includes several stocks of summer steelhead, usually in subbasins of large river systems and above seasonal hydrologic barriers. Rainbow trout (nonanadromous, or resident *O. mykiss*) co-occur with the anadromous form in the Puget Sound region; however, the relationship between these forms in this geographic area is unclear.

The West Coast Steelhead BRT, having defined the Puget Sound ESU, considered a variety of information in determining the risk of extinction for this ESU. Their conclusion that the ESU was not presently at risk was based on the following considerations (from Busby et al. 1996):

The BRT concluded the Puget Sound Steelhead ESU is neither presently in danger of extinction nor likely to become endangered in the foreseeable future. Despite this conclusion, the BRT has several concerns about the overall health of this ESU and about the status of certain stocks within the ESU. Recent trends in stock abundance are predominantly downward, although this may be largely due to recent climate conditions. Trends in the two largest stocks (Skagit and Snohomish rivers), however, have been upward.

The majority of steelhead produced within the Puget Sound region appears to be of hatchery origin, but most hatchery fish are harvested, and estimates of hatchery fish escaping to spawn naturally are all less than 15% of total natural escapement, except for the Tahuya and Morse Creek/Independents stocks where the hatchery proportion is approximately 50%. We are particularly concerned that the majority of hatchery production originates from a single stock, Chambers Creek. This could increase genetic homogenization of the resource despite management efforts to minimize introgression of the hatchery gene pool into natural populations via separation of hatchery and natural run timing and high harvest rates focused on hatchery runs.

The status of certain stocks within the ESU is also of concern, especially the depressed status of most stocks in the Hood Canal area and the steep declines of Lake Washington winter steelhead and Deer Creek summer steelhead.

These conclusions are tempered by two substantial uncertainties. First, there is very little information regarding the abundance and status of summer steelhead in the Puget Sound region. Although the numbers of summer steelhead have historically been small relative to winter steelhead, they represent a substantially different life history strategy and loss of these fish would diminish the ecological and genetic diversity of the entire ESU. Second, there is uncertainty regarding the degree of interaction between hatchery and natural stocks. Although WDFW's conclusion that there is little overlap in spawning between natural and hatchery stocks of winter steelhead throughout the ESU is generally supported by available evidence, for many basins it is based largely on models and assumptions regarding run timing rather than empirical data.

On 9 August 1996 NMFS proposed that 10 of the 15 West Coast steelhead ESUs identified be listed under the ESA. NMFS determined listing was not warranted for four of the remaining five ESUs (Puget Sound, Olympic Peninsula, Southwest Washington, and the Upper Willamette River), while a fifth ESU (Middle Columbia River) was designated as a candidate species (61 FR 41451). On 18 August 1997 two steelhead ESUs (Southern California and Upper Columbia River) were listed by NMFS as endangered and three steelhead ESUs (Central California Coast, South Central California Coast, and Snake River) were listed as threatened under the ESA (62 FR 43937). NMFS listed the Lower Columbia River and Central Valley steelhead ESUs as threatened on 19 March 1998 (63 FR 1347). NMFS listed the Middle Columbia steelhead ESU and Upper Willamette River steelhead ESU as threatened under the ESA on 25 March 1998 (64 FR14517). The Northern California steelhead ESU was listed as threatened on 7 June 2000 (66 FR 17845).

Current Petition to List Puget Sound Steelhead

On 13 September 2004 NMFS received a petition submitted by Sam Wright (Wright 2004) to list Puget Sound steelhead as endangered or threatened. The petition describes several factors that justify a reexamination of the extinction risk for the Puget Sound Steelhead ESU. These factors include declines in steelhead abundances such that "not a single entire river basin, large or small … had a significant upward short-term trend," and that these declines have occurred under a harvest regime that prohibits the retention of wild (unmarked) adults by recreational anglers. The petition disputed the assertion by WDFW that winter run steelhead hatchery stocks (predominately Chambers Creek Hatchery) were substantially spatially separated from natural winter run steelhead populations and cited studies of hatchery-wild steelhead interactions that substantiate the deleterious impact of hatchery fish on natural reproduction and sustainability. The conclusion of the petitioner was that these factors justify a determination that Puget Sound steelhead are in danger of extinction throughout all or a significant portion of its range or are likely to become so in the foreseeable future.

ESU Determination

The petitioner provided a synopsis of the Puget Sound Steelhead ESU definition (Wright 2004) and found no compelling recent information that would justify a reexamination of the ESU boundary identified in Busby et al. (1996).

Artificial Propagation

Two hatchery stocks constitute the majority of steelhead hatchery production in Puget Sound: Chambers Creek winter run steelhead and Skamania Hatchery summer run steelhead. The petitioner asserts hatchery production has increased since the time of the last status review and this increase only heightens the risks of hybridization between domesticated hatchery fish and natural fish. Furthermore, the petition references a study by Washington Trout that reports hatchery and natural origin steelhead are not temporally reproductively isolated, but instead interbreed in areas where they co-occur. Additionally, increased artificial propagation increases the potential for competition between hatchery origin and natural origin juveniles, as well as predation on emergent and juvenile natural steelhead by residualized hatchery steelhead.

Viability Analysis

The petitioner provided a review of Puget Sound steelhead viability using the VSP criteria described in McElhany et al. (2000). The VSP criteria have provided the basis for risk assessments in recent status review updates.

Abundance

In the 10 years since the previous status review by Busby et al. (1996), the abundance of naturally produced steelhead in Puget Sound has decreased at a steady pace. The petition provides recent abundance estimates for those steelhead populations that have been monitored. The petition asserts steelhead within four geographic regions within Puget Sound—Juan de Fuca Strait, Bellingham Bay, Hood Canal, South Puget Sound—are all approaching functional extinction (i.e., approaching an abundance level at which intrinsic biological factors cannot prevent future extinction, even if external threats are removed). In particular, absolute abundances have fallen to levels where density depensation effects are likely and most populations are at risk of extirpation by adverse environmental conditions. The Skagit River was the one basin identified as containing steelhead populations large enough to resist adverse environmental or depensatory forces.

Productivity

Based on the abundance information provided, the petitioner asserts every basin showed either a significant short- or long-term downward trend. This assertion contrasts with the earlier assessment of Busby et al. (1996), who reported basin-wide trends for Puget Sound that were negative on a short-term basis or were not significantly different from zero. The petition underscored the fact that this decline in productivity has occurred at a time when fishery impacts on naturally produced steelhead presumably declined substantially with the advent of hatchery-only retention in the sports fishery and curtailment of most tribal fisheries.

Diversity

The petitioner reiterated several risk factors identified in Busby et al. (1996). The extensive use of Chambers Creek Hatchery winter run steelhead and Skamania Hatchery summer run steelhead throughout the ESU were considered substantial risks to ESU diversity, especially in light of the new information that suggests introgression by the Chambers Creek stock into natural populations. Interspecies hybridization between *O. mykiss* and cutthroat trout (*O. clarkii*) is also discussed as a threat to the genetic diversity of the ESU. Studies by Marshall et al. (2004) and Ostberg and Rodriquez (2002) were cited as evidence of widespread hybridization between these two species. However, it is unclear whether this latter hybridization is due to anthropogenic factors or a natural evolutionary process.

Spatial structure/connectivity

The petitioner argued there has been an overall degradation in the spatial structure characteristics of Puget Sound steelhead. In part, this degradation has been due to the loss of connectivity between populations with the decline in abundance for most populations. The petition specifically identifies the loss of connectivity between the Duwamish (Green) and Snohomish rivers due to the near extirpation of steelhead in the Lake Washington and Lake Sammamish watersheds.

Review of Steelhead Life History Information

General Life History

Of all the Pacific salmonids, *O. mykiss* probably exhibits the greatest diversity in life history throughout its native, geographic range from Kamchatka, Russia, to southern California. However, even within the confines of Puget Sound and the Strait of Georgia there is considerable life history variation compared with other salmonid species. Rainbow trout complete their life cycle completely in freshwater. Steelhead reside in freshwater for their first 1 to 3 years before emigrating to the ocean for 1 to 3 years. Unlike other species of Pacific salmon, *O. mykiss* is iteroparous, capable of repeat spawning. Averaged across all West Coast steelhead populations, 8% of spawning adults have spawned previously, with coastal populations having a higher incidence of repeat spawning relative to inland populations (Busby et al. 1996).

There are two major life history types expressed by steelhead, related to the degree of sexual development at the time of adult freshwater entry (Smith 1969, Burgner at al. 1992). Stream-maturing steelhead, also called summer run steelhead, enter fresh water at an early stage of maturation, usually from May to October. These summer run steelhead migrate to headwater areas and hold for several months prior to spawning in the spring. Ocean-maturing steelhead, also called winter run steelhead, enter fresh water from November to April at an advanced stage of maturation, spawning from March through June. While there is some temporal overlap in spawn timing between these forms in basins where both winter and summer run steelhead are present, summer run steelhead spawn farther upstream, usually above a partially impassable barrier (Behnke 1992, Busby 1996).

In many cases it appears the summer migration timing evolved to access areas above a series of falls or cascades that presents a velocity barrier to migration during high winter flow months (especially in rain and snow driven basins), but are passable during low summer flows. The winter run of steelhead is the predominant run in Puget Sound, in part because there are relatively few basins in the Puget Sound ESU with the geomorphological and hydrological characteristics necessary to establish the summer run life history. The summer run steelhead's extended freshwater residence prior to spawning results in higher prespawning mortality levels relative to winter run steelhead. This survival disadvantage may explain why winter run steelhead predominate where no migrational barriers are present[1] or freshwater migration distances to salt water are less than 200 km.

Puget Sound Steelhead Life History

There are a number of early descriptions of steelhead in Puget Sound, although inconsistencies in the early classification of salmonids resulted in steelhead apparently being listed under multiple scientific names. Suckley (1858) described the square-tailed salmon, *Salmo*

[1] D. Rawding, WDFW, Vancouver, WA. Pers. commun., 12 April 2005.

truncatus, from fish captured in the Strait of Juan de Fuca in January and February 1857. Suckley noted this species is very similar to *Salmo gairdneri*. It was reported to enter Puget Sound from the middle of autumn and into December. River entry apparently occurred through December and January; these fish were also reported in the Hood Canal in January.

The fish was known to the Klallam Tribe as "klutchin" and to the Nisqually Tribe as "Skwowl." Suckley (1858) also reported this fish did not enter freshwater in large schools as did other salmon, but that the run was more drawn out. In contrast, Suckley (1858) described another square-tailed salmon, *S. gairdneri*, captured in the Green River but which had a later run timing. The fish, known to the Skagits as "yoo-mitch," entered freshwater from mid-June to August, a run timing that corresponds to existing summer run steelhead.

In 1900 a study by the Smithsonian Institution reported steelhead begin to return to fresh water as early as November, but that the principal river fisheries occurred in January, February, and March, when "the fish are in excellent condition" (Rathbun 1900). The average weight for returning steelhead was 3.6 to 6.8 kg (8 to 15 lb), although fish weighing 11.4 kg (25 lb) or more were reported. The principal fisheries were in the Skagit River basin, although in "nearly all other rivers of any size the species seems to be taken in greater or less quantities" (Rathbun 1900). The spawning season of (winter run) steelhead was described as occurring in the early spring, but possibly beginning in the latter part of winter. The predominant run timing in Puget Sound appears to have been the winter run. Information on summer run steelhead in Puget Sound is very limited. In fact, in its 1898 report, the Washington State Fish Commission concluded the Columbia River was "the only stream in the world to contain two distinct varieties of Steel-heads" (Little 1898). Little (1898) did indicate, however, the winter run of steelhead continued until the first of May and overlapping populations of winter run and summer run steelhead may have been considered a single run. Evermann and Meek (1898) reported B. A. Alexander examined a number of steelhead caught near Seattle in January 1897, and that the fish were in various stages of maturation: "a few fish were spent, but the majority were well advanced and would have spawned in a short time."

Much of the early life history information comes from the collection and spawning of steelhead intercepted at hatchery weirs. The U.S. Fish Commission Hatchery at Baker Lake collected steelhead returning to Baker Lake using gillnets. Fish were collected from 9 March to 8 May, few survived to spawn, and no spawning date was given (USBF 1900). Steelhead were spawned at the Quilcene National Fish Hatchery (NFH) in Hood Canal from 27 February to 7 June 1922 (USBF 1923). Pautske and Meigs (1941) indicated the steelhead run arrived in two phases: "In the early run the fish are small, averaging 8 or 9 pounds. The later run is composed of fish as large as 16 or 18 pounds." It was unclear whether these phases were distinct runs or different segments of the same run.

Winter Run Steelhead

In general winter run, or ocean maturing, steelhead return as adults to the tributaries of Puget Sound from December to April (WDF et al. 1973). Spawning occurs from January to mid-June, with peak spawning occurring from mid-April through May (Table 1). Prior to spawning, maturing adults hold in pools or in side channels to avoid high winter flows.

Steelhead tend to spawn in moderate to high gradient sections of streams. In contrast to semelparous Pacific salmon, steelhead females do not guard their redds, or nests, but return to the ocean following spawning (Burgner et al. 1992). Spawned out females that return to the sea are referred to as "kelts."

Summer Run Steelhead

The life history of summer run steelhead is highly adapted to specific environmental conditions. Because these conditions are not common in Puget Sound, the relative incidence and size of summer run steelhead populations is substantially less than that for winter run steelhead. Summer run steelhead also have not been widely monitored, in part, because of their small population size and the difficulties in monitoring fish in their headwater holding areas. Sufficient information exists for only 4 of the 16 Puget Sound summer run steelhead populations identified in the 2002 Salmonid Stock Inventory (SaSI) to determine the population status (WDFW 2002).

Juvenile Life History

The majority of steelhead juveniles reside in fresh water for 2 years prior to emigrating to marine habitats (Tables 2-4), with limited numbers emigrating as 1- or 3-year-old smolts. Smoltification and seaward migration occur principally from April to mid-May (WDF et al. 1972). Two-year-old naturally produced smolts are usually 140–160 mm in length (Wydoski and Whitney 1979, Burgner et al. 1992). The inshore migration pattern of steelhead in Puget Sound is not well understood; it is generally thought that steelhead smolts move quickly offshore (Hartt and Dell 1986).

Ocean Migration

Steelhead oceanic migration patterns are poorly understood. Evidence from tagging and genetic studies indicates Puget Sound steelhead travel to the central North Pacific Ocean (French et al. 1975, Hartt and Dell 1986, Burgner et al. 1992). Puget Sound steelhead feed in the ocean for 1 to 3 years before returning to their natal stream to spawn. Typically, Puget Sound steelhead spend 2 years in the ocean although, notably, Deer Creek summer run steelhead spend only a single year in the ocean before spawning (Tables 3 and 4).[2]

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[2] Steelhead are typically aged from scales or otoliths based on the number of years spent in freshwater and salt water. For example, a 2/2 aged steelhead spent 2 years in fresh water prior to emigrating to the ocean where, after 2 years in the ocean, the fish returned to spawn.

Table 1. Timing of freshwater entry (shaded months) and spawning (letters) for native populations of steelhead in Puget Sound and the eastern Strait of Juan de Fuca. SSH denotes summer run and WSH winter run steelhead. P indicates month of peak spawning, and s indicates months when nonpeak spawning occurs. (Source: WDFW et al. 2002.)

Population	Run	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July
Nooksack River	WSH											s	s	s	P	s	
Samish River	WSH											s	s	P	s	s	
Skagit River	WSH												s	s	P	s	
Sauk River	SSH													s	s		
Cascade River	SSH										s	s	s	s			
Stillaguamish River	WSH												s	s	P	s	
Deer Creek	SSH													s	s		
S. Fk. Stillaguamish	SSH										s	s	s	s			
Snohomish River	WSH												s	P	s	s	
N. Fk. Skykomish R.	SSH																
Lake Washington	WSH												s	P	s	s	
Green River	WSH												s	P	s	s	
Puyallup River	WSH												s	P	s	s	
Nisqually River	WSH												s	P	s	s	
Deschutes River	WSH										s	P	s	s			
S. Sound Inlets	WSH											s	P	P			
Tahuya River	WSH											s	s	P	s		
Skokomish River	WSH											s	s	P	s	s	
Dewatto River	WSH											s	s	P	s		
Discovery Bay	WSH											s	s	P	s	s	
Dungeness River	WSH												s	s	P	s	
Morse Creek	WSH											s	s	P	s	s	

Table 2. Freshwater age at migration to ocean. The frequency in boldface indicates the most common age. Populations in italics are representative of adjacent ESUs. (Source: Busby et al. 1996.)

Population	Run	1	2	3	4	Reference
Chilliwack River	*WSH*	0.02	**0.62**	0.36	<0.01	Maher and Larkin 1956
Skagit River	WSH	<0.01	**0.82**	0.18	<0.01	WDFW 1994b
Deer Creek	SSH	--	**0.95**	0.05	--	WDF et al. 1993
Snohomish River	WSH	0.01	**0.84**	0.15	<0.01	WDFW 1994b
Green River	WSH	016	**0.75**	0.09	--	Pautzke and Meigs 1941
Puyallup River	WSH	0.05	**0.89**	0.06	--	WDFW 1994b
Nisqually River	WSH	0.19	**0.80**	0.01	--	WDFW 1994b
Hoh River	*WSH*	0.03	**0.91**	0.06	--	Larson and Ward 1952

Table 3. Ocean age at first spawning. The frequency in boldface indicates the most common age. Populations in italics are representative of adjacent ESUs. (Source: Busby et al. 1996.)

Population	Run	0	1	2	3	4	Reference
Chilliwack River	*WSH*	--	<0.01	**0.50**	0.49	<0.01	Maher and Larkin 1955
Skagit River	WSH	--	--	**0.57**	0.42	0.01	WDFW 1994b
Deer Creek	SSH		**1.00**	**--**	--	--	WDF et al. 1993
Snohomish River	WSH	--	--	**0.57**	0.42	0.01	WDFW 1994b
Green River	WSH	0.02	0.07	**0.66**	0.25	--	Pautzke and Meigs 1941
Puyallup River	WSH	--	--	**0.70**	0.30	--	WDFW 1994b
Nisqually River	WSH	--	--	**0.63**	0.36	0.01	WDFW 1994b
Hoh River	*WSH*	--	0.02	**0.81**	0.17	--	Larson and Ward 1952

Table 4. Frequencies of life history patterns. Age structure indicates freshwater age/ocean age. Population in italics are representative of adjacent ESUs. (Source: Busby et al. 1996.)

Population	Run	Primary		Secondary		Reference
Chilliwack River	*WSH*	2/2	0.31	2/3	0.31	Maher and Larkin 1956
Skagit River	WSH	2/2	0.48	2/3	0.33	WDFW 1994b
Deer Creek	SSH	2/1	0.95	3/1	0.05	WDF et al. 1993
Snohomish River	WSH	2/2	0.47	2/3	0.36	WDFW 1994b
Green River	WSH	2/2	0.52	2/3	0.17	Pautzke and Meigs 1941
Puyallup River	WSH	2/2	0.61	2/3	0.28	WDFW 1994b
Nisqually River	WSH	2/2	0.51	2/3	0.28	WDFW 1994b
Hoh River	*WSH*	2/2	0.74	2/3	0.14	Larson and Ward 1952

Genetic Studies

Busby et al. (1996) presented the results from a number of genetic studies that described the population structure of steelhead throughout Washington and the Pacific Northwest. Collectively, these studies provided the genetic evidence for the establishment of the 16 steelhead ESUs that currently exist. The following summary will focus on those studies that are relevant to the delineation of the Puget Sound ESU.

Early work by Allendorf (1975) with protein electrophoresis identified two major *O. mykiss* lineages in Washington, the inland and coastal forms that are separated by the Cascade Crest. This pattern also exists to the north in British Columbia (Utter and Allendorf 1977, Okazaki 1984, Reisenbichler et al. 1992). Reisenbichler and Phelps (1989) analyzed genetic variation from 9 populations in Northwest Washington using 19 gene loci. Their analysis indicated there was relatively little between-basin genetic variability, which may have been due to the extensive introduction of hatchery steelhead throughout the area. Alternatively, Hatch (1990) suggested the level of variability detected by Reisenbichler and Phelps (1989) may be related more to the geographical proximity of the nine populations rather than the influence of hatchery fish.

The number and morphology of chromosomes in a fish offers an alternative indicator of differences in lineage. Analysis of chromosomal karyotypes from steelhead and rainbow trout by Thorgaard (1977, 1983) indicated fish from the Puget Sound and Strait of Georgia had a distinctive karyotype. In general, steelhead have 58 chromosomes; however, fish from Puget Sound had between 58 and 60 chromosomes. Further study by Ostberg and Thorgaard (1994) verified this pattern through more extensive testing of native origin populations.

Phelps et al. (1994) and Leider et al. (1995) reported results from an extensive survey of Washington state steelhead and rainbow trout populations. Populations from Puget Sound and the Strait of Juan de Fuca were grouped into three clusters of genetically similar populations: 1) Northern Puget Sound (including the Stillaguamish River and basins to the north, 2) south Puget Sound, and 3) the Olympic Peninsula (Leider et al. 1995). Additionally, populations in the Nooksack River basin and the Tahuya River (Hood Canal) were identified as outliers. Leider et al. (1995) also reported on the relationship between the life history forms of steelhead. They found a close genetic association between anadromous and resident fish in both the Cedar and Elwha rivers. Phelps et al. (1994) indicated there were substantial genetic similarities between hatchery populations that had exchanged substantial numbers of fish during hatchery operation. Within Puget Sound, hatchery populations of winter run steelhead in the Skykomish River, Chambers Creek, Tokul River, and Bogachiel River show a high degree of genetic similarity. There was also a close genetic association between natural and hatchery populations in the Green, Pilchuck, Raging, mainstem Skykomish, and Tolt rivers, suggesting a high level of genetic exchange. On the other hand, there were several distinct, naturally sustained steelhead populations in Puget Sound (Cedar River, Deer Creek, North Fork Skykomish, and North Fork Stillaguamish rivers) that appeared to have undergone minimal hatchery introgression.

ESU Determination

ESU Configuration

The BRT received no new information to consider in reevaluating the current geographic configuration of the Puget Sound Steelhead ESU. A recent publication by Beacham et al. (2004) included two Puget Sound steelhead populations in a population genetic analysis of British Columbia and Washington steelhead, but the BRT concluded these analyses provided no reason to change the ESU's current boundaries.

Resident and Anadromous Life Histories

Several studies (McCusker et al. 2000, Zimmerman and Reeves 2000, Docker and Heath 2003, Pearson et al. 2003) have shown native steelhead and rainbow trout within a drainage are closely related, and likely to interbreed at some level. In the period since Busby et al. (1996) last reviewed the status of Puget Sound steelhead, there has been considerable discussion regarding the inclusion of rainbow trout into ESUs that potentially contain both resident and anadromous life history forms. An important question has arisen from this discussion: If rainbow trout are included in an ESU, to what extent does their presence influence the overall viability of the ESU?

In the BRT's 2003 update of the status of listed ESUs of salmon and steelhead (Good et al. 2005), three different categories of interaction were identified that generally reflected the range of geographic relationships between resident and anadromous forms within different watersheds: 1) no obvious physical barriers, either currently or historically, to interbreeding between resident and anadromous forms; 2) long-standing natural barriers (e.g., a waterfall) separate resident and anadromous forms such that resident fish can pass downstream but anadromous fish cannot pass upstream; and 3) relatively recent (e.g., within last 100 years) human actions (e.g., construction of a dam without provision for upstream fish passage) separate resident and anadromous forms.

Where there was no obvious physical barrier to interbreeding between the two life history forms (Category 1), the BRT's default assumption was that rainbow trout and steelhead were part of the same ESU. This assumption was based on empirical studies that show resident and anadromous *O. mykiss* are typically very similar genetically when they co-occur with no physical barriers to migration or interbreeding. Additional information presented to the Puget Sound steelhead BRT during a 20 June 2005 technical meeting provided additional Puget Sound-specific information describing the interbreeding of rainbow trout and steelhead where no migrational barriers exist (Category 1). In particular, studies on the Cedar River in the Lake Washington watershed in Puget Sound (Marshall et al. 2004) and on the Quileute River on the Olympic Peninsula (J. McMillan presentation to the BRT, 20 June 2005) indicate rainbow trout produce outmigrating smolts in these systems.

The BRT agreed that, in the Puget Sound Steelhead ESU where resident and anadromous *O. mykiss* co-occur, there is likely interbreeding between the two life history forms. Some BRT members considered that, in some cases, rainbow trout were probably nonmigratory male progeny of steelhead parents rather than a separate breeding population. Several BRT members voiced their opinion that rainbow trout represented one of a number of life history forms or polymorphisms within a population, and that the relative expression of these life histories in a population was related to environmental variability and demographic conditions. In all of the scenarios described, there was concurrence among BRT members that rainbow trout had a close biological relationship to steelhead. The BRT therefore determined that all naturally produced *O. mykiss* below long-standing man-made or natural barriers, regardless of their life history, were part of the Puget Sound Steelhead ESU.

There was some additional discussion by the BRT regarding the status of rainbow trout above culverts. In general, and in view of widespread culvert failures or removals, it was determined the majority of culverts do not represent "long-standing" barriers. Culverts may present relatively ephemeral impediments to migration for days, months, or even years, but are unlikely to result in reproductive isolation on a time scale that would lead to substantial divergence of populations above and below them. Moreover, domesticated rainbow trout of hatchery origin are not typically stocked above culverts as a fishery management strategy, which is not the case for reservoirs upstream of dams (see Category 3, below). Therefore, the BRT concluded that *O. mykiss* above culverts are to be included in the ESU in the absence of specific contrary evidence.

Where rainbow trout exist above a long-standing natural barrier (e.g., Snoqualmie Falls) the BRT did not consider those fish to be part of the ESU (Category 2 fish in Good et al. 2005). These barriers result in nearly complete reproductive isolation, although there is some probability that upstream fish populations can move downstream past the barriers. Empirical studies (cited in Good et al. 2005) indicate in these cases the resident fish typically show substantial genetic and life history divergence from the nearest downstream anadromous populations.

In cases where the resident fish were separated from the anadromous form by relatively recent human actions (Category 3 fish), the 2003 BRT determined that there was insufficient information currently available to establish a default relationship between below barrier and above barrier *O. mykiss* populations. The two life history forms most likely existed without any barriers to interbreeding prior to the establishment of the man-made barrier(s); however, as a result of rapid divergence in a novel environment, or displacement by or introgression from nonnative hatchery rainbow trout, these resident populations may no longer represent the evolutionary legacy of the steelhead ESU (Good et al. 2005). These cases therefore need to be treated on a case-by-case basis.

Analysis of an Alaska population of steelhead isolated above a man-made barrier for nearly 20 generations suggests the ability to produce outmigrating smolts can be diminished, but not eliminated over that time frame (Thrower et al. 2004). Furthermore, preliminary results suggest in this system the marine survival of smolt progeny of rainbow trout parents is substantially less than that of smolt progeny of steelhead parents (Thrower and Joyce 2004, F. Thrower presentation to the BRT on 20 June 2005). It is unclear, however, whether or how rapidly (in generations) natural selection might restore anadromous competency to previously residualized fish.

The existence of resident rainbow trout populations above man-made barriers is a potentially important issue for management of the Puget Sound Steelhead ESU, given the planned restoration of fish passage in a number of Puget Sound basins through barrier removal or the establishment of trap and haul programs. The BRT discussed implications of the planned removal of the two Elwha River dams (Elwha and Glines Canyon), initiation of the trap and haul program at Howard Hanson Dam on the Green River, and proposed passage programs at other Puget Sound dams. Restoration activities need to consider the ESU membership of upstream resident populations. The BRT members felt that ESU membership cannot necessarily be determined a priori, but rather must be ascertained on a case-by-case basis. The BRT identified ongoing research programs to examine genetic and morphological similarities between steelhead populations above and below the barriers on the Elwha, Green, and Cedar rivers as examples of the types of efforts necessary to address the issue of ESU membership. Presently, there is insufficient information available to resolve this issue for any of the Category 3 populations in the Puget Sound ESU.

Artificial Propagation of Puget Sound Steelhead

State and federal hatcheries have attempted to propagate steelhead in Puget Sound since 1900. Hatchery rearing techniques developed during the first decades of operation were not well suited to steelhead, and were only moderately successful with Pacific salmon. In general during the early 1900s, most hatchery-produced steelhead in Puget Sound were reared for only a few days or weeks prior to release (Figure 2). It was not until the 1940s that extended rearing programs were developed for steelhead (Pautzke and Meigs 1940). Crawford (1979) observed that, prior to the work of Clarence Pautzke and Robert Meigs, steelhead runs in many streams were reduced by the hatcheries that were attempting to increase their numbers.

Busby et al. (1996) determined hatchery fish were widespread, spawn naturally throughout the Puget Sound region, and were largely derived from a single stock (Chambers Creek). The estimated proportion of spawning escapement comprised of hatchery fish ranged from less than 1% (Nisqually River, southern Puget Sound) to 51% (Morse Creek, along the Strait of Juan de Fuca). In general, hatchery proportions were higher in Hood Canal and the Strait of Juan de Fuca than in southern or northern Puget Sound. WDFW on its SaSI Web site has provided information supporting substantial temporal separation between hatchery and natural winter run steelhead in this region (see also Hatchery Scientific Review Group [HSRG] 2002, 2003, 2004). Given the lack of strong trends in abundance for the major stocks and the apparently limited contribution of hatchery fish to production of the winter run stocks (Phelps et al. 1979), Busby et al. (1996) determined hatchery production of winter run steelhead in Puget Sound contributes little or nothing to the viability of the naturally spawning steelhead populations.

Of the 30 steelhead programs reviewed by the HSRG Recommendations (2002, 2003, 2004), all but three utilized fish derived from either Chambers Creek winter run steelhead or Skamania summer run steelhead. The widespread use of these two stocks, accounting for

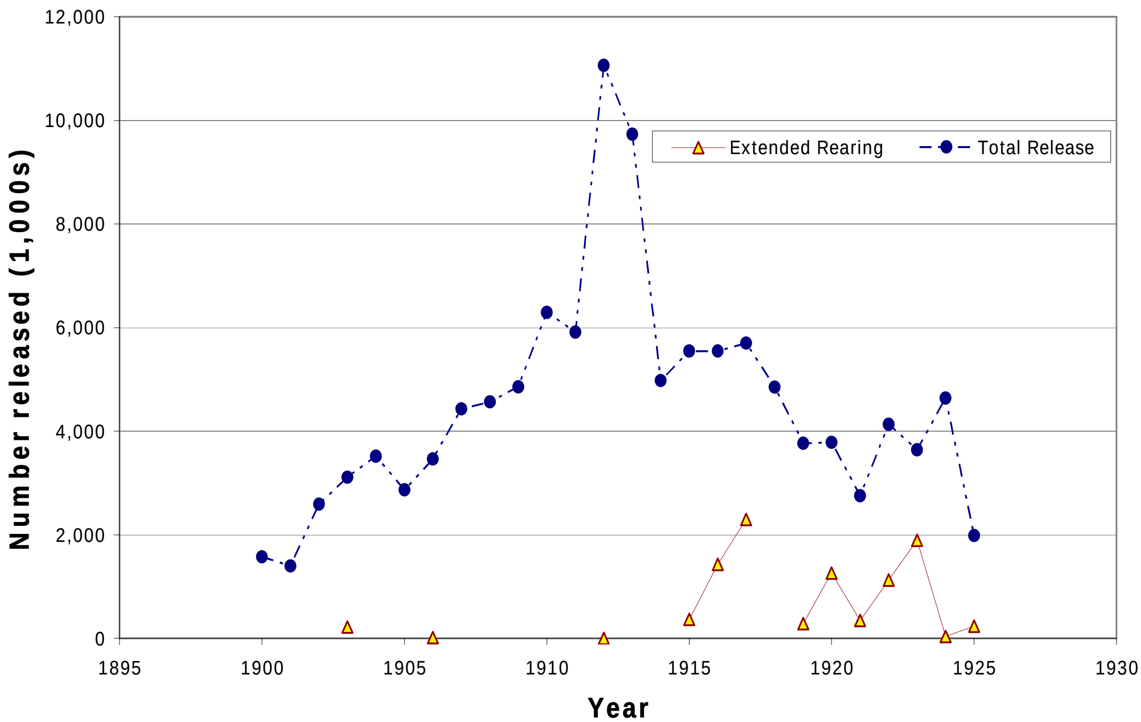


Figure 2. Releases of hatchery propagated steelhead (*O. mykiss*) from state and federal hatcheries in Puget Sound from 1900 to 1925. The ordinate axis is total number of fish. The duration of culture under extended rearing varied from hatchery to hatchery, but generally continued beyond 3 months postemergence and sometimes up to 1 year postemergence.

approximately 95% of steelhead hatchery production in the ESU, has raised concerns about their influence on the genetic diversity of the entire ESU.

