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Identifying Historical Populations of Steelhead within the Puget Sound Distinct Population Segment

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Dedication

Robert August Hayman
27 February 1952–20 December 2011

In the midst of developing and drafting this document, the Puget Sound Steelhead Technical Recovery Team was saddened by the death of one of its members, Bob Hayman. His contributions to the TRT went beyond his extensive knowledge of the Skagit River basin; it was his determination that the TRT process be logical, consistent, and transparent that ensured its work would meet the highest standards. Bob’s good-natured and humble manner made him likeable even when he was challenging your thinking. He was a tireless worker, and the determination he displayed in both his professional endeavors and battling cancer was inspiring. We all miss him.

Executive Summary

The Puget Sound Steelhead Technical Recovery Team (PSS TRT) convened in March 2008 to review information relevant to the identification of historical demographically independent populations (DIPs) of steelhead (*Oncorhynchus mykiss*) in the Puget Sound steelhead distinct population segment (DPS). The PSS TRT identified three major population groups (MPGs) containing a total of 32 steelhead DIPs in Puget Sound.

Steelhead in the Puget Sound DPS exhibit two distinct life history strategies: summer-run and winter-run migrations. Winter-run steelhead, also known as ocean-maturing steelhead, return to freshwater during the winter and early spring months and spawn relatively soon after entering freshwater. Alternatively, summer-run (stream-maturing) steelhead return to freshwater during late spring and early summer in a relatively immature state and hold there until spawning in the following winter/spring. Generally, but not necessarily, summer-run steelhead return-timing is coordinated with river flow patterns that allow access past barriers to headwater spawning areas. Presently and historically, winter-run steelhead numerically represent the predominant life history type in Puget Sound.

Steelhead exhibit considerable diversity in age at smoltification, age at return or maturation, and spawning timing and repeat spawning (iteroparity). Overall, there were few clear trends in these life history traits across the Puget Sound DPS. Steelhead in lowland, rain-dominated streams tended to spawn earlier than fish in upland or headwater, snowfall-dominated streams. Information on life history characteristics is limited for all but a few DIPs and completely absent for others, especially for summer-run populations. Additionally, there is little information available on ocean migratory patterns outside of Puget Sound and, until recently, steelhead tagging studies have not been undertaken to any great degree.

The PSS TRT reviewed available information on Puget Sound steelhead, which included life history and genetic data. This information was not universally available for all populations and, in many cases, ecological information was used to estimate life history characteristics. In the absence of historical demographic information (e.g., abundance, spatial structure), the TRT also used basin characteristics to estimate the potential historical size and level of interaction between prospective populations. The TRT initially utilized an expert panel system to develop criteria for establishing DIP criteria, but ultimately incorporated these criteria into a decision support system to identify DIPs. DIPs were in turn organized in MPGs. These larger scale units delineate DPS-wide spatial structure. The TRT identified MPGs based on the geographic and ecological characteristics of the DPS and the genetic clustering of existing steelhead populations in Puget Sound.

As a preliminary filter for putative DIPs, the TRT only considered basins with intrinsic productivity (based on stream area) equal to or greater than that estimated for Snow Creek, an apparently self-sustaining, small, wild population located on the northeastern corner of the

Olympic Peninsula. The decision support system relied on basin intrinsic potential, basin elevation, snow cover, distances between potential DIPs, genetic differences between potential DIPs, life history differences between potential DIPs, and the presence of temporal migrational barriers between potential DIPs. The decision support system, or gatekeeper model, required that the TRT estimate for each factor a threshold value that indicated populations were demographically independent with a very high certainty. One of the benefits of this system was that missing information did not bias the outcome.

The boundaries for historical DIPs were in part established using information related to two isolating mechanisms: homing fidelity and migration timing. Homing fidelity was examined to estimate the extent of adult exchange among putative spawning populations. Analysis of the terminal recoveries of adult marked hatchery fish indicates that less than 10% of the recoveries occur more than 50 km from the mouth of their natal stream (stream of release). Within a basin, temporal differences in return migration and spawn timing provided mechanisms for establishing demographically and reproductively isolated populations. Adult run and spawn timing are often coordinated with stream hydrology and temperature, which in turn are strongly affected by basin elevation. Major run-timing (e.g., summer and winter) differences were used as one criterion for distinguishing DIPs in the gatekeeper decision support system, especially where temporal barriers provided a reproductive barrier between presumptive DIPs.

In the Puget Sound DPS, three MPGs were identified: Northern Cascades, Central and South Puget Sound, and Hood Canal and Strait of Juan de Fuca. Within the Northern Cascades MPG, 16 DIPs (8 winter run, 3 summer/winter run, 5 summer run) were identified as historically present. In the Central and South Puget Sound MPG, 8 winter-run DIPs were historically present. There was some discussion regarding the presence of an additional historical summer-run DIP in the Green River or, alternatively, that the Green River winter-run DIP should be designated as a mixed summer/winter-run DIP, although the information available was not considered compelling. Additionally, while there are no known native-origin summer-run steelhead currently in the Green River (i.e., the summer-run steelhead currently released into and naturally spawning in the Green River originated from the Skamania Hatchery in the Columbia River basin), it is possible that resident *O. mykiss* above Howard Hansen Dam may contain the genetic legacy of a summer run. The Hood Canal and Strait of Juan de Fuca MPG historically contained 8 DIPs (1 summer/winter run and 7 winter run, with 2 of these winter runs possibly historically including summer-run components).

Where steelhead population information was available, especially genetic information, it was possible to identify steelhead DIPs with a relatively high degree of certainty. In other cases, ecological information provided a reasonable proxy for population data. The TRT strongly recommends further life history and genetics sampling and evaluation, especially in those areas currently less well studied. For some populations, basic abundance data are still lacking and need to be collected. It is likely that, in the process of collecting additional information on these populations, some revision in the DPS population structure will be necessary and should be undertaken.

Acknowledgments

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The able assistance and cooperation of several biologists and technicians from various agencies were very helpful to the PSS TRT's efforts. For their help with steelhead (*Oncorhynchus mykiss*) information and comments on aspects of this report, we thank Brett Barkdull, the late Steve Foley, Annette Hoffman, Thom Johnson, Robert Leland, and Kris Ryding, Washington Department of Fish and Wildlife; Will Beattie, Northwest Indian Fisheries Commission; Ned Currence, Nooksack Tribe; Kit Rawson, Tulalip Tribe and the Recovery Implementation Technical Team; Alan Chapman, Lummi Tribe; Eric Beamer and Casey Ruff, Skagit River System Cooperative; Larry Wasserman, Swinomish Indian Tribal Community; Dave Pflug, Seattle City Light; Ian Courter, Cramer and Associates; Frank Thrower, Alaska Fisheries Science Center (ret.); Fred Goetz, U.S. Army Corps of Engineers; and Bruce Ward, Department of Fisheries and Oceans Canada (ret.).

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Abbreviations

DIP	demographically independent population
DPS	distinct population segment
EPA	U.S. Environmental Protection Agency
ESU	evolutionarily significant unit
FCA	factorial correspondence analysis
IP	intrinsic potential
MPG	major population group
NMFS	National Marine Fisheries Service
PSS TRT	Puget Sound Steelhead Technical Recovery Team
SaSI	Salmonid Stock Inventory
SASSI	Salmon and Steelhead Stock Inventory
VSP	viable salmonid population
WDF	Washington Department of Fisheries
WDFG	Washington Department of Fish and Game
WDFW	Washington Department of Fish and Wildlife
WDG	Washington Department of Game

Introduction

One of the goals of the Puget Sound Steelhead Technical Recovery Team (PSS TRT) is to identify historical demographically independent populations (DIPs) of steelhead (*Oncorhynchus mykiss*) in the Puget Sound distinct population segment (DPS). First, we consider historical population structure because the historical template is the only known sustainable configuration for the DPS. Second, we consider demographic populations as fundamental biological units and the smallest units for viability modeling. For each putative DIP, where possible, we describe the historical abundance and productivity, life history, phenotypic diversity, and spatial distribution of spawning and rearing groups. Understanding these population characteristics is critical to viability analyses, recovery planning, and conservation assessments. In many cases, the populations we identify will be the same as or similar to those identified by state agencies and tribal governments. Washington Department of Fisheries (WDF) et al. (1993) identified steelhead populations in their Salmon and Steelhead Stock Inventory (SASSI) and further refined them in the Washington Department of Fish and Wildlife (WDFW) Salmonid Stock Inventory (SaSI) document (WDFW 2002). Alternatively, differences in population structure may occur as a result of inherent differences in the criteria used to define populations and the underlying management purpose of some classification schemes. In the end, there is likely to be some uncertainty in historical populations presented in this document; however, we present a reasonable scenario that can then be used as a template for establishing a sustainable DPS. The populations identified in this document are those considered when answering the recovery goal question: How many and which populations are necessary for persistence of the DPS?