The Chambers Creek winter run steelhead stock was founded in 1945 with the trapping of steelhead returning to Chambers Creek (Crawford 1979). Through the use of warmer well water at the South Tacoma Trout Hatchery, the maturation of adults was accelerated to provide an earlier and more uniform spawn timing. Subsequent egg incubation and rearing in warm water, in combination with the development of improved dry feeds, accelerated growth to produce a larger smolt, released at approximately 22.5 g (20 smolts/lb). Throughout the program the earliest maturing fish were selected, resulting in the advancement of average spawn timing from April to December and January. From Chambers Creek Hatchery, winter run steelhead were transferred to hatcheries throughout Puget Sound, the Washington Coast, and the lower Columbia River. While many of these “satellite” hatcheries may have subsequently incorporated local native winter run steelhead into their broodstock, genetic analysis by Phelps et al. (1997) indicated there is a high degree of similarity among these hatchery populations.

The Skamania Hatchery summer run steelhead stock was founded in the 1950s from wild fish collected in the Washougal and Klickitat rivers, and transferred to several other facilities where broodstocks are now collected (Howell et al. 1985, Hymer et al. 1992). As with the Chambers Creek winter run steelhead stock, continued use of the earliest spawning adults resulted in an advancement in spawn timing. In Puget Sound, Skamania Hatchery-origin summer run steelhead programs continue in the Stillaguamish, Snohomish, and Green River basins. Genetically, hatchery populations founded using Skamania Hatchery summer run steelhead and feral Skamania Hatchery fish are genetically distinct from Puget Sound populations (Busby et al. 1996, Phelps et al. 1997). Skamania summer run steelhead are also distinct from Puget Sound steelhead populations in that they possess 58 chromosomes, in contrast to the 60 chromosomes commonly found in Puget Sound *O. mykiss.*

New Information

In the nearly 10 years since steelhead artificial propagation programs in Puget Sound were reviewed by Busby et al. (1996) there have been a number of independent studies of these programs, most notably by the HSRG (2002, 2003, 2004). Information on steelhead artificial propagation was also submitted by WDFW and the Western Washington Treaty Tribes in preparation for the BRT review of the petition to list Puget Sound steelhead. This information included recent release levels for winter run (Figure 3) and summer run (Figure 4) steelhead in Puget Sound (see also Appendix D).

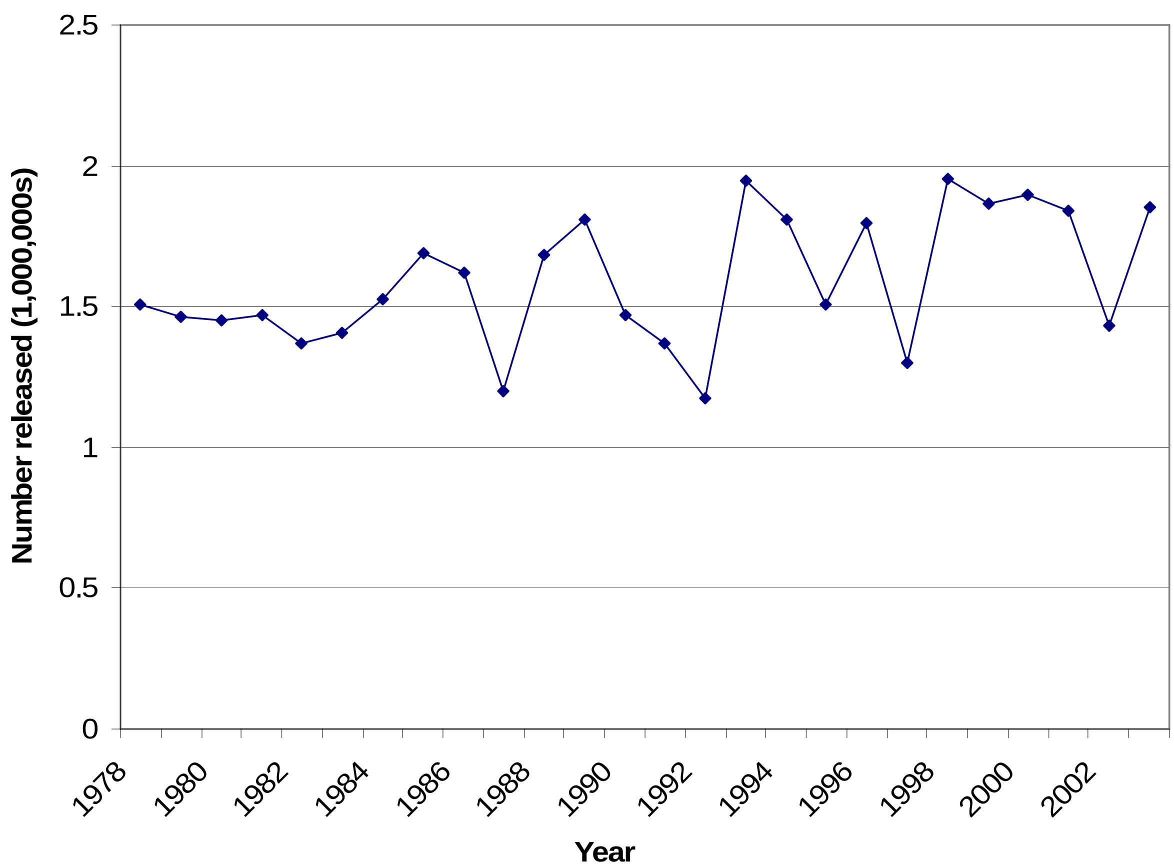


Figure 3. Total releases of winter run steelhead smolts in the Puget Sound Steelhead ESU from 1978 to 2003. (Source: WDFW 2005.)

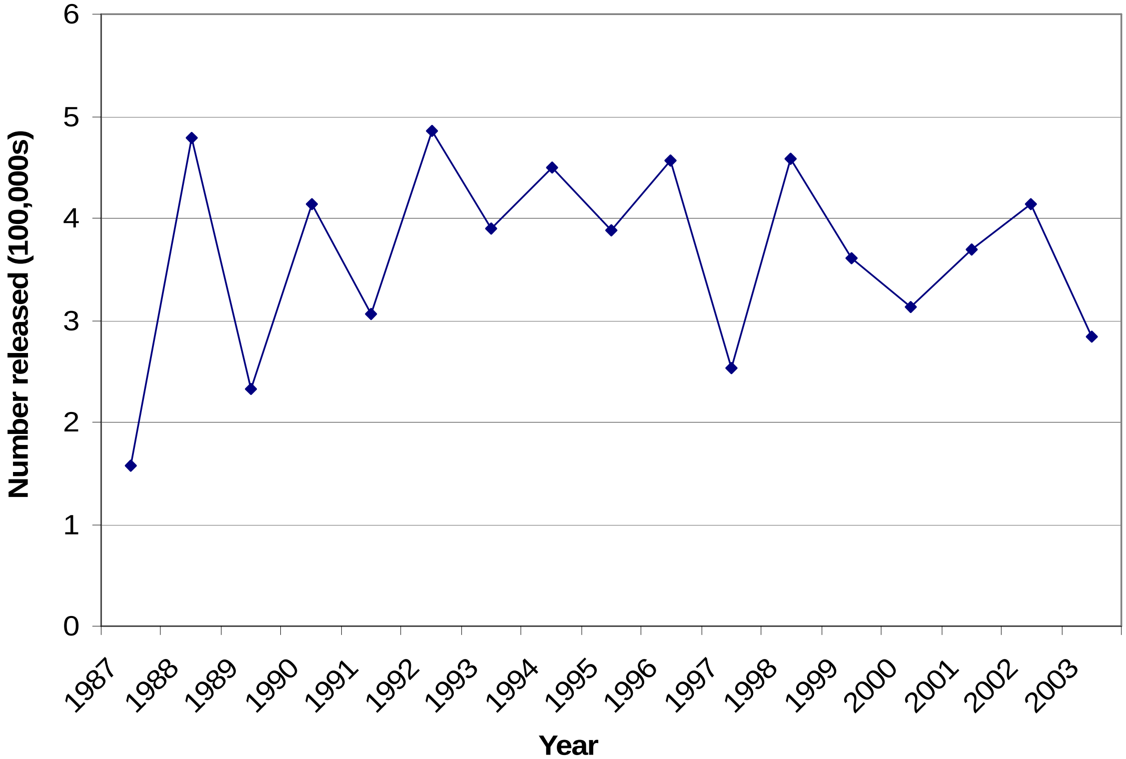


Figure 4. Total releases of summer run steelhead smolts in the Puget Sound Steelhead ESU from 1987 to 2003. (Source: WDFW 2005.)

In general, release levels for steelhead have remained relatively constant over the last two decades. Hatchery produced winter run steelhead have been released in nearly every basin in the ESU, with the exception of the Cedar River and some smaller tributaries to Puget Sound and Hood Canal (WDFW 2005). The vast majority of these releases consist of hatchery stocks largely derived from the Chambers Creek winter run steelhead stock. Releases of hatchery-produced summer run steelhead have been less widespread and of a lower magnitude. Summer run steelhead are released predominantly in the Stillaguamish, Snohomish, and Green river basins. All of these releases utilized hatchery stocks that were developed using Skamania Hatchery (Washougal River, Lower Columbia River Steelhead ESU) summer run stock.

Inclusion of Hatchery Populations in the ESU

Prior to the meeting of the Puget Sound steelhead BRT, the Salmon Steelhead Hatchery Assessment Group (SSHAG) was convened to review the relationships of steelhead hatchery populations to the Puget Sound ESU. SSHAG reviewed the stock histories for 25 hatchery programs. Hatchery stocks were assigned to one of four categories depending on the relationship between the hatchery population and the naturally produced populations within the ESU (see Appendix B, Table B-1). Briefly, Category 1 hatchery populations have a close genetic and life history affinity to local naturally produced populations; Category 2 stocks are no more than moderately diverged from the local natural populations; Category 3 stocks are substantially diverged from these local natural populations; and Category 4 hatchery populations are derived from out-of-ESU stock sources or had undergone "extreme" divergence from the local natural populations (see Appendix B). SSHAG based its assessments on the hatchery broodstock histories, which contain information on stock transfers, hatchery practices, and genetic and life history information where available (Appendix C).

Guidance provided by NMFS Northwest Region indicated the BRT should consider "hatchery fish with a level of genetic divergence between hatchery stocks and the local natural populations that is no more than what would be expected between closely related populations within the ESU" as appropriate for inclusion in the ESU (Lohn 2005). This level of divergence would include both Category 1 and 2 hatchery populations.

The BRT was presented with the findings of the SSHAG group (Table 3), which recommended only three hatchery stocks for inclusion in the Puget Sound Steelhead ESU: Lake Washington winter run steelhead, Green River natural winter run steelhead, and Hamma Hamma winter run steelhead. In the resulting discussion, the BRT excluded the Lake Washington winter run steelhead "stock" from inclusion because the program had been unable to acquire broodstock for the past 6 years and therefore this stock currently does not exist. The remaining hatchery stocks were all derived from one of two sources: Chambers Creek winter run steelhead or Skamania Hatchery summer run steelhead.

The majority of the BRT concluded the Chambers Creek stock and its derivatives were Category 3, and the Skamania stock and its derivatives were all Category 4 (Table 5). Some members asserted the Chambers Creek stock and its derivatives should also be considered a Category 4 population because of the substantial changes that this population had undergone during hatchery domestication. This view was supported by comments received from WDFW that hatchery-derived winter run steelhead have not contributed to natural production as a result of poor spawning success. Genetic analysis by Phelps et al. (1997) indicated, in many larger river basins, little if any detectible influence was evident from many years of Chambers Creek Hatchery winter run steelhead introductions. This result suggests a large degree of reproductive divergence between hatchery and wild winter run fish. In either case, the BRT concluded none of Chambers Creek or Skamania-derived stocks is part of the Puget Sound Steelhead ESU.

Table 5. Hatchery category assignment by SSHAG for steelhead hatchery programs releasing fish in Puget Sound. Hatchery categorization was based on the average (rounded to nearest integer) of the allocation votes.

Hatchery stock	**Category**
Chambers Creek WSH[a]	3
Skamania Hatchery SSH[b]	4
Regional Egg Pool WSH	3
Bogachiel Hatchery WSH	3
Nooksack River Hatchery WSH	3
Whatcom Creek Hatchery WSH	3
Samish River Hatchery WSH	3
Skagit River Hatchery WSH	3
Stillaguamish Hatchery WSH	3
North Fork Stillaguamish SSH	4
South Fork Stillaguamish SSH	4
Snohomish River Hatchery WSH	3
Snohomish River Hatchery SSH	4
Lake Washington WSH[c]	1
Green River Natural WSH	2
Green River Hatchery WSH	3
Green River Hatchery SSH	4
Puyallup River Hatchery WSH	3
White River Hatchery WSH	3
Deschutes River Hatchery WSH	3
Hamma Hamma River WSH	2
Hood Canal Hatchery WSH	3
Dungeness Hatchery WSH	3
Morse Creek Hatchery WSH	3
Elwha Hatchery WSH	3

[a] WSH: winter run steelhead.
[b] SSW: summer run steelhead.
[c] When it existed. Based on available information, the BRT concluded few if any fish from this stock currently exist.

The “Extinction Risk” Question

Risk Assessment Approach

In its risk assessment of the current Puget Sound Steelhead ESU, the BRT considered a variety of information in evaluating the level of risk faced by the Puget Sound Steelhead ESU. It should be noted for the Puget Sound Steelhead ESU that the BRT included scientists representing three major federal agencies involved in natural resource management and several had considerable expertise in steelhead biology. The information considered in their risk evaluation included magnitudes and trends in abundance of naturally spawning steelhead (adult counts, redd counts, smolt counts, juvenile densities, relative abundance of hatchery and naturally produced fish, and catch statistics), estimates of steelhead productivity (e.g., recruits per spawner data), the distribution and size of summer and winter run steelhead populations in the ESU, steelhead harvest rates, releases of hatchery *O. mykiss* in the ESU, the occurrence of rainbow trout (both native and nonnative) in the ESU, recent management changes, and environmental risk factors.

The BRT’s analyses of these data included evaluations of abundance of naturally produced fish and overall abundance, longer-term and shorter-term trends in escapement and run size, estimates of recruits per spawner and long-term population growth rate, and age structure.

Viable Salmon Population Approach to Risk Analysis

In recent status review updates for Pacific salmon and steelhead (Good et al. 2005), BRTs have adopted a risk assessment method that has been used for Pacific salmon recovery planning and is outlined in the VSP report (McElhany et al. 2000). In this approach, risk assessment is addressed first at the population level, then at the overall ESU level.

In this approach, individual populations are assessed according to the four population viability criteria: abundance, growth rate/productivity, spatial structure, and diversity. The condition of individual populations is then summarized on the ESU level, and larger scale issues are considered in evaluating the status of the ESU as a whole. These larger scale issues include total number of viable populations, geographic distribution of these populations (to ensure inclusion of major life history types and to buffer the effects of regional catastrophes), and connectivity among these populations (to ensure appropriate levels of gene flow and recolonization potential in case of local extirpations). The considerations are reviewed in McElhany et al. (2000).

The revised risk matrix (Table 6) integrates the four major population viability criteria (abundance, productivity, spatial structure, and diversity) directly into the risk assessment process. After reviewing all relevant biological information for the ESU, each BRT member assigns a risk score (see below) to each of the four population viability criteria. The scores are tallied and reviewed by the BRT before making its overall risk assessment. Although this process helps to integrate and quantify a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into an assessment of overall risk. For example, simply averaging the values of the various risk factors would not be appropriate; an ESU at high risk for low abundance would be at high risk even if there were no other risk factors.

Scoring population viability criteria: Risks for each population viability factor are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. Very low risk. Unlikely that this factor contributes significantly to risk of extinction throughout all or a significant portion of the range, either by itself or in combination with other factors.
2. Low risk. Unlikely that this factor contributes significantly to risk of extinction throughout all or a significant portion of the range by itself, but some concern that it may, in combination with other factors.
3. Moderate risk. This factor contributes significantly to long-term risk of extinction throughout all or a significant portion of the range, but does not in itself constitute a danger of extinction in the near future.
4. High risk. This factor contributes significantly to long-term risk of extinction throughout all or a significant portion of the range and is likely to contribute to short-term risk of extinction in the foreseeable future.
5. Very high risk. This factor by itself indicates danger of extinction throughout all or a significant portion of the range in the near future.

Recent events: The “recent events” category considers events that have predictable consequences for ESU status in the future but have occurred too recently to be reflected in the population data. Examples include a climatic regime shift or El Niño event that may be anticipated to result in increased or decreased predation in subsequent years. This category is scored as follows:

++ (double plus)	expect a strong improvement in status of the ESU,
+ (single plus)	expect some improvement in status,
0	neutral effect on status,
– (single minus)	expect some decline in status,
– – (double minus)	expect strong decline in status.

Table 6. Risk evaluation sheet for the Puget Sound Steelhead ESU.

Risk category	**Score**
Abundance[a] *Comments*	
Growth and productivity[a] *Comments*	
Diversity[a] *Comments*	
Spatial structure and connectivity[a] *Comments*	
Recent events[b]	

[a] Rate overall risk for each VSP category on a 5-point scale (1-very low risk; 2-low risk; 3-moderate risk; 4-moderate/high risk: 5-high risk)
[b] Rate recent events from double plus (++) strong benefit to double minus (– –) strong detriment.

The BRT's analysis of overall risk to the ESU, throughout all or a significant portion of its range, used categories that correspond to definitions in the ESA: in danger of extinction, likely to become endangered in the foreseeable future, or neither. These evaluations do not consider protective efforts, and therefore are not recommendations regarding listing status. The overall risk assessment reflected professional judgment by each BRT member. This assessment was guided by the results of the risk matrix analysis as well as expectations about likely interactions among factors. For example, a single factor with a high risk score might be sufficient to result in an overall score of "in danger of extinction throughout all or a significant portion of the range," but a combination of several factors with more moderate risk scores could also lead to the same conclusion.

To allow for uncertainty in judging the actual risk facing the ESU, the BRT adopted a "likelihood point" method, often referred to as the FEMAT method because it is a variation of a method used by scientific teams evaluating options under former President Bill Clinton's Forest Plan (Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team, or FEMAT). In this approach, each BRT member distributes 10 likelihood points among the three ESU risk categories, reflecting his opinion of how likely that category correctly reflects the true ESU status. Thus if a member were certain the ESU was in the "not at risk" category, all 10 points could be assigned to that category. A reviewer with less certainty about ESU status could split the points among two or even three categories. This method has been used in all status review updates for anadromous Pacific salmonids since 1999.

Historical Abundance Estimates

Estimates of historical steelhead abundance in Puget Sound have largely been based on catch records. There are a number of considerations that need to be taken into account to convert catch data into run size estimates. First, during the late 1800s and early 1900s, Chinook salmon was the preferred species for canning. Second, steelhead have a protracted run time relative to Chinook salmon and do not tend to travel in large schools, making them less susceptible to harvest. Finally, winter run steelhead return from December through March when conditions in Puget Sound and the rivers that drain into it are not conducive to commercial fishing operations.

The earliest commercial fisheries catch records from 1889 indicate 41,168 kg (90,570 lb) of steelhead were caught in the Puget Sound District (Rathbun 1900). Rathbun (1900) indicated fishermen targeted steelhead because the winter run occurred at a time when salmon fisheries were at a seasonal low. Assuming an average weight of 5.5 kg (12 lb), the catch would represent 7,548 steelhead. Analysis of the catch records from 1889 to 1920 (Figure 5) indicates the catch peaked at 163,796 steelhead in 1895. Using a harvest rate range of 30%–50%, the estimated peak run size for Puget Sound would range 327,592–545,987 fish. The majority of the harvest occurred in terminal fisheries (i.e., gill nets or pound nets) in Skagit, Snohomish, King, and Pierce counties (Cobb 1911), which would suggest that there was little inclusion of Fraser River steelhead in these catch estimates. By 1898 the Washington State Fish Commissioner noted, "The run of this class of fish in the state on the whole has greatly depreciated, and the output for the present season from the best information possible is not 50 percent of what it was two or three years ago. Very little has been done towards the protection of this class of salmon …" (Little 1898). Catches continued to decline from 1900 through the 1920s (Figure 5).

Steelhead management was ultimately transferred to the newly formed Washington Department of Game (WDG) in 1921. In 1925 the Washington State Legislature classified steelhead as a game fish, but only above the mouth of any river or stream (Washington Department of Fisheries and Game [WDFG] 1928). Commercial harvest of steelhead in Puget Sound fell to levels generally below 10,000 fish. In 1932, the newly formed Washington State Game Commission prohibited the commercial catch, possession, or sale of steelhead (Crawford 1979). After 1932, estimates of Puget Sound steelhead run size were based on sportfishing catch records and spawning ground surveys.

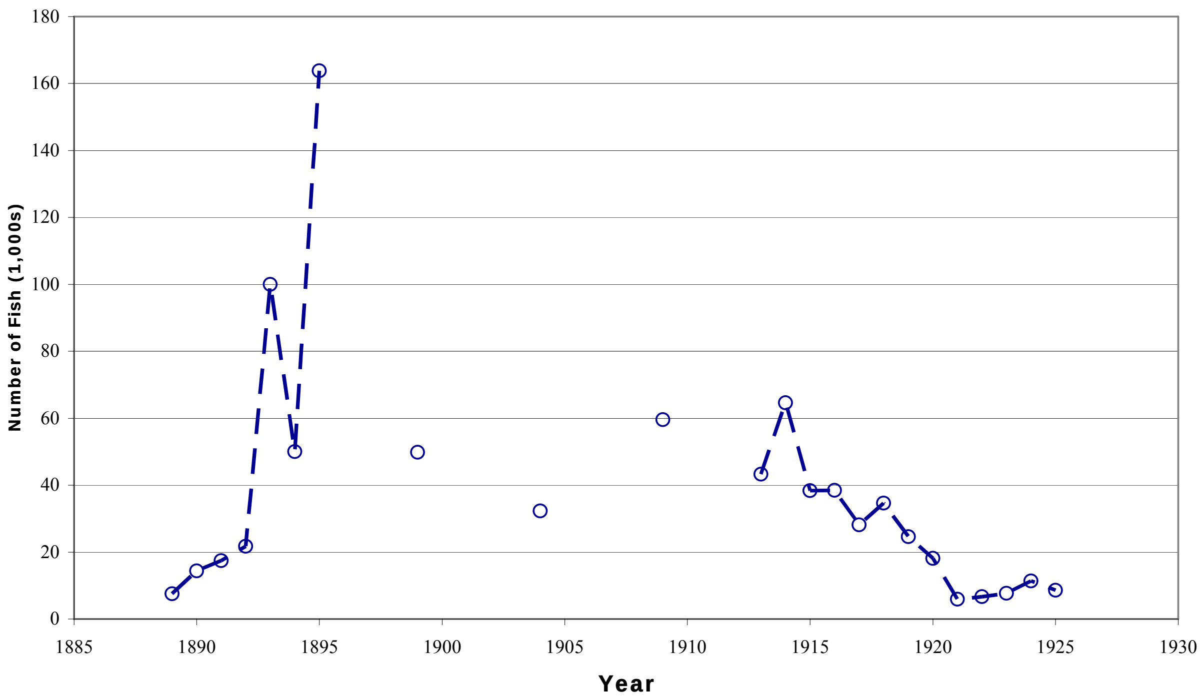


Figure 5. Harvest of steelhead in Puget Sound, 1889–1925. The y-axis is total catch in number of fish. In years without data points, harvest was reported as a combined salmon/steelhead harvest. (Sources: Washington Department of Fisheries Annual/Biannual Reports 1890-1920, Rathbun 1900, Wilcox 1902, and Cobb 1911.)

Historical Distribution

Steelhead are found in most accessible larger tributaries to Puget Sound and the eastern Strait of Juan de Fuca. A survey of the Puget Sound District in 1929 and 1930, which did not include Hood Canal (Appendix A), identified steelhead in every major basin except the Deschutes River (WDFG 1932). The propensity for steelhead to spawn in side channels and tributaries during winter and spring months when flows are high and visibility is low would likely have resulted in an underreporting of steelhead sightings. Additionally, by the late 1920s steelhead abundance had already undergone significant declines and many marginal or ephemeral populations may have already disappeared.

Recent Abundance Estimates through 1996

Total steelhead run size (catch and escapement) for Puget Sound in the early 1980s can be calculated from estimates in Light (1987) to be approximately 100,000 winter run and 20,000 summer run fish. Light provided no estimate of hatchery proportions specific to Puget Sound streams, but for Puget Sound and coastal Washington combined, he estimated 70% of steelhead in ocean runs were of hatchery origin. The percentage in escapement to spawning grounds would be substantially lower due to differential harvest and hatchery rack returns.

In the 1990s the total run size for major stocks in this ESU was greater than 45,000, with the total natural escapement about 22,000. Busby et al. (1996) estimated 5-year average natural escapements for streams with adequate data range from less than 100 to 7,200, with corresponding total run sizes of 550–19,800. Nehlsen et al. (1991) identified nine Puget Sound steelhead stocks at some degree of risk or concern. WDF et al. (1993) considered 53 stocks within the ESU, of which 31 were considered to be of native origin and predominantly natural production. Their assessment of the status of these 31 stocks was 11 healthy, 3 depressed, 1 critical, and 16 of unknown status. Their assessment of the status of the remaining (not native/natural) stocks was 3 healthy, 11 depressed, and 8 of unknown status.

Of the 21 populations in the Puget Sound ESU reviewed by Busby et al. (1996), 17 had declining and 4 increasing trends, with a range from 18% annual decline (Lake Washington winter run steelhead) to 7% annual increase (Skykomish River winter run steelhead). Eleven of these trends (9 negative, 2 positive) were significantly different from zero. These trends were for the late run naturally produced component of winter run steelhead populations; no adult trend data were available for summer run steelhead. Most of these trends were based on relatively short data series. The two basins producing the largest numbers of steelhead (Skagit and Snohomish rivers) both had modest overall upward trends at the time of the Busby et al. (1996) report.

There are substantial habitat blockages by dams in the Skagit and Elwha River basins, and minor blockages, including impassable culverts, throughout the region. The Washington Salmon and Steelhead Stock Inventory (SASSI) (WDF et al. 1993) appendices noted habitat problems, including flooding, unstable soils, and poor land management practices, for most stocks in this region. In general, habitat has been degraded from its pristine condition, and this trend is likely to continue with further population growth and resultant urbanization in the Puget Sound region. Because of their limited distribution in upper tributaries, summer run steelhead may be at higher risk than winter run steelhead from habitat degradation in larger, more complex watersheds.

New Information

New abundance, productivity, diversity, and spatial structure information on steelhead populations in the Puget Sound ESU and neighboring regions was compiled by staff of the NWFSC. Additional information and analyses were submitted by comanaging agencies (state and tribal), nongovernmental organizations, and members of the public. This information was presented in a number of different formats: anecdotal descriptions, genetic analyses, weir/dam counts, spawning ground spawner counts, redd counts, and harvest estimates.

Comments Received

In a joint communication, the National Wildlife Federation, American Rivers, and Trout Unlimited (Moryc et al. 2005), underscored the issues put forth in the petition submitted to NMFS by Wright (2004). Primarily, they pointed out the two largest steelhead producing basins (the Skagit and Snohomish rivers) that had been highlighted as stable in the 1996 NMFS Status Review (Busby et al. 1996) no longer had stable growth trends, but have displayed negative trends in abundance since 1996. In spite of the cessation of directed harvest on wild (unmarked) steelhead in most of Washington’s basins, naturally produced populations have continued to decline. Moryc et al. (2005) suggested the underlying cause for these declines has been habitat degradation (hydropower dams, floodplain development, water withdrawals, and logging). They recommended NMFS list Puget Sound steelhead as threatened or endangered.

An analysis of stock-recruit relationships for the five major winter run steelhead populations was submitted to NMFS by Nick Gayeski for Washington Trout (Gayeski 2005). For all five populations (the Skagit, Stillaguamish, Snohomish, Puyallup, and Nisqually rivers), Gayeski (2005) calculated a general declining trend in abundance. Similarly, spawner-recruit relationships were negative, indicating a steady decrease in productivity beginning the late 1980s and early 1990s (further analysis of the Gayeski report can be found in the Risk Assessment Summary subsection of the next section, ESU Risk Assessment). Based on the analysis of the ESU's five largest populations, Gayeski (2005) concluded the ESU should be listed as threatened.

Desmond Wiles submitted a letter supporting the petition to list steelhead in Puget Sound under the ESA (Wiles 2005). The letter emphasized the dramatic decline in numbers of wild steelhead and the current lifting of the moratorium on taking wild (unmarked) steelhead. Issues relating to harvest and hatchery management were put forth in a letter from Fred Habenicht (Habenicht 2005). In general, Mr. Habenicht believed the steelhead populations on Washington's coast and along the Strait of Juan de Fuca were stable, although recently the Elwha and Bogachiel River runs of winter run steelhead appeared to be depressed. He discouraged the continued use of hatchery releases from "a few select sources" and supported the development of local broodstocks of steelhead as the source for hatchery releases. Mr. Habenicht was concerned the use of early returning steelhead had compressed the current fishing season into a 4–6 week time frame and limited the harvest opportunities for steelhead retention. In addition, the letter suggested tribal fisheries and sea lion predation were causal factors in the decline of steelhead in steelhead populations along the coast and the Strait of Juan de Fuca, rather than habitat degradation or sport fisheries.

Summary of Major Risks and Status Indicators

The BRT considered the major risk factors facing Puget Sound steelhead to be widespread declines in abundance and productivity for most natural steelhead populations in the ESU, including those in Skagit and Snohomish rivers, previously considered strongholds for steelhead in the ESU; the low abundance of several summer run populations; and the sharply diminishing abundance of some steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Continued releases of out-of-ESU hatchery fish from Skamania-derived summer run and Chambers Creek-derived winter run stocks were a major diversity concern. Although information on genetic and ecological interactions between natural and hatchery origin steelhead within specific Puget Sound populations is largely unavailable, studies conducted elsewhere (e.g., Kalama River, lower Columbia River, Forks Creek, and Willapa River) indicate hatchery impacts can be substantial, even when mean individual performance of hatchery origin fish is poor, because of the large numbers of returning hatchery origin adults that significantly outnumber natural origin adults. Similarly, despite the divergence in run and spawn times between hatchery origin and natural origin winter run steelhead, the potential for interbreeding effects is still considerable given the large number of returning hatchery fish and the small number of natural origin fish. At present, the major threat from hatcheries to Puget Sound steelhead comes from past and present hatchery practices involving hatchery stocks that were either founded outside the ESU or have undergone extensive hatchery domestication (see discussion above).

The BRT concluded it was not possible at present to fully evaluate the contributions resident fish make to ESU viability. Indeed, obtaining a better understanding of how rainbow trout contribute to steelhead viability appears to be a critical question for future research. Nevertheless, based on the information available, a majority of BRT members concluded rainbow trout, in general, constitute a minor component of the Puget Sound ESU, and the contribution of resident fish to overall abundance and productivity of the ESU is likely to be small, due to relatively low numbers of resident fish and lack of evidence for resident populations demographically independent from anadromous populations in the same watersheds. This issue is discussed more fully below.

Inclusion of Rainbow Trout in the Risk Analysis

In evaluating whether to include rainbow trout in an ESU, the BRT must consider the effect of these resident fish on the viability of the entire ESU. This task is especially difficult because little or no information is available about the abundance and distribution of resident fish, or about the extent and nature of their interactions with anadromous populations. The 2003 BRT incorporated information about rainbow trout populations into their analyses of the four VSP criteria and their assessments of extinction risk for *O. mykiss* ESUs (Good et al. 2005). In several ESUs, Good et al. (2005) concluded the presence of relatively numerous rainbow trout populations reduced risks to ESU abundance. However, there is considerable scientific uncertainty regarding the potential of the resident form to contribute to the productivity, spatial structure/connectivity and diversity of steelhead ESUs (Varanasi 2004).

Good et al. (2005) underscored the importance of the anadromous life history form in reducing risks to these latter three VSP parameters, and thus in contributing to a viable *O. mykiss* ESU in total. Although there is the potential for rainbow trout populations to generate steelhead migrants, it may be short-lived if the reproductive success of steelhead offspring is low. Finally, the BRT concluded if the anadromous life history form in an ESU is extirpated or critically depressed, it is unlikely the resident life history form is capable of maintaining the productivity, connectivity, and diversity necessary for a viable *O. mykiss* ESU (NMFS 2003).

Subsequent to the conclusions of the 2003 BRT, NMFS solicited opinions from two expert panels to review the issue of viability in ESUs that contain both rainbow trout and steelhead. The independent Recovery Science Review Panel (RSRP) identified anadromy as "an evolutionarily significant component of *O. mykiss* diversity" (RSRP 2004). In its review of available information the panel concluded "resident populations by themselves should not be relied upon to maintain long-term viability of an ESU." Similarly, the Independent Scientific Advisory Board (ISAB) found the long-term consequences of the extirpation of a major life history form would have deleterious consequences on the entire ESU (ISAB 2005):

> To be viable an ESU needs more than simple persistence over time; it needs to be in an ecologically and evolutionarily functional state. Evaluation of ESU viability should not only rest on the numbers of component populations or on the abundance and productivity of those individual populations, but also should be based on the integration of population dynamics within the ecosystem as a whole.

> This concept of ESU viability does not accommodate the loss of populations or the anadromous or resident life history form from any given ESU, because that loss would represent a loss in diversity for the ESU that would put its long-term viability at risk.

Where both life history forms are present, the ISAB considered that the resident forms contribute to the overall abundance and diversity of an ESU, but were unsure of the contribution by resident fish to connectivity and spatial structure. Overall, the presence of both resident and anadromous life history forms is "critical for conserving the diversity of steelhead/rainbow trout populations and, therefore, the overall viability of ESUs."

In a review of currently listed steelhead ESUs, the Northwest Fisheries Science Center (NWFSC) concluded "None of these ESUs is likely to persist in total into the foreseeable future because substantial parts of the ESUs are at risk of extinction" (Varanasi 2004). The NWFSC review supported the 2003 BRT conclusions that the ESUs were at risk of extinction, now or in the foreseeable future, because the anadromous life history represented a "significant portion of the species 'range,' such that its loss is a direct threat to the ESUs" (Varanasi 2004).

Puget Sound Steelhead BRT Conclusions

The BRT members believed the persistence of rainbow trout in the ESU below long-standing barriers is likely to reduce imminent risk of extinction throughout all or a significant portion of the ESU's range, but that anadromy is necessary for the long-term persistence of the ESU. Threats to the ESU from loss of the anadromous form include lower productivity and resilience and greater risk of catastrophic loss. Whether the resident form contributes to ESU viability through productivity, spatial structure, and diversity remains unknown, although evidence is growing from several studies that the resident form can retain the genetic basis for anadromy over periods of several decades or more. However, whether rainbow trout above barriers produce seaward migrants in sufficient numbers to buffer demographic stochasticity substantially in small steelhead populations is not known either. Because this potential may be short-lived if selection against migrants in a resident population is sufficiently strong, the BRT concluded resident populations are unlikely to significantly reduce the risk of extinction of anadromous populations over the long term.

In the Puget Sound ESU, rainbow trout are probably associated with many, if not most, of the steelhead populations. Unfortunately, little information and no quantitative abundance or trend data on these residents were available to the BRT for review. Although most BRT members agreed rainbow trout are likely to provide some demographic benefit to steelhead if reproductive connectivity between these forms is sufficient, many also concluded rainbow trout appear to be a minor component of steelhead productivity in the Puget Sound ESU and are not likely to contribute substantially to metapopulation dynamics in these mixed systems. Most of the information relevant to this question is from the Cedar River where research is ongoing on resident and anadromous fish below and above Landsberg Dam, which was opened to steelhead migrating upstream in 2002 after decades of isolation.

The Cedar River study indicated sympatric steelhead and rainbow trout in the system are very similar genetically, but a somewhat more distant relationship existed between steelhead above and below the barrier (Marshall et al. 2004). It also appeared rainbow trout may be contributing to the smolt outmigration, a pattern also observed in the Quileute River on the Olympic Peninsula (presentation by J. McMillan to the BRT, 20 June 2005). The BRT members believed these studies are central to understanding the relationship between rainbow trout and steelhead, although some BRT members were concerned the highly disturbed nature of the Cedar River, which was diverted from the Duwamish River in the early 1900s, may restrict this study's relevance to steelhead in other river basins.

The BRT noted resident *O. mykiss* tend to occur as large, self-sustaining populations only where there are major hydrological modifications of the watersheds (e.g., in the Cedar River in the Puget Sound ESU, or upstream from dams, above barriers in the Sacramento-San Joaquin River and elsewhere). Rivers west of the Cascade Mountains rarely support rainbow trout populations unless the watersheds have been significantly modified, and resident native populations appear to be relatively rare above natural barriers.

The BRT members unanimously believed the loss of anadromy represents a substantial threat to viability in a mixed ESU. The presence of rainbow trout is likely to reduce long-term extinction risk only when this form maintains the ability to express the natural range of life history variation in this species, including anadromy. Even though resident populations might persist if anadromous fish are lost from a population, the contribution of resident populations depends on whether the genetic basis of anadromy is maintained in the resident form. This is not yet known for any Puget Sound steelhead population.

Habitat Conditions

Habitat utilization by steelhead has been most dramatically affected by a number of large dams in basins feeding Puget Sound. In addition to eliminating accessibility to habitat, dams affect habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and the movement of large woody debris.

Many of the lower reaches of rivers and their tributaries in Puget Sound have been dramatically altered by urban development. Urbanization and suburbanization have resulted in the loss of historical land cover in exchange for large areas of imperious surface (buildings, roads, parking lots, etc.). The loss of wetland and riparian habitat has dramatically changed the hydrology of many urban streams, with increases in flood frequency and peak flow during storm events and decreases in groundwater driven summer flows (Moscrip and Montgomery 1997, Booth et al. 2002, May et al. 2003). Flood events result in gravel scour, bank erosion, and sediment deposition. Land development for agricultural purposes has also altered the historical land cover; however, because much of this development took place in river floodplains, there has been a direct impact on river morphology. River braiding and sinuosity have been reduced by dikes, hardening of banks with riprap, and channelizing the main stem. Constriction of the river, especially during high flow events, increases likelihood of gravel scour and the dislocation of rearing juveniles. Side channels are spawning habitat for steelhead and other salmonids. Additionally, side channel areas provide juvenile rearing habitat, especially overwintering habitat (Beechie et al. 2001, Collins and Montgomery 2002, Pess et al. 2002).

There are two major dams in the Nooksack Basin, the Nooksack Falls power plant diversion dam (completed 1906) above the impassable Nooksack Falls at river kilometer (RKM) 104.6 and the water diversion dam (1960) on the Middle Fork Nooksack River (RKM 11.6). The Nooksack Falls project is upstream of an inaccessible falls and has been out of operation since a fire in 1997; however, there is concern that renewed operation may alter natural flows. The water diversion dam on the Middle Fork Nooksack River currently prevents upstream access to historical steelhead habitat; furthermore, the dam diverts a considerable proportion of the summer flow to Lake Whatcom for eventual use by the City of Bellingham (Smith 2002). Comanagers currently are evaluating the passage of salmon and steelhead over the Middle Fork Diversion Dam.

The Skagit River Basin contains two dam complexes, the Lower and Upper Baker dams on the Baker River, and the Ross, Diablo, and Gorge dams on the Skagit River. Lower Baker Dam was completed in 1927 at RKM 1.8 of the Baker River. Passage above the dams is accomplished through a trap and haul program and downstream passage is accomplished via a smolt collection facility at Upper Baker Dam (known as the "gulper"). Passage efficiency is higher for larger (yearling) smolts that migrate near the surface, for example, coho salmon, sockeye salmon (*O. nerka*), and steelhead, than for subyearling smolts of Chinook salmon, chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*). The other dam complex, incorporating the Ross, Diablo, and Gorge dams, limits access at RKM 155.3 on the Upper Skagit River.

Surveys undertaken during the 1920s, prior to the construction of the first of the dams, report steelhead were not present at or above the proposed location of the dams (Smith and Royal 1924). Similarly, the Seattle City Light diversion dam on the South Fork Tolt River in the Snohomish River basin is located above the limit of steelhead migration (an impassable waterfall is located at RKM 12.9). While these dams do not limit the habitat accessibility, they can affect downstream steelhead population through changes in flow, or by blocking downstream recruitment of gravel and large woody debris.

Landsburg Dam (RKM 35.1) on the Cedar River has blocked steelhead access to approximately 27.4 km of mainstem habitat since 1900. Preliminary studies are currently underway to provide passage for steelhead and other salmonids above the dam. Plans are also being studied for restoring passage to the upper Green River. In 1913 the Tacoma Water Headworks Diversion Dam eliminated access to 47.9 km of mainstem habitat. The construction of Howard Hanson Dam (RKM 98.1) above the diversion dam in 1962 blocked access to several kilometers of mainstem and tributary habitat (Kerwin and Nelson 2000). It is thought a summer run of steelhead historically existed in the Green River, but that the run was extirpated following loss of access to headwater spawning areas following the construction of the diversion dam.

The Buckley Diversion Dam (RKM 39.1, completed 1911) and the Mud Mountain Dam (RKM 47.6, completed 1942) impede upstream passage on the White River. Returning adults are collected at a trap associated with the Buckley Diversion Dam and trucked around both dams. Downstream smolt passage occurs through the dams rather than through a trap and haul system. In addition to upstream and downstream migration effects on salmonids, flow diversion and ramping rates can result in dewatered redds, fish strandings, delayed migration, and degraded water conditions. In the Puyallup River Basin, the Electron Dam (RKM 67.3) has blocked upstream passage for more than 90 years. Construction of a fish ladder in 2000 has provided access over 16 km of mainstem habitat. Adult and juvenile fish passage studies are currently underway.

In the Nisqually River Basin, the LaGrande Dam (RKM 63.5, completed 1945) and Alder Dam (RKM 66, completed 1944) block upstream migration. At present there are no plans to provide passage around these dams.

The two Cushman dams, Dam No. 1 (RKM 31.5, completed 1926) and Dam No. 2 (RKM 27.8, completed 1930) eliminated steelhead access to much of the North Fork Skokomish River. Anecdotal evidence suggests steelhead utilized much of the North Fork, although it is not clear whether these were winter or summer run fish. Additionally, the diversion of flow from the North Fork to the powerhouse has reduced the overall flow of the Skokomish River by 40% (USFS 1995).

In the Elwha River Basin, two dams, the Elwha (RKM 7.9, completed 1911) and the Glines Canyon (RKM 21.6, completed 1927) block access to more than 100 km of historical mainstem and tributary habitat. Both dams are scheduled for removal beginning in 2012.

Artificial Propagation

Artificial propagation is important to consider in ESA evaluations of steelhead for several reasons. First, although natural fish are the focus of ESU determinations, both positive and negative effects of artificial propagation on natural populations must be evaluated (NMFS 2005). For example, stock transfers might change the genetic or life history characteristics of a natural population in such a way that the population might seem either less or more distinctive than it was historically. Artificial propagation can also alter life history characteristics such as smolt age and migration and spawn timing. In contrast to other risks, the effects of artificial propagation can be cumulative. Domestication and genetic introgression represent processes with effects that increase over time, even if applied at the same intensity over time.

Second, artificial propagation poses risks to natural populations that may affect their risk of extinction or endangerment. In contrast to most other types of risk for salmon populations, those arising from artificial propagation are often not reflected in traditional indices of population abundance. For example, to the extent that habitat degradation, overharvest, or hydropower development have contributed to a population's decline, these factors will already be reflected in population abundance data and accounted for in the risk analysis.

The same is not true of artificial propagation. Hatchery production may mask declines in natural populations that will be missed if only raw population abundance data are considered. Therefore a true assessment of the viability of natural populations cannot be attained without information about the contribution of naturally spawning hatchery fish. Furthermore, even if such data are available, they will not in themselves provide direct information about possibly deleterious effects of fish culture. Such an evaluation requires consideration of the genetic and demographic risks of artificial propagation for natural populations.

In its review of Puget Sound artificial programs, the BRT identified only two hatchery stocks that genetically represent native local populations (Hamma Hamma and Green River natural winter run). The remaining programs, which account for the vast preponderance of production, are either out-of-ESU-derived stocks or were within-ESU stocks that were substantially diverged from local populations. Intentional and inadvertent selection on life history in Chambers Creek winter run steelhead has resulted in dramatic changes in important life history characteristics (Crawford 1979, Busby et al. 1996). These changes have resulted in a domesticated strain with a highly modified average run and spawn timing. Such changes were generally considered by the BRT to have a detrimental effect on fitness in the wild. This view was substantiated by comments made by WDFW that hatchery-derived winter run steelhead do not contribute to natural production due to poor spawning success (see also Berejikian and Ford 2004).

Genetic analyses by Phelps et al. (1997) indicated in some naturally spawning populations in larger river basins there is little if any detectable influence from the years of Chambers Creek Hatchery winter run steelhead introductions, a result that suggests reproductive isolation of, and poor spawning success by, hatchery origin fish. There was, however, some evidence for introgression by hatchery releases into winter run steelhead populations in tributaries to the Strait of Juan de Fuca, although this may have been due to the relatively small size of the naturally spawning populations relative to the hatchery introductions. Efforts by WDFW to limit interactions between hatchery and wild fish through the use of early returning Chambers Creek winter run steelhead may have reduced the probability of interbreeding through temporal separation; however, many members of the BRT considered the fitness consequences of hatchery-wild crosses that do occur may be highly detrimental.

The BRT was also concerned that WDFW has focused on collecting abundance information after the 15 March date WDFW uses to delineate hatchery and native winter run spawning. This approach does not appear to always provide an accurate estimate of the contribution of hatchery origin fish to natural production and could bias productivity estimates. In the absence of definitive information regarding the contribution of artificial production programs to natural production in ESU, there was some uncertainty in the risk evaluation. In general, given the genetic and life history relationships between hatchery programs derived from Chambers Creek Hatchery and Skamania Hatchery and the naturally spawning populations, the BRT concluded these effects would be detrimental, and potentially substantially so. The two hatchery programs that were derived recently from their naturally spawning population counterparts were relatively small and had not been in operation long enough to adequately assess what contribution they made to the ESU. Even if these contributions are positive, the BRT concluded these two small programs in themselves were unlikely to have a significant effect on ESU viability.

ESU Risk Assessment

Salmonid ESUs are typically metapopulations, that is, they are usually composed of multiple populations with some degree of interconnection, at least over evolutionary time periods. These multiple populations make the assessment of extinction risk difficult. The approach to this problem that NMFS adopted for recovery planning is outlined in the VSP report (McElhany et al. 2000). In this approach, risk assessment is addressed at two levels: first at the population level, then at the overall ESU level. The BRT's risk assessment for the Puget Sound Steelhead ESU incorporated VSP criteria.

The BRT assessed risk in individual populations according to the four VSP criteria: abundance, growth rate/productivity, spatial structure, and diversity. It then summarized the condition of individual populations on the ESU level and considered larger-scale issues in evaluating the status of the ESU as a whole. These larger-scale issues included total number of viable populations, geographic distribution of these populations (to ensure inclusion of major life history types and to buffer the effects of regional catastrophes), and connectivity among these populations (to ensure appropriate levels of gene flow and recolonization potential in case of local extirpations). McElhany et al. (2000) described these considerations.

The BRT used the revised risk matrix for the overall ESU evaluation (Good et al. 2005). This matrix (Table 6) integrates the four major VSP criteria (abundance, productivity, spatial structure, and diversity) directly into the risk assessment process. The BRT reviewed relevant biological information, including recent data provided by Washington state and tribal comanagers on abundance and productivity in Puget Sound *O. mykiss*. The BRT also reviewed additional information on the production of hatchery fish and occurrence of resident fish in the Puget Sound ESU. Following a discussion of each of these issues, each BRT member assigned a risk score (see below) to each of the four VSP criteria. The BRT tallied and reviewed the scores before making its overall risk assessment. This process helps quantify and integrate diverse information; however, there is no easy way to translate the risk matrix scores directly into an overall assessment of risk. Just averaging the values of the various risk factors, for example, would not be appropriate: an ESU that is at high risk for low abundance would be at high risk even if there were no other risk factors.

Risk Assessment Methods

The BRT adopted methods described by Good et al. (2005) to evaluate data that affect the four VSP parameters in the Puget Sound Steelhead ESU; these methods are described briefly below. State and tribal comanagers provided data on abundance, the fraction of hatchery origin spawners, harvest, age structure, and hatchery releases to the BRT. Data on adult returns were obtained from a variety of sources, including time series of freshwater spawner surveys, redd counts, catch data, and juvenile density estimates. Time series were assembled and analyzed for each population that had sufficient data.

State and tribal comanagers reviewed the data for accuracy and completeness. Population level estimates of the fraction of hatchery origin spawners were obtained from comanager data on proportions of adipose fin clipped fish (i.e., hatchery fish). Estimates of harvest were provided for most stocks.

Recent Abundance

Recent abundance of natural spawners is reported as the geometric mean (and range) of the most recent data to be consistent with previous coastwide status reviews of these species. Geometric means were calculated to represent the recent abundance of natural spawners for each population or quasi-population within an ESU. Geometric means were calculated for the most recent 5 years; these time frames were selected to correspond with modal age at maturity for each species. Zero values in the data set were replaced with a value of 1, and missing data values within a multiple-year range were excluded from geometric mean calculations. The geometric mean is the *n*th root of the product of the *n* data:

$$\overline{X}_G = \sqrt[n]{N_1 N_2 N_3 \ldots N_n} \quad (1)$$

where N_t is the abundance of natural spawners in year t. Arithmetic means (and ranges) were also calculated for the most recent abundance data:

$$\overline{X}_A = \frac{\sum_{t=1}^{n} N_t}{n} \quad (2)$$

where N_t is the abundance of natural spawners in year t.

Trends in Abundance

Short-term and long-term trends were calculated from time series of the total number of adult spawners. Short-term trends were calculated using data from 1995 to the most recent year (2004). Long-term trends were calculated using all data in a time series. Trend was calculated as the slope of the regression of the number of natural spawners (log-transformed) over the time series. To mediate for zero values, 1 was added to natural spawners before transforming the data. Trend was reported in the original units as exponentiated slope, such that a value greater than 1 indicates a population trending upward, and a value less than 1 indicates a population trending downward. The regression was calculated as

$$\ln(N+1) = \beta_0 + \beta_1 X + \varepsilon \quad (3)$$

where N is the natural spawner abundance, β_0 is the intercept, β_1 is the slope of the equation, and ε is the random error term.

Confidence intervals (95%) for the slope, in their original units of abundance, were calculated as

$$\exp(\ln(b_1) - t_{0.05(2),df}\, s_{b_1}) \le \beta_1 \le \exp(\ln(b_1) + t_{0.05(2),df}\, s_{b_1}) \quad (4)$$

where b_1 is the estimate of the true slope, β_1, $t_{0.05(2), df}$ is the two-sided t-value for a confidence level of 0.95, df is equal to $n - 2$, n is the number of data points in the time series, and s_{b_1} is the standard error of the estimate of the slope, b_1.

Population Growth Rate

In addition to analyses of trends in natural spawners, the median short-term population growth rate (λ) of natural origin spawners was calculated where possible as a measure for comparative risk analysis. Lambda more accurately reflects the biology of steelhead, as it incorporates overlapping generations and calculates running sums of cohorts. It is an essential parameter in viability assessment, as most population extinctions are the result of steady declines, λ < 1. It has been developed for data sets with high sampling error and age-structure cycles (Holmes 2001). These methods have been extensively tested using simulations for both threatened and endangered populations as well as for stocks widely believed to be at low risk (Holmes 2004), and cross-validated with time series data (Holmes and Fagan 2002).

Where possible, the λ of natural origin spawners was calculated on the basis of natural production alone. Where it was not possible to separate hatchery and natural production, we computed λ based on the mixture of hatchery and natural spawners. A multistep process based on methods developed by Holmes (2001) and Holmes and Fagan (2002) and described in McClure et al. (2003) was used to calculate estimates for λ, its 95% confidence intervals, and its probability of decline [P(λ < 1)]. The first step was calculating 4-year running sums for natural origin spawners as

$$R_t = \sum_{i=1}^{4} N_{t-i+1} \tag{5}$$

where N_t is the number of natural-origin spawners in year t. A 4-year running sum window was used for all species, as analysis by McClure et al. (2003) indicates this is an appropriate window for a diverse range of species life histories.

Next, an estimate of μ, the rate at which the median of R changes over time (Holmes 2001), was calculated as

$$\hat{\mu} = mean\left(\ln\left(\frac{R_{t+1}}{R_t}\right)\right) \tag{6}$$

the mean of the natural log-transformed running sums of natural origin spawners. The point estimate for λ was then calculated as the median annual population growth rate,

$$\hat{\lambda} = e^{\hat{\mu}} \tag{7}$$

Confidence intervals (95%) were calculated for $\hat{\lambda}$ to provide a measure of the uncertainty associated with the growth rate point estimate. First, an estimate of variability for each population was determined by calculating an estimate for σ^2_{pop} using the slope method (Holmes 2001). The slope method formula is

$$\hat{\sigma}^2_{pop} = \text{slope of } \operatorname{var}\left(\ln\left(\frac{R_{t+\tau}}{R_t}\right)\right) \text{vs. } \tau \qquad (8)$$

where τ is a temporal lag in the time series of running sums.

Individual population variance estimates were highly uncertain, so a more robust variance estimate, σ^2_{avg}, was obtained by averaging the σ^2_{pop} estimates from all the populations in an ESU. This average variance estimate was then applied as the variance for every population in an ESU. The degrees of freedom associated with the average variance estimate are obtained by summing the degrees of freedom for each of the individual population variance estimates. The degrees of freedom for the individual population estimates were determined using the method of Holmes and Fagan (2002), which identifies the adjusted degrees of freedom associated with slope method variance estimates. The calculation for the adjusted degrees of freedom is

$$df = 0.212n - 1.215 \qquad (9)$$

where n is the length of the time series. Using the average variance estimate and the summed degrees of freedom, the 95% confidence intervals for λ were calculated as

$$\exp\left(\hat{\mu} \pm t_{.05(2),df}\sqrt{\hat{\sigma}_{slp}{}^2/(n-4)}\right) \qquad (10)$$

Recruitment

Recruits, or spawners in the next generation, from a given brood year were calculated as

$$C_t = \sum_{i=1}^{MaxAge} N_{t+i} A(i)_{t+i} \qquad (11)$$

where C_t is the number of recruits from brood year t, N_t is the number of natural origin spawners in year t, and $A(i)_t$ is the fraction of age i spawners in year t. The estimate of preharvest recruits is similarly

$$C(preHarvest)_t = \sum_{i=1}^{MaxAge} P_{t+i} A(i)_{t+i} \qquad (12)$$

where $C(preHarvest)_t$ is the number of preharvest recruits in year t, P_t is the number of natural origin spawners that would have returned in year t if there had not been a harvest, and $A(i)_t$ is the fraction of age i spawners in year t had there not been a harvest. (Because P_t is in terms of the number of fish that would have appeared on the spawning grounds had there not been a harvest, it can be quite difficult to estimate, thus simplifying assumptions are often made).

Population Viability Analysis

A variety of quantitative approaches to population viability analysis (PVA) have been used with Pacific salmonids. However, because no consensus has emerged on how best to model population viability in steelhead and because the available data were insufficient to conduct a robust PVA, we did not conduct one for this report.

Resident Fish Considerations

As mentioned, *O. mykiss* exhibits varying degrees of anadromy, even in coastal populations. Nonanadromous forms are usually called rainbow trout. Although the anadromous and nonanadromous forms have long been taxonomically classified within the same species, in any given area the exact relationship between the forms is not well understood. In coastal populations, it may be less common for the two forms to co-occur; they are frequently separated by a natural or man-made migration barrier. As part of its review, the BRT made a concerted effort to seek biological information for resident populations of steelhead in the Puget Sound ESU.

The BRT had to consider in general terms how to conduct an overall risk assessment for an ESU that includes both resident and anadromous populations, particularly when the rainbow trout individuals may outnumber the steelhead ones but their biological relationship is unclear or unknown. Some guidance is found in Waples (1991), which outlined the scientific basis for the NMFS ESU policy. That paper suggested an ESU that contains both forms could be listed based on a threat to only one of the life history traits "if the trait were genetically based and loss of the trait would compromise the 'distinctiveness' of the population" (p. 16). That is, if anadromy were considered important in defining the distinctiveness of the ESU, loss of that trait would be a serious ESA concern. In discussing this issue, the NMFS ESU policy (NMFS 1991) affirmed the importance of considering the genetic basis of life history traits such as anadromy and recognized the relevance of a question posed by one commenter: "What is the likelihood of the nonanadromous form giving rise to the anadromous form after the latter has gone locally extinct?"

The BRT discussed another important consideration: the role steelhead populations play in providing connectivity and linkages among different spawning populations within the ESU. An ESU in which all steelhead populations are lost and the remaining rainbow trout populations are fragmented and isolated would have a very different future evolutionary trajectory than one in which all populations remain linked genetically and ecologically by steelhead forms. Furthermore, the geographic area utilized by anadromous (but not resident) fish may represent a "significant portion of the range" of the ESA species, especially if the area encompassed by the marine migration is considered.

Despite concerted efforts to collect and synthesize available information on rainbow trout forms of *O. mykiss*, existing data are very sparse, particularly regarding interactions between resident and anadromous forms. The 2003 coast wide BRT struggled with the complexity of the relationship between resident and anadromous forms, given this paucity of key information. To focus the issue, this BRT considered a hypothetical scenario that has varying degrees of relevance to individual steelhead ESUs. In this scenario, a once abundant and widespread anadromous life history is extinct, or nearly so, but relatively healthy native populations of resident fish remain in many geographic areas. The question the BRT considered was: Under what circumstances would one conclude that such an ESU was not in danger of extinction or likely to become endangered throughout all or a significant portion of its range? The BRT identified the required conditions as follows:

1. The resident forms are capable of maintaining connectivity among populations to the extent that the ESU's historical evolutionary processes are not seriously disrupted.
2. The anadromous life history is not permanently lost from the ESU but can be regenerated from the resident forms.

Regarding the first criterion, although some resident salmonid forms are known to migrate considerable distances in freshwater, extensive river migrations have not been demonstrated to be an important behavior for resident *O. mykiss*, except in rather specialized circumstances (e.g., forms that migrate from a stream to a large lake or reservoir as a surrogate for the ocean). Therefore, the BRT felt that loss of the anadromous form would, in most cases, substantially change the character and future evolutionary potential of the Puget Sound Steelhead ESU.

Regarding the second criterion, it is well established that resident forms of *O. mykiss* can occasionally produce anadromous migrants and vice versa (Mullan et al. 1992, Zimmerman and Reeves 2000, Kostow 2003, Thrower et al. 2004). However, available information indicates these occurrences are relatively rare, and there is even less empirical evidence that, once lost, a self-sustaining anadromous run can be regenerated from a resident salmonid population. Although regeneration is likely to have occurred during the evolutionary history of *O. mykiss,* the BRT found no reason to believe such an event would occur with any frequency or within a specified time period. This would be particularly true if the conditions that promote and support the anadromous life history continue to deteriorate. In this case, the expectation would be that natural selection would gradually eliminate the migratory or anadromous trait from the population, as individuals inheriting a tendency for anadromy migrate out of the population but do not survive to return as adults and pass on their genes to subsequent generations (but see also Thrower et al. 2004).

Given the above considerations, the Puget Sound Steelhead BRT focused primarily on information for anadromous populations in the risk assessment for the Puget Sound Steelhead ESU. This was particularly true with respect to Category 3 resident fish populations, most of which are of uncertain ESU status.

Risk Assessment Summary

Recent Abundance

Although populations of steelhead in the Puget Sound ESU include both summer and winter run life history types, the ESU is composed primarily of winter run populations. WDFW (SaSI 2002) has identified 53 populations of steelhead in this ESU, of which 37 (69.81%) are winter run. However, no abundance estimates exist for most of the summer run populations; all appear to be small, most averaging less than 200 spawners annually. Summer run populations are distributed throughout the ESU but are concentrated in northern Puget Sound and Hood Canal; only the Elwha River and Canyon Creek support summer run steelhead in the rest of the ESU. The existing Elwha River summer run is largely or wholly descended from introduced Skamania Hatchery summer run steelhead, while historical summer runs in the Green River and Elwha River are thought to have been extirpated early in the 1900s.

Steelhead are most abundant in the ESU in northern Puget Sound, with winter run steelhead in the Skagit and Snohomish rivers supporting the two largest populations (Table 5 and Figure 6). In recent years, the Skagit and Snohomish river winter run populations have been three to five times larger than the other populations in the ESU, and average approximately 3,000 (Snohomish) and 5,000 (Skagit) total adult spawners annually. Populations in Hood Canal and along the Strait of Juan de Fuca are generally small, averaging less than 100 spawners annually. The geometric means of most populations have declined in the last five years; recent means for many populations are 50%–80% of the corresponding long-term means (Table 7).

Exceptions to this trend include winter run populations in the Samish River (northern Puget Sound) and the Hamma Hamma River (Hood Canal), both of which appear to be growing rapidly (Figures 6 and 7). In the case of the Samish River, the increasing trend in abundance is difficult to explain. The consistent increase in natural abundance since 1998 may reflect an influence of hatchery spawners. HSRG (2002, 2003, 2004) noted hatchery steelhead produced in the Whatcom Creek Hatchery had run timing similar to wild steelhead in the Samish. Thus, because run timing is likely to be heritable, recent abundance estimates in the Samish River may include some later returning hatchery fish, or naturally produced progeny of hatchery fish that returned with wild fish. Recent abundance in the Hamma Hamma River reflects the effect of a hatchery supplementation program operating with local broodstock since 2001.

Since its 1992 SASSI report, WDFW (SaSI 2002) observed a general downgrade in the status of steelhead populations in this ESU. Over this period, the number of populations considered to be “healthy” declined from 14 (26% of all populations in the ESU) to 5 (9%), and the number of populations of “depressed” status increased from 14 (26%) to 19 (35%). One population (1%) remained “critical,” and the number of populations of unknown status increased from 24 (45%) to 27 (50%).

According to WDFW, naturally produced adult steelhead make up a substantial fraction of recent escapements in most steelhead populations (Table 7), despite reduced harvest of hatchery steelhead in recent years and in the presence of continued releases of hatchery steelhead in many systems.

Trends in Abundance

The BRT evaluated trends in abundance of natural steelhead over the entire data sets and over the most recent decade. Trends were measured for total run size to the river (catch and escapement) as well as escapement, as trend in run size better reflects changes in productivity. Most populations showed significantly declining trends in natural escapement, especially in southern Puget Sound (Cedar, Lake Washington, Nisqually, and Puyallup winter run populations), but also in some populations in northern Puget Sound (Stillaguamish winter run), Hood Canal (Skokomish winter run), and along the Strait of Juan de Fuca (Dungeness winter run) (Table 8 and Figures 8 and 9). Positive trends were observed in the Samish winter run (northern Puget Sound) and the Hamma Hamma winter run (Hood Canal) (Figures 6 and 7). The increasing trend on the Hamma Hamma River appears to be due to a captive rearing program, however, rather than to natural escapement (Figure 7).

Table 7. Geometric mean estimates of escapement for Puget Sound steelhead. For each population, estimates are provided for both the entire data set (all years, ca. 1980–2004 for most populations) and for the most recent years (5 years, 2000–2004). Estimates are based on hatchery and natural spawners (H+N columns) or on only natural spawners (N columns). Note that hatchery fish are not considered part of the Puget Sound Steelhead ESU. NPS = Northern Puget Sound, SPS = Southern Puget Sound, HC = Hood Canal, SJF = Strait of Juan de Fuca, SSH = summer run steelhead, WSH = winter run steelhead, N/A = data not available.