Definition of a Population

The definition of a population that we apply is defined in the National Marine Fisheries Service (NMFS) viable salmonid population (VSP) document for use in conservation assessments for Pacific salmonids (McElhany et al. 2000). In the VSP context, NMFS defines an independent population much along the lines of Ricker's (1972) definition of a stock. That is, an independent population is a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season. For our purposes, not interbreeding to a "substantial degree" means that two groups are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year period (McElhany et al. 2000). The exact level of reproductive isolation that is required for a population to have substantially independent dynamics is not well understood, but some theoretical work suggests that substantial independence will occur when the proportion of a population that consists of migrants is less than about 10% (Hastings 1993). Thus independent populations are units for which it is biologically meaningful to examine extinction risks that are intrinsic factors, such as demographic, genetic, or local environmental stochasticity. In general, the conditions necessary to maintain demographic independence (isolation) are not as strict as the conditions to maintain reproductive or genetic independence at the population level.

Independent populations will generally, but not necessarily, be smaller than a whole DPS and will generally inhabit geographic ranges on the scale of whole river basins or major subbasins that are relatively isolated from outside migration. Demographically and biologically, independent populations are the primary unit for viability assessments and recovery planning.

Structure above the Population Level

Just as there may be substructuring within a population, there may be structure above the level of a population. This is explicitly recognized in the designation of a DPS or an evolutionarily significant unit (ESU). A DPS or ESU may contain multiple populations that are connected by some common element. Thus organisms can be grouped into a hierarchical system in which we define the levels from individual to species. Although reproductive isolation forms a continuum, it probably is not a smooth continuum, and there is a biological basis for designating a hierarchy of levels. The concept of “strata” was developed by the Willamette Lower Columbia River TRT to help describe, where necessary, a level of structure intermediate between populations and DPSs (McElhany et al. 2003). A similar multiple population unit was developed for Chinook salmon (*Oncorhynchus tshawytscha*) by the Puget Sound TRT (geographic regions) and the Interior Columbia River TRT (major population groups). For consistency, the term major population groups (MPGs) has been adapted by the TRTs to describe these population aggregates. MPGs are generally used to capture major life history differences, distinct ecological zones, or geographic structuring. Where specific information was unavailable, we considered implied life history differences to exist where populations occupied a suitably large geographic region with unique ecological conditions (e.g., hydrology, thermal regime, estuarine conditions, etc.). Previous TRTs underscored the importance of MPGs by including them in the viability criteria. While criteria for DPS viability vary among the TRTs, there is some provision in all TRT viability criteria requiring the viability of all extant MPGs. Previous TRTs identified MPGs in conjunction with the development of viability criteria; we have elected to concurrently define DIPs and MPGs prior to establishing viability criteria.

Structure below the Population Level

Below the population level, there often will be aggregations of fish that are to some degree reproductively isolated from other groups of fish within the population, but that are insufficiently isolated to be considered independent by the criteria adopted here. These fish groups are referred to as subpopulations. Subpopulations play an important role in the sustainability and evolution of populations. However few populations have been studied sufficiently in depth to characterize any component subpopulations. The presence of subpopulations can have important consequences in the characterization of a VSP. Additionally, subpopulations can strongly influence population spatial structure, one of the four key parameters (along with abundance, productivity, and diversity) for evaluating the status of a population. Where possible, the TRT endeavored to describe internal variability in life history, ecological, or geographic structure for each population. For example, in some steelhead populations, returning adult winter-run and summer-run fish appear to comingle on the spawning grounds. At present there is insufficient information to determine the degree to which these two life history types are reproductively isolated in basins where they appear to co-occur in spawning habitats. As an interim measure, the TRT has identified these life history types as subpopulations within those specific populations rather than create separate DIPs. It is important to recognize multiple life history forms and the habitats that they rely on. Subsequent recovery actions must address this level of diversity in order to ensure the sustainability of the population. In many cases, the scale of available information limited the ability of the TRT to distinguish between DIPs and subpopulations, and ultimately the size of many DIPs was determined by the size of existing census or sampling units. Additionally, in some cases where there was only anecdotal information that a distinct population may exist or may have existed, the TRT used the subpopulation designation as a placeholder. Ultimately, the extent to which populations and subpopulations can be distinguished is determined by the acuity of the information available. The TRT thought it likely that future monitoring, especially on a finer scale, could provide sufficient new information to designate additional independent populations.

Conceptual Approach to Identifying Populations

To date, several TRTs have identified historical populations, extinct and extant, within listed salmonid ESUs and DPSs in the Pacific Northwest and California Recovery domains. There are marked differences in the methodologies utilized by the TRTs in identifying populations (McClure et al. 2003, Myers et al. 2006, Ruckelshaus et al. 2006, Lawson et al. 2007), although the underlying definitions for both population and MPGs are similar. These differences have evolved in part from the varying quantity and quality of historical and current data on listed fish within each of the recovery domains. Differences also reflect biological differences among species, ESUs, and DPSs that are in turn related to major geographic and ecological differences in recovery domains. For example, ecological conditions in coastal or interior areas have a strong influence on life history characteristics, interpopulation interactions, and overall metapopulation structure. Additionally, the factors influencing reproductive isolation are likely to be different for tributaries to a large river system compared to independent basins along the Pacific coastline. As a starting point for this process, we have relied on the work done by the SASSI (WDF et al. 1993) and SaSI (WDFW 2002) steelhead stock inventory processes (Appendix A).

We also reviewed previous TRT work on Puget Sound Chinook salmon (Ruckelshaus et al. 2006). It is likely that, in general, Puget Sound steelhead have responded similarly to the ecological and geographic topography that shaped the distribution and discreteness of Chinook salmon populations. Given that there is considerably more genetic, life history, migration, and abundance information available for Puget Sound Chinook salmon populations than for steelhead, the population structure developed for Chinook salmon provided a useful preliminary template. However, there are considerable differences in life history strategies and habitat utilization between Chinook salmon and steelhead. At a minimum, in contrast to Chinook salmon and other Pacific salmon, steelhead are iteroparous, can exist as a resident or anadromous form, generally have much longer freshwater juvenile residency, spawn and rear in a wider range of stream sizes, and spawn in the spring on a rising thermograph. Spring spawning may also diminish the potential for steelhead redds to be scoured by major rain or rain-on-snow events. In most cases, the TRT concluded that these life history differences resulted in substantial differences in the overall population structure between Chinook salmon and steelhead in Puget Sound, with steelhead populations capable of inhabiting smaller watersheds and persisting at lower abundance levels. Some inferences were also drawn from the Willamette and Lower Columbia River TRT's population document (Myers et al. 2006) that identified populations for co-occurring coastal Chinook salmon, coho salmon (*O. kisutch*), and chum salmon (*O. keta*) and steelhead populations. Ultimately, the TRT relied on both these previous efforts and historical and contemporary Puget Sound steelhead information to establish criteria for identifying DIPs for the Puget Sound DPS.

Part of the suite of information needed to identify demographically independent populations includes interpopulation migration rates and the demographic and genetic consequences of those migrations. In practice, information regarding straying of naturally produced salmon and steelhead between streams is rarely available. Where population-specific information was lacking, our approach for identifying population structure was to use other sources of information as proxies for understanding the degree of reproductive isolation between fish groups. Each source of information contributes to our understanding of population boundaries, but none alone provides us with complete certainty in our conclusion. In the following six subsections, we briefly outline the different information sources employed to help identify steelhead populations. They are discussed in order of the strength of inference that can be made about population structure from each indicator, beginning with relatively high inference that can be made with geographic and migration-rate indicators. Depending on the particular data quality and the genetic and demographic history of steelhead in different regions, the utility of these indicators in any one area can vary.