Region	Run type	Population	H+N, all years	H+N, 5 years	N, all years	N, 5 years
NPS	SSH	Canyon	N/A	N/A	N/A	N/A
NPS	SSH	Skagit	N/A	N/A	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A	N/A	N/A
NPS	WSH	Canyon	N/A	N/A	N/A	N/A
NPS	WSH	Dakota	N/A	N/A	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A	N/A	N/A
NPS	WSH	Samish	684.2	852.2	500.8	852.2
NPS	WSH	Skagit	7,720.4	5,608.5	6,993.9	5,418.8
NPS	WSH	Snohomish	5,283.0	3,230.1	5,283.0	3,230.1
NPS	WSH	Stillaguamish	1,027.7	550.2	1,027.7	550.2
NPS	SSH	Tolt	129.2	119.0	129.2	119.0
SPS	SSH	Green	N/A	N/A	N/A	N/A
SPS	WSH	Cedar	137.9	36.8	137.9	36.8
SPS	WSH	Green	2,050.6	1,625.5	1,802.1	1,619.7
SPS	WSH	Lk. Washington	247.1	36.8	308.0	36.8
SPS	WSH	Nisqually	1,136.7	392.4	1,115.9	392.4
SPS	WSH	Puyallup	1,881.5	1,001.0	1,714.4	907.3
HC	WSH	Dewatto	27.0	24.7	24.0	24.7
HC	WSH	Dosewallips	70.6	76.7	70.6	76.7
HC	WSH	Duckabush	16.6	17.7	16.6	17.7
HC	WSH	Hamma Hamma	29.6	51.9	29.6	51.9
HC	WSH	Quilcene	16.8	15.1	16.8	15.1
HC	WSH	Skokomish	439.3	202.8	439.3	202.8
HC	WSH	Tahuya	131.8	117.0	113.9	117.0
HC	WSH	Union	57.1	55.3	55.0	55.3
SJF	SSH	Elwha	N/A	N/A	N/A	N/A
SJF	WSH	Dungeness	311.2	173.8	311.2	173.8
SJF	WSH	Elwha	459.5	210.0	N/A	N/A
SJF	WSH	McDonald	N/A	N/A	149.8	96.1
SJF	WSH	Morse	132.6	103.0	105.8	103.0

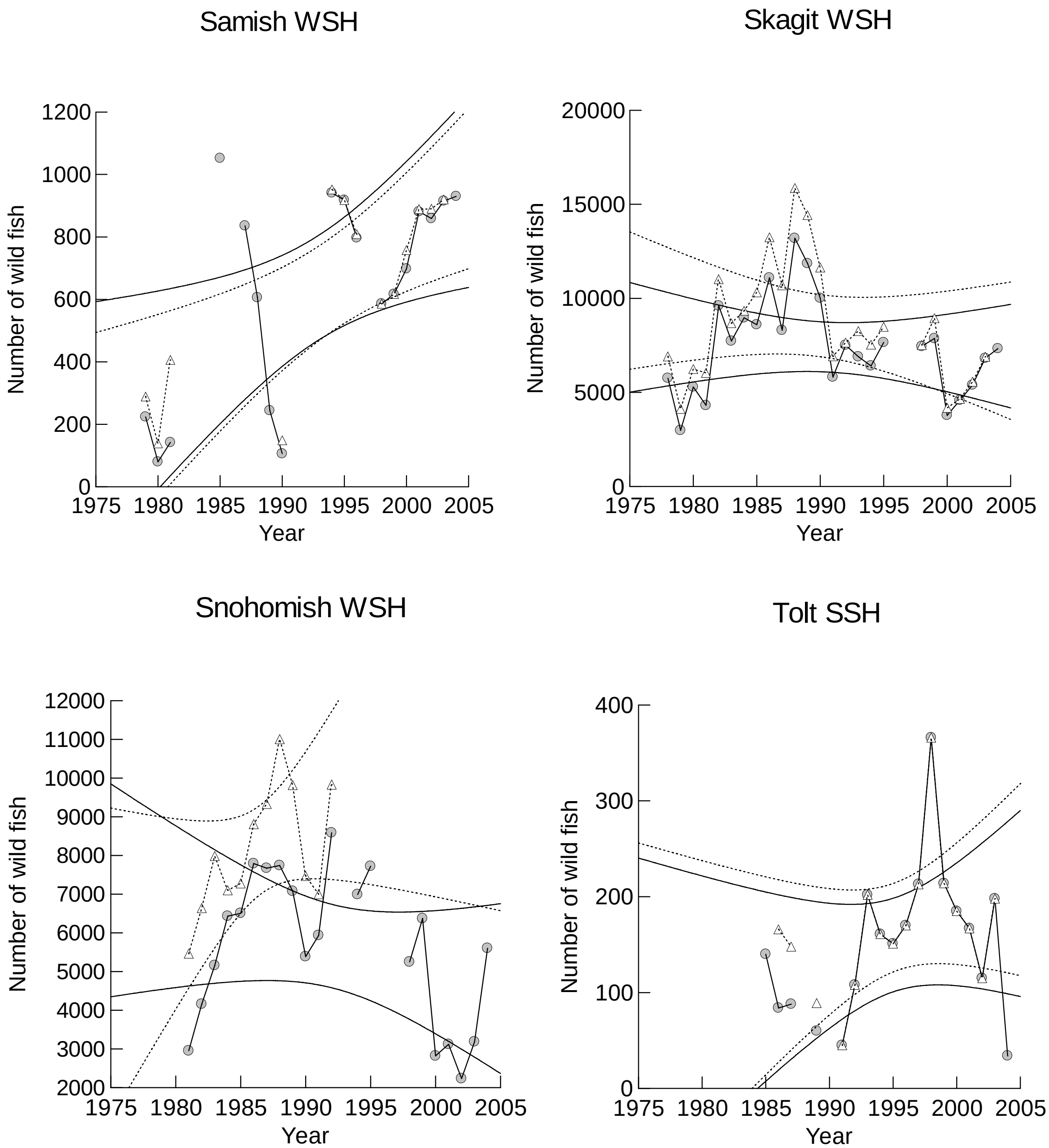
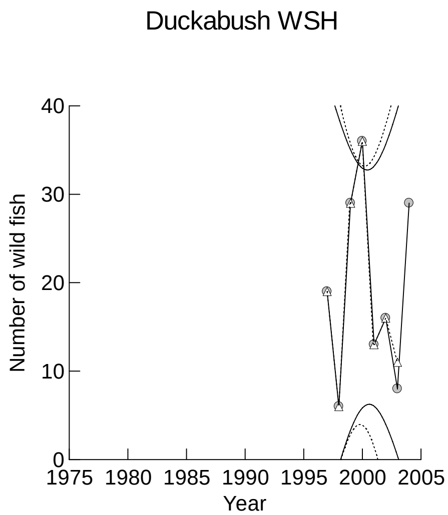
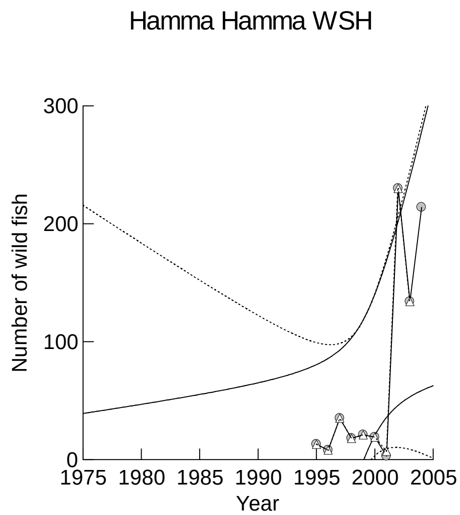
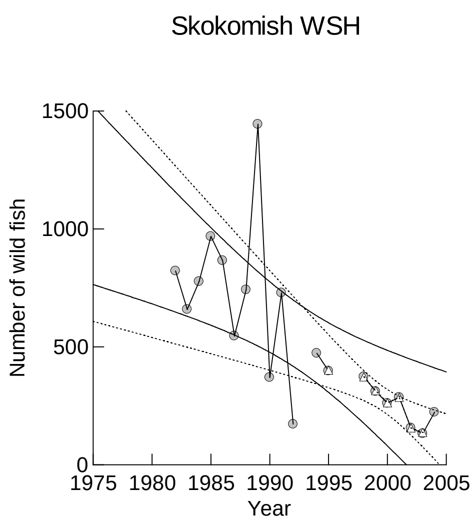
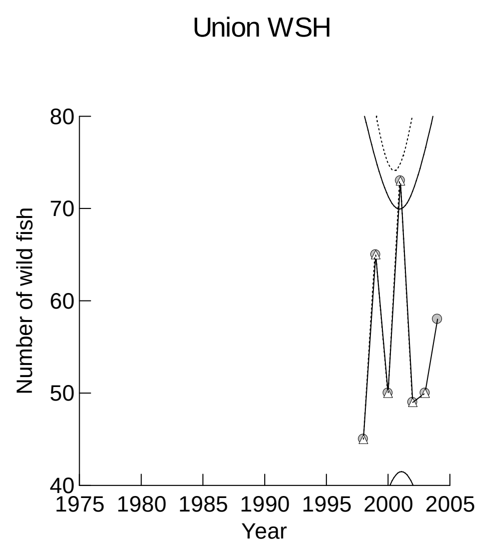


Figure 6. Trends in natural escapement and run size for steelhead in the northern Puget Sound region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–), run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish. Note that the Tolt population is a summer run population; all others are winter run populations. SSH = summer run steelhead, WSH = winter run steelhead.









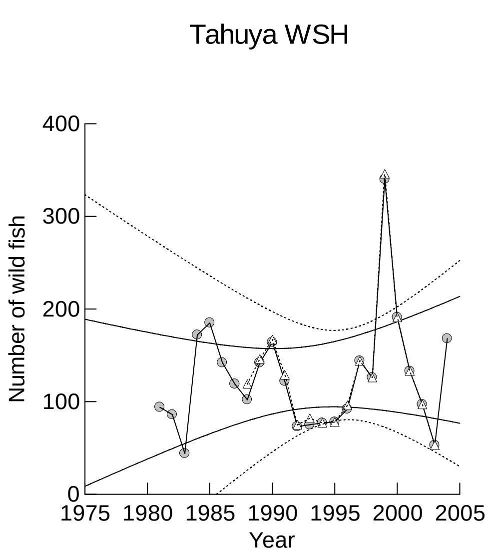
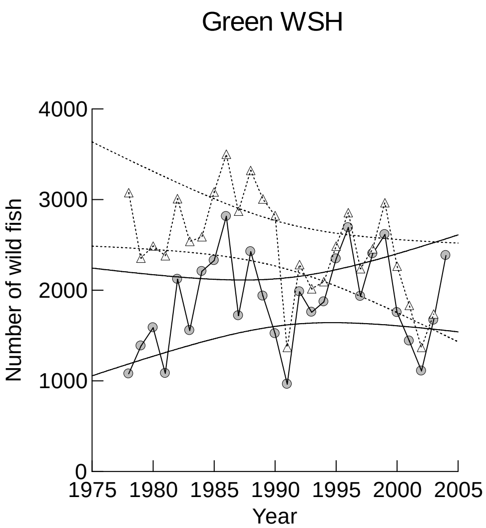


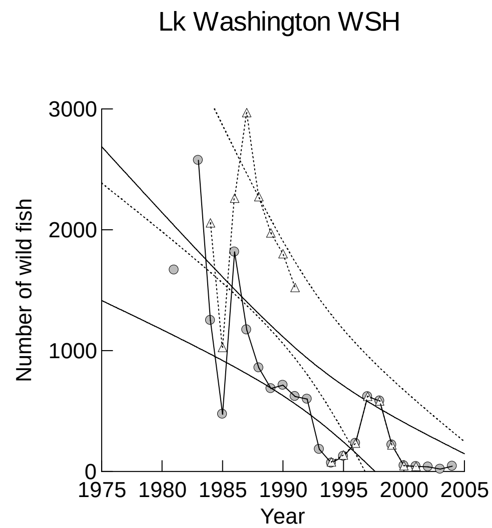
Figure 7. Trends in natural escapement and run size for steelhead in the Hood Canal region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–), run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish, except for the Hamma Hamma population, which has employed a hatchery supplementation program involving local broodstock since 2001. WSH = winter run steelhead.

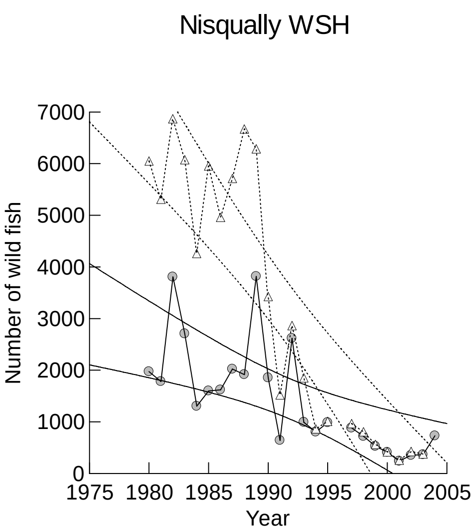
Table 8. Estimates of temporal trends in escapement (E) and total run size (R) (transformed by natural logarithms) for Puget Sound steelhead. Estimates are the slopes of the regressions of natural log (spawners or run size) on year. For each population, trends are provided for both the entire data set (all years) and for the most recent 10 years. Estimates are based on naturally produced fish. *, P < 0.05; **, P < 0.01; ***, P < 0.001; ****, P < 0.0001 (all other values are not significant).

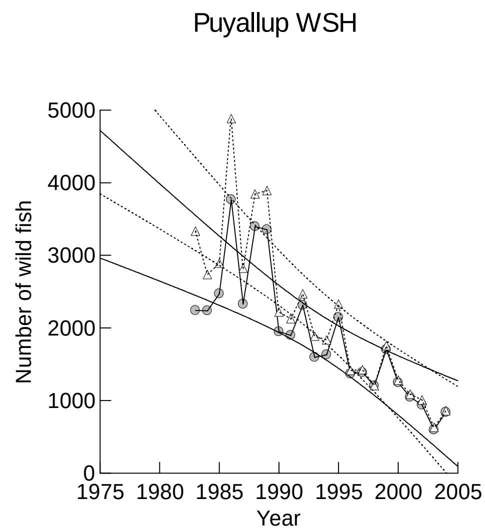
Region	Run type	Population	E, all years	E, 10 years	R, all years	R, 10 years
NPS[a]	SSH[b]	Canyon	N/A[c]	N/A	N/A	N/A
NPS	SSH	Skagit	N/A	N/A	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A	N/A	N/A
NPS	WSH[d]	Canyon	N/A	N/A	N/A	N/A
NPS	WSH	Dakota	N/A	N/A	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A	N/A	N/A
NPS	WSH	Samish	+0.067**	+0.061**	+0.019	+0.014
NPS	WSH	Skagit	–0.002	–0.010	–0.021	–0.056
NPS	WSH	Snohomish	–0.019	+0.035*	–0.086	N/A
NPS	WSH	Stillaguamish	–0.065****	N/A	–0.110*	N/A
NPS	SSH	Tolt	+0.025	+0.034	–0.107	–0.021
SPS[e]	SSH	Green	N/A	N/A	N/A	N/A
SPS	WSH	Cedar	–0.179**	N/A	–0.299*	N/A
SPS	WSH	Green	+0.008	–0.016**	–0.048	–0.069*
SPS	WSH	Lk. Washington	–0.180****	–0.215****	–0.300*	–0.274
SPS	WSH	Nisqually	–0.084****	–0.147****	–0.097	–0.159**
SPS	WSH	Puyallup	–0.062****	–0.074****	–0.103**	–0.103**
HC[f]	WSH	Dewatto	N/A	N/A	N/A	N/A
HC	WSH	Dosewallips	N/A	N/A	N/A	N/A
HC	WSH	Duckabush	+0.017	–0.018	+0.017	–0.019
HC	WSH	Hamma Hamma	+0.291*	+0.264	+0.291*	+0.264
HC	WSH	Quilcene	–0.006	N/A	–0.006	N/A
HC	WSH	Skokomish	–0.075****	–0.136**	–0.109*	–0.136**
HC	WSH	Tahuya	+0.009	–0.002	+0.004	–0.021
HC	WSH	Union	+0.008	+0.002	+0.008	+0.002
SJF[g]	SSH	Elwha	N/A	N/A	N/A	N/A
SJF	WSH	Dungeness	–0.076****	–0.093**	–0.083	–0.093
SJF	WSH	Elwha	N/A	N/A	N/A	N/A
SJF	WSH	McDonald	–0.031	+0.009	–0.362**	–0.221*
SJF	WSH	Morse	–0.006	–0.015	–0.030	–0.050

[a] NPS = Northern Puget Sound.
[b] SSH = Summer run steelhead.
[c] N/A = Data not available.
[d] WSH = Winter run steelhead.
[e] SPS = Southern Puget Sound.
[f] HC = Hood Canal.
[g] SJF = Strait of Juan de Fuca.









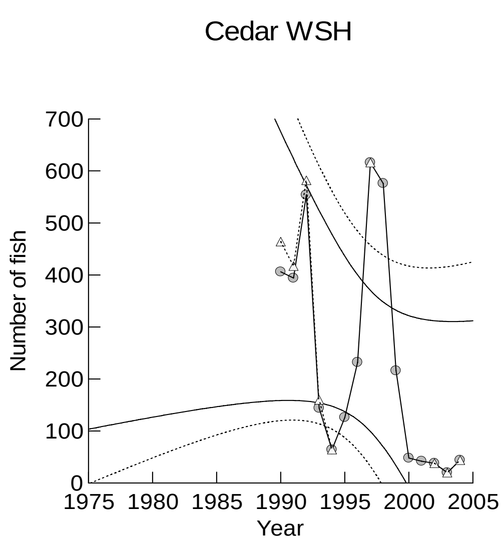


Figure 8. Trends in escapement and run size for steelhead in the southern Puget Sound region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–), run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish, except for the Cedar population, which includes hatchery as well as natural fish. WSH = winter run steelhead.

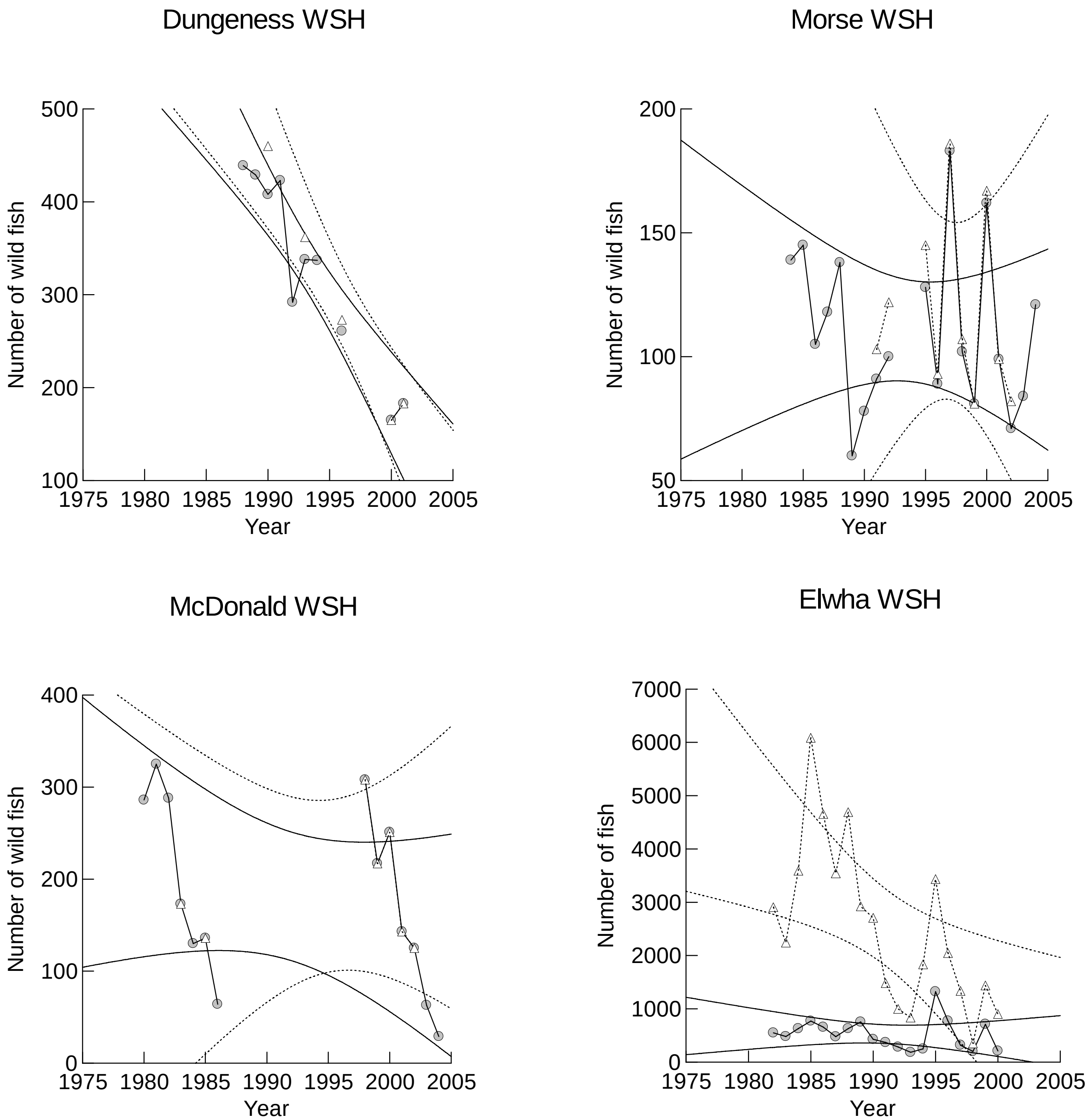


Figure 9. Trends in escapement and run size for steelhead in the Strait of Juan de Fuca region of the Puget Sound ESU. Escapements are represented by shaded circles and solid lines (–○–), run sizes are represented by open triangles and dotted lines (··Δ··). The curved lines indicate 95% confidence bounds of linear regressions of abundance on year (solid, escapement trends; dotted, run size trends). All estimates are for naturally produced fish, except for the Elwha population, which includes hatchery as well as natural fish (see Table 5). WSH = winter run steelhead.

Several of the negative trends in escapement of naturally produced fish result from peaks in natural escapement in the early 1980s. Trends over the most recent decade were also strongly negative for several populations, especially in southern Puget Sound (Green, Lake Washington, Nisqually, and Puyallup winter run), Hood Canal (Skokomish winter run), and along the Strait of

Juan de Fuca (Dungeness winter run) (Table 8 and Figures 8 and 9). Recent positive trends are evident in natural escapement for the Samish and Hamma Hamma winter run populations, and also in the Snohomish winter run (Table 8 and Figures 6 and 7).

Run sizes of naturally produced steelhead generally show less consistent temporal trends than escapement of naturally produced steelhead because of management for numerical escapement goals for steelhead in the ESU (Figures 6–9). Nevertheless, marked declines in natural run size are evident in all areas of the ESU, a pattern that reflects widespread reduced productivity of natural steelhead. Declines over the entire series are observed in northern Puget Sound (Stillaguamish winter run), southern Puget Sound (Cedar, Lake Washington, and Puyallup winter run), Hood Canal (Skokomish winter run), and along the Strait of Juan de Fuca (McDonald winter run) (Table 8 and Figures 8 and 9).

More recently, even sharper declines are observed in southern Puget Sound (Green and Nisqually winter run) and in Hood Canal (Skokomish winter run); significant declines persist in others, including southern Puget Sound (Puyallup winter run) and along the Strait of Juan de Fuca (McDonald winter run) (Table 8 and Figures 8 and 9). No population, with the exception of the small Hamma Hamma winter run, is showing evidence of improved productivity in more recent years, as measured by natural run size. During the BRT's discussion, one member familiar with the Hamma Hamma population indicated the recent increase in the Hamma Hamma River's run size was due to inclusion of fish produced from a hatchery supplementation program in the abundance estimates.

Throughout the ESU, natural steelhead production has shown at best a weak response to reduced harvest since the mid-1990s. Declines in natural production and productivity are most pervasive in southern Puget Sound but occur throughout much of the ESU. These trends reflect patterns primarily in winter run steelhead, for which available data are most plentiful.

Patterns for most summer run populations are unknown (Table 8). The trends in natural escapement and run size for summer run steelhead are best characterized in the Tolt River population, which is showing weak increases in escapement but weak declines in run size, both over the entire data series and in more recent years (Table 8 and Figure 6).

The BRT noted declines in productivity in Puget Sound steelhead show remarkable similarity to those observed for steelhead in British Columbia, especially along the Strait of Georgia and eastern Vancouver Island. The declines in abundance and productivity of these Canadian populations appear to have accelerated since about 1990; the reasons for the declines remain unknown but potential causes include changes in climate (measured as changes in coastal upwelling, various ocean and atmospheric climate indices, and freshwater habitat quality), hatchery production and harvest management, and increased ultraviolet radiation (Smith and Ward 2000, Smith et al. 2000, Ward 2000, and Welch et al. 2000).

Population Growth Rate

The BRT estimated median population growth rates (λ) for several populations in the ESU, using the 4-year running sums method described above (Holmes 2001, Holmes and Fagan 2002, see also McClure et al. 2003). Actual age-structure data was available for only five winter run populations (the Skagit, Snohomish, Stillaguamish, Nisqually, and Puyallup); for the others, an average age structure was applied based on a mean of age structures within the region or across the ESU. As expected the estimates of λ (Table 9) are consistent with the trends in natural run size: λ is less than one, indicating declining population growth, for nearly all populations in the ESU. Exceptions include the Tolt summer run population in northern Puget Sound and the Dewatto and Hamma Hamma winter run populations in Hood Canal. Of the populations showing evidence of declining recent population growth, some show only slight declines (e.g., Samish and Skagit winter run in northern Puget Sound, and Quilcene and Tahuya winter run in Hood Canal).

However, most other populations show more pronounced declines, and these populations are distributed across the ESU. Estimates of population growth rate are alarmingly low for several populations throughout the ESU. These populations include the Snohomish and Stillaguamish winter run in northern Puget Sound; the Cedar, Lake Washington, and Puyallup winter run in southern Puget Sound; Skokomish winter run in Hood Canal; and McDonald winter run along the Strait of Juan de Fuca. If the analyses are restricted to populations for which natural production data could be used to compute population growth rates, the Snohomish winter run (northern Puget Sound) and Puyallup winter run (southern Puget Sound) populations show evidence of significantly declining growth rate (Table 9). Thus there is evidence for declining population growth in large winter run populations in the major production areas of northern and southern Puget Sound. Relevant data are not available for nearly all of the smaller populations, several of which show some evidence for declines. Similarly, relevant data are not available for virtually all summer run populations in the ESU; the sole exception is the Tolt summer run population, which is showing evidence of increasing productivity. Trends in marine survival were not available for any of the populations in the ESU.

Recruitment

Estimates of natural recruitment (naturally produced recruits per spawner [R/S]) are highly variable among populations (Table 10). Low estimates (R/S < 1) are represented in winter run populations across the ESU range: the Stillaguamish winter run (northern Puget Sound), Puyallup winter run (southern Puget Sound), Skokomish winter run (Hood Canal), and Dungeness and Morse winter run (Strait of Juan de Fuca). High estimates (R/S > 1) are also represented in winter run populations across most of the ESU range: the Skagit and Snohomish winter run (northern Puget Sound); Cedar, Green and Nisqually winter run (southern Puget Sound); and Dewatto and Tahuya winter run (Hood Canal). Most estimates, regardless of size, have high sampling variances (Table 10), and most time series are too short to account for autocorrelation.

Trends in R/S over time, where they are significant, generally reflect declines in natural recruitment rate. Declines in natural recruitment rate are evident in both of the largest populations in northern Puget Sound, the Skagit and Snohomish winter run populations (Table 10). Significant declines are also evident in the Green and Puyallup winter run populations in southern Puget Sound, and in the Skokomish winter run population in Hood Canal. The Cedar winter run population in southern Puget Sound shows evidence of strongly increasing recruitment, but this may be due to one or two strong cohorts in the 1990s (Figure 7).

Table 9. Median short-term population growth rate estimates (λ) and their 95% confidence intervals for Puget Sound steelhead. For each population, estimates are computed for the most recent 10 years of data, 1995–2004. Estimates in boldface are based on natural spawners alone, according to WDFW delineations of hatchery and natural fish (note that the "natural" Hamma Hamma population has included a supplementation program since 2001).

Region	Run type	Population	λ	95% CI (λ)
NPS[a]	SSH[b]	Canyon	N/A[c]	N/A
NPS	SSH	Skagit	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A
NPS	WSH[d]	Canyon	N/A	N/A
NPS	WSH	Dakota	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A
NPS	WSH	Samish	0.988	0.997-0.998
NPS	WSH	Skagit	0.997	0.997-0.998
NPS	WSH	Snohomish	**0.804**	N/A
NPS	WSH	Stillaguamish	**0.885**	**0.884-0.885**
NPS	SSH	Tolt	1.018	1.017-1.018
SPS[e]	SSH	Green	N/A	N/A
SPS	WSH	Cedar	**0.808**	**0.804-0.811**
SPS	WSH	Green	0.932	0.932-0.933
SPS	WSH	Lk. Washington	0.802	0.800-0.803
SPS	WSH	Nisqually	0.918	0.917-0.918
SPS	WSH	Puyallup	**0.882**	**0.881-0.882**
HC[f]	WSH	Dewatto	**1.020**	**1.008-1.020**
HC	WSH	Dosewallips	N/A	N/A
HC	WSH	Duckabush	N/A	N/A
HC	WSH	Hamma Hamma	1.013	N/A
HC	WSH	Quilcene	**0.988**	N/A
HC	WSH	Skokomish	**0.865**	N/A
HC	WSH	Tahuya	0.983	0.982-0.983
HC	WSH	Union	**0.969**	N/A
SJF[g]	SSH	Elwha	N/A	N/A
SJF	WSH	Dungeness	0.924	0.924-0.924
SJF	WSH	Elwha	0.966	0.965-0.966
SJF	WSH	McDonald	**0.732**	N/A
SJF	WSH	Morse	0.945	0.945-0.946

[a] NPS = Northern Puget Sound.
[b] SSH = summer run steelhead.
[c] N/A = not available.
[d] WSH = winter run steelhead.
[e] SPS = Southern Puget Sound.
[f] HC = Hood Canal.
[g] SJF = Strait of Juan de Fuca.

Table 10. Means and variances of recruits per spawner, and estimates of the slope of the regression of recruits per spawner on year, for Puget Sound steelhead. Estimates are based on naturally produced spawners. Estimates in italics are computed from empirical age-structure estimates; all others assume an average age structure constructed for each region (Gayeski 2005). An asterisk indicates a significant (P < 0.05) temporal trend in recruits per spawner.

Region	Run type	Population	Mean R/S	Variance in R/S	Slope, R/S vs. year
NPS[a]	SSH[b]	Canyon	N/A[c]	N/A	N/A
NPS	SSH	Skagit	N/A	N/A	N/A
NPS	SSH	Snohomish	N/A	N/A	N/A
NPS	SSH	Stillaguamish	N/A	N/A	N/A
NPS	WSH[d]	Canyon	N/A	N/A	N/A
NPS	WSH	Dakota	N/A	N/A	N/A
NPS	WSH	Nooksack	N/A	N/A	N/A
NPS	WSH	Samish	N/A	N/A	N/A
NPS	WSH	Skagit	*1.460*	*0.457*	*–0.148**
NPS	WSH	Snohomish	*1.294*	*0.285*	*–0.156**
NPS	WSH	Stillaguamish	*0.686*	*0.034*	*–0.054*
NPS	SSH	Tolt	N/A	N/A	N/A
SPS[e]	SSH	Green	N/A	N/A	N/A
SPS	WSH	Cedar	2.302	6.608	+1.499*
SPS	WSH	Green	1.218	0.253	–0.127*
SPS	WSH	Lk. Washington	N/A	N/A	N/A
SPS	WSH	Nisqually	*1.327*	*0.647*	*+0.578*
SPS	WSH	Puyallup	*0.848*	*9.989*	*–0.052**
HC[f]	WSH	Dewatto	1.945	4.725	–0.182
HC	WSH	Dosewallips	N/A	N/A	N/A
HC	WSH	Duckabush	N/A	N/A	N/A
HC	WSH	Hamma Hamma	N/A	N/A	N/A
HC	WSH	Quilcene	N/A	N/A	N/A
HC	WSH	Skokomish	0.785	0.125	–0.113*
HC	WSH	Tahuya	1.640	2.109	–0.028
HC	WSH	Union	N/A	N/A	N/A
SJF[g]	SSH	Elwha	N/A	N/A	N/A
SJF	WSH	Dungeness	0.758	0.001	+0.030
SJF	WSH	Elwha	N/A	N/A	N/A
SJF	WSH	McDonald	N/A	N/A	N/A
SJF	WSH	Morse	0.819	0.094	+0.063

[a] NPS: Northern Puget Sound.
[b] SSH: Summer run steelhead.
[c] N/A: Data not available.
[d] WSH: Winter run steelhead.
[e] SPS: Southern Puget Sound.
[f] HC: Hood Canal.
[g] SJF: Strait of Juan de Fuca.

Washington Trout Analysis of Puget Sound Steelhead Productivity

Washington Trout (WT) submitted to the BRT an analysis of productivity in five major winter run steelhead populations of the Puget Sound ESU (Gayeski 2005) for consideration as part of the evaluation of the listing petition. The five populations were the Nisqually, Puyallup, Snohomish, Stillaguamish, and Skagit. WT asserted these five populations represent a broad spatial array of populations in the ESU and include its two most robust steelhead populations, in the Skagit and the Snohomish rivers. WT stated this analysis would therefore provide a conservative assessment of the recent productivity of the ESU.

WT evaluated stock-recruit data derived from natural run size and escapement data provided by WDFW, using age composition from Skagit River winter run steelhead sampled in the late 1980s and early 1990s for analyses of the three northernmost populations (Snohomish, Stillaguamish, and Skagit), and age composition skewed toward younger fish for Puyallup and Nisqually. WT's recruitment analyses encompassed data through years 2001 for the Stillaguamish population, to 2002 for the Snohomish and Nisqually, and 2003 for the Puyallup and Skagit populations.

The analyses involved primarily fitting spawner-recruit data to two density-dependent stock recruit models, the Ricker and Beverton-Holt models, and examining the detrended residuals from the fitted estimates. WT's analyses indicated a substantial declining trend in the time series of spawning and recruitment for all five populations since the late 1980s (similar to that observed in several coastal steelhead populations in southern British Columbia [Smith and Ward 2000, Smith et al. 2000, Ward 2000, Welch et al. 2000]). A principal components analysis of the residuals indicated a common response in the populations.

WT concluded from its analysis these populations of winter run steelhead in the Puget Sound Steelhead ESU have experienced a period of pronounced declines in abundance, recruitment, and productivity beginning around 1989 and continuing to the present. WT also concluded the strongly coherent pattern among the five populations indicates the declines are ESU-wide or nearly so.

The BRT examined WT's analysis and comments on it submitted by comanagers and two scientists from the NWFSC familiar with the analytical approach. Their comments indicated the analysis suffers from several problems, most of which stem from either the use of an average age structure to estimate recruits or failing to account for errors in estimates of spawner abundance. Zabel and Levin (2002) showed that failing to account for temporal variability in age structure can bias estimates of productivity by overestimating recruitment in small cohorts and underestimating recruitment in large cohorts. R. Kope of the BRT, in an unpublished manuscript, has further explored this problem and found a similar pattern but indicated additional biases may result in even more complex effects on the estimates. In its own analyses, the BRT could not avoid all these sources of bias but tried to minimize them by basing calculations on empirical age structure distributions that varied over time, where they were available, and identifying where this was not possible.

The BRT noted the fit of the stock-recruit data was not evaluated quantitatively by WT, and the BRT therefore attempted to fit these data to alternative models. In general the fit of the data to either the Ricker or the Beverton-Holt model was very poor; for each of the five populations, a simple density-independent model such as the random-walk model with trend (Bulmer 1975) provided fits equally as good (analyses not shown). Nevertheless, the fits to the random-walk model were also poor.

One commenter familiar with the data pointed out WT's analysis was also plagued by errors in estimates of spawners or recruits. He observed natural escapement estimates for most of these populations are still higher than current maximum sustained yield escapement levels. Thus the reviewer questioned the validity of the analysis and WT's conclusions drawn from it. After a review of these comments and its own analysis of productivity described above, the BRT concluded that, although these issues with the analysis taken collectively cast some doubt on the specific values of the stock-recruitment estimates and the precise magnitude of the trends in productivity, a general decline in productivity is still evident from the data. The BRT noted this decline is consistent with the declines observed in most populations from a simple examination of temporal trend in natural run size, and is apparent to some degree even in the two largest populations, the Skagit and Snohomish (Figure 6).

The BRT explicitly considered both the potential positive and potential negative effects of hatchery production on the ESU. Because the BRT considered virtually all hatchery steelhead produced in Puget Sound to be excluded from the Puget Sound Steelhead ESU, the BRT determined the negative effects of these programs were almost certain to outweigh any potential positive effects. The two "in ESU" programs, the Hamma Hamma River and the Green River, have the potential to benefit natural populations in those rivers, but neither program has yet collected sufficient data to estimate their positive (or negative) effects with any certainty. It does appear the Hamma Hamma program has successfully increased the number of natural spawners in the population, but the success of the program will not be known until the natural offspring of the captively reared spawners return (Berejikian et al. 2004).

Risks associated with hatchery programs in Puget Sound included potential effects of outbreeding depression resulting from the natural interbreeding of hatchery and wild fish, and adverse ecological interactions between hatchery and wild steelhead, including density-dependent effects on growth and survival. Some BRT members believe one or both of these effects may be contributing to the declines in natural steelhead productivity, but the magnitude of the contribution could not be ascertained. In contrast to statements made in the petition (Wright 2004), WDFW indicated the magnitude of hatchery releases had not increased in recent years and offsite releases had been reduced (see Appendix D for release records). Several BRT members were concerned the genetic effects of hatchery-wild interactions are cumulative and the risk to wild populations is increasing over time, even if the absolute numbers of released hatchery fish have been reduced.

Risk Assessment Conclusions

Each of the BRT members assessed the contribution to extinction risk of Puget Sound steelhead for each of the four VSP criteria: abundance, productivity, diversity, and connectivity/spatial structure. Each member used a scale of 1 (very low risk) to 5 (very high risk) (see Table 6). In evaluating the four VSP criteria, the BRT concluded that low and declining abundance and low and declining productivity were substantial risk factors for the ESU. Loss of diversity and spatial structure were judged to be moderate risk factors.

Abundance

For this VSP criterion and risk category, the BRT's scores ranged from 3 to 4, with a modal value of 4 (mean, 3.7). These scores reflect the BRT's assessment that the risk of declining steelhead abundance to ESU viability is high. Because of the BRT's conclusion that virtually all hatchery summer run and winter run steelhead populations in Puget Sound should be considered to be excluded from the ESU, the BRT focused its attention where possible on abundance of naturally produced fish. Trends in escapement and run size of natural steelhead were predominantly downward throughout much of the ESU, over both longer-term (since about 1980 for most systems) and shorter-term (since the mid-1990s) time series. For several populations, the shorter-term trends are even more sharply negative than the longer-term trends that incorporate large abundance estimates for several populations in the early 1980s.

All BRT members noted the declines in both natural escapement and natural run size for the two largest steelhead populations in the ESU (the Skagit and Snohomish river winter run populations in northern Puget Sound), and observed that most of the other populations in the ESU are small, especially those in Hood Canal and the Strait of Juan de Fuca. These trends have occurred despite widespread reductions in direct harvest of natural steelhead in this ESU since the mid-1990s. Although steelhead populations in large systems such as the Skagit and Snohomish rivers remain relatively large (>5,000 natural adults annually), the escapements are still far below those estimated as recently as the mid-1980s, when harvest rates on natural fish were higher. Other populations in the ESU are substantially smaller, some as large as 500–1,000 adults but many exhibiting natural spawning escapements <50–100 fish annually. Summer run population abundances were all small, and although historically they may never have been very large, there was concern regarding considerable number of populations for which no data were available.

Growth/Productivity

For this VSP criterion and risk category, the BRT's scores ranged from 3 to 5, with a modal value of 4 (mean, 4.0). These scores reflect an assessment that declining steelhead productivity poses high risk to ESU viability. The BRT noted natural run sizes (sum of harvest and escapement) for most populations show even more marked declining trends than indicated by escapements, indicating the substantially reduced harvest rates for natural fish since the early 1990s have not resulted in a rebound in steelhead production in Puget Sound. Estimates of the mean number of recruits per spawner are less than 1.0 in several systems, as are long-term population growth rates (λ); it is not known whether, as is the case for some British Columbia steelhead populations (Smith and Ward 2000, Ward 2000, Welch et al. 2000), there is also evidence of declining smolt-adult survival rates.

For many of the Puget Sound populations, the decline in adult recruits per spawner has been precipitous. Each of these measures reflects productivity declining to levels that indicate unsustainable long-term natural steelhead production if the trends continue unabated. A single exception is the relatively small Samish River winter run steelhead population in northern Puget Sound, which has shown strong upward trends in abundance and productivity in recent years.

Diversity

For this VSP criterion and risk category, the BRT's scores ranged from 2 to 4, with a modal value of 3 (mean, 3.1). These scores reflect an assessment that current *O. mykiss* diversity in the ESU poses moderate risk to ESU viability. Most BRT members expressed concern over the status of the summer run populations of steelhead in the ESU. Populations of summer run steelhead occur throughout the Puget Sound ESU but are concentrated in northern Puget Sound area, are generally small, and are characterized as isolated populations adapted to streams with distinct attributes. For the one summer run population that has associated natural escapement and run size data, the BRT observed the trend in abundance was predominantly negative. Indeed, several BRT members were concerned that some historical accounts discuss significant early runs of wild fish, but that these early wild spawners have apparently disappeared from several systems. The largest summer run steelhead population in Puget Sound is in the Tolt River; this population exhibits a negative trend in natural run size and a flat trend in natural escapement. Most other populations are very small, with annual escapements below 50 fish, and some include substantial production of Skamania stock summer run hatchery fish (e.g., the Green River and South Fork Skykomish populations).

Although offsite releases and releases of steelhead fry and parr have largely ceased in the ESU, annual releases of hatchery steelhead smolts derived from nonlocal populations (Skamania summer run steelhead) or from domesticated populations originally founded within the ESU (Chambers Creek winter run steelhead) persist in most systems, and several of these releases are still composed of tens or hundreds of thousands of fish. This sustained hatchery management practice has elevated opportunities for interbreeding and ecological interaction between wild and hatchery fish in spite of the apparent differences in average spawning time, and its associated adverse fitness consequences for both summer and winter run steelhead. As one BRT member noted, even low levels (e.g., <5%) of gene flow per year from a non-ESU hatchery stock to a naturally spawning population can have a highly significant genetic impact after several generations. High harvest rates before the mid-1990s may have removed a substantial proportion of wild summer run and early-returning/spawning wild winter run fish from many of these systems.

Present day high harvest rates for marked hatchery origin fish are likely to result in continued mortality of early returning naturally spawning steelhead through poaching and hook-and-release mortalities. For example, although unmarked natural origin steelhead must be released in most streams, restricted sport fishing gear that precludes baited hooks may not be required. Several BRT members were concerned that interbreeding with hatchery steelhead may be contributing to reduced productivity of natural fish. Several members also believed the presence of these hatchery fish is likely to pose an ecological threat to wild fish through competition in estuaries and marine environments, manifested as reductions in density-dependent growth and survival at critical life history stages.

Alternatively, some BRT members indicated any conclusions about changes in diversity in this ESU are constrained by the lack of data on changes in age structure, life history, or genetic diversity in Puget Sound *O. mykiss*, especially for resident fish.

Spatial Structure/Connectivity

For this VSP criterion and risk category, the BRT's scores ranged from 2 to 4, with a modal value of 3 (mean, 2.8). These scores reflect an assessment that spatial structure of *O. mykiss* in the ESU poses moderate risk to its viability. A strong majority of BRT members concluded the ESU is likely to be at elevated risk due to reduced complexity of spatial structure of its steelhead populations and, consequently, diminishing connectivity among them. Several members believed declines in natural abundance for most populations, coupled with large numbers of anthropogenic barriers such as impassable culverts, sharply reduce opportunities for natural adfluvial movement and migration between steelhead aggregations in different watersheds.

The sharp reduction in escapement of natural steelhead to the centrally located Lake Washington watershed in recent years was of considerable concern to most BRT members, especially given the weakening trends in abundance for populations in neighboring Puget Sound systems. Nevertheless, most BRT members believed rainbow trout below migration barriers in watersheds throughout the ESU may provide short-term buffers against demographic stochasticity in many of these populations. However, the lack of information on abundance and distribution on rainbow trout in Puget Sound watersheds makes it impossible to characterize the effectiveness of such buffers. In general resident rainbow trout are considered a relatively minor component of these anadromous populations, based on field surveys of juvenile fish in fresh water.

Recent Events

For recent events, the BRT's scores ranged from double minus to double plus (– – to ++), with a modal value of 0. These scores reflect an assessment that recent events, considered collectively, are likely to have a minor impact (positive or negative) on ESU viability. Reduced harvest levels and recent changes in management of natural steelhead, the recent onset of recovery efforts in Puget Sound and Hood Canal for Chinook salmon and summer run chum salmon prompted by the listing of those ESUs, and reduced off-site plantings of hatchery steelhead were all considered as recent positive actions.

However, continued releases of out-of-ESU hatchery summer and winter run steelhead throughout the region, reductions in escapement goals to help support harvest opportunity in several systems (e.g., the Skagit River where WDFW has reduced natural fish escapement goals from 10,000 adults/year to 6,000), evidence for diminishing marine survival rates, a recent increase in the PDO Index reflecting a general climate change in the region toward warmer, drier conditions (Figure 10), increases in pinniped populations in Puget Sound, degradation of water quality in Hood Canal and southern Puget Sound, and continued land development and urbanization with associated impacts on freshwater habitat are likely to increase risk to the ESU. The effects of these recent positive and negative events are difficult to estimate; most members concluded the net effect is likely to be neutral or possibly slightly negative.

Overall Risk

The BRT's scores for overall risk category, as specified for all or a significant portion of the range of the ESU, ranged from "neither at risk of extinction nor likely to become so" to "at risk of extinction," with a strong majority of members considering the ESU "likely to become at risk of extinction" in the foreseeable future. Uncertainty among the members in this conclusion was relatively low, and overall risk scores were highly consistent. Two of the 13 BRT members allocated their 10 likelihood points between the "not at risk" and "likely to become at risk of extinction" risk categories at ratios of 60–70% (6–7 points) and 30–40% (3–4 points), respectively. However, all other members allocated at least 6 (and some at least 9) of their 10 points to the "likely to become at risk of extinction" category. No BRT member allocated more than 2 of their points to the "at risk of extinction" category. Thus the conclusion that steelhead in the Puget Sound ESU are likely to become at risk of extinction in the foreseeable future in all or a significant portion of their range—but are not currently in danger of extinction—reflected the collective scientific opinion of an overwhelming majority of the BRT.

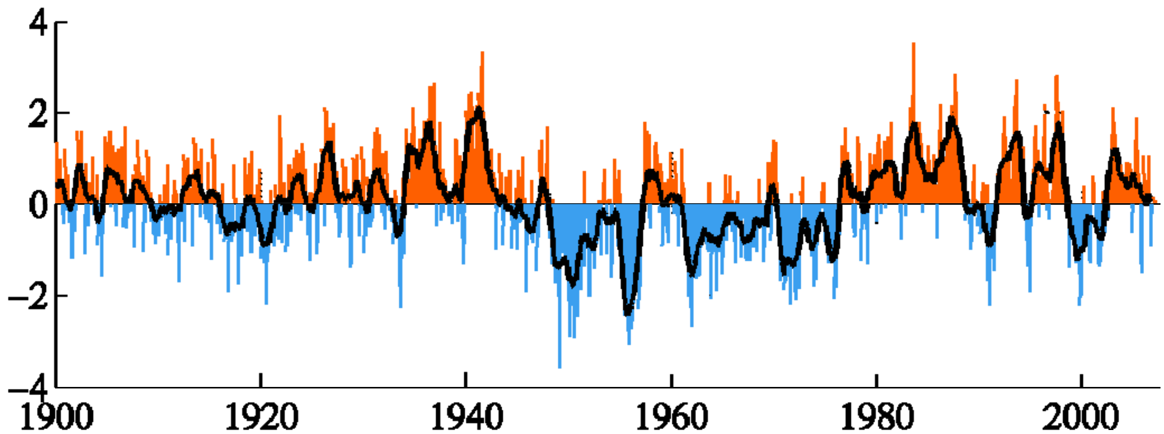


Figure 10. Monthly values for the Pacific Decadal Oscillation (PDO) index, 1900–2007, which is based on sea surface temperatures in the North Pacific. Values shown are deviations from the long-term mean. The negative values of the index reflect "cool" PDO regimes, while the positive values reflect "warm" PDO regimes (like those dominating from 1925–1946 and from 1977 through (at least) the mid-1990s. Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm periods have seen enhanced coastal ocean biological productivity in Alaska and reduced productivity off the West Coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity. (Source: Online at http://tao.atmos.washington.edu/pdo/.)

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Appendix A: Survey of Steelhead Abundance

The Washington Department of Fisheries and Game conducted a survey of steelhead (*Oncorhynchus mykiss*) abundance in Puget Sound streams during 1929 and 1930 (Table A-1). Abundance codes (from the original source, WDFG 1932): A = large, B = medium, C = scarce, D = very scarce, X = absent. N/A = not available.

Table A-1. Survey of steelhead abundance.

Watershed	Main river	Tributaries	Migration distance	Survey date	Abundance
Whatcom Co.		California Cr.	12.0	7/1/1930	X
		Dakota Cr.	10.0	6/30/1930	B
		Terrill Cr.	N/A	7/1/1930	X
Nooksack River	Nooksack River		33.0		B
		Ten Mile Cr.	N/A	6/11/1930	X
		Betrand Cr.	10.0	6/11/1930	D
		Fishtrap Cr.	10.0	6/10/1930	X
		Anderson Cr.	7.0	6/12/1930	X
		Weiser Cr.	N/A	6/10/1930	X
		Smith Cr.	4.0	6/12/1930	X
	South Fork Nooksack River		43.0	7/10/1930	B
		Hutchinson Cr.	0.5	7/15/1930	B
		Skookum Cr.	12.0	7/2/1930	B
		Edfro Cr.	NA	7/3/1930	X
		Cavanaugh Cr.	N/A	7/3/1930	X
		Howard Cr.	N/A	7/15/1930	X
	North Fork Nooksack River		30.0	6/25/1930	B
		Wells Cr.	N/A	6/26/1930	X
		Thompson Cr.	3.5	6/23/1930	X
		Racehorse Cr.	4.0	6/21/1930	C
		Maple Cr.	1.0	6/20/1930	D
		Kendall Cr.	6.0	6/21/1930	C
		Glacier Cr.	8.0	6/23/1930	X
		Deadhorse Cr.	N/A	6/26/1930	X
		Cornell Cr.	0.8	6/24/1930	D
		Coal Cr.	0.3	6/16/1930	D
		Cascade Cr.	0.3	6/26/1930	C
		Canyon Cr.	1.0	6/20/1930	X
		Boulder Cr.	1.5	6/20/1930	X
		Bell Cr.	5.0	6/16/1930	C
		Bear Cr.	3.0	6/21/1930	X

Table A-1 continued. Survey of steelhead abundance.

Watershed	Main river	Tributaries	Migration distance	Survey date	Abundance
Nooksak River continued	Middle Fork Nooksack River		8.0	6/24/1930	C
		Galbraith Cr.	N/A	6/24/1930	X
		Canyon Creek	2.5	6/23/1930	B
		Clearwater Cr.	N/A	6/19/1930	X
		Porter Creek	1.5	6/19/1930	X
Skagit	Skagit River		80.0	3/29/1930	A
		Powell Creek	5.0	5/12/1930	D
		Sorenson Cr.	4.5	5/17/1930	X
		Alder Creek	7.0	5/23/1930	D
		Finney Creek	9.0	7/18/1930	A
		Nookachamps Cr.	15.0	5/8/1930	D
		Boyds Creek	N/A	5/27/1930	X
		Cumberland Cr.	1.0	5/22/1930	D
		Day Creek	12.0	5/14/1930	C
		Gilligan Creek	2.0	5/17/1930	C
		Grandy Creek	7.0	5/21/1930	A
		Hansen Creek	7.0	5/15/1930	X
		Jones Creek	7.0	5/19/1930	X
		Loretta Creek	2.0	5/22/1930	C
		Mill Creek	1.5	5/28/1930	D
		Muddy Creek	6.0	5/26/1930	X
		O'Toole Creek	0.5	5/27/1930	D
		Pressentin Cr.	1.0	5/29/1930	D
		Red Cabin Cr.	5.0	5/20/1930	X
		Slide Creek	N/A	6/5/1930	X
		Swift Creek	1.0	6/8/1930	X
		Bacon Creek	8.0	6/7/1930	A
		Diobsud Creek	3.0	6/2/1930	C
		Illabat Creek	12.0	7/5/1930	D
		Jackman Creek	2.0	6/4/1930	X
		Rocky Creek	N/A	6/3/1930	X
	Baker River		17.50	8/25/1930	B
		Rocky Creek	N/A	8/16/1930	X
		Sulphur Creek	N/A	8/16/1930	X
		Bear Creek	N/A	8/15/1930	X
		Big Creek	N/A	8/15/1930	X
		Silver Creek	N/A	8/28/1930	X
		Morovitz Creek	4.0	8/28/1930	C
		Thunder Creek	N/A	8/28/1930	X
	Cascade River		11.0	8/8/1930	B
		Jordan Creek	5.5	8/6/1930	A
		Marble Creek	1.0	8/7/1930	C
		Boulder Creek	1.0	8/8/1930	C
		Clark Creek	1.0	8/6/1930	X
		Sibley Creek	0.5	8/7/1930	C

Table A-1 continued. Survey of steelhead abundance.

Watershed	Main river	Tributaries	Migration distance	Survey date	Abundance
Skagit River continued	Sauk River		29.0	8/14/1930	B
		Dan Creek	3.0	8/4/1930	B
		Backman Cr.	0.8	8/1/1930	C
		Clear Creek	1.0	7/31/1930	C
		Goodman Cr.	1.0	8/1/1930	D
		Murphy Creek	0.5	8/1/1930	C
		Copper Creek	N/A	8/4/1930	X
		Texas Creek	1.0	6/8/1930	X
	Suiattle River		10.5	8/14/1930	C
		Tenas Creek	1.5	8/13/1930	X
		Big Creek	1.5	8/13/1930	D
Stillaguamish River	Stillaguamish River		15.0	7/1929	A
		Pilchuck Cr.	10.0	7/1929	B
		Harvey Creek	4.0	7/1929	C
	North Fork Stillaguamish R.		40.0	7/1929	A
		Rock Creek	2.0	7/1929	C
		Bucker Hill Cr.	N/A	7/1929	X
		Deer Creek	35.0	7/1929	A
		Grant Creek	2.0	7/1929	C
		Boulder Creek	6.0	7/1929	B
		French Creek	3.0	7/1929	B
		Squire Creek	12.0	7/1929	B
	South Fork Stillaguamish R.		15.0	7/1929	A
		Jim Creek	6.0	7/1929	B
		Canyon Creek	2.0	7/1929	A
Snohomish River	Snohomish River		25.0	6/1/1929	A
		Heartgravel Slough	N/A	6/1/1929	X
		Slough No. 2	N/A	6/2/1929	X
		Slough No. 3	N/A	6/2/1929	X
	Pilchuck River		25.0	6/5/1929	A
		Sexton Creek	1.0	6/3/1929	X
		T N Creek	5.0	6/8/1929	C
		T M Creek	1.0	6/8/1929	D
		T L Creek	1.0	6/9/1929	D
		T H Creek	N/A	6/10/1929	X
		West Branch	8.0	6/15/1929	C
		T O Creek	3.0	6/16/1929	D
		T R. Creek	4.0	6/18/1929	D
		T P Creek	1.0	6/17/1929	D
		French Creek	2.0	6/19/1929	X

Table A-1 continued. Survey of steelhead abundance.

Watershed	Main river	Tributaries	Migration distance	Survey date	Abundance
Snohomish River continued	Skykomish River		40.0	6/28/1929	A
		Woods Creek	7.0	7/2/1929	B
		WF Woods Cr.	12.0	7/3/1929	C
		Ki Creek	1.0	6/28/1929	X
		Sultan River	8.0	6/20/1929	A
		Elwell Creek	N/A	6/24/1929	C
		Proctor Creek	1.0	7/15/1929	C
		Wallace River	N/A	6/24/1929	B
		SF Skykomish River	3.0	6/27/1929	B
		NF Skykomish River	15.0	7/1/1929	B
		Salmon Creek	3.0	7/1/1929	C
	Snoqualmie River		48.0	8/1/1929	B
		Cherry Creek	8.0	8/2/1929	C
		Harris Creek	3.0	7/25/1929	C
		Griffin Creek	2.0	7/25/1929	C
		Tark Creek	N/A	7/24/1929	X
	Tolt River		10.0	9/1/1929	A
		SF Tolt River	7.5	9/1/1929	B
		NF Tolt River	5.0	9/1/1929	A
		Lynch Creek	2.0	9/2/1929	C
		Stossel River	2.5	9/2/1929	C
		N. Fork Creek	5.0	9/3/1929	C
		Ragging River	9.0	9/4/1929	B
Lake Washington		May Creek	8.0	9/2/1929	X
		Mercer Slough	N/A	9/3/1930	X
		Cedar River	19.0	9/2/1930	C
		Evans Creek	5.0	9/3/1930	X
		Bear Creek	10.0	9/3/1930	X
Duwamish River	Green River		50.0	7/28/1930	A
		Burns Creek	2.0	7/22/1930	C
		Newaukum Cr.	14.0	7/24/1930	C
		Spaight Creek	0.5	7/24/1930	D
		Soos Creek	11.0	7/23/1930	A
Puyallup River	Puyallup River		50.0	7/12/1930	A
		Clear Cr. No. 1	1.0	7/21/1930	D
		Clear Cr. No. 2	0.3	7/28/1930	D
		Stoney Creek	2.0	7/28/1930	D
		Clark Creek	2.0	7/15/1930	D
		Deer Creek	N/A	7/15/1930	X
		McMullan Cr.	3.5	8/1/1930	C
		Mowitch Cr.	N/A	7/18/1930	X

Table A-1 continued. Survey of steelhead abundance.

Watershed	Main river	Tributaries	Migration distance	Survey date	Abundance
Puyallup River continued	Puyallup River continued	Rushing Water Creek	N/A	7/19/1930	X
		Carbon River	25.0	7/29/1930	A
		Voights Creek	3.0	8/16/1930	B
		Wilkeson Cr.	7.0	8/1/1930	X
		Evans Creek	N/A	8/16/1930	X
		S. Prairie Cr.	12.0	7/31/1930	B
	White River		60.0	8/8/1930	B
		Boise Creek	3.5	8/2/1930	D
		East Twin Cr.	N/A	8/13/1930	X
		West Twin Cr.	N/A	8/12/1930	X
		WF White R.	15.0	8/13/1930	C
		Goat Creek	N/A	8/9/1930	X
		Greenwater R.	9.0	8/7/1930	C
		28 Mile Creek	N/A	8/7/1930	X
		Slippery Creek	N/A	8/14/1930	X
		Silver Creek	N/A	8/7/1930	X
		Scatter Creek	N/A	8/11/1930	X
Nisqually River	Nisqually River		35.0	7/8/1930	B
		Mashel River	10.0	6/30/1930	B
		Beaver Creek	N/A	6/28/1930	D
		Big Creek	N/A	7/12/1930	X
		Busy Wild Cr.	N/A	6/30/1930	D
		Catt Creek	N/A	7/6/1930	X
		Lynch Creek	1.0	6/26/1930	D
		O'Hop Creek	6.0	6/26/1930	D
		Mineral Creek	N/A	7/10/1930	X
		Muck Creek	16.0	6/24/1930	C
		Little Nisqually River	N/A	7/3/1930	X
		Yelm Creek	1.0	4/3/1930	C
		Lower Mashel River	0.3	7/4/1930	D
Deschutes River			N/A	6/27/1930	X

Appendix B: Hatchery Population Evaluation Procedure

In the Salmon Steelhead Hatchery Assessment Group (SSHAG) document, each hatchery stock was assigned to a category based on variation across three axes (Table B-1): 1) the degree of genetic divergence between the hatchery stock and the natural populations that occupy the watershed into which the hatchery stock is released, 2) the origin of the hatchery stock, and 3) the status of the natural populations in the watershed (from Good et al. 2005).

The first axis, genetic divergence, has four categories: minimal, moderate, substantial, and extreme. Minimal divergence means that, based on the best information available, there is no appreciable genetic divergence between the hatchery stock and the natural populations in the watershed (e.g., because the hatchery and wild populations are well mixed in each generation). Moderate divergence means the level of divergence between the hatchery stocks and the local natural populations is no more than what would be expected between closely related populations within the ESU. Substantial divergence is roughly the level of divergence expected between more distantly related populations within the ESU. Extreme divergence is divergence greater than what would be expected among natural populations in the ESU, such as that caused by deliberate artificial selection or inbreeding.

The second axis describes the origin of the hatchery stock, and it can either be local, nonlocal but predominantly from within the ESU, or predominantly from outside of the ESU. The third axis describes the status of the natural populations in the watershed of the same species as the hatchery stock, which can either be native or nonnative.

Category 1 stocks are characterized by no more than minimal divergence between the hatchery stock and the local natural populations and regular, substantial incorporation of natural origin fish into the hatchery broodstock. Within Category 1, Category 1a stocks are characterized by the existence of a native natural population of the same species in the watershed, and Category 1b stocks are characterized by the lack of such a population (i.e., the local, naturally spawning population was introduced from elsewhere). Note that a Category 1a designation can describe a range of biological scenarios, and does not necessarily imply the hatchery stock and the associated natural population are close to a "pristine" state. For example, a hatchery program started many years ago with local broodstock and regularly incorporated local natural origin fish in substantial proportions thereafter would likely be a Category 1a even if both the hatchery stock and the local natural population have diverged from what the natural population was like historically.

Category 2 stocks are no more than moderately diverged from the local, natural populations in the watershed. Category 2a stocks were founded from a local, native population in the watershed in which they are released. Category 2b stocks were founded nonlocally, but from within the ESU, and are released in a watershed that does not contain a native natural population. Category 2c stocks were founded nonlocally, but from within the ESU, and are released in a watershed that contains a native natural population.

Category 3 stocks are substantially diverged from the natural populations in the watershed in which they are released. The a, b, and c designations are the same as described for Category 2 above.

Category 4 stocks are characterized either by being founded predominantly from sources that are not considered part of the ESU in question, or by extreme divergence from the natural populations in the watershed in which they are released, regardless of founding source.

Table B-1. Summary of the hatchery program categorization system.

Degree of genetic divergence	**Local; native natural population**	**Nonlocal but within ESU; no native local natural population**	**Nonlocal but within ESU; native local natural population exists**	**Nonlocal and predominantly from outside of ESU**
Substantial natural origin fish in broodstock and minimal divergence	1a	1b	NA[a]	4
Moderate to few natural-origin fish in broodstock and no more than moderate divergence[b]	2a	2b	2c	4
Substantial divergence[c]	3a	3b	3c	4
Extreme divergence[d]	4	4	4	4

[a] NA = not applicable.
[b] Moderate divergence = no more than observed between similar populations within ESU.
[c] Substantial divergence = comparable to divergence observed within entire ESU.
[d] Extreme divergence = greater than divergence observed within ESU or substantial artificial selection or manipulation.

Appendix C: Hatchery Broodstock Review

The conclusions of the Puget Sound Salmon Steelhead Hatchery Assessment Group (SSHAG) members (Jonathan Drake, Michael Ford, Richard Gustafson, Jeffrey Hard, James Myers, Tim Tynan, and F. William Walknitz) were highly consistent across all of the hatchery programs being reviewed (Table C-1). SSHAG members were unanimous in assigning the majority of allocation votes to a specific category for all of the programs, except for the Lake Washington, Green River natural, Hamma Hamma, and Elwha River winter run steelhead (*Oncorhynchus mykiss*) programs.

Table C-1. Distribution of hatchery allocation votes by SSHAG for steelhead hatchery programs releasing fish in Puget Sound. Shaded cells indicate the overall average category.