Migration Rates

The extent to which individuals move between populations determines the demographic independence among sites and, to a lesser degree, reproductive isolation among sites. As described earlier, demographic independence may exist with migration rates as high as 10% (McElhany et al. 2000). Empirical stray rates are particular to the group of fish, season, and streams in which they are estimated; thus they provide useful information about straying under specific conditions, but should be applied cautiously as a general estimate. Given the limited monitoring efforts for steelhead, it is impossible to estimate the magnitude of among-group migration variation over long time periods (e.g., 100 years) except through estimates of gene flow based on population genetic analysis. It should be noted that demographic rates of exchange (movement of adults between populations) can be several times greater than the genetic rates of exchange (the successful reproduction of adults migrating between populations).

Migration rates usually are estimated using the recovery of tagged adults. Fish are tagged using a variety of external tags or internal coded wire tags or passive integrated transponder (PIT) tags. Hatchery-origin fish are generally marked for a variety of data needs including contribution to fisheries, identifying hatchery fish on natural spawning grounds, and identifying broodstock sources for hatcheries. Unfortunately, compared to Chinook or coho salmon, few steelhead releases are tagged. Coded wire tags have been utilized for the management of coastal mixed stock fisheries and, because the majority of steelhead appear to move quickly offshore, there are very few inshore recoveries of steelhead, tagged or untagged. Directed steelhead fisheries, primarily tribal and sport, are in terminal (e.g., riverine) areas and not in coastal mixed-stock areas, thus there has been minimal incentive to tag steelhead other than marking hatchery-origin fish with a fin clip. In addition, as steelhead are iteroparous, carcass recoveries on or near the spawning grounds are rare. In contrast, tag recoveries from spawned-out Pacific salmon carcasses are a major source of information on straying and the contribution of hatchery fish to naturally spawning populations. In addition, the majority of winter-run and summer-run steelhead hatchery populations in the Puget Sound DPS are unrepresentative of the native populations in basins into which those hatchery fish are released. Finally, hatchery fish are readily transferred between hatchery sites for rearing and incubation, factors that would likely reduce homing fidelity for hatchery fish to the point of release.

In general, the homing fidelity of steelhead is thought to be at least as finely tuned as that of Chinook salmon. For hatchery-origin Chinook and coho salmon, the majority (>95%) of adult recoveries occurred within 25 km of the juvenile release sites (Myers et al. 2006, Ruckelshaus et al. 2006). In addition to observational mark-recapture data and other direct estimates of straying, genetically based estimates of intergroup isolation can be used to estimate straying between fish groups integrated over longer time periods. More importantly, genetic monitoring of migration between populations provides a measure of successful introgression by migrants, rather than simply the physical presence of migrants in a nonnatal watershed.

Some caution should be used in interpreting available data on migration rates. Substantial decreases in fish abundance during the past century may have dramatically reduced the connectivity between populations. In addition, as population abundance decreases, the rate of within-population genetic drift (random changes in allele gene frequencies) increases and genetic divergence between populations may arise that was not historically present. Alternatively, with the decrease in the size of spawning populations, the genetic influence of each successfully reproducing migrant increases. Although interpopulation migration rates are useful in identifying independent populations, there was little empirical information available that is directly relevant to Puget Sound steelhead.

Genetic Attributes

There are two categories of genetic differences that can be used to distinguish populations. Physical or behavioral traits, specifically ones with a genetic basis, and base-pair coding variation of specific sequences, are both useful in understanding the distinctiveness of populations. Phenotypic (expressed) traits may be under natural selection and reflect different environmental pressures. Alternatively, measures of differences in DNA coding can be expressed as allozyme variation in the specific sequence variation at specific loci (microsatellite DNA and single nucleotide polymorphism) and are generally thought to reflect neutral (random) variation in the genome. Neutral genetic markers are useful in identifying salmon and steelhead populations because they indicate the extent of reproductive isolation among groups. In contrast, genetically influenced phenotypic differences may be useful in distinguishing populations that experience different environmental conditions, but cannot readily distinguish reproductively isolated populations that share common habitat conditions. However, reliance on phenotypic traits may also incorrectly distinguish fish within a population exhibiting variable life history strategies.

While genetic variability can provide information on the breeding structure within and relationships between provisional populations, neutral marker results can sometimes be difficult to interpret, because patterns may reflect hatchery breeding practices or nonequilibrium conditions such as population bottlenecks or genetic drift. Additionally, DIPs that have only recently become isolated may not yet express genetic divergence. For example, the Cedar, White, and Green rivers have all experienced dramatic changes in their flow paths within the last 100 years that created three geographically distinct basins from what was historically a single basin. The genetic analysis of steelhead present in these three basins shows very little divergence among them, reflecting their shared genetic lineage. While neutral genetic markers provide a relatively direct measure of genetic differences, differences in morphology or life history characteristics may also be useful as expressions of underlying genetic differences, depending on the mechanism of expression. Adaptive life history differences between presumptive populations are likely reflective of ecological differences in the natal streams and are in part indicative of underlying genetic differences. Since the degree of isolation necessary to maintain genetic independence is much higher than that for demographic independence, genetic information will tend to give a more conservative measure of demographic population structure. That is, populations that are genetically significantly different are almost certainly demographically independent; alternatively, some populations that do not appear to be genetically distinct may still be largely independent demographically.

Our knowledge of steelhead population genetics in Puget Sound is based on a number of older allozyme-based studies (e.g., Phelps et al. 1997) and several recent but more geographically limited studies using microsatellite DNA markers (e.g., Kassler et al. 2008). In some cases, interpretation of results from these studies may be limited by uncertainty in estimating the degree of introgression by nonnative hatchery fish into populations. We lack genetic data for populations prior to the large, widespread, and sustained releases of hatchery stocks. Thus we cannot directly estimate genetic impacts to population structure from hatchery fish spawning naturally over the time period of interest. Phelps et al. (1997) suggested that there was little evidence for hatchery introgression in most basins sampled. Kassler et al. (2008) found evidence of interbreeding between native North Fork Skykomish River steelhead and the nonnative summer-run hatchery stock (Columbia Basin origin) released in the Skykomish River. A number of steelhead genetics studies are underway throughout Puget Sound and we used preliminary results from some of these. Final results from projects are pending. Although the state of knowledge of Puget Sound steelhead population genetics is growing, it is clear that much more work is needed. The TRT used what genetic data and results were available to best meet the requirements of identifying DIPs and MPGs. Analysis of recent genetic collections from Puget Sound steelhead populations can be found in Appendix B. As appropriate data become available, it will be important to reevaluate population genetic relationships and DIP designations.

Geography

The boundaries of a steelhead population are influenced in part by the spatial confines of its spawning habitat. Physical features such as a river basin's topographical, hydrological, and temperature characteristics dictate to a large degree where and when steelhead can spawn and delimit the spatial area over which a single group of fish can be expected to interact. For example, the TRT distinguished between streams draining directly to Puget Sound and those that were tributaries to larger river systems in the assessment of population independence because of potential differences in homing fidelity. Geographic features such as elevation, geology, and precipitation will determine flow distribution, riverbed characteristics (substrate size, stream width, and depth) and water conditions. Geographic constraints on population boundaries (such as distance between streams) can provide a useful starting point, but geographic constraints will not generally support strong inferences at a finer scale (e.g., distinguishing separate populations within tributaries of a subbasin). In addition, biogeographical characteristics and historical connections between river basins on geological time scales can be informative in defining population boundaries.

Patterns of Life History and Phenotypic Characteristics

Phenotypic traits based on underlying genetic variation (rather than environmentally induced variation) are useful in identifying distinct populations defined on the basis of reproductive isolation and demographic independence. Variation in spawning time, fecundity, age at juvenile emigration, age at maturation (including repeat spawning), and ocean distribution are, to some degree, genetically influenced (Busby et al. 1996, Hard et al. 2007). Differences in the expression of those traits that influence fitness are generally thought to be indicative of long-term selection for local conditions, although depending on the trait, a substantial portion of most variation observed is still due to purely environmental effects. Hydrological conditions (i.e., water temperature, times of peak and low flows, etc.) influence the time of emigration and return migration and spawning, and over time (several generations) will influence life history traits best adapted to local conditions. While a population may be genetically adapted to general conditions in its natal basin, individual fish within the population will still vary in their life history traits due to genetic variability and in their individual response to environmental cues. In the face of dramatic ecological fluctuations (e.g., El Niños, Pacific decadal oscillations) each population is expected to strike a balance between being highly adapted to local conditions and maintaining multiple life history strategies (bet hedging).