	Hatchery category				
Hatchery stock	**1.00**	**2.00**	**3.00**	**4.00**	**Average**
Chambers Creek WSH[a]	0.00	0.33	9.67	0.00	2.97
Skamania Hatchery SSH[b]	0.00	0.00	0.00	10.00	4.00
Regional Egg Pool WSH	0.00	0.17	9.83	0.00	2.98
Bogachiel Hatchery WSH	0.00	0.33	8.17	1.50	3.12
Nooksack River Hatchery WSH	0.00	0.50	9.50	0.00	2.95
Whatcom Creek Hatchery WSH	0.00	1.00	9.00	0.00	2.90
Samish River Hatchery WSH	0.00	0.00	10.00	0.00	3.00
Skagit River Hatchery WSH	0.00	1.00	9.00	0.00	2.90
Stillaguamish Hatchery WSH	0.00	1.00	9.00	0.00	2.90
North Fork Stillaguamish SSH	0.00	0.00	1.00	9.00	3.90
South Fork Stillaguamish SSH	0.00	0.00	1.00	9.00	3.90
Snohomish River Hatchery WSH	0.00	1.00	9.00	0.00	2.90
Snohomish River Hatchery SSH	0.00	0.00	1.83	8.17	3.82
Lake Washington WSH	5.67	3.83	0.50	0.00	1.48
Green River Natural WSH	3.83	3.67	2.50	0.00	1.87
Green River Hatchery WSH	0.00	0.67	9.33	0.00	2.93
Green River Hatchery SSH	0.00	0.00	1.83	8.17	3.82
Puyallup River Hatchery WSH	0.00	0.67	9.33	0.00	2.93
White River Hatchery WSH	0.00	0.67	9.33	0.00	2.93
Deschutes River Hatchery WSH	0.00	0.50	9.33	0.17	2.97
Hamma Hamma River WSH	6.33	2.17	1.50	0.00	1.52
Hood Canal Hatchery WSH	0.00	0.50	9.33	0.17	2.97
Dungeness Hatchery WSH	0.00	0.50	8.33	1.17	3.07
Morse Creek Hatchery WSH	0.00	1.00	8.83	0.17	2.92
Elwha Hatchery WSH	0.50	2.17	5.17	2.17	2.90

[a] WSH = winter run steelhead. [b] SSH = summer run steelhead.

Puget Sound Steelhead Derived from Chambers Creek Hatchery

What follows are lists of 10 characteristics of each hatchery stock (N/A = not available).

Chambers Creek
Winter Run Steelhead Stock

- Broodstock origin and history: The Chambers Creek winter run steelhead (CCWS) stock was founded in the 1920s from the collection and spawning of native adult fish trapped in Chambers Creek, a south Puget Sound tributary. The propagation of Chambers Creek steelhead at this location occurred through 1945, when a new steelhead rearing program was initiated, leading to marked changes in this stock. In the new program, adult steelhead captured in Chambers Creek were transferred to the South Tacoma Hatchery in the upper watershed, where relatively warm water (12º C) was available to accelerate spawning maturation time. Additionally, the earliest maturing fish were selected for propagation. Continuous year-to-year use of these practices, combined with the warmer water and nutritional advances provided by newly developed dry diets, allowed the production of smolts in one year instead of two. The first hatcheries outside the Chambers Creek watershed to use this stock were on the Green and Puyallup rivers and Tokul Creek. The progeny of adult returns established through CCWS transplants to these and other Puget Sound hatchery release sites were transferred back to Chambers Creek when needed to offset egg take shortfalls, and were incorporated back into the winter run steelhead population maintained at the site (Crawford 1979). However, as a standard practice, Chambers Creek was maintained as the lone annual source of eggs for other hatcheries.

  The Chambers Creek Hatchery, originally a private trout hatchery, was purchased by the Washington Department of Game in 1972 and rebuilt. The hatchery was subsequently used to propagate and further develop the Chambers Creek winter run steelhead stock and became the major source of winter run steelhead broodstock for Western Washington. Chambers Creek-derived winter run steelhead have been propagated and released from most Puget Sound steelhead facilities, including Reiter Ponds, Tokul Creek, Wallace River, Dungeness, Bogachiel, Hurd Creek, Eells Springs, Kendall Creek, McKinnon Ponds, Samish, Lake Whatcom, Puyallup, Soos Creek, Voights Creek, Marblemount, Barnaby Slough, Grandy Creek, Fabors Ferry, Baker River, Davis Slough, Whitehorse Ponds, Arlington, and the Chambers Creek facilities. Most of the programs using this transplanted stock are still active. Due to an outbreak of infectious hematopoietic necrosis (IHN), no winter run steelhead have been transferred out of or propagated at the Chambers Creek facility since 1984.

- Year founded: Current Chambers Creek winter run steelhead lineage began in 1945.
- Broodstock size and natural population size: N/A
- Subsequent events after founding: Early adult return and maturation timing were continually selected to produce a one-year-old smolt and to provide an early returning adult that could be harvested in November through January instead of February through June. An artifact of this program was that the early spawning time of the CCWS stock reduced the likelihood of spawning with native stock. In most years prior to the mid-1980s, CCWS adult returns established at other Puget Sound hatchery release sites were not collected for use as broodstock or to create a localized return based on the transplanted stock. Eggs collected

from broodstock returning to hatcheries other than Chambers Creek were sometimes used to augment egg take or smolt production deficiencies at Chambers Creek Hatchery. These eggs were mixed at a central hatchery (through an approach known as the "Regional Egg Pool Program") and distributed to meet smolt production quotas at the various release sites within the Puget Sound region. This centralized egg production approach was revised beginning in the 1990s due to genetic considerations, fish disease control requirements, and chronically declining adult return levels at Chambers Creek. Transplanted CCWS stock adult returns established at most rearing locations in the region are now collected at each specific release site as broodstock to meet on-station egg and smolt production objectives (Crawford 1979, Busby et al. 1996).

- Recent events since 1990: In 1993, protocols at hatcheries using Chambers Creek-derived stock were modified so that eggs and fry were returned to their hatchery of origin, if possible. The modified protocols still allowed for transplantation of Chambers Creek derivative stock from another location to offset any egg take shortfalls at a particular release location.
- Relationship to current natural population (interaction between hatchery and wild fish): The original goal of the Chambers Creek program was to produce an early returning adult steelhead that smolted after one year. By the mid-1970s, it was realized that the advanced adult spawn timing selected to meet the yearling smolt objective created temporal separation in natural spawning areas between CCWS and native late-winter spawning steelhead, reducing the likelihood of interbreeding (Crawford 1979, Busby 1996).
- Program goal or use of broodstock: The Chambers Creek Hatchery program was designed to collect all returning adults to Chambers Creek in order to fill regional production needs. The hatchery is no longer used to collect or propagate this winter run steelhead stock.
- Genetic data: The original Chambers Creek winter run steelhead stock was collected from native returns to Chambers Creek, with the likelihood of significant genetics changes due to selection for early maturation. Smolts originating from adults returning to the Green (Soos Creek), Nemah and Samish rivers have apparently been released into Chambers Creek, so this stock presumably has a rather complicated gene background. The mixture has proven adaptable to Puget Sound streams. By 1979 as much as 90% of the total catch in some streams was attributable to plants of Chambers Creek stock. Effective population size is not known due to pooling of gametes during spawning at Chambers Creek. Historical genetic data for the original Chambers Creek stock allowing for quantification of this divergence are lacking, but differences imposed in run, spawn, and smolt emigration timing for the Chambers stock would support the hypothesis that there have been attendant, major genetic diversity changes in the population.
- Phenotypic data: Winter run steelhead returned to Chambers Creek Hatchery from mid-December to February. The original winter run steelhead population in Chambers Creek has been subjected to purposeful selection for more than six decades, and is very likely more than moderately diverged from the donor native population.
- Category and rationale: Although the Chambers Creek Hatchery winter run steelhead broodstock was initially established using local origin adults, SSHAG considered the intentional and unintentional selection of life history traits as a major factor in their evaluation. The advancement in run and spawn timing of the Chambers Creek winter run

steelhead (almost two months) has dramatically altered the reproductive connectivity between the hatchery origin and naturally spawning adults. Additionally, the sole use of hatchery origin fish for hatchery broodstocks greatly increases the potential for hatchery domestication. Comments provided by WDFW suggest Chambers Creek winter run steelhead have a poor rate of natural spawning success. Members allocated the 96% of their votes for Chambers Creek winter run steelhead to Category 3.

Chambers Creek Derivatives

The majority of winter run steelhead hatchery broodstocks in Puget Sound are derived from the Chambers Creek population. In general there has been an active exchange of broodstock among hatcheries. Recently, mass marking has assured that hatcheries only utilize hatchery propagated fish in their broodstocks. Prior to marking, run and spawn timing was used to identify hatchery origin fish. Given the exchange between hatcheries and efforts to exclude local naturally produced fish, it is unlikely that there has been much local adaptation by the hatchery broodstocks. For convenience, we have listed the hatchery broodstocks derived from Chambers Creek below, with special notation of conditions that might influence the hatchery category score.

Regional Egg Pool Stock

- Broodstock origin and history: The Regional Egg Pool stock is a CCWS derivative population maintained at South Tacoma Hatchery. This stock was established using the warmer water available at the hatchery to accelerate spawning time and encourage CCWS to smolt at one year of age rather than two, thereby significantly reducing the cost for rearing this species in fresh water. Rearing in warmer water also helped provide uniform size smolts for distribution to Puget Sound Rivers.
- Year founded: 1960s.
- Broodstock size and natural population size: Initially broodstock was collected at the mouth of Chambers Creek. However, over the years, eggs collected at several locations were reared at the South Tacoma Hatchery for the Regional Egg Pool, including eggs transferred from the Skykomish, Skagit, Stillaguamish, and Bogachiel rivers, and Tokul Creek.
- Subsequent events after founding: By the 1970s it became evident that the early run timing that allowed the production of smolts in one year could also be used to help segregate naturally spawning hatchery steelhead from native stocks in most streams tributary to Puget Sound, thereby decreasing the opportunity for hybridization.
- Recent events since 1990: N/A.
- Relationship to current natural population (mixing between hatchery and wild):
- Program goal or use of broodstock: Incubate and rear Puget Sound winter run steelhead for transfer to other hatcheries to augment deficiencies in smolt production.
- Genetic data: The original Chambers Creek winter run steelhead stock was founded using native adult returns. The stock later became an admixture of Chambers Creek derivative stocks, through incorporation of eggs transferred back into the program from other Puget

Sound watersheds location where the stock had become established through repeated hatchery releases. The mixing of eggs, combined with selective practices applied at the hatchery, likely led to significant genetics changes.

- Phenotypic data: N/A.
- Category and rationale: N/A.

Bogachiel Hatchery
Winter Run Steelhead Stock

- Broodstock origin and history: This stock is derived from Chambers Creek Hatchery stock, with an unknown, but likely small contribution from Bogachiel River (Olympic Peninsula Steelhead ESU 2) native winter run steelhead. The Bogachiel Hatchery program began producing steelhead in 1967 with a combination of native Bogachiel River winter run fish and Chambers Creek fish. Chambers Creek derivative winter run steelhead were transferred from several hatchery locations to stock the newly constructed Bogachiel Pond in the mid-1970s. A trap was operated at the base of the pond outlet to collect early returning adults that recruited as volunteers. Since the initial transfer and establishment of the Chambers Creek derivative stock at the ponds, the source of broodstock used to sustain the Bogachiel Hatchery winter run steelhead program has been these early returning adult fish volunteering to the hatchery trap. Two acclimation ponds were constructed on the Calawah River in 1976, and adult returns to the site were initiated using Chambers Creek stock. However, fish for release at the Calawah River site are currently obtained as progeny of Bogachiel Hatchery returns (Crawford 1979, HSRG 2004).
- Year founded: Bogachiel Hatchery was founded in 1967. The Bogachiel Pond became operative in the mid-1970s, and the Calawah Ponds began production in 1976.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: In the Puget Sound ESU, Bogachiel Hatchery origin winter run steelhead have been transferred into the Nooksack, Samish, Skagit, Stillaguamish, Skykomish, Snoqualmie, Green, Puyallup, Deschutes, Union, Tahuya, Dewatto, Skokomish, Duckabush, Dosewallips, Quilcene, Dungeness, and Elwha rivers, and Whatcom, Kennedy, Goldsboro, and Morse creeks.
- Recent events since 1990: N/A.
- Relationship to current natural population (mixing between hatchery and wild): Only returning adults marked with an adipose clip are spawned; wild fish are returned to the river. Surplus returning hatchery fish are directly harvested (distributed or disposed of) and not returned to the river.
- Program goal or use of broodstock: The Bogachiel Pond is designed to rear 200,000 winter run steelhead smolts, and the two Calawah Ponds 220,000 smolts. These ponds were built to increase production of winter run and summer run steelhead in the Quillayute River system and to provide winter run steelhead eggs for other programs.

- Genetic data: This is considered to be a locally adapted, nonnative stock. Genetic samples taken in 1993 show the Bogachiel stock to be very similar to the CCWS hatchery stock (Phelps et al. 1997).
- Phenotypic data: Winter run steelhead return to these hatcheries from late November through February.
- Category and rationale: Largely due to the Chambers Creek Hatchery broodstock influence, more than 80% of the allocation votes were for Category 3. The possibility of local Bogachiel River winter run steelhead being included in the broodstock resulted in a 15% allocation of votes into Category 4.

Nooksack River Hatchery
Winter Run Steelhead Stock–WDFW

- Broodstock origin and history: This program was started with transfers from Tokul Creek Hatchery, and augmented with eggs from Barnaby Slough, Marblemount Hatchery, and Bogachiel Hatchery (all Chambers Creek winter run steelhead derivatives).
- Year founded: The Kendall Creek Hatchery winter run steelhead program began in 1991, and the satellite program at McKinnon Ponds began in 1988. Hatchery winter run steelhead have been released here since at least 1950. Small numbers of summer run steelhead were released between 1972 and 1981 (HSRG 2003).
- Broodstock size and natural population size: 86 to 100 fish are needed for broodstock. In 2000, only 18 were trapped (8 females).
- Subsequent events after founding: It has been generally not possible to meet program needs without transferring eggs from the Skagit, Tokul Creek, or Bogachiel hatcheries.
- Recent events since 1990: 2001 was the first year all of the eggs for the program were taken at Kendall Creek Hatchery.
- Relationship to current natural population (mixing between hatchery and wild): All releases are marked. Early spawn timing apparently minimizes inbreeding with wild stocks. Only marked fish are used as broodstock.
- Program goal or use of broodstock: The program goal is to produce fish for recreational and tribal harvest; 10,000 smolts are released on station, and 50,000 are transferred to McKinnon Pond (first release in 1988) for release into the Middle Fork Nooksack River after several months of imprinting. The goal is to spawn all fish from early December through January and only spawn in February when the run size is small.
- Genetic data: Genetic studies indicate little gene flow between CCWS and naturally spawning populations, due to difference in spawn timing.
- Phenotypic data: N/A.
- Category and rationale: This program, founded with Chambers Creek origin broodstock, continues to be operated in a manner to isolate it from native naturally spawning winter run steelhead in the Nooksack River. SSHAG members allocated more than 90% of their votes to Category 3.

Whatcom Creek Hatchery Winter Run Steelhead Stock—Bellingham Technical College and WDFW

- Broodstock origin and history: This program began with transplants from Tokul Creek, Barnaby Slough, Marblemount, and Bogachiel hatcheries (HSRG 2003).
- Year founded: 1979.
- Broodstock size and natural population size: Fish are imported annually from Kendall Creek for release. Any wild (unmarked) fish are passed upstream. Only marked fish are used as broodstock. Prior to the initiation of the hatchery program, it is not clear if steelhead were present in Whatcom Creek. WDFW's Hatchery and Genetic Management Plan for the program states there were no natural steelhead in Whatcom Creek prior to releases by the hatchery.
- Subsequent events after founding: This program has been augmented with eggs from the Barnaby Slough, Marblemount, Bogachiel, and Kendall Creek hatcheries. The program is currently maintained by transplants from Kendall Creek, with eggs received from Marblemount or Tokul Creek when necessary.
- Recent events since 1990: Recently, returns to Whatcom Creek have been augmented with transfers from Kendall Creek, which in turn is augmented with transfers from Marblemount and Tokul Creek hatcheries.
- Relationship to current natural population (mixing between hatchery and wild): All releases are marked. Run timing of hatchery fish and wild fish seem to be similar, suggesting that wild fish represent naturally spawning descendents of hatchery releases. In 1979 14.3% of natural spawners were hatchery fish, in 1980 9.5% were hatchery fish, and in 1981 26.8% were hatchery fish.
- Program goal or use of broodstock: 5,000 yearling smolts are released at Bellingham Technical College after early rearing at Kendall Creek. Winter run steelhead are also reared here for release into the Samish River (35,000 yearlings per year).
- Genetic data: N/A.
- Phenotypic data: N/A.
- Category and rationale: The relatively continuous release of Chambers Creek origin winter run steelhead over the last several years, in addition to the small size of the natural origin run, was influential in the allocation of over 90% of the votes to Category 3.

Samish River Hatchery Winter Run Steelhead Stock—Bellingham Technical College and WDFW

- Broodstock origin and history: Stock was originally imported from the South Tacoma Hatchery (CCWS). Significant subsequent transfers into the Samish Hatchery have come from the Skagit, Tokul Creek, and Bogachiel hatcheries (all CCWS derivatives) (HSRG 2003).
- Year founded: Hatchery winter run steelhead have been released here since at least 1950.
- Broodstock size and natural population size: N/A.

- Subsequent events after founding: N/A.
- Recent events since 1990: Direct transfers from Kendall Creek Hatchery were discontinued in 2003. Production for the program is now supplied through annual transfers from Whatcom Creek Hatchery (HSRG 2003).
- Relationship to current natural population (mixing between hatchery and wild): All releases are marked. Fish are released with no acclimation period and may not have sufficient time for imprinting. Early spawn timing is thought to minimize inbreeding with wild stocks.
- Program goal or use of broodstock: 35,000 yearling smolts released into the Samish River each year, with incubation and early rearing at Kendall Creek Hatchery and seven months of rearing at Whatcom Creek Hatchery.
- Genetic data: N/A.
- Phenotypic data: N/A.
- Category and rationale: The continued predominance of Chambers Creek Hatchery origin winter run steelhead in this hatchery was the major factor in placing all of the allocation votes in Category 3.

Skagit River Hatchery
Winter Run Steelhead Stock—WDFW

- Broodstock origin and history: Originally this stock was maintained through transplants from the South Tacoma Hatchery (CCWS), with final rearing at Barnaby Slough Ponds before release into the Skagit River. All fish presently used for broodstock are marked, with hatchery origin fish returning to the Skagit River basin release sites (HSRG 2003).
- Year founded: Hatchery winter run steelhead have been released here since 1950. Summer run steelhead were planted in the Skagit River system from 1970 to 1998.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: Until 1995 this stock was a mixture of fish from the Regional Egg Pool/Chambers Creek Hatchery and returns to the Skagit River, except in those years when adult returns were sufficient to meet egg production goals.
- Recent events since 1990: Program is now maintained by adult returns to Marblemount Hatchery and Barnaby Slough Pond, and marked fish at the Baker River trap. A total of 535,000 smolts are released each year from facilities at Marblemount, Barnaby Slough, Grandy Creek, Fabors Ferry, Baker River, and Davis Slough.
- Relationship to current natural population (mixing between hatchery and wild: Released fish are all adipose fin clipped with no coded wire tag. Hatchery fish comprise a portion of the natural spawning population, but no introgression has been documented. Spawn timing differences are thought to minimize wild/hatchery interactions. The hatchery stock is of locally adapted Chambers Creek origin and is segregated from the wild population genetically and temporally (WDFW 2003). Surplus hatchery fish are returned to the lower river to provide harvest opportunities.

- Program goal or use of broodstock: Goal is to provide 5,000 adults for recreational and tribal harvest, and to return 400 adults to both the Marblemount Hatchery and Barnaby Slough, as well as to supply eggs to other regional programs. Adults are trapped December 1 to February 28, with peak spawning in mid-January. Only clipped fish used for broodstock. Between 1995 and 2001, an average of 99 females (range: 17 to 277) returned to Marblemount, with an average of 100 females (range: 15 to 227) returning to Barnaby Slough.
- Genetic data: Although samples were not available from the Skagit River Hatchery program, the Skagit River naturally produced populations are distinct from other Chambers Creek-derived hatchery broodstock (Phelps et al. 1997). In fact, the Skagit River and Chambers Creek are located in different Genetic Diversity Units established by WDFW (Phelps et al. 1997).
- Phenotypic data: N/A.
- Category and rationale: Hatchery broodstock collection protocols encourage the isolation of this Chambers Creeks origin program. Continued isolation in this and other programs could increase the rate of domestication. Ninety percent of the allocation votes were for Category 3.

Stillaguamish Hatchery Winter Run
Steelhead Stock—WDFW and Stillaguamish Tribe

- Broodstock origin and history: Derived from transfers from the South Tacoma Hatchery (CCWS). CCWS have been planted in the Stillaguamish River system for more than 50 years (HSRG 2002).
- Year founded: Whitehorse Ponds were built in 1955 and the Arlington Hatchery was built in 1939. Hatchery winter run steelhead have been released here since at least 1950.
- Broodstock size and natural population size: The broodstock goal is about 75–100 females. Since 1994 an average of 80 females have returned to the Whitehorse trap.
- Subsequent events after founding: Since the 1980s this stock has been maintained by returnees to Whitehorse Ponds on the North Fork of the Stillaguamish River and supplemented by eggs from Tokul Creek or Reiter Ponds winter run steelhead.
- Recent events since 1990: All eggs are collected and eyed at Whitehorse Ponds, but incubation and juvenile rearing is undertaken at the Arlington Hatchery (Whitehorse release) and Harvey Creek Hatchery. Up to 25,000 Snohomish River winter run steelhead from Reiter Ponds are planted annually in Pilchuck and Canyon creeks, with an additional 15,000 released from the Masonic Park acclimation pond into the South Fork Stillaguamish River. Prior to 1993 eggs collected in the Stillaguamish system were placed into the Regional Egg Pool. Since 1993 priority has been given to on-station release of progeny of adults that returned to Whitehorse Ponds (HSRG 2002).
- Relationship to current natural population (mixing between hatchery and wild): Winter run steelhead return to Whitehorse Pond from late November through February, with peak spawning in mid-January. Surplus hatchery broodstock are held in the hatchery until they spawn, and are then released back into the river.

- Program goal or use of broodstock: This program requires interfacility transfers of eggs and fish to meet the goal of producing winter run steelhead for Stillaguamish and Skykomish river tribal and recreational fisheries. Some 100,000 winter run steelhead are targeted for release into the north fork of the Stillaguamish River, and 80,000 for other locations. Acceptable stocks are CCWS-derived Stillaguamish winter run steelhead or any CCWS derivative.
- Genetic data: Genetic studies have shown limited amounts of hatchery introgression into the natural populations in the watershed associated with use of this stock (Phelps et al. 2003).
- Phenotypic data: The hatchery population originated from Chambers Creek Hatchery returns and is distinct in its return timing of December to early February versus February to early May for the wild winter run steelhead population (HSRG 2003).
- Category and rationale: This broodstock has been substantially influenced by transfers of Chamber Creek origin winter run steelhead. The SSHAG allocated 90% of its votes to Category 3, with the remaining 10% allocated to Category 2. Some members suggested there was a small probability that local winter run steelhead had been included in the hatchery broodstock, or that there was some natural reproduction by hatchery origin fish.

Snohomish River Hatchery
Winter Run Steelhead Stock—WDFW

- Broodstock origin and history: Derived from Tokul Creek Hatchery (CCWS derivative from the Snoqualmie River Basin) and Reiter Ponds (Skykomish River Basin). CCWS have been planted in the Snohomish River system for more than 50 years.
- Year founded: The current Tokul Creek hatchery program started in the early 1960s with CCWS returns collected at the station. Initial winter run steelhead releases were made at the site in the 1930s. Reiter Ponds were built in 1974 and an incubation building was built in 1988. Hatchery winter run steelhead have been released here since 1950.
- Broodstock size and natural population: Broodstock needs for both winter run steelhead programs in the watershed are met through collection of 900 adult fish (goal level) at the Tokul Creek Hatchery weir. Since 1993, an annual average of 317 females have been spawned from fish trapped at the weir, located in Tokul Creek, a right bank tributary to the Snoqualmie River near the base of Snoqualmie Falls. After annual production needs for the Tokul and Reiter Ponds programs are met, surplus eyed eggs are transferred to other hatcheries throughout Puget Sound. Excess hatchery fish are returned to the river to provide harvest opportunities (HSRG 2002).
- Subsequent events after founding: This stock has been propagated from adults returning to Tokul Creek Hatchery and (if needed) from Whitehorse Ponds (Stillaguamish River) since the late 1970s. Tokul Creek Hatchery was a primary contributor to the Regional Egg Pool of winter run steelhead eggs for Puget Sound hatcheries.
- Recent events since 1990: In the mid-1990s full-term rearing was initiated at Tokul Creek Hatchery.
- Relationship to current natural population (mixing between hatchery and wild): This hatchery stock returns from late November through February, with peak spawning in February.

Surplus adults are returned to the river at Tokul Creek and Reiter Ponds to provide additional harvest opportunities.

- Program goal or use of broodstock: 270,000 yearlings are released into the Skykomish River at various points each year. Eggs are collected primarily from adults returning to the Tokul Creek Hatchery from November 20 to February 10. The Wallace River Hatchery provides intermediate and final rearing for the fish released into the Wallace River and intermediate rearing for the group released from Reiter Ponds. About 185,000 yearlings are released each year into the Snoqualmie River basin, primarily from the Tokul Creek facility, and 15,000 yearlings from the Whitehorse Ponds are released into the Pilchuck River. Acceptable stocks include CCWS-derived Skykomish winter run steelhead or any CCWS derivative. This program is a source for interfacility transfers of eggs and fish.
- Genetic data: Analysis by Phelps et al. (1997) suggests little introgression by Chambers Creek-derived broodstock.
- Phenotypic data: N/A.
- Category and rationale: The category allocation for this hatchery broodstock was similar to other Chambers Creek-derived populations: 90% in Category 3 and 10% in Category 2. This reflects the view that Snohomish River winter run steelhead are substantially diverged from the Chambers Creek winter run steelhead.

Green River Hatchery Winter Run Steelhead Stock—WDFW and Muckleshoot Tribe

- Broodstock origin and history: This program was started with introductions from CCWS and is currently maintained by adult returns to Palmer Ponds, with supplementation from Tokul Creek or Bogachiel hatcheries when needed. In the last few years, more than 50% of the eggs for this program have come from Tokul Creek Hatchery (HSRG 2003).
- Year founded: Hatchery winter run steelhead have been released into the Green River watershed through this program since at least 1950. The current program was initiated in 1969.
- Broodstock size and natural population size: Broodstock goal is 200 adult steelhead: 100 females and 100 males.
- Subsequent events after founding: At Palmer Ponds, winter run and summer run steelhead juveniles are merged into one pond prior to release. At Soos Creek Hatchery, juvenile winter run and summer run steelhead are reared separately. At Palmer Ponds, adult winter run and summer run steelhead are held in separate ponds. At Soos Creek Hatchery, adult winter run and summer run steelhead are held in the same area.
- Recent events since 1990: In the years from 1997 to 2001, 5, 6, 56 (from Tokul Creek), 7, and 6 females, respectively, returned to Palmer Ponds and were used as broodstock. Between 1992 and 2001 smolt-to-adult returns (SARs) averaged 1.09%, with a range of 0.28% to 2.44%. The program SAR goal is 5% (HSRG 2003).
- Relationship to current natural population (mixing between hatchery and wild): Fish return from late November through February, with peak spawning in mid-January. Early spawn timing minimizes inbreeding with native stocks. Only marked, hatchery origin fish are used

for broodstock. Approximately 8% of the returning adults from this program spawn naturally, mostly prior to mid-March. All releases are adipose clipped.

- Program goal or use of broodstock: Program goal is to augment recreational and tribal harvest. The goal is to release 80,000 yearlings from Palmer Ponds, 35,000 yearlings from Soos Creek Hatchery, and 10,000 from Flaming Geyser Ponds. Acceptable alternative stocks are Tokul Creek winter run steelhead or any CCWS derivative. Green River Hatchery winter run steelhead have no known unique attributes.
- Genetic data: Green River naturally spawning winter run steelhead are genetically distinct from Chambers Creek winter run steelhead (Phelps et al. 1997).
- Phenotypic data: Early spawn timing minimizes inbreeding with wild stocks.
- Category and rationale: More than 93% of the allocation votes were for Category 3, based in part on efforts to select Chambers Creek winter run steelhead for early run timing and hatchery protocols at the Green River Hatchery to isolate hatchery fish.

Puyallup River Hatchery
Winter Run Steelhead Stock—WDFW

- Broodstock origin and history: The stock of steelhead used at Voights Creek Hatchery is considered Chambers Creek stock, founded with CCWS from South Tacoma Hatchery and through transfers from Tokul Creek and Bogachiel hatcheries. However, in recent years the emphasis is to utilize as many locally adapted fish as possible for the program. In years when egg take goals cannot be met with locally adapted fish, stocks from the Bogachiel and Tokul Creek hatcheries are used to secure an egg take. Both Bogachiel and Tokul Creek stocks are considered Chambers Creek derivatives (HSRG 2003).
- Year founded: 1947.
- Broodstock size and natural population size: Due to low population numbers in recent years, all returning adults are spawned. Since 1997, an average of 28 females have been collected at the Voights Creek trap. The broodstock goal for Voights Creek is 250 fish, 125 males and 125 females.
- Subsequent events after founding: This program released CCWS into the mainstem Puyallup and Carbon rivers from the 1950s until the 1990s.
- Recent events since 1990: Beginning in the mid-1990s, most steelhead were acclimated and released from the Voights Creek Hatchery to reduce straying and facilitate adult recovery. Since 1996 the program has been maintained by volitional returns, supplemented with fish from Bogachiel and Tokul Creek hatcheries when necessary. Fish from the 2001 brood year are the first group released entirely from Voights Creek. In the late 1990s, the Puyallup Tribe maintained a separate winter run steelhead program at Diru Creek using CCWS. This program has been eliminated.
- Relationship to current natural population (mixing between hatchery and wild): All releases are adipose fin clipped, and only adipose fin clipped adults are collected for spawning purposes. Early spawn timing is thought to minimize inbreeding with wild stocks. Over the last 5 years, using March 15 as a separation date, hatchery fish averaged 5.8% of the natural

spawners in the Puyallup River, ranging from 2.1% to 10.5%. The majority of returning hatchery origin fish are harvested.

- Program goal or use of broodstock: 200,000 yearlings are released each year from Voights Creek hatchery to augment recreational and tribal harvests. Any CCWS derivative is acceptable for release into the Puyallup River system. In the years between 1997 and 2000, 8, 17, 25, and 2 females, respectively, returned to Voights Creek Hatchery.
- Genetic data: WDFW considers this stock is to be an introduced, nonadapted stock. Early spawn timing minimizes inbreeding with wild stocks. WDFW suggests there are genetic differences between the hatchery broodstock and naturally spawning native Puyallup River winter run steelhead (SaSI 2002, HSRG 2003).
- Phenotypic data: SARs have declined recently. Percent survival from 1984 to 1988 was 4.7%, from 1989 to 1993 was 1.0%, and from 1994 to 1999 was 0.4%.
- Category and rationale: The reliance of this program on out-of-basin Chambers Creek winter run steelhead broodstocks suggests there has been little local adaptation and overall fitness is low. Much of the rationale is similar to other Chambers Creek derivatives. More than 93% of the votes were allocated to Category 3.

White River Hatchery
Winter Run Steelhead Stock—WDFW

- Broodstock origin and history: Founded with fish transferred from the Puyallup Hatchery, this program is not run independently, but is dependent on the Puyallup Hatchery winter run steelhead program. The hatchery outplant program in the White River was terminated after springtime releases in 2002.
- Year founded: Hatchery winter run steelhead had been released here since at least 1970.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: N/A.
- Recent events since 1990: Beginning in release year 2003, all fish originally destined for planting into the White River from the Puyallup Hatchery are released into the Puyallup River system from Voights Creek facility.
- Relationship to current natural population (mixing between hatchery and wild): All releases made into the White River prior to the program's termination were fin clipped. Early spawn timing of the hatchery stock is thought to reduce the potential for genetic interaction with naturally spawning fish. Over the last 5 years, using March 15 as a separation date, hatchery fish averaged 0.8% of the natural spawners in the White River.
- Program goal or use of broodstock: Program terminated.
- Genetic data: N/A.
- Phenotypic data: N/A.

- Category and rationale: Dependence on the Puyallup Hatchery winter run program determined SSHAG voting. Although this program has been terminated, there are still fish from the program returning to the White River.