Observed variation in life history traits can be used to infer genetic variation and may indicate similarities in the selective environments experienced by salmonids in different streams. In some cases, similarities in phenotype may arise independently in distinct populations, and the absence of phenotypic differences does not preclude that populations are distinct. The TRT accepted the premise that phenotypic differences in life history traits between populations (especially those that have recently diverged) do provide a strong level of support for geographic separation and the presence of distinct populations.

Population Dynamics

Abundance data can be used to explore the degree to which demographic trajectories of two fish groups are independent of one another. All else being equal, the less correlated two time series of abundance are between two fish groups, the less likely they are to be demographically interrelated. For steelhead, however, the majority of population abundance estimates are based on index area redd counts taken in the winter and spring when periods of relatively high flow and poor visibility can result in considerable uncertainty in the accuracy of these data. Further complicating the interpretation of correlations in abundance are the potentially confounding influences of correlated environmental characteristics, such as shared estuarine and ocean conditions or region-wide drought. Harvest effects also may result in correlations of abundance when distinct populations share oceanic and inshore migratory routes or simply share harvest management goals. However, the majority of Puget Sound steelhead sport and tribal harvest takes place in freshwater and shared harvest effects would predominantly only affect populations within the same river basin. Similarly, hatchery releases can confound any correlation between two populations, especially if the magnitude of releases is different and the relative contribution of hatchery fish to escapement is unknown or subject to a high degree of uncertainty.

When fish groups in close proximity are not correlated in abundance over time, they are likely to be demographically independent. Alternatively, as discussed above, when a strong positive correlation in abundance between fish groups is detected, it is not necessarily true that the two provisional populations are really one population. The TRT considered population dynamics as a "one-way" discriminatory character. The lack of a positive correlation between populations strongly suggests demographic independence, while the existence of correlated trends does not necessarily rule out the existence of distinct populations. Examining trends in population abundance offers an intuitively straightforward method of establishing demographic independence; however, in practice this criterion was only of limited use in identifying DIPs, given the relatively poor quality of escapement data. Additionally, most populations in the DPS were experiencing substantial declines in abundance.

Environmental and Habitat Characteristics

In identifying demographically independent populations, environmental characteristics can influence population structure in two ways. First, environmental characteristics can directly isolate populations. Physical structures, falls or cascades, can isolate resident from anadromous populations or allow only one-way (downstream) migration, or anadromous populations within a basin can be separated by temporal migration barriers (run timing) or simply distance. Thermal or flow conditions in a river can create temporal migrational barriers that prevent interactions between populations (e.g., the cascades on lower Deer Creek, North Fork Stillaguamish River). Second, environmental conditions may exert a selective influence on salmonid populations, which in turn over time may influence the expression of life history characteristics, producing populations that are highly adapted to local conditions. The strength of the correlation between habitat and life history characteristics may be related to homing fidelity and the degree to which populations in ecologically different freshwater habitats are effectively reproductively isolated (e.g., thermal differences may produce differences in spawn timing). If immigrants from other populations are less fit, they will not contribute to the long-term demographics of the receiving population. Alternatively, populations from ecologically similar regions that are geographically separated will still function as distinct demographic units. Therefore, environmental factors alone may have a sufficiently strong effect on the isolation of geographically proximate populations (e.g., a higher elevation summer-run population separated from a lowland winter-run population by a cascade or falls), justifying their designation as independent populations. Alternatively, when life history characteristics are especially plastic, fish migrating between populations will effectively "blend in" with the local population with little potential for environmental selection.

Classifying basins according to their predominant ecological characteristics was useful in comparing presumptive populations. There was some concern however that large river basins (e.g., Nooksack, Skagit, and Snohomish rivers) included a wide diversity of ecological conditions, from high-gradient snowmelt-dominated streams to lowland rain-dominated streams, and an overall basin classification system might ignore this. Reproductively isolated populations along gradients of environmental conditions might not be evident based only on proximity of spawning ground locations. Thus we particularly scrutinized potential effects of environmental conditions on population structure within large basins. Lack of population structuring in large basins may indicate that steelhead populations are more phenotypically plastic and less locally adapted than environmental conditions would suggest. We also acknowledge that there may be multiple distinct populations in an environmentally diverse basin, which are undetectable using existing data.

Identifying Historical Populations of Salmonids

The first goal of the PSS TRT was to identify historical populations of steelhead in the Puget Sound DPS. Having established historical DIPs, the second goal of the TRT was to provide a historical overview of the diversity of life history characteristics, ecological conditions, productivity, and abundance for recovery planning purposes. It is not the TRT's task to develop recovery plans to restore historical conditions completely, but rather to determine in general the population structure necessary to restore the needed aspects of life history diversity, population distribution, and abundance in order to provide for a sustainable DPS into the foreseeable future. Definitions of sustainability and the necessary conditions for achieving sustainability will be provided by the TRT in a subsequent technical memorandum: Viability Criteria for Steelhead within the Puget Sound Distinct Population Segment (Hard et al. in press).

Criteria for Identifying the Distribution of Historical Populations

Tier 1 Criteria

The task of identifying historical populations in the Puget Sound Steelhead DPS is challenging because 1) there are few detailed historical (pre-1900) accounts of steelhead populations and 2) anthropogenic factors (hatchery releases, hatchery transfers between populations, harvest effects, habitat degradation and elimination) most likely have significantly influenced the characteristics and distribution of present-day populations. Additionally, because there are relatively few offshore or coastal fisheries for steelhead, there have been only limited efforts to collect population-level information useful for managing mixed-stock fisheries. As a result, detailed biological profiles are available for only a few contemporary steelhead populations in Puget Sound. To compensate for lack of specific information, we used habitat-based productivity models to develop a template for general geographic and ecological characteristics of an independent population. A stepwise process (Appendix C) was utilized by the TRT to guide the discussion and evaluation of potential DIPs. In general, three primary (Tier 1) criteria were used to identify historical DIPs:

1. Documented historical use,
2. Sustainability under historical conditions, and
3. Demographic independence.

For the majority of presumptive DIPs, there was insufficient information to directly address the sustainability and demographic independence criteria, and few populations satisfied all three Tier 1 criteria. To address the sustainability issue, one would need a historical assessment of productivity and abundance. Historical sources can provide some quantitative measures of abundance, primarily harvest estimates (commercial, tribal, and sports fisheries) and hatchery weir counts. More frequently, historical documents provided qualitative measures, generally reporting the presence of significant spawning aggregations in reports or surveys. In the absence of information on harvest intensity or hatchery collection protocols, any expansion of this information to estimate total run size cannot be done with great precision. Anecdotal accounts were useful in establishing historical presence, but it was more challenging to quantify abundance from notations such as "They were thick as crickets" (Stone 1885). For the purpose of identifying DIPs, it is only necessary to establish a minimum threshold for sustainability, whereas estimating historical run size is more useful in population viability modeling. At best, however, the available historical information is useful for identifying major centers of abundance, but is less helpful in describing the relationships between populations, especially those in smaller independent tributaries.

The TRT discussed at length what a minimum size metric for a sustainable steelhead population would be. Based in part on recommendations in Allendorf et al. (1997), the TRT concluded that an effective population size (N_e) of 500 per generation was an appropriate minimum size for a DIP. The relationship between effective population size and census size (N) also was discussed at length. Waples et al. (1993) suggested that, for Interior Columbia Basin Chinook salmon populations, this ratio is on the order of 0.20 to 0.25. Ford et al. (2004) found similar results for Oregon coastal coho salmon. Steelhead life history characteristics are in many ways substantially different from those of Pacific salmon. Overall, the net effect of these differences would result in an increase in the ratio between N_e and N. Araki et al. (2007) estimated the N_e/N ratio to range from 0.17 to 0.40, depending on the influence of resident *O. mykiss* and hatchery-origin breeders. It is likely that the presence of resident *O. mykiss* that produce anadromous adult offspring, either by interbreeding directly with their anadromous counterparts or independently, contributes significantly to abundance dynamics of the anadromous population. This contribution may be especially important when ocean conditions are poor and the survival of the anadromous component is low. The fact that steelhead are iteroparous further increases the number of effective parents in a population and may reduce between-year variability. Assuming Puget Sound steelhead have an average generation time of 4 years, a minimum effective steelhead population size of 500 anadromous fish per generation translates to an effective number of breeders (N_b) of 125 fish per year. If the N_e/N ratio for steelhead is higher than that for semelparous Pacific salmon, perhaps as high as 0.50, then the minimum annual escapement for a population would need to be 250 fish. In other words, with 250 anadromous spawners in a year, one could expect 125 effective breeders that year. A number of TRT members voiced some disagreement about the estimate of 250 fish per year being the minimum escapement needed to meet effective size threshold. Alternative escapement estimates were roughly balanced at levels below and above the 250 fish estimate. Varying escapement estimates were utilized in combination with habitat-based models of productivity to establish a relative run size minimum for a sustainable population.

Tier 2 Criteria

Demographic independence can be directly established through an interpopulation migration estimate using genetic information or physical tags. However, much of this type of information is very limited for steelhead in general and does not exist for many contemporary steelhead populations. In lieu of a direct measure, indirect measures of isolation (Tier 2 criteria) were employed to gauge the degree of demographic independence. These included:

1. Basin size and stream characteristics (length and wetted area);
2. Temporal isolation (different run or spawn timing);

3. Geographic isolation (migration distance between populations[1]);
   - Relative population size—where population size differentials exist, small migration rates from large populations into small populations could preclude independence of the small population;
4. Basin-specific information (e.g., barrier falls or cascades);
5. Ecological distinctiveness;
   - Ecoregion—geology, rainfall, temperature, elevation;
   - Hydrology—rain or snow driven, timing and magnitude of peak and low flows;
   - Streambed characteristics (gradient, confined, etc.); and
   - Within-basin elevation.

Geographic criteria were developed to infer selective and isolating factors that may be instrumental in establishing and maintaining DIPs. This information was used in the absence of relevant biological information delineating historical salmonid populations. In some instances, presumptive populations that did not meet the criteria for DIPs but exhibited one or more of the characteristics of distinct populations were considered subpopulations. Subpopulation designations were intended to highlight areas where some level of population structuring may exist and where further study should be directed. For example, in the Skagit and Sauk rivers summer-run and winter-run steelhead spawning aggregations are temporally but not geographically separated, and further data are needed to establish whether these two life histories are demographically and genetically distinct. Where present, subpopulations are an important diversity component and are considered in the diversity piece of the population viability assessment.

Sustainability and Independence

For an independent population to persist in the face of environmental fluctuations and other stochastic events, it must maintain a sufficiently large population size. Whether a population must contain hundreds or thousands of individuals to be sustainable is the subject of considerable debate, but at a minimum, hundreds of individuals are likely necessary. Thus the potential for a watershed to sustain a population large enough to be independent will be strongly related to the size of the basin, the size of the river, and the productivity of the river. The size of a basin and the topography and flow of the river may also influence homing accuracy. The presence of a seasonal or complete migration barrier or barriers provides an added if not substantial degree of reproductive isolation.

Boundaries between distinct populations could be inferred where rivers diverge into distinct tributaries or where sizable areas of poor or absent spawning habitat effectively separate spawning areas. If large enough, tributary basins may provide ecologically distinctive habitats and characteristic homing (olfactory) cues that reinforce the establishment of independent

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[1] Ideally, the distance would be measured between spawning areas, but because that information was not always available and subject to year-to-year variability, the TRT opted for tributary mouth-to-mouth distance over water as a conservative measure of the distance.

populations. At a minimum, differences in ecology may minimize the "attractiveness" of a nonnatal stream type. Lawson et al. (2007) considered distance between mouths of independent rivers entering marine waters a very important isolating mechanism.

Steelhead in the Puget Sound DPS spawn in streams from the northwest boundary with Canada, through South Puget Sound, in Hood Canal, and throughout the Strait of Juan de Fuca to and including the Elwha River (Figure 1). Many of the contemporary spawning distributions are well-known (WDF et al. 1993, WDFW 2002), in contrast to information for most basins on the location of present day juvenile rearing areas or historical spawning distributions. Disjunct spawning areas can suggest discontinuity between populations, especially where ecological differences or physical barriers coincide with separations between spawning aggregations. Geographic data on spawning reaches were available for only a limited number of rivers; in addition, there is considerable annual variability in spawner distribution. Therefore, geographic distances (kilometers) separating spawning areas were defined as the shortest nautical distance separating river mouths (Appendix D). This measure was considered a conservative estimate of the minimum distance between presumptive populations. Distances were calculated using network routing tools in ArcMap (Esri, Redlands, California) and 1:100,000 scale National Hydrography Dataset (U.S. Geological Survey) streams. The "starting" and "ending" locations (such as river mouths) were used to create a network from the National Hydrography Dataset data.

The theory of island biogeography (MacArthur and Wilson 1967), when applied to salmon populations, suggests that a "minimum catchment area" could exist which defines the minimum watershed area needed to support a self-sustaining steelhead population. Catchment areas for major Puget Sound river basins vary by almost two orders of magnitude. SaSI populations (WDFW 2002) range from more than 3,946 km^2 for the entire Skagit River basin to slightly less than 80 km^2 in the Dewatto River basin or Snow Creek. Myers et al. (2006) did not establish a minimum catchment area for steelhead in the Lower Columbia River, but speculated that it could be smaller than the 25,000 ha/250 km^2 threshold utilized for Chinook salmon DIPs in the Lower Columbia River.

After reviewing existing run sizes and basin areas, the TRT concluded that 80 km^2 may be the minimum basin size threshold for a sustainable, demographically independent steelhead population in Puget Sound. This threshold was based on the basin size for the Snow/Salmon Creek basin (89 km^2), a system that many in the TRT concluded was representative of a self-sustaining population. Setting the threshold basin size slightly below that of the Snow/Salmon Creek basin was thought to ensure an inclusive set of potential DIPs to be considered. It was also recognized that specific conditions might exist in some basins to significantly raise or lower this threshold. For example, basin productivity and hydrology may be positively influenced by the presence of a lake (inaccessible or not) in the basin, as is the case with the Snow Creek basin. Lakes may act positively by increasing productivity (nutrient input into the stream) or may simply attenuate the hydrograph to minimize flooding scour events. Ultimately, it was concluded that the use of a 80 km^2 basin size or 104,000 m^2 high intrinsic potential (IP) (see Table 1) criteria was probably not a definitive threshold, but minimized the likelihood of a

Figure 1. Location of winter-run and summer-run stocks within the Puget Sound Steelhead DPS. Stock designations are based on WDFW (2002) SaSI designations. Not all SaSI steelhead stocks are included in the DPS; specifically not included are South Fork Stillaguamish River (above Granite Falls), South Fork Skykomish River (Sunset Falls), and the Deschutes River.

Table 1. Stream habitat rating matrix (below natural barriers) for Puget Sound steelhead. Stream size and gradient categories were assigned by TRT members based on consideration of the Interior Columbia TRT's IP model and on expert opinion. The TRT used these basin characteristics to calculate the IP of Puget Sound steelhead basins in order to establish whether a large enough population could be sustained into the foreseeable future.

Stream gradient	**Bankfull width**		
(percent)	0–3 m	3–20 m	>20 m
0.0–0.25	High	Moderate	Low
0.25–4.0	Moderate	High	Moderate
>4.0	Low	Low	Low

Type II error (failure to reject a false null hypothesis) and provided a useful first filter for prospective DIPs.

We calculated catchment area for each entire basin (based on a topographical Geographic Information System [GIS] model) and for accessible portions of each basin for Puget Sound streams using both known natural and man-made barriers (Williams et al. 1975, StreamNet 2012). In large watersheds such as the Skagit River, which contain major tributaries (Appendix D), the calculation of catchment area excluded portions of the watershed above major upstream confluences (e.g., the lower Skagit River includes the area from the river's mouth to its confluence with the Sauk River). We adopted these estimates as a preliminary step in developing a list of prospective steelhead DIPs. Gibbons et al. (1985) directly measured *O. mykiss* juvenile (parr) densities in a number of Puget Sound streams and categorized stream area productivity according to stream size and gradient. The TRT generated estimates of stream length, stream area (wetted bankfull area), and stream gradient using GIS-based models. Gradient was calculated using 100 m reaches. To estimate historical capacity, these data were integrated into an IP model adapted from the Interior Columbia TRT's model based primarily on stream size and gradient. For Puget Sound steelhead, we simplified the model to only three stream gradient classes, 0–0.25%, 0.25– 4%, and greater than 4% gradient, and to three stream widths: 0–3 m, 3–20 m, and greater than 20 m. Stream habitat was initially classified as having low, moderate, and high productivity (Table 1).