Deschutes River Hatchery
Winter Run Steelhead Stock—WDFW

- Broodstock origin and history: This program relies on annual outplants of CCWS from the Puyallup, Tokul Creek, and Eells Springs hatcheries.
- Year founded: Hatchery winter run steelhead have been released here since 1955. The current program began in 1975.
- Broodstock size and natural population size: Steelhead and other anadromous salmon are not native to the Deschutes River due to a natural migratory blockage at Tumwater Falls at the mouth, which was not laddered until 1953. No broodstock are collected from returning adults.
- Subsequent events after founding: From 1975 to 1996 this program was maintained primarily by adult returns to the Eells Springs Hatchery (HSRG 2002).
- Recent events since 1990: After 1997 this program has been maintained primarily through adult returns to the Puyallup Hatchery.
- Relationship to current natural population (mixing between hatchery and wild): If a naturally spawning population is present, it represents feral CCWS.
- Program goal or use of broodstock: 24,500 yearlings are released into the Deschutes River at River Mile (RM) 15.5 each year to provide harvest for recreational anglers. Prior to release, fish are reared at the Puyallup Hatchery. Since 1994, an average of seven hatchery winter run steelhead have been harvested in the Deschutes River each year.
- Genetic data: No information.
- Phenotypic data: N/A.
- Category and rationale: Historically, there was no anadromous migration above Tumwater Falls on the Deschutes River. This program is primarily operated to provide harvest opportunities and it is unknown if a feral run of winter run steelhead has been established. Regardless, SSHAG review treated this program similarly to other Chambers Creek derivatives, with more than 90% of the vote allocations going to Category 3.

Hood Canal Hatchery
Winter Run Steelhead Stock—WDFW

- Broodstock origin and history: This hatchery stock was derived from CCWS. Initially eyed eggs from Tokul Creek Hatchery were reared to fingerling stage at the Puyallup Hatchery, then transferred to Eells Springs Hatchery prior to release. Currently steelhead from the Bogachiel Hatchery are used for this program (HSRG 2004).
- Year founded: Hatchery winter run steelhead were released into the Skokomish River beginning in 1953 and the Duckabush and Dosewallips rivers beginning in 1950. Summer

run steelhead (stock unknown) were also released into the Dosewallips River between 1964 and 1981. The winter run steelhead program began in 1976. Winter run steelhead releases from Eells Springs Hatchery into the three Hood Canal rivers will be terminated beginning with the 2005–2006 brood year.

- Broodstock size and natural population size: No adults are collected at the Hood Canal hatchery rearing and release sites.
- Subsequent events after founding: The outplanting program was terminated in 2005.
- Recent events since 1990: Stocking of CCWS-derived winter run steelhead has been terminated in all Hood Canal streams. For example, the Hamma Hamma River has not been stocked since 1954, the Big Quilcene and Dewatto rivers since 1990, and the Union and Tahuya rivers since 1994. All other outplant programs were terminated in 2005.
- Relationship to current natural population (mixing between hatchery and wild): All releases were adipose clipped. Early spawn timing minimizes inbreeding with wild stocks. However, due to very low number of natural origin returns, there is some concern about mixing between the CCWS hatchery stock and native stocks in the Dosewallips and Duckabush rivers.
- Program goal or use of broodstock: SAR rates between 1988 and 2001 ranged from 0.0 to 1.23% in the Duckabush River, 0.0 to 0.33% in the Dosewallips River, and 0.03 to 2.1% in the Skokomish River. Between 1988 and 2000, sport harvest in these three streams has ranged 0–115 fish in the Duckabush River, 0–118 in the Dosewallips River, and 3–100 in the Skokomish River. Over the same period, tribal harvest has ranged 2–31 fish in the Skokomish River. There has been no tribal harvest in the Duckabush and Dosewallips rivers since 1994.
- Genetic data: Based on samples collected from the Dosewallips River, there has been little introgression by this program into the naturally spawning population (Phelps et al. 1997).
- Phenotypic data: N/A.
- Category and rationale: Fish in this program are currently obtained from the Bogachiel Hatchery. The SSHAG scores reflected this origin, with the vast majority of votes (93%) allocated to Category 3, and the remainder in Category 2 and 4.

Stock Name: Dungeness Hatchery
Winter Run Steelhead—WDFW

- Broodstock origin and history: Derived from Bogachiel Hatchery (CCWS) stock.
- Year founded: Hatchery winter run steelhead have been released here since 1955. The current program was initiated in 1994.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: This program is maintained through the collection and spawning of fish returning to Dungeness Hatchery in addition to annual supplementation by fish or eggs from the Bogachiel Hatchery. In most years the majority of the production released from the hatchery has been from Bogachiel Hatchery transfers. For example, in

2000 only two females returned to the hatchery, while in 2001 only one female returned (HSRG 2002).

- Recent events since 1990: Program founded in 1994.
- Relationship to current natural population (mixing between hatchery and wild): Considered a segregated program. The small number of fish released in combination with poor return rates poses a low risk of competition or integration with other populations.
- Program goal or use of broodstock: The program is designed to provide harvest in the Dungeness River without impacting naturally spawning steelhead. The program presently relies on annual eyed egg transfers from Bogachiel Hatchery, but WDFW is attempting to establish adult returns to a level that would allow the program to be self-sustaining. From the years 1995 to 2000, 84 hatchery origin steelhead were harvested in the Dungeness River.
- Genetic data: Phelps et al. (1997) reported naturally produced steelhead in the Dungeness River were distinct from winter run steelhead from the Bogachiel Hatchery (the source for this broodstock).
- Phenotypic data: N/A.
- Category and rationale: The Bogachiel Hatchery has been a continuing source for this program. SSHAG scores reflected the influence of these transfers, with 83% of the votes allocated in Category 3, 12% in Category 4, and 5% in Category 2.

Morse Creek Hatchery
Winter Run Steelhead Stock

- Broodstock origin and history**:** Outplants from the Bogachiel Hatchery.
- Year founded: These small streams were first planted in1962.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: Releases into Morse Creek were terminated in 2005.
- Recent events since 1990: N/A.
- Relationship to current natural population (mixing between hatchery and wild): Overlap of spawn timing with wild spawners poses some risk over the long term. Busby et al. (1996) reported that half of the escapement to Morse Creek consisted of hatchery origin adults.
- Program goal or use of broodstock: Plant 25,000 smolts in the Lyre River, and 10,000 in the Pysht River.
- Genetic data: Phelps et al. (1997) reported the winter run steelhead sampled from Morse Creek were genetically similar to Chambers Creek-derived hatchery broodstocks.
- Phenotypic data: N/A.
- Category and rationale: This broodstock is largely derived from the Bogachiel Hatchery and the SSHAG determination largely reflected this, with more than 88% of the allocation votes assigned to Category 3.

Elwha Hatchery Winter Run
Steelhead Stock—Lower Elwha Klallam Tribe

- Broodstock origin and history: The steelhead program at the Lower Elwha Fish Hatchery began in 1976 utilizing a composite of available hatchery stocks, including importations from Quinault National Fish Hatchery (NFH) 26,297 eggs 1976–1977, Eagle Creek NFH 41,277 eggs 1976–1977, and Chambers Creek 37,673 eggs 1976–1977. Since the initiating year, all broodstock has originated from returning Elwha River broodstock and has included adults from both the imported (early timed) and natural origin (late timed) populations. WDFW has had an extensive history of planting both summer run and winter run steelhead salmon in the river. These outplants originated from a variety of the WDFW fish culture facilities, including Shelton, Aberdeen, South Tacoma, Bogachiel, and Calawah Ponds (HSRG 2002).
- Year founded: 1958; the current program began in 1976.
- Broodstock size and natural population size: The program requires 120 adults per year for use as broodstock. The combined (hatchery and natural origin) average run size to the Elwha River is 2,229.
- Subsequent events after founding: Since 1977 the program has been maintained with returns to the Lower Elwha Hatchery.
- Recent events since 1990: N/A.
- Relationship to current natural population (mixing between hatchery and wild): This is considered a segregated program, with early returning hatchery fish having a low probability of spawning with native late winter run steelhead. It is unclear to what degree a native population of winter run steelhead has persisted in the Lower Elwha subsequent to the construction of the Elwha and Glines Canyon Dams. The number of natural fish incorporated into the hatchery program annually prior to 1997 is unknown. Mass marking of all hatchery origin fish was initiated in 1997.
- Program goal or use of broodstock: Goal is release 120,000 smolts annually into the Elwha River to produce adult returns for tribal and recreational harvest. The HSRG (2002) did not consider this stock as being suitable for recovery activities in the upper Elwha River.
- Genetic data: Two discrete populations of winter run steelhead salmon have been identified on the Elwha River (USDI 1996, Phelps et al. 1997): The early component is a hatchery derived population that forms the basis for the existing enhancement program at the Lower Elwha Fish Hatchery. Entry timing for this population begins in December and continues through February with peak spawning occurring in January. The late component is a natural origin population whose entry into the river begins in February and continues through June.
- Phenotypic data: N/A.
- Category and rationale: The SSHAG was somewhat more uncertain of the status of this broodstock. This was due to the incorporation of native late winter run steelhead into the broodstock, and the location of the Elwha River, on the western edge of the ESU (which might lead to the incorporation of out-of-ESU fish into the hatchery). The majority of SSHAG votes (52%) were allocated to Category 3, with equal weighting for Category 2 and Category 4 votes.

Puget Sound Winter Run Steelhead Not Derived from Chambers Creek Hatchery

Lake Washington
Wild Winter Run Steelhead Stock

- Broodstock origin and history: This program is based on the collection of naturally produced (unmarked) fish returning to the Lake Washington system captured at the Ballard Locks for broodstock. No hatchery winter run steelhead have been released into the Lake Washington system since 1993 (HSRG 2003).
- Year founded: 1997. Hatchery winter run steelhead were released between 1953 and 1993.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: This program is currently not operating because broodstock collection criteria have not been met in recent years. Seventy-five adults must return to the Ballard Locks before broodstock can be collected for the program.
- Recent events since 1990: Substantial loss of returning steelhead adults at the Ballard Locks resulting from California sea lion predation has been largely addressed through harassment and deportation of individual offending animals.
- Relationship to current natural population (mixing between hatchery and wild): Juvenile steelhead were planted in north Lake Washington tributaries. Released juveniles appear to be residualizing in Lake Washington. There have been no confirmed ocean returns from this program.
- Program goal or use of broodstock: Eggs were incubated at the Cedar River Hatchery and then transferred to Issaquah Hatchery for rearing prior to release. Releases of up to 20,000 yearlings from Issaquah Creek Hatchery and 30,000 fingerlings into North Lake Washington tributaries are planned.
- Genetic data: Phelps et al. (1997) reported Cedar River winter run steelhead were distinct from Chambers Creek Hatchery populations. Similarly Marshall et al. (2004) found genetic differences between winter run steelhead captured at the Ballard Locks and Chambers Creek fish.
- Phenotypic data: N/A.
- Category and rationale: Based on the natural origin source for this broodstock the SSHAG allocation votes were primarily assigned to Category 1 (57%) and Category 2 (38%). Review of the SSHAG evaluation by the Puget Sound Steelhead BRT resulted in this program being removed from consideration. At the time of the BRT meeting (June 2005) this program was considered inactive.

Green River Natural Winter Run
Steelhead Stock—Muckleshoot Tribe and WDFW

- Broodstock origin and history: Adults are collected by hook and line in the Green River, then matured, spawned, incubated, and hatched at WDFW's Soos Creek Hatchery. Final rearing and acclimation occurs at the Crisp Creek Rearing Ponds, a Muckleshoot tribal facility in the Green River basin. The fish are released from the Crisp Creek facility at RM 1.1 (HSRG 2002).

- Year founded: 2002.
- Broodstock size and natural population size: The target annual broodstock collection size is up to 50 adults. In 2002, 12 females and 30 males were collected for use as broodstock.
- Subsequent events after founding: N/A.
- Recent events since 1990: The program was initiated in 2002.
- Relationship to current natural population (mixing between hatchery and wild): If annual escapement objectives are met (10 to 20 females), fingerlings are adipose clipped and planted. When escapement objectives are not met, presmolts are unmarked and planted in areas with low natural spawning.
- Program goal or use of broodstock: Plant up to 250,000 adipose clipped and ventrally marked yearlings from Crisp Creek Rearing Ponds.
- Genetic data: The program is designed to propagate and enhance the native Green River winter run steelhead population, relying on the annual collection of naturally spawning adult fish from the mainstem river. Genetic analyses by Phelps et al. (1994) grouped Green River winter run steelhead most closely with winter run steelhead from the Cedar River, while also showing affinity to winter run steelhead populations in the Snohomish and Stillaguamish watersheds.
- Phenotypic data: N/A.
- Category and rationale: Although this program is designed to collect naturally spawning native winter run steelhead, the SSHAG was somewhat more uncertain about the origin of the fish collected. Hatchery origin winter and summer run steelhead are know to spawn naturally in Green River drainage (SaSI 2002, HSRG 2003), and there is some potential for the (unmarked) progeny of hatchery origin fish to be collected as broodstock. SSHAG allocation votes were almost equally split between Category 1 (38%) and Category 2 (37%), with the remaining 25% in Category 3.

Hamma Hamma River Winter Run Steelhead Stock—Long Live the Kings, Hood Canal Salmon Enhancement Group, NOAA Fisheries, Point No Point Treaty Council, USFWS, WDFW

- Broodstock origin and history: Broodstock collected for this program are thought to represent indigenous winter run steelhead. There have been very few hatchery stock transfers into the Hamma Hamma River watershed. Eyed eggs are collected from naturally spawned steelhead redds. Incubation and rearing occurs at Johns Creek Hatchery. Captive rearing of adults occurs at the Lilliwaup Hatchery (HSRG 2004).
- Year founded: 1998. Hatchery (CCWS) winter run steelhead were released here once in 1954.
- Broodstock size and natural population size: N/A.

- Subsequent events after founding: The planned duration of the program is up to 12 years. Recent low ocean survival trends of steelhead may hamper this program.
- Recent events since 1990: In 2002, 197 captively reared 4-year-old adults were released into the Hamma Hamma River and were observed spawning.
- Relationship to current natural population (mixing between hatchery and wild): Small effective size of broodstock could lead to genetic swamping effects. Due to the newness of the program, there is no information to evaluate the impact of returning hatchery reared fish.
- Program goal or use of broodstock: Release up to 5,000 two-year-old smolts and 200 captively reared adults into the Hamma Hamma River. All releases are adipose clipped.
- Genetic data: N/A.
- Phenotypic data: N/A.
- Category and rationale: In light of the short duration of this program and the methods used for obtaining progeny, the SSHAG allocated the majority (63%) of its votes to Category 1, with remaining 22% and 15% of the votes in Categories 2 and 3, respectively. There was some uncertainty regarding the extent that captive rearing would lead to domestication effects. Similarly, some SSHAG members were unsure to what degree past hatchery introductions or current hatchery strays may have influenced this population.

Skamania Hatchery
Summer Run Steelhead Stock

- Broodstock origin and history: This stock was founded from fish in the Washougal and Klickitat rivers in 1963, and then transferred to many facilities for release in many ESUs, including Puget Sound, where established broodstocks are now collected (Crawford 1979, Good et al. 2005). Releases occurred at the collection locations, but were also made through off-station transfers into other areas in the Puget Sound region. The hatchery programs in the Puget Sound Steelhead ESU that currently propagate and release Skamania origin summer run steelhead collected from broodstock returns of the transplanted stock to the release site or from another Puget Sound location are: Whitehorse Springs Hatchery (on-station, and off-station into three other locations in the North Fork Stillaguamish River watershed at Canyon Creek, RM 55 and RM 60); Reiter Ponds (releases on-station, and into two other locations in the Skykomish River watershed at North Fork Skykomish and Sultan rivers, and one in the Snoqualmie watershed at Raging River); and Palmer Ponds, Soos Creek Hatchery, and Keta Creek Hatchery in the Green River watershed.
- Year founded: Founded in the 1963 from wild fish in the Washougal and Klickitat rivers in Washington. It is possible that wild Washougal steelhead continued to be incorporated into the broodstock after the initial founding.
- Broodstock size and natural population size: Not available. This stock is no longer transferred from Skamania Hatchery for use in Puget Sound, as sufficient adult returns of this stock have been established at Reiter Ponds and potentially Soos Creek Hatchery for use as broodstock.

- Subsequent events after founding: After the original broodstock was established at Skamania Hatchery, it was transferred to other facilities in Washington and Oregon. Independent broodstocks supported by artificial propagation were subsequently established and collected at those locations. Current broodstock programs in Puget Sound streams rely on returning hatchery adults. According to SaSI (2002) native populations of summer run steelhead are present in two Puget Sound watersheds where Skamania stock artificial propagation programs are operated (Stillaguamish basin and the North Fork Skykomish River).
- Recent events since 1990: Transfers of this stock from its Columbia River basin origin into Puget Sound were terminated after summer run steelhead returns based on this stock were established at levels sufficient to sustain hatchery summer run steelhead production in the region.
- Relationship to current natural population (mixing between hatchery and wild): The Skamania Hatchery summer run steelhead stock is an introduced stock in all Puget Sound streams where it is planted, including some streams that had no summer run steelhead run prior to its introduction. Feral summer run steelhead populations have become established in some rivers, including the Green River, the South Fork Skykomish River, and the South Fork Stillaguamish River.
- Program goal or use of broodstock: This broodstock is used to provide fish for recreational harvest.
- Genetic data: Wild summer run steelhead in all Puget Sound watersheds are genetically distinct from Skamania Hatchery summer run steelhead (Phelps et al. 1997).
- Phenotypic data: This broodstock has undergone artificial selection for size, spawning time (advanced by more than 3 months), and smoltification timing (1 year rather than 2).
- Category and rationale: Due to the out-of-ESU origin of this broodstock, the SSHAG allocated 100% of its votes to Category 4.

Skamania Summer Run Steelhead Hatchery Derivatives

The use of Skamania Hatchery broodstock has been fairly widespread through Puget Sound, although in the past few years the number of programs, especially off-site releases has been reduced. The remaining hatchery programs largely, if not entirely, consist of Skamania Hatchery origin summer run steelhead, with limited introgression into the local naturally spawning population. These remaining programs follow.

North Fork Stillaguamish River Hatchery
Summer Run Steelhead Stock—WDFW

- Broodstock origin and history: Derived from transfers of stock from the Skamania Hatchery (ESU 4 Lower Columbia River). Current source is Skamania-derived summer run steelhead transferred from Reiter Ponds on the Skykomish River (HSRG 2002).
- Year founded: 1959.
- Broodstock size and natural population size: No broodstock are taken at Whitehorse Ponds.

- Subsequent events after founding: For the last 20 years the program has been maintained primarily from adult returns to Reiter Ponds in the Skykomish River drainage.
- Recent events since 1990**:** Eggs are collected and eyed at Reiter Ponds and hatched and reared at the Arlington Hatchery. All releases are marked.
- Relationship to current natural population (mixing between hatchery and wild): Skamania stock summer run steelhead return to Whitehorse from May through December, with peak spawning in December. First time returns to the Whitehorse trap are marked with an operculum punch and returned downstream to provide an additional opportunity for harvest. Second time returns (those marked with an operculum punch) to the Whitehorse Ponds trap are killed and used for watershed nutrient enhancement. SaSI (2002) recognizes three naturally producing summer run steelhead stocks in the Stillaguamish watershed. One (Deer Creek) is considered native and self-sustaining. A second population in Canyon Creek is considered of mixed, hybridized stock. The third stock in the South Fork Stillaguamish River is considered nonnative, but self-sustaining. The latter two were founded, or are currently influenced by, the Whitehorse Springs Hatchery summer run steelhead program (HSRG 2002).
- Program goal or use of broodstock: 70,000 yearlings are released from Whitehorse Ponds into the North Fork Stillaguamish each year. This program requires interfacility transfers of eggs and fish. Acceptable stocks are summer run steelhead returning to the Stillaguamish and Skykomish rivers, or any other Skamania Hatchery summer run stock derivative.
- Genetic data: WDFW considers this stock is to be an introduced, nonadapted stock. There is potential for genetic interaction with native wild summer run steelhead in the North Fork Stillaguamish River, although genetic studies indicate the Deer Creek (native) population is distinct from Skamania Hatchery broodstock (Phelps et al. 1997).
- Phenotypic data: N/A.
- Category and rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 90% of its votes to Category 4. The remaining 10% were allocated to Category 3, suggesting that there may have been some introgression with local naturally spawning fish.

South Fork Stillaguamish River
Hatchery Summer Run Steelhead Stock

- Broodstock origin and history: Derived from transfers of stock from the Skamania Hatchery (ESU 4 Lower Columbia River).
- Year founded: 1959.
- Broodstock size and natural population size: N/A.
- Subsequent events after founding: For the last 20 years the program has been maintained from adult returns to Reiter Ponds in the Skykomish River drainage.
- Recent events since 1990: Eggs are collected and eyed at Reiter Ponds hatching and early rearing is done at the Arlington Hatchery. Final rearing and release occurs at Reiter Ponds. All releases are marked.

- Relationship to current natural population (mixing between hatchery and wild): see North Fork Stillaguamish River Hatchery information above for this characteristic.
- Program goal or use of broodstock: Planned annual releases include 20,000–30,000 yearlings planted in the river above Granite Falls and 10,000 released into Canyon Creek, a tributary to the South Fork Stillaguamish River.
- Genetic data: WDFW considers this stock is to be an introduced, nonadapted stock. There is a potential for genetic interaction with native wild summer run steelhead in Canyon Creek. Summer run steelhead in the South Fork Stillaguamish River are genetically similar to Lower Columbia River summer run steelhead from the Skamania Hatchery.
- Phenotypic data: N/A.
- Category and rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 90% of its votes to Category 4. The remaining 10% were allocated to Category 3, suggesting that there may have been some introgression with local naturally spawning fish.

Snohomish River Hatchery
Summer Run Steelhead Stock

- Broodstock origin and history: Derived from transfers from the Skamania Hatchery (ESU 4 Lower Columbia River), Reiter Ponds stock (Skamania) summer run steelhead, and an unknown contribution of indigenous North Fork Skykomish River basin stock. The program has been self-sustaining through adult returns to Reiter Ponds for 20 years (HSRG 2002).
- Year founded: Summer run steelhead have been planted into the Snoqualmie River since 1950 and the Skykomish River since 1959. The current program was initiated in 1974.
- Broodstock size and natural population size: Average broodstock take is 600.
- Subsequent events after founding: Since the 1980s this stock has been maintained by adults returning to Reiter Ponds. Eggs are incubated and reared at Wallace River Hatchery, with final release and distribution from Reiter Ponds. Throughout the 1980s, the stock was a mixture of Skamania Hatchery-derived summer run steelhead and native fish.
- Recent events since 1990: Beginning in the late 1980s, late spawning hatchery fish were not propagated in order to increase separation between wild and hatchery spawners.
- Relationship to current natural population (mixing between hatchery and wild): SaSI (2002) delineates three summer run steelhead stocks in the Snohomish watershed: Tolt River (unknown origin with wild production), North Fork Skykomish (largely native, with wild production), and South Fork Skykomish (nonnative origin, with wild production). Summer run steelhead have been observed in the South Fork Skykomish River since Sunset Falls was laddered in 1958. The spawn timing of the hatchery stock is believed to overlap with naturally spawning native summer run steelhead, but the overlap may be diminished because of current broodstock collection procedures. Wild summer run steelhead spawn from early March through June, while hatchery summer run steelhead spawn from late December through April. Releasing hatchery fish in the mainstem of the Skykomish and Snoqualmie rivers also reduces interactions with natural summer run steelhead. Once annual hatchery

broodstock collection goals have been met, the hatchery trap is closed and surplus adults remain in the river to provide additional harvest opportunities for sports anglers (although there is an increase in the probability of hatchery fish naturally spawning).

- Program goal or use of broodstock: The goal is to release 150,000 Skamania-derived Skykomish summer run steelhead into the Skykomish River and 150,000 into other local rivers. Returns to Reiter Ponds have numbered 259 (1995), 252 (1996), 300 (1997), 259 (1998), 222 (1999), 175 (2000), and 227 (2001) fish. Acceptable stocks are Skamania-derived Skykomish summer run steelhead or any other Skamania Hatchery derivative. This program is a source for interfacility transfers of eggs and fish.
- Genetic data: WDFW considers this stock is to be an introduced, nonadapted stock. Summer run steelhead in the South Fork Skykomish River are genetically similar to Lower Columbia River summer run steelhead from the Skamania Hatchery (Phelps et al. 1997). WDFW is currently studying the genetic composition of fish spawning above Sunset Falls to establish the contribution of Skamania origin fish to escapement.
- Phenotypic data: N/A.
- Category and rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 82% of its votes to Category 4. The SSHAG scores also reflected the higher potential for native summer run steelhead to have been incorporated into the hatchery broodstock.

Green River Hatchery Summer Run Steelhead Stock—WDFW and Muckleshoot Tribe

- Broodstock origin and history: Derived from transfers of stock from the Skamania Hatchery (ESU 4 Lower Columbia River) via Reiter Ponds in the Snohomish River system. This stock was largely developed from Skamania-derived hatchery stocks but some native origin Skykomish fish have likely been included (HSRG 2003).
- Year founded: 1969.
- Broodstock size and natural population size: The program broodstock collection goals are for 80 adults (40 females and 40 males). In 1999, 2000, and 2001, 1, 4, and 25 Green River origin females respectively were spawned. Summer run steelhead were not thought to be native to the Green River prior to the introduction of Skamania Hatchery stock (SaSI 2002). There is now some limited natural production by feral summer run steelhead. Adult production levels have averaged 947 fish over the last 12 years, ranging from 189 to 1830.
- Subsequent events after founding: At Palmer Ponds, winter and summer run juvenile steelhead are merged into one pond prior to release. At Soos Creek Hatchery, juvenile winter and summer run steelhead are reared separately. At Palmer Ponds, adult winter and summer run steelhead are held in separate ponds. At Soos Creek Hatchery, adult winter and summer run steelhead are held in the same area, increasing the risk of inadvertent hybridization.
- Recent events since 1990: Recently the program has required the transfer of Skamania-derived summer run steelhead from the Reiter Ponds. Currently, the program is maintained by returns to Soos Creek Hatchery and Palmer Ponds, with additional transfers from Reiter Ponds as necessary (ranging from 0% to 100% over the last few years). Efforts to trap

returning adults at Keta Creek and Palmer Ponds began in 2000, with the goal of developing a local summer run steelhead broodstock from the Skamania/Skykomish stock. Adult collection occurs at Soos Creek and Keta Creek hatcheries from August 1 to November 30, and at Palmer Ponds from late September to late November (HSRG 2003).

- Relationship to current natural population (mixing between hatchery and wild): All releases are adipose clipped. Fish are released in May in order to reduce the probability of residualization and to reduce co-occurrence with emigrating fall Chinook salmon (*Oncorhynchus tshawytscha*) juveniles in the mainstem river. An estimated 3% of the hatchery population spawns naturally in Green River; the remainder are collected at the hatchery rack or harvested. Early spawn timing is thought to minimize interbreeding with wild stocks.
- Program goal or use of broodstock: Program goal is to augment recreational and tribal harvest. Goals are to release 40,000 yearlings at Palmer Ponds, 30,000 at Soos Creek, and 10,000 from Keta Creek Hatchery. Acceptable stocks are summer run steelhead from the Skykomish River (Reiter Ponds) or any Skamania derivative.
- Genetic data: WDFW considers this stock is to be an introduced, nonadapted stock (SaSI 2002). There are no known extant native summer run steelhead in the Green River, although Skamania Hatchery fish are distinct from all native Puget Sound steelhead populations (Phelps et al. 1997).
- Phenotypic data: N/A.
- Category and rationale: Based on the out-of-ESU source of the Skamania hatchery broodstock, SSHAG allocated 82% of its votes to Category 4. The SSHAG scores also reflected the inclusion of Skykomish River fish into the broodstock.

Appendix D: Artificial Propagation of Steelhead in Puget Sound

State, federal, and tribal releases of fish weighing less than 10 grams are not included in Table D-1, except where noted with an asterisk (*). Data are from the National Marine Fisheries Service, Washington Department of Fish and Wildlife, Northwest Indian Fisheries Commission, and U.S. Fish and Wildlife Service. SSH = summer run steelhead, FSH = fall-run steelhead, and WSH = winter run steelhead.

Table D-1. Artificial propagation of steelhead (*Oncorhynchus mykiss*) in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Nooksack	Independent streams	WSH	1950–1993	13	Unknown	106,914
			1982–1986	5	Chambers Creek	30,307
	Lummi sea ponds	WSH	1974–1986		Quinault River	111,796
	Nooksack River	SSH	1972–1981	4	Unknown	35,804
			1988	1	Yakima River	52,306
		WSH	1995–2001	2	Bogachiel River	106,477
			1982–1992	11	Chambers Creek	788,751
			1983	1	NF Nooksack R.	15,600
			1982–2004	10	Nooksack River	542,833
			1975–1984	4	Quinault River	306,264
			1999–2000	2	Skagit River	68,900
			1996	1	Stillaguamish R.	17,563
			1996–2002	4	Tokul Creek	197,814
			1950–1994	19	Unknown	697,133
			2004	1	Van Winkle Creek	127,000
	Whatcom Creek	WSH	1995	1	Bogachiel River	5,058
			1982–1992	11	Chambers Creek	184,593
			1999–2003	3	Skagit River	46,295
			1996–1998	3	Tokul Creek	35,023
			1955–1994	6	Unknown	46,345
			1999	1	Whatcom Creek.	4,205
Lower Skagit-Samish	Sauk River	SSH	1981–1993	2	Unknown	12,427
		WSH	1997–2004	2	Bogachiel River	28,655
			1982–1992	10	Chambers Creek	245,212
			1982–1985	4	Sauk River	75,866
			1998–2003	4	Skagit River	64,229
			1995–2002	7	Stillaguamish R.	151,024
			1955–1994	30	Unknown	1,231,809

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Lower Skagit-Samish continued	Skagit River	SSH	1983–1992	6	Skykomish River	151,700
		SSH	1995–1998	3	Stillaguamish R.	71,256
			1971–1994	12	Unknown	1,245,943
			1988–1991	3	Washougal River	62,851
		WSH	1996–1997	2	Baker River	85,977
			1982–2004	3	Bogachiel River	319,127
			1979–1998	15	Chambers Creek	1,873,235
			1953–1962	8	Columbia River	211,135
			1985	1	Green River	39,647
			1988–1992	3	NF Stillaguamish R.	60,535
			1982–2004	23	Skagit River	4,466,956
			1988–1992	5	Snohomish River	682,980
			1999	1	Stillaguamish R.	4,380
			1997	1	Tokul Creek	22,135
			1950–1994	34	Unknown	5,661,359
	Samish River	SSH	1988	1	Yakima River	40,881
		WSH	1995	1	Bogachiel River	19,275
			1977–1991	11	Chambers Creek	538,970
			1953	1	Columbia River	1,850
			1985	1	Green River	30,075
			1997–2000	4	Skagit River	94,091
			1992	1	Snohomish River	27,000
			1995–1996	2	Stillaguamish R.	34,658
			1996–1998	3	Tokul Creek	27,961
			1950–1994	30	Unknown	1,365,562
			1999	1	Whatcom Creek	2,532
Stillaguamish	Deer Creek	SSH	1958–1981	4	Unknown	78,585
		WSH	1981	1	Unknown	10,004
	NF Stillaguamish R.	SSH	1982–1997	7	Skykomish River	271,790
			2000–2003	4	Snohomish River	178,704
			1995–1998	4	Stillaguamish R.	159,961
			1964–1994	20	Unknown	894,962
			1987–1991	5	Washougal River	306,472
		WSH	1997–1998	2	Bogachiel River	111,521
			1982–1992	11	Chambers Creek	633,227
	SF Stillaguamish R.	WSH	1999	1	Skagit River	32,351
			1995–2003	9	Stillaguamish R.	860,686
			1950–1994	32	Unknown	1,843,221
		SSH	1984–1996	9	Skykomish River	212,961
			2002	1	Snohomish River	38,823
			1995–1996	2	Stillaguamish R.	26,531

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Stillaguamish	SF Stillaguamish R.		1964–1994	19	Unknown	556,133
continued	continued	FSH	1995–1999	2	NF Stillaguamish R.	43,143
		WSH	1982–1997	15	Chambers Creek	318,242
			1998	1	Skagit River	3,960
			1996–1997	2	Skykomish River	20,494
			1998–2002	5	Snohomish River	52,616
			2001–2003	2	NF Stillaguamish R.	31,676
			1997	1	Tokul Creek	4,489
			1950–1994	27	Unknown	539,749
	Stillaguamish River	SSH	1998–2004	5	Snohomish River	224,324
			1987	1	Washougal River	3,525
		WSH	1982–1997	16	Chambers Creek	369,425
			1998	2	Skagit River	13,995
			1998	1	Snohomish River	18,044
			1996–2004	4	NF Stillaguamish R.	174,491
			1951–1994	26	Unknown	562,380
Snohomish	NF Skykomish R.	SSH	1982–1997	12	Skykomish River	205,879
			1998–2004	6	Snohomish River	235,957
			1959–1994	15	Unknown	593,222
		WSH	1982–1992	11	Chambers Creek	210,556
			1996	1	Skykomish River	15,176
			1998–2004	5	Snohomish River	77,772
			1950–1994	27	Unknown	592,809
	SF Skykomish R.	SSH	1982–1992	9	Skykomish River	170,695
			2001	1	Snohomish River	16,300
		SSH	1964–1981	8	Unknown	124,707
	SF Skykomish R.	WSH	2001	1	Snohomish River	9,100
			1950–1968	4	Unknown	36,086
	Skykomish River	SSH	1982–1997	13	Skykomish River	1,294,502
			1998–2004	7	Snohomish River	986,525
			1961–1994	16	Unknown	871,797
			1990	1	Wenatchee River	14,950
			1987	1	Willamette River	16,263
		WSH	1982	1	Bogachiel River	32,794
			1982–1995	12	Chambers Creek	1,800,903
			1996–1997	2	Skykomish River	222,799
			1998–2004	7	Snohomish River	1,343,605
			1996–1997	2	Tokul Creek	67,603
			1950–1994	34	Unknown	2,840,449
	Snoqualmie River	SSH	1982	1	Chambers Creek	11,865
			1982–1997	13	Skykomish River	649,886
			1998–2004	7	Snohomish River	310,587

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Snohomish continued	Snoqualmie River continued		1950–1994	20	Unknown	885,208
		WSH	1995	1	Bogachiel River	51,748
			1982–1992	11	Chambers Creek	1,214,960
			1996	1	Skykomish River	9,996
			1998–2004	7	Snohomish River	1,373,651
			1995–1997	3	Tokul Creek	344,993
			1950–1994	34	Unknown	2,757,163
	Pilchuck River	WSH	1997–1998	2	Bogachiel River	15,432
			1995	1	Chambers Creek	10,009
			1999	1	Skagit River	5,347
			1996	1	Skykomish River	8,606
			1999–2004	6	Snohomish River	111,058
			1995–2004	10	Stillaguamish River	120,983
			1997	1	Tokul Creek	4,756
			1982	1	Bogachiel River	17,000
			1982–1992	11	Chambers Creek	324,805
			1985	1	Green River	10,083
			1950–1981	28	Unknown	789,983
	Tulalip Creek	WSH	1985–1986	2	Quinault River	135,000
Cedar-Sammamish	Lake Washington	SSH	1966	1	Unknown	30,800
		WSH	1982–1987	3	Cedar River	93,666
			1982–1991	9	Chambers Creek	443,433
			1984	1	Green River	30,798
			1982–1990	4	Lake Washington*	46,759
			1988	1	Lake Union	12,207
			1998–2002	4	Lk Wash. Native*	44,489
			1987	1	NF Stillaguamish R.	75,200
			1953–1993	25	Unknown	870,310
	N. Lk. Wash. Tribes	Native	1997–1999	3	Lake Wash. Native	39,299
Duwamish-Green	Green River	SSH	2002–2004	3	Green R. Native	77,400
			2004	1	Snohomish River	23,900
			1990–2004	4	Green R. Native	194,649
			1982–1999	14	Skykomish River	950,830
			2000–2004	3	Snohomish River	135,933
			1970–1994	14	Unknown	1,283,161
			1982	1	Washougal River	70,238
		WSH	1999–2002	4	Grn+Tokul Wi-Sky Su	257,000
			1982–2004	6	Bogachiel River	462,256
			1982–1997	16	Chambers Creek	1,797,065
			1989–1991	2	Crisp Creek	181,070

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Duwamish-Green continued	Green River continued		1984–1991	5	Green River	462,899
			1986–2004	15	Green R. Native*	1,115,389
			1990	1	Keta Cr. H.	94,844
			1992	1	NF Stillaguamish R.	11,297
			2000–2003	2	Snohomish River	230,883
			1995–1999	4	Tokul Creek	581,967
			1985	1	Undetermined or mixed	52,000
			1950–1994	31	Unknown	735,439
			2004	1	Van Winkle Creek	6,885
			1985	1	White River	5,425
Puyallup-White	Puyallup River	SSH	1973–1980	2	Unknown	89,032
		WSH	1995–1999	3	Bogachiel River	69,475
		WSH	1978–1994	15	Chambers Creek	1,062,102
			1995–2000	6	Diru Creek	340,540
			1984–1986	3	Green River	50,062
			2004	1	Humptulips River	216,925
			1987–1992	6	NF Stillaguamish R.	426,964
			1982–2004	11	Puyallup River	921,225
			1981–1992	10	Quinault River	735,806
			1999	1	Skagit River	61,000
			1993–1998	5	Tokul Creek.	667,139
			1950–2003	38	White River	3,868,625
	White River	WSH	1984–2001	4	Puyallup River	64,232
			1982–1984	3	Quinault River	33,732
			1999	1	Skagit River	18,210
		WSH	1995–1998	4	Tokul Creek	87,138
			1952–1994	18	Unknown	409,926
			1982–1985	4	White R.	114,225
Chambers-Clover	Chambers Creek	WSH	1977–1996	14	Chambers Cr.	781,862
			1987–1992	6	NF Stillaguamish R.	258,750
			1950–1993	33	Unknown	1,950,900
Nisqually	Nisqually River	SSH	1984–1985	2	Chehalis River	36,683
			1983–1992	7	Skykomish River	125,374
			1983	1	Soleduck River	14,185
			1964–1994	18	Unknown	445,082
			1982	1	Washougal River	25,403
		WSH	1958–1981	19	Unknown	387,437
Deschutes	Deschutes River	SSH	1958–1959	2	Unknown	10,540
			1991–1992	2	Van Winkle Creek	6,337
		WSH	1982–2004	15	Bogachiel River	423,430
			1997	1	Chambers Creek	6,937

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Deschutes continued	Deschutes River continued		2000	1	Puyallup River	13,511
			1987–1991	2	Quinault River	19,600
			1999	1	Skykomish River	26,911
			1989	1	Tokul Creek	34,314
			1955–1994	24	Unknown	644,098
Kennedy-Goldsborough	SSH Sound Independent	WSH	1982–1996	9	Bogachiel River	185,068
		WSH	1984	1	Burley Creek	18,070
			1984–1991	6	Quinault River	462,764
			1989	1	Tokul Creek	29,950
			1956–1994	16	Unknown	285,490
Kitsap	Dewatto River	WSH	1982–1990	7	Bogachiel River	74,002
			1987	1	Quinault River	3,000
			1984	1	Snow Creek	10,980
			1989	1	Tokul Creek	14,799
			1969–1994	12	Unknown	109,763
	Grovers Creek	WSH	1984–1988	3	Grovers Creek	34,736
			1983–1990	8	Quinault River	558,794
	Kitsap Independent	WSH	1957–1979	5	Unknown	62,915
	Tahuya River	WSH	1982–1988	6	Bogachiel River	63,854
			1987	1	Quinault River	10,000
			1989	1	Tokul Creek	15,002
			1950–1994	16	Unknown	210,345
	Union River	WSH	1982–1992	8	Bogachiel River	84,444
			1991	1	Quinault River	5,000
			1989	1	Tokul Creek	14,849
			1958–1994	21	Unknown	199,420
Skokomish-Dosewallips	Skokomish River	SSH	1972–1975	4	Unknown	82,233
			1998–1999	2	Snohomish River	19,334
		WSH	1982–1994	14	Bogachiel River	470,114
			1984	1	Burley Creek	18,090
			1986	1	Elwha River	1,680
			1987–1991	2	Quinault River	39,959
			2000–2002	3	Snohomish River	193,612
			1989	1	Tokul Creek	39,975
			1953–1994	27	Unknown	609,131
	Dosewallips River	SSH	1964–1981	7	Unknown	133,130
		WSH	1982–2003	13	Bogachiel River	214,196
			1987–1991	2	Quinault River	21,572
			2000–2002	2	Snohomish River	37,593

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Skokomish-	Dosewallips River		1989	1	Tokul Creek	25,028
Dosewallips	continued		1950–1994	30	Unknown	623,158
continued	Duckabush River	WSH	1982–2003	13	Bogachiel River	196,312
			1987	1	Quinault River	5,000
			2000–2002	3	Snohomish River	30,211
			1989	1	Tokul Creek	19,987
			1950–1994	29	Unknown	527,090
	Hamma Hamma R.	WSH	2002	1	Hamma Hamma native	196-adult
			1999–2003	5	Hamma Hamma native	7,391
			1954	1	Unknown	5,920
	Independent	WSH	1990–1978	3	Bogachiel River	52,326
	streams		1954–1955	2	Unknown	32,156
Quilcene-	Independent	WSH	1979–1980	2	Unknown	730,062
Snow	streams		1984–1986	3	Bogachiel River	9,179
			1991	1	NF Stillaguamish R.	953
	Quilcene River	SSH	1951–1981	15	Unknown	178,485
		WSH	1982–1990	7	Bogachiel River	80,960
			1987	1	Quinault River	5,300
	Snow Creek	WSH	1993	1	Unknown	1,274
Elwha-Dungeness	Dungeness River	SSH	1990	1	Bogachiel River	6,120
			1984–1986	3	Chehalis River	20,521
			1983–1992	4	Quillayute River	34,384
			1974–1994	10	Unknown	163,781
			1982–1987	2	Washougal River	20,168
		WSH	1982–2001	17	Bogachiel River	239,409
			2001–2004	4	Dungeness River	41,931
			1991	1	Lower Elwha	30,000
			1955–1994	23	Unknown	464,208
	Elwha River	Hybrid	1969–1971	3	Unknown	39,307
		SSH	1990	1	Bogachiel River	15,000
			1984–1986	3	Chehalis River	59,981
			1983–2000	10	Quillayute River	169,432
			1968–1993	15	Unknown	334,893
			1982–1987	2	Washougal River	37,641
		WSH	1982–1995	7	Bogachiel River	235,930
			1981	1	Chambers Creek	72,608
			1978–1979	2	Eagle Creek NFH	64,044

Table D-1 continued. Artificial propagation of steelhead in Puget Sound.

Watershed	Release site	Race	Duration	Years	Stock	No. of fish
Elwha-Dungeness continued	Elwha River continued		1979–2004	19	Elwha River	1,861,234
			1981–2001	12	Lower Elwha	1,600,721
			1958–1981	19	Unknown	430,280
	Morse Creek	WSH	1982–2004	19	Bogachiel River	192,694
			1991	1	Hoko River	14,655
			1987	1	Quinault River	15,227
			1962–1994	10	Unknown	108,230

Appendix E: Peer Review Comments on the Draft Status Review Update

In November 2005 we asked several scientists with expertise in steelhead (*Oncorhynchus mykiss*) biology and viability analysis to review the draft Status Review Update for Puget Sound Steelhead completed in July 2005. We received comments from four reviewers and respond to them here; where appropriate, we have incorporated these responses into this document, representing the final review. We have summarized and organized the reviewers' comments into categories relevant to issues raised by the Biological Review Team (BRT). The peer reviewers' unabridged comments are included in this appendix; reviewers are identified by number in order to preserve their anonymity.

Four reviewers provided comments on the draft Status Review Update for Puget Sound Steelhead. In general, the reviewers strongly supported the conclusions of the Puget Sound Steelhead BRT, composed of 13 federal scientists from four agencies (National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, U.S. Geological Survey, and U.S. Forest Service) with expertise in salmon and steelhead conservation biology. However, some of the reviewers were critical of aspects of the analytical methods employed by the BRT to assess the status of populations within the Puget Sound Steelhead distinct population segment (DPS).[3] Two of the reviewers also provided additional information that further underscored threats to Puget Sound steelhead identified by the BRT.

Substantive Scientific Comments

Status of the Puget Sound steelhead DPS

Review

Reviewer 1 stated the conclusions of the BRT were well supported by the information and analysis provided. Reviewer 2 agreed with the findings of the BRT that "steelhead in the Puget Sound ESU are biologically unhealthy and could become at risk of extinction in the future." Reviewer 3 concluded the status review was "thorough" and "provides an assessment of the status of Puget Sound steelhead with methods that cannot be faulted other than in the provision of empirical data and description of data collection methods." Reviewer 4 also agreed with the BRT's conclusions, concluding the review was "very thorough" and finding "the

[3] DPS as described under the ESA and defined in the joint policy with the U.S. Fish and Wildlife Service (61 FR 4722-4755; 7 February 1996). Previously, NOAA Fisheries Service defined DPSs for steelhead as evolutionarily significant units (ESUs), and the BRT's Status Review and reviewers' comments use the ESU designation. The geographic boundaries of the Puget Sound DPS and Puget Sound ESU for steelhead are identical, although the former formally excludes—for the purpose of assessing status—nonanadromous rainbow trout in response to a joint policy decision by NOAA Fisheries Service and the U.S. Fish and Wildlife Service (70 FR 67130-67134; 4 November 2005).

evidence presented to convincingly support the conclusion of the Biological Review Team that this ESU is likely to become at risk of extinction in the near future."

Response

No response is required.

Relative condition of winter and summer run steelhead

Review

Reviewer 1 felt the analysis focus should be on the status of winter run steelhead, given the predominance of this life history type throughout Puget Sound, currently and historically. Reviewer 2 was concerned about the lack of information on summer run steelhead populations in Puget Sound. Although summer run steelhead may naturally persist at low abundance levels, the reviewer was concerned they were at a high risk of demographic extinction, especially during poor ocean conditions. Reviewer 2 believed the summer run life history was an important diversity component, that once lost is unlikely to be reestablished within short evolutionary time frames (e.g., hundreds to thousands of years). Reviewer 2 did not agree with the BRT's hypothesis on the evolution of summer run steelhead in most basins (instead considering winter run steelhead to be derived from summer run steelhead in coastal rivers where they co-occur), but the reviewer did concur with the BRT on the potential impact of their loss. Reviewers 3 and 4 had no substantive comments on the relative condition of the two life history types.

Response

We agree with the reviewers' comments generally. The focus of the status review on winter run steelhead was dictated by the information available for *O. mykiss* in Puget Sound. We agree with the concern of Reviewer 2 about the lack of information on summer run steelhead and their elevated risk. Regardless of the actual evolutionary relationship between the two life history types, we concur with Reviewer 2 that the presence of winter run fish does not guarantee the persistence of a summer run form and that a lost summer run population would be difficult to restore naturally. We therefore agree the low abundance and limited distribution of summer run steelhead in Puget Sound is a major threat to the overall diversity of the DPS as a whole. No change to the status review is required.

Status of steelhead populations in Puget Sound

Review

Reviewer 2 concurred with the risk findings of the BRT. Reviewer 2 added the lack of an apparent rebound following poor ocean conditions in the 1990s was worrisome. More southern steelhead populations in southwestern Washington and in Oregon exhibited a resiliency in productivity with improvements in ocean conditions that was not evident in Puget Sound populations. Reviewer 3 felt the lack of an analysis of abundance data for wild winter run steelhead from Snow Creek, a small stream on the Olympic Peninsula, was a serious omission from the status review. Reviewer 4's opinion was that the methods used in the status review for evaluating population status did not explicitly consider habitat condition, which he considered to be a critical element in understanding population trends.

Response

We agree with Reviewer 2 that the lack of a recent resurgence in abundance of Puget Sound steelhead—since ocean conditions in the region have generally improved and since harvest rates have declined—is key to understanding the factors that limit steelhead productivity in this DPS, an argument the BRT made in its review.

Reviewer 3 makes a valid point about the trends in abundance of Snow Creek winter run steelhead. This population represents one of the region's longest term, watershed-scale studies on this species. However, the Snow Creek drainage system is not representative of the level of human development seen in many other Puget Sound streams. The watershed enters Hood Canal near its northernmost end. Steelhead do not have to navigate a long fjord to and from their freshwater home. There is development along Snow Creek (including one of the most extensive clear cuts in the state), but the stream lacks the urban and industrial changes seen in many other areas. Based on these differences, the BRT members are reluctant to extrapolate trends in the Snow Creek steelhead population to those of southern Puget Sound (as implied by the reviewer). We are examining Snow Creek steelhead abundance data to evaluate their patterns relative to other Puget Sound steelhead trends, and it appears that the recent trend in abundance of Snow Creek steelhead is similar to those observed for several Puget Sound steelhead populations, including some surrounding populations from the Strait of Juan de Fuca; Snow Creek steelhead show a recent sharp decline in adult abundance with a very recent modest upswing.

Reviewer 4 is correct that the BRT did not explicitly consider habitat condition in the status review, but issues such as this one are typically evaluated extensively in a subsequent "Factors for Decline" document prepared after a final listing determination is reached by NOAA Fisheries Service. That said, we agree that variability in habitat condition is an important factor contributing to the viable salmonid population (VSP) parameters for steelhead in this DPS. However, the principal factors contributing to the decline in abundance of steelhead, and their current status in Puget Sound, are not clear. As a result, many scientific uncertainties need to be addressed as part of overall recovery planning.

Statistical analysis of population abundance

Review

Reviewer 1 described the assessment process as "legitimate," adding the suite of quantitative methods and measures employed by the BRT were similar to other accepted analyses. Further, Reviewer 1 believed most if not all of the relevant and available data had been utilized. Although Reviewer 2 agreed with the BRT's conclusions and believed the status assessment was "sound," there was some concern expressed over the use of λ (lambda, a measure of population growth rate) to evaluate population abundance trends. Reviewer 2 suggested a formal population viability analysis (PVA) would have provided more useful information for analysis of extinction risk. In particular, Reviewer 2 believed spawner-recruit functions would be useful in evaluating population productivity, especially at low spawner abundance; he also believed the BRT's criticisms of Washington Trout's analyses of spawner-recruit relationships for five Puget Sound steelhead populations were somewhat misguided.

Reviewer 3 "found little fault" in the writing or analytical techniques; however, the lack of empirical data "limited the review and its veracity." Reviewer 3 further indicated the collection of information on smolts per spawner, smolt-to-spawner survival, and the smolt/spawner ratio relative to the absolute number of spawners (as an indicator of density dependence) was critical to understanding the factors underlying the trends in abundance observed for each population. Additionally, population-specific information was necessary for the statistical analysis of population trends with confidence limits.

In the interim, Reviewer 3 suggested data collected for winter run steelhead in Snow Creek should have been included in the status review as a possible indicator of annual ocean conditions and used as a reference for interpreting the other data sets from the Puget Sound DPS. Reviewer 4 did not comment specifically on the population analyses used to evaluate VSP parameters and risk. However, he did conclude the BRT's two-stage method employed to first assess viability of individual populations in the DPS (based on the VSP parameters of abundance, productivity, spatial structure, and diversity) and then assess the viability of the entire DPS (based on number, distribution, and connectivity of constituent populations) was "sensible."

Response

With a few exceptions, there was little information with which to develop statistical trends in abundance. A form of PVA was provided by Washington Trout to the BRT for five of the largest steelhead populations in Puget Sound. This was possible because relatively complete adult abundance data (in the form of expanded redd counts) and time series of population age structure were known for these populations. The BRT reviewed these analyses and concluded they were useful in corroborating additional analyses of trends in productivity and abundance. The BRT also concluded the utility of this approach was limited by the use of an average age structure taken from historical data to estimate recruits and by failing to account for errors in estimates of spawner abundance.

Reviewer 2 is correct in pointing out concerns regarding the use of an average age structure in evaluating recruitment relationships may be relatively minimal compared to other factors; however, the BRT believed the fact that this age structure is based on much older data than the spawner-recruit time series may impose undue bias on the analyses. While the size and escapement data used in Washington Trout's analysis for the five populations were recent (through 2001–2003, depending on the population), age structures were not. Age structure data were obtained from scales and tags recovered in the late 1980s and early 1990s, a period not coincident with the abundance data. Not accounting for temporal variability in age structure can bias productivity estimates by overestimating recruitment in small cohorts and underestimating recruitment in large cohorts. Furthermore, and more importantly, errors surrounding estimates of spawner abundance remain unknown (but are likely quite high, e.g., the proportion of redds dug by hatchery-origin steelhead). Thus the BRT concluded the WT analyses had significant limitations. In its own analyses, the BRT could not avoid all these sources of bias but tried to minimize them by basing calculations on empirical age structure distributions that varied over time, where they were available, and identifying where this was not possible.

The BRT also noted the fit of the stock-recruit data in Washington Trout's analysis was not evaluated quantitatively, and the BRT therefore attempted to fit these data to alternative models. In general, the fit of the data to either Ricker or Beverton-Holt stock-recruit models was very poor; for each of the five populations, a simple density-independent model such as the random-walk model with trend provided fits equally as well. Nevertheless, the fits to the random-walk model with trend were also poor. The BRT therefore used several analyses to look for emergent patterns in the abundance and productivity trends, including estimates of trend, population growth rates, and estimates of recruits per spawner. We agree with Reviewer 2 that analysis of population growth rates does not account for density-dependent productivity; however, the ability to detect such factors with the available data is limited because of the scientific uncertainties and assumptions associated with the spawner-recruit relationships.

Furthermore, although (as Reviewer 2 indicates) most of these methods do not capture the productivity of salmon/steelhead populations at low abundance—and thus may be most suitable for evaluating progress toward recovery as a population rebounds from low abundance—most BRT members believed this was not the only important consideration, and that the variability in the estimates of recruits per spawner at low density limited the confidence with which they could estimate this productivity. Nevertheless, the conclusions drawn from the BRT's analyses were remarkably similar to those drawn by Washington Trout, despite flaws in the methods of all of them, and the conclusions all support concern over low abundance and eroding productivity in even the largest and most robust populations in the DPS.

We agree with Reviewer 3 on the need for more complete data sets; however, in the absence of such information, it was necessary for the BRT to employ statistically conservative methods (i.e., averages and trends) to retain an acceptable level of confidence. Similarly, we agree with Reviewer 3 that information from Snow Creek winter run steelhead is likely to be useful in interpreting trends from other populations in the DPS. Partitioning effects that influence population trends may be useful if potentially cyclic climatic changes (e.g., decadal oscillations in marine upwelling and productivity) can be separated from long-term freshwater or inshore habitat changes or other biological effects (e.g., disease, predation).

For the purposes of the status review, distinguishing between short-term (transitory) and long-term (semistable or permanent) effects is important in determining the certainty that observed trends will continue in the immediate future. For example, if the primary factors for decline are temporally stable or difficult to reverse, then it is not necessary to prioritize factors for decline but simply establish the risk of extinction based on existing conditions. As mentioned above, factors for decline are generally identified by NOAA Fisheries Service subsequent to a final listing determination.

Influence of hatchery origin steelhead

Review

Reviewer 2 agreed with the BRT's decision to exclude Chambers Creek winter run steelhead from the DPS, citing evidence of Chambers Creek winter steelhead reproductive failure in nature as proof of the extent to which this stock had become domesticated. The reviewer concurred with the BRT's concerns on the potential interaction between natural origin and hatchery origin steelhead. Reviewer 2 stated the BRT did not emphasize the full suite of risks presented by hatchery origin steelhead. Specifically, the ecological interactions that occur between hatchery and natural origin steelhead during juvenile freshwater, estuarine, and marine rearing can substantially reduce the productivity of natural origin steelhead.

Reviewer 2 challenged the Washington steelhead management "paradigm" that there was little interbreeding or interaction between early returning Chamber's Creek winter steelhead and natural origin winter steelhead, noting that "even if hatchery and wild fish are temporally separated at spawning, their offspring are not." Reviewer 2 also stated a concern that much of the abundance data, including analysis of trend in recruits per spawner, was confounded by the potential presence of hatchery-origin steelhead. Reviewer 3 was similarly concerned by the potential negative interactions between hatchery and wild fish, but he did note much of this concern was based on speculation rather than definitive research ("albeit accurate in my view"). He noted "wild" steelhead productivity has declined while harvest rates fell and hatchery releases increased, indicating the situation is somewhat complicated. Reviewer 4 believed the BRT's conclusions regarding the effects of hatchery on wild fish were "reasonable."

Response

Washington Department of Fish and Wildlife (WDFW, formerly Washington Department of Game) made a deliberate choice in steelhead propagation several decades ago to rely primarily on single broodstock sources for winter run and summer run hatchery programs, respectively. The winter run stock was derived initially (1945–1955) from Chambers Creek (southern Puget Sound) and selected rapidly for early run and spawn timing for several generations to produce smolt-size fish in one year. The summer run stock was derived (1957–1963) from a genetic admixture of Washougal and Klickitat River steelhead, propagated at the Skamania Hatchery on the Washougal River (lower Columbia River basin). Skamania steelhead were also selected artificially for early run and spawn timing to produce smolt-size fish in one year. Skamania steelhead were also selected artificially for large body size.

The WDFW now asserts those selective breedings for early run and spawn timing minimize natural interbreeding and negative genetic interactions between hatchery and natural origin fish, thus justifying—from its perspective—continuation of those existing programs. However, reducing opportunities for direct interaction also elevates the adverse consequences of those interactions when they do occur. For example, as Reviewer 2 noted, "I think it is important to dispel the myth that as long as the hatchery fish spawn at different times within the basin that their adverse impact is unlikely—this just isn't true."

The BRT felt strongly that the opportunities for genetic and ecological interactions between hatchery and wild steelhead in Puget Sound were substantial, and that the biological consequences of those interactions on reducing natural productivity were potentially significant. Those interactions are further enhanced by the common practice of outplanting from hatchery trucks steelhead smolts into streams where there is no opportunity to recapture returning adults that escape local freshwater fisheries. Moreover, the arbitrary March 15 threshold used by WDFW to separate censuses of hatchery and wild fish confounds evaluations of those potential hatchery fish effects, thus increasing scientific uncertainties.

Unfortunately, research on the interaction between hatchery and wild steelhead has been very limited in the past, especially in Puget Sound. Recently published studies suggest the level of interaction is far greater than has been assumed. Whether such interactions have also reduced the fitness of wild steelhead remains an open question, but studies of other salmonids generally indicate this reduction in productivity can occur, possibly within a few generations.

Furthermore, at least one recent study in the Hood River (Oregon) indicates the productivity of naturally spawning hatchery steelhead relative to wild steelhead clearly depends on the degree to which the hatchery steelhead have been domesticated. Until studies more clearly indicate the effects of interbreeding between hatchery and wild steelhead, reducing both opportunity for interaction between these fish and the consequences of that interaction (e.g., by eliminating outplanting and by using hatchery broodstocks genetically and phenotypically similar to local wild fish) are prudent management choices.

Role of resident *O. mykiss* in sustaining steelhead populations

Review

Reviewers 1 and 2 concurred with the BRT's decision to include resident fish below long-standing natural and artificial barriers. Both reviewers and Reviewer 4 agreed with the BRT in regarding rainbow trout (*O. mykiss*) as a minor contributor to the long-term sustainability of Puget Sound steelhead populations. Reviewer 2 provided qualified comments in that, although rainbow trout are unlikely to maintain productivity, connectivity, and diversity for the entire DPS for a protracted time, they may be capable of providing a short-term (a few years) reproductive cushion. Reviewer 3 indicated it is critical to separate freshwater and marine life stages of steelhead in analysis of stock status and trends, indicating "there is potential for resident trout to function in a temporary manner to help bridge steelhead populations through rare, but extreme periods of low marine survival." Reviewer 4 agreed with the BRT's conclusions, noting this life history form was "unlikely to maintain connections to other populations, and that the anadromous life history was an important component of the ESU's diversity and viability."

Response

The BRT was concerned with the ability of resident *O. mykiss to* ameliorate the risk of DPS extinction in the foreseeable future, a period covering 20 to 100 years in most risk analyses. There was very limited information available on the abundance and genetic contribution of rainbow trout to steelhead populations, and information presented indicated although there was some interbreeding between resident and anadromous fish, this was not a significant contribution to long-term viability of a DPS highly dominated in abundance by the anadromous form (i.e., steelhead). It is possible this interaction may provide a short term demographic resiliency, although loss of the anadromous form would result in a catastrophic decline in diversity.

Ultimately, the BRT's task was in assessing the longer term risk of extinction facing Puget Sound steelhead, and to accomplish this task it focused on the primary data available: trends in abundance and productivity of anadromous fish. Although the steelhead life history appears to be extraordinarily plastic, and resident and anadromous fish both may produce the alternate life history form, the extent to which resident fish produce anadromous adults is largely unknown. In addition, the freshwater "trout niche" in Puget Sound is already occupied primarily by native coastal cutthroat trout (*O. clarkii*), and the extent that rainbow trout alone can maintain self-sustaining natural populations in direct competition with cutthroat trout is unknown.

Although the present NOAA policy on steelhead DPS removes the necessity to consider rainbow trout, the reviewer's comments are still useful in supporting the separation of the two life history types for assessing extinction risks in Puget Sound; the inclusion of rainbow trout with Puget Sound steelhead failed to diminish the DPS's estimated risk of extinction within the foreseeable future. No change to the status review is required.

Minor Scientific Comments: Hybridization between *O. mykiss* and *O. clarkii*

Review

Reviewer 3 suggested that the effects of hybridization between rainbow/steelhead and cutthroat trout on diversity be assessed. Specifically, the reviewer indicated the presence of localized hybrid swarms may have a negative effect on the fitness of wild fish, and the incidence of these swarms may be related to fish stocking activities. Although "it is not likely a key factor" for decline, Reviewer 3 indicated the effect of hybrid fish on overall DPS viability should be considered.

Response

The BRT discussed rainbow/steelhead and cutthroat hybridization in its report. Although specific areas with relatively high incidences of hybrid fish have been identified, it is unclear how extensive this occurrence is. Additionally, in the absence of an historical baseline it is unclear if the hybridization observed represents a natural process or one that is influenced by anthropogenic activities such as fish introductions or habitat disturbances. Unfortunately, much of this discussion was not captured in the BRT's status review, but in the event of a listing the issue can be discussed in greater detail in a "Factors for Decline" document. No change to the status review is required.

Editorial Comments

None were received.

Policy-related Comments

None were received.

Summary of Reviewer Criticisms

Review

The reviewers each agreed with the overall conclusions of the BRT in the status review. The primary criticisms of the status review were:

1. A lack of empirical data on key abundance and productivity parameters, and a weak explanation for how these data were derived.
2. A clearer separation between freshwater and marine life history stages and their influence on productivity.
3. A clearer appraisal of the proportion of naturally spawning fish of hatchery origin and, if possible, a more rigorous assessment of the impacts of these fish on wild steelhead.
4. Reliance on population growth rate rather than spawner-recruit relationships to evaluate productivity at low spawner abundance.
5. Omission of Snow Creek winter run steelhead information.

Response

We appreciate the reviewers' comments which largely concur with the BRT on the composition of the Puget Sound *O. mykiss* DPS and its estimated extinction risk. On the main points of the status review, each reviewer agreed with the team's conclusions, and the primary criticisms summarized above do not detract from the review's primary conclusions. We agree with the reviewers that the analyses are limited by the absence of comprehensive data and the lack of clarity on how some viability indices were produced by steelhead managers in Washington. For example, the BRT's analyses relied heavily on WDFW's identification of "wild" and "hatchery" steelhead, and an assumption that spawn timing differences between these classes are maintained across successive generations—an assumption that is unlikely to be true.

Most BRT members stated the status review provides conservative appraisals of the abundance of naturally spawning hatchery fish and consequent genetic and ecological impacts of these fish on wild stocks. The lack of abundance data and productivity metrics at distinct life history stages also restricted the BRT's ability to evaluate factors that limit viability of steelhead in this DPS. The BRT's reliance on estimates of population growth rate (λ) is somewhat overstated by Reviewer 2, we believe. Although we concur inspection of spawner-recruit relationships and their residuals at low spawner abundance can provide insight into limits to productivity when populations are depressed, these data are highly variable, have inherent problems (including no clear way to ascertain their variability), and seem to augment what the BRT's other analyses are providing. The addition of the Snow Creek winter run steelhead data to the BRT's analyses is an important suggestion because of limited influences of hatchery production, harvest, and resident fish. This data set is one we intend to explore further.

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