There are a number of estimates for steelhead freshwater productivity. Chapman (1981) estimated freshwater production under pristine conditions at 0.0877 parr/m^2 (equivalent to 0.0263 smolts/m^2). Gibbons et al. (1985) developed a more complex productivity model, based on stream gradient and size, with parr productivity for Puget Sound streams varying from 0.05 to 0.12 parr/m^2, with small independent tributaries having some of the highest productivities. On average, western Washington stream productivity was 0.0717 parr/m^2 with 0.0265 spawners/parr (Gibbons et al. 1985). Similarly, the U.S. Army Corps of Engineers (1988) estimated potential steelhead freshwater productivity at 0.067 parr/m^2 for streams and 0.041 parr/m^2 for rivers. We used an average estimate for parr productivity of 0.0754 parr/m^2 with the Chapman (1981) parr-to-smolt survival of 0.30, to establish a 0.023 smolts/m^2 level of productivity. Low productivity areas (those with gradients >4%) were not included in the estimate of potential parr numbers. There was also considerable discussion on the productivity of large rivers (>50 m wide), because much of the bankfull area in larger rivers is not utilized by juvenile salmonids in the absence of in-river structures. With the exception of a few river systems, most notably the Skagit, relatively little of the IP habitat area considered included larger width rivers.

Overall, our IP estimates were similar to those for the Keogh River, 0.032 smolts/m^2 (Tautz et al. 1992). Smolt-to-adult survival was calculated using a range conservatively based on Keogh River studies, 10 to 20% (Ward and Wightman 1989), to estimate average precontact estuary and ocean productivity. Providing a range of smolt-to-adult survivals helps underscore the uncertainties in the productivity estimates and environmental stochasticity.

Given the simplicity of this model, the TRT acknowledges that there is considerable uncertainty in the capacity estimates. The TRT used the IP estimate for Snow Creek (274–548 steelhead for 10–20% smolt-to-adult survival) as a minimum value for identifying candidate DIPs. Where independent tributaries did not meet the IP threshold, multiple independent tributaries were combined to create presumptive DIPs; in some cases multiple iterations of independent tributaries were assessed. Collectively, the IP estimates for all of the Puget Sound Steelhead DPS represent a total production range of 306,831–613,662 steelhead using the 10–20% smolt-to-adult survivals, respectively. The high estimate is about one-half to two-thirds of the historical estimates put forth by Hard et al. (2007) and Gayeski et al. (2011). Review of IP estimates and historical data also suggests that the IP capacity estimates tend to greatly underestimate productivity of summer-run steelhead basins with higher gradient stream reaches. In cases where IP estimates for summer-run steelhead DIPs were especially low, below threshold levels generally thought to represent sustainable populations, minimum abundance levels were established (Appendix D). IP estimates of productivity and historical peak escapement estimates should not be considered synonymous.

Ecological Information

The fidelity with which salmonids return to their natal streams implies a close association between a specific breeding aggregation and its freshwater environment. The selective pressures of different freshwater environments may be responsible for differences in life history strategies among stocks. Miller and Brannon (1982) hypothesized that local temperature regimes are the major factor influencing life history traits. If the boundaries of distinct freshwater habitats coincide with differences in life histories that have a heritable component, this may indicate that conditions promoting reproductive isolation exist. Therefore, identifying distinct freshwater, terrestrial, and climatic (ecological) regions may be useful in identifying distinct populations.

The U.S. Environmental Protection Agency (EPA) established the “ecoregion” system of hierarchical designations (Figure 2) based on soil content, topography, climate, potential vegetation, and land use (Omernik and Gallant 1986, Omernik 1987). On a regional scale (i.e., Pacific Northwest), there is a strong relationship between ecoregions and freshwater fish assemblages (Hughes et al. 1987). For Puget Sound, ecoregions were largely differentiated based on elevation and the associated flora and precipitation. Also included in the ecological descriptions are present day river flow, modeled river flows, water temperature information, and climate data. Details of this analysis are more comprehensively covered in Appendix D.

Ruckelshaus et al. (2006) identified hydrologic regime (rain-, snow-, or rain/snow-dominated precipitation) as a major factor influencing life history characteristics in Chinook salmon. It is probable that steelhead life history characteristics are similarly affected, perhaps more so because of the longer freshwater residency of steelhead relative to Chinook salmon. In reviewing ecological characteristics, the TRT focused on stream hydrology (annual flow pattern and flow rate), precipitation, stream temperature, water chemistry (where available), stream size (length, area, width), stream confinement, elevation, and gradient in their analysis. Basin characteristics were provided to the TRT in a number of different formats, including cluster and principle component analyses.

The differences in geography, hydrology, precipitation, vegetation, and geology identified among Level III ecoregions probably are substantial enough to differentially select for variations in life history strategy and provide a basis for ecological and geographic separation. In other words, ecoregions likely indicate separation substantial enough to result in reproductive isolation. Ruckelshaus et al. (2002) identified five ecological regions in Puget Sound for

Chinook salmon: Nooksack, Northern Puget Sound (Samish River to Snohomish River), Southern Puget Sound, Hood Canal, and Strait of Juan de Fuca. These regions are conceptually similar to the ecological zones described for the Lower Columbia and Upper Willamette rivers (McElhany et al. 2003). For both Puget Sound Chinook salmon and Lower Columbia River Domain ESUs and DPSs, higher level ecological differences were ultimately used in the process for identifying MPGs.

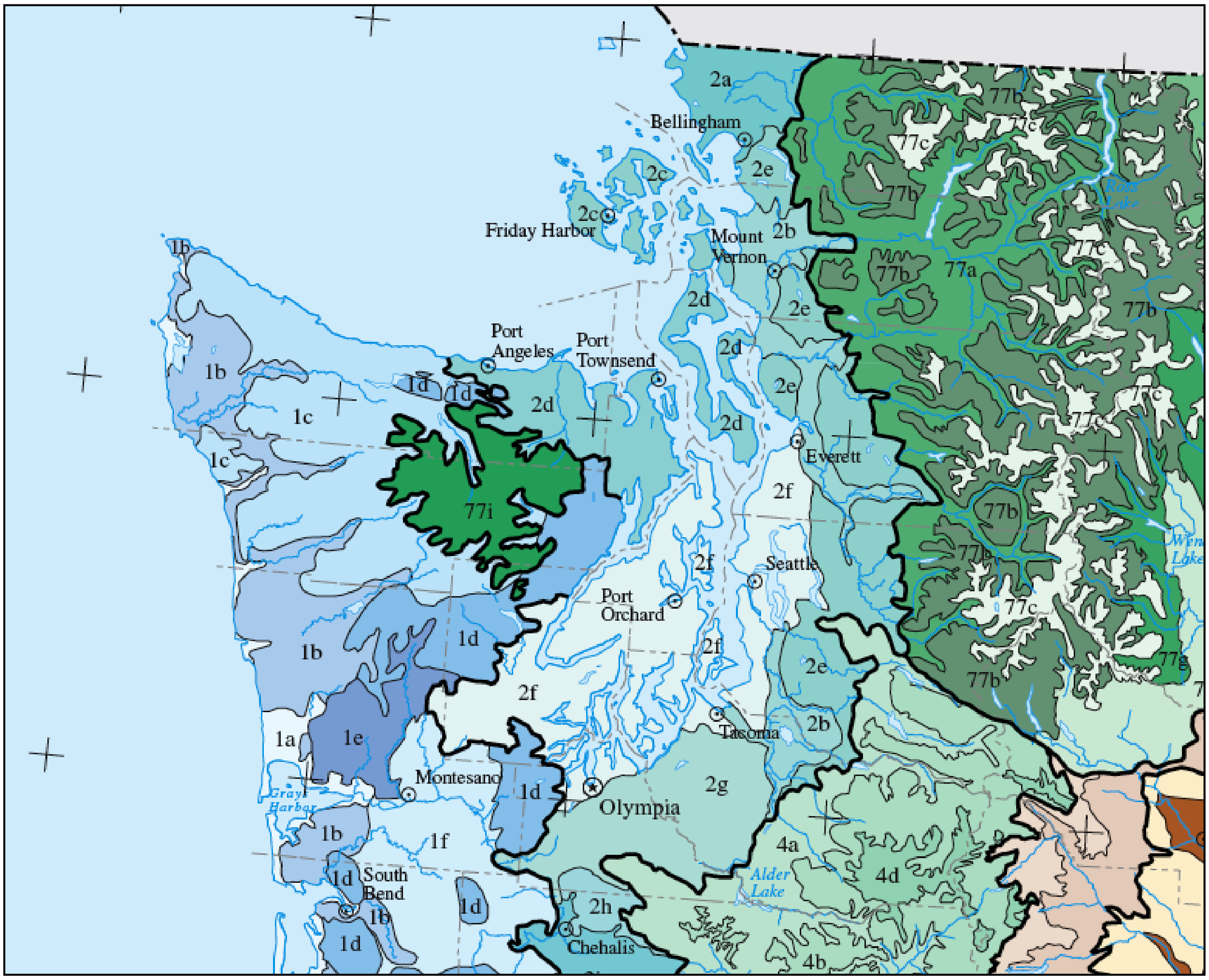

Figure 2. Level III and IV ecoregions of the Northwestern United States map were compiled primarily at a scale of 1:250,000; it depicts revisions and subdivisions of earlier Level III ecoregions that were originally compiled at a smaller scale (Omernik and Gallant 1986, Omernik 1987). Level III ecoregions are indicated by a numeric code: 1 = Coast Range, 2 = Puget Lowlands, 4 = Cascades, and 77 = North Cascades. Level IV ecoregions are indicated by a lower case letter suffix. (Map and supporting documentation online at http://www.epa.gov/wed/pages/ecoregions/level_iv.htm.)

Biological Data

While homing fidelity is a major determinant of population structure and plays a key role in defining a population's geographic bounds, estimates of homing fidelity or the rate and distance of interpopulation migration (aka straying) are largely unavailable for steelhead in Puget Sound. Interpopulation migration rates are most commonly estimated for salmonid species using coded wire tag–marked fish releases (primarily from hatcheries). In general, neither natural-origin nor hatchery-origin steelhead have been marked with coded wire tags or similar origin-specific tags to any great extent, hence the lack of data on steelhead stray rates. The results from recent experiments with acoustic tags in winter steelhead from Puget Sound will not be available in the near term, but will ultimately begin providing information that may or may not confirm the assumptions made by the TRT. Additionally, summer steelhead, which have an extended freshwater prespawning phase, seek cold water refuges in deep holding pools prior to spawning, and often these can be in nonnatal streams (or hatchery holding ponds). Therefore, unless adult summer-run steelhead are sampled at the time of spawning, there is little certainty that the collection point represents their natal stream. Some straying data exist for hatchery-origin steelhead, but many aspects of hatchery rearing and release programs are known to reduce the homing fidelity of returning fish. Schroeder et al. (2001) determined that stray hatchery winter steelhead comprised an average of 11% of the escapement in coastal Oregon streams. Furthermore, hatchery fish that were transported out of their natal stream and released accounted for the majority of these strays. Although Schroeder et al. (2001) did not specify the actual distances that the steelhead strayed from their point of release, it was apparent that straying rate was inversely proportional to the distance from the natal stream. As a conservative measure of migration rate, when distances between river mouths were used with the Schroeder et al. (2001) data, the rate of exchange dropped to low levels 25 km from the point of release and beyond 50 km was mostly below 5% (Figure 3). Finally, there is some debate regarding the homing accuracy of steelhead relative to Chinook or coho salmon. It is thought that the extended duration of freshwater rearing expressed by steelhead should result in better homing accuracy than Chinook and possibly coho salmon. Further, the persistence of summer-run steelhead in specific small basins around Puget Sound has been suggested as evidence for relatively higher fidelity to their natal stream. Overall, while homing is an important consideration in establishing independent populations and there is an expectation that steelhead home with high acuity, there is little direct information to quantify this.

Age structure has been used historically to identify steelhead from different freshwater environments as a proxy for population identification (Rich 1920, Marr 1943). Analysis of scales from naturally spawning adults was utilized to identify similarities in age at marine emigration and maturation among proposed populations. This information was used with caution because of the unknown origin of unmarked naturally spawning fish, the potential bias of fishery gear type or harvest rate on age structure, and the modification or loss of habitats that would preclude specific juvenile life history strategies. With a few notable exceptions, age structure did not appear to be an important diagnostic for identifying independent populations of Puget Sound steelhead.

Historical documentation of fish presence and abundance was based on harvest information, stream surveys, and observations reported by the Bureau of Commercial Fisheries (the progenitor to NMFS), WDF and Washington Department of Game (WDG, later combined to

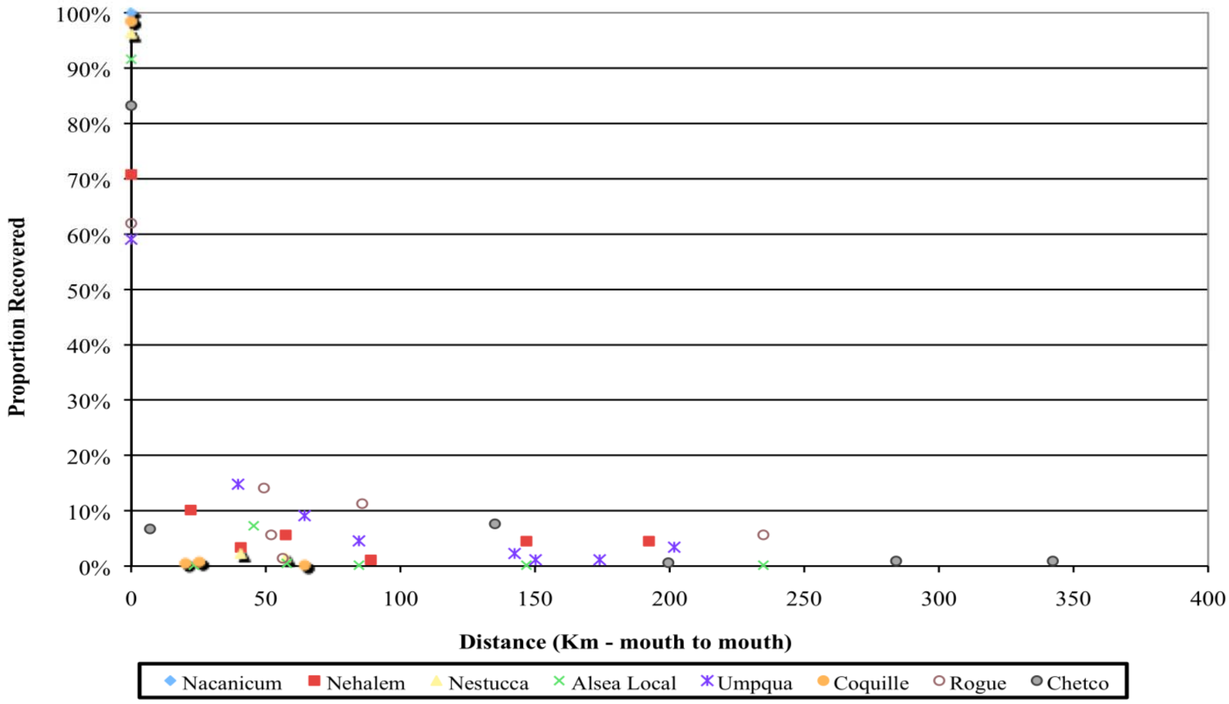

Figure 3. Steelhead homing rates. Distance from point of juvenile release (river mouth to river mouth) for returning adult steelhead. Proportion recovered is calculated separately for each river release group. (Recovery data from Schroeder et al. 2001).

Washington Department of Fish and Game [WDFG], now WDFW), the trade journal Pacific Fisherman, tribal accounts, popular sports literature, and various other sources. State and federal hatchery records also provided valuable insight into historical abundance and life history characteristics. Hatchery operations in Puget Sound were undertaken in nearly every major basin in the Puget Sound DPS. Where hatchery records were available, the number of returning adults and the timing of their return and maturation were of primary interest. Although studies with Pacific salmon species have documented the relative influence of hatchery introductions on local populations, the situation is less clear for steelhead. Early hatchery operations stressed the release of large numbers of sac fry that provided little benefit to populations they were intended to supplement or the fisheries to which they were intended to contribute.

The Pacific Fisherman (June 1914) article on rearing and feeding salmon fry summarized this practice:

> To the thoughtful person, the system in vogue for many years of depositing salmon and other fry in the water as soon as possible after being hatched or after the yolk sac had been absorbed, seemed far from an ideal one…. The desire on the part of some fish commissions to make a large statistical showing of fry deposited at a small cost has also aided in perpetuating this method.

Although there were subsequent changes in hatchery protocols during the 1920s and 1930s to extend the rearing period prior to release by a few weeks, it is likely that this provided little benefit in the survival of steelhead that normally reside in freshwater for 1–3 years. Until late in the 1940s, the majority of hatchery-propagated steelhead was released as subyearling juveniles. Studies by Pautzke and Meigs (1940, 1941) strongly suggested that these releases had little or no positive influence on subsequent runs and may have simply served to "mine" the natural run. Hatchery broodstock collections prior to 1940 therefore give some insight into the size and sustainability of some populations in spite of continuous broodstock mining, which in some cases continued for decades.

Some caution should be used in applying historical hatchery production figures to the overall analysis. For example, a review of hatchery operations in 1915 (WDFG 1916) discovered that "The superintendent supposedly in charge [of the Nisqually Hatchery] was discovered to be sojourning in the City of Tacoma with his entire family, although diligently maintaining his place on the state's payroll." In spite of the likely padding of some production numbers, it is clear that for several decades thousands of returning adult steelhead, both natural and hatchery-origin, were intercepted annually from streams in Puget Sound in order to sustain the very artificial propagation programs that were intended to improve the steelhead runs (Appendix E). More recent genetic studies by Phelps et al. (1994, 1997) detected introgression by hatchery steelhead stocks primarily in situations where hatchery fish had been introduced into relatively small stream basins with numerically few natural-origin steelhead. Additionally, hatchery steelhead have been established in some river basins or tributaries following the laddering of, or trapping and hauling operations at, falls or cascades that were natural migration barriers (e.g., Granite Falls on South Fork Stillaguamish River, Tumwater Falls on the Deschutes River, Sunset Falls on South Fork Skykomish River).

Furthermore, because of the magnitude of more recent hatchery releases, similarities or differences in abundance trends (especially those based on redd counts) do not necessarily indicate demographic independence or lack thereof. Hatchery fish can influence demographic data in three ways.

- When present on natural spawning grounds, they inflate the abundance of naturally spawning fish.
- Large releases of hatchery fish may reduce the survival of naturally-produced juveniles.
- Hatchery releases reduce estimates of natural productivity by adding more adults to the adult-to-spawner relationship. This is especially true if hatchery fish produce redds, but subsequent progeny survival is not equivalent to that of naturally produced fish.

For the purpose of population identification, hatchery influence on population demographics may not be as important a factor as it is in the estimation of population viability. In any event, there are few populations with sufficient information to test the correlation in abundance trends between populations. Furthermore, a number of TRT members identified ocean conditions as having a major influence on population demographics, enough so to obscure freshwater-derived differences.

Genetic analysis of spawning aggregations normally provides a quantitative method for establishing population distinctiveness. However, the influence of hatchery fish spawning naturally (potential genetic introgression) and the reduced abundance of naturally spawning populations has potentially affected the present day genetic structure of steelhead populations in

Puget Sound, although in many cases it is possible to identify and remove hatchery-origin individuals from genetic analyses. In the absence of a historical genetic baseline, it is impossible to estimate the effects of hatcheries or abundance bottlenecks on steelhead population structure, although as more information becomes available, it may be possible to better quantify the effects of artificial propagation. These issues underscore the problem of identifying historical population structure based on contemporary sampling of existing populations. Despite these caveats, genetic information available from contemporary samples provided a useful framework for population structure in the Puget Sound Steelhead DPS.

Population Boundaries for Fish and Habitat

In determining population boundaries, both the accessible and inaccessible areas of the basin were considered. The accessible area of a basin is directly occupied during spawning, initial rearing, and migration, while estimates for the entire basin were based on topography and includes portions not occupied by the population (a GIS-based model estimated the boundaries of the watershed). By considering the entire basin, one acknowledges that inaccessible portions of the basin influence stream conditions in the occupied portion of the basin. It is important to consider historical and contemporary conditions in unoccupied headwater areas and their impact on the abundance and life history strategies of downstream fish assemblages. This approach does not affect the boundaries of the DPS, which include only the anadromous portion of each basin (see NMFS 2007).

Historical Documentation

Taxonomic Descriptions and Observations

Specific information on steelhead abundance, distribution, and life history in Puget Sound is fairly limited prior to the 1890s. Early confusion in identifying salmon and trout species prevented the consolidation of abundance and life history information. The fact that steelhead adults return to freshwater in the winter and spring when flows are high and visibility is low also limited observations. Furthermore, because steelhead are iteroparous, early settlers and naturalists were not confronted by streams lined with steelhead carcasses (in contrast to the numerous accounts of rotting salmon carcasses along streams). The Pacific Railroad surveys (aka the U.S. Exploring Surveys) conducted during the 1850s provided the first widely available descriptions of fish species in the Pacific Northwest, although Walbaum, a naturalist working for the Russian Imperial Court, had described the Pacific salmon species some 60 years previously. Two of the leading naturalists for the Pacific Railroad surveys, Girard (1858) and Suckley (1858), compiled species descriptions from their own observations or from a number of other sources. Their efforts would later attract considerable criticism. Jordan (1931, p. 157) would later comment that, “Girard indeed did all a man could do to make it difficult to determine the trout.” Jordan’s opinion of Suckley was equally critical: “He succeeded in carrying the confusion to an extreme, making as many as three genera from a single species of salmon, founded on differences of age and sex” (Jordan 1931, p. 157). In the appendices to the Pacific Railroad surveys, Girard (1858) describes at least four species that could have represented the anadromous or resident *O. mykiss*, steelhead and rainbow trout, respectively: *Salmo gairdneri, S. gibbsii, S. argyreus* and *S. truncates*. Regardless of their inaccurate taxonomy, the Pacific

Railroad surveys provide a number of important early observations of steelhead in the Pacific Northwest and specifically the Puget Sound area.

In the Pacific Railroad surveys and other documents of the time, steelhead are commonly referred to as salmon-trout, although there is some possibility that the reference could be describing sea-run cutthroat trout (*O. clarki*) or, less likely, sea-run bull trout (*Salvelinus confluentus*) or Dolly Varden (*S. malma*).[2] For the Puget Sound region, bull trout would be the predominant of the two Salvelinus species. It is generally possible to identify the proper species by considering the morphological descriptions and references to run and spawn timing. For example, Girard (1858, p. 326–327) quotes Gibbs describing a "salmon" that enters the Puyallup at the end of December, holds in the river until the snows begin melting (spring), then ascends the stream. These fish were apparently not abundant (relative to salmon at the time) and did not travel in schools. The fish weighed between 15 and 18 pounds (6.8 to 8.2 kg) and were silver with a bluish-gray dorsal surface.[3] Girard (1858) also describes a *S. truncates* caught in the Straits of Fuca [sic] in February 1857, noting that this species rarely achieves weights over 12 pounds and generally less. These fish enter rivers in the beginning of December and continue through January. They do not run up the streams in schools, but the run is more "drawn out." The caudal fin is truncated, not forked. The fish was known to the Klallam Tribe as "klutchin" and to the Nisqually Tribe as "Skwowl." Suckley (Girard 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 Skagetts [sic] as "yoo-mitch," entered freshwater from mid-June to August, a run timing that corresponds to existing summer-run steelhead or less likely early returning (spring-run or summer-run) Chinook salmon. Another account by Girard (1858) described a *S. gairdneri* caught in the Green River as being bright and silvery, 28 inches long (71 cm), and not having a forked tail. Another probable steelhead description was provided to Girard by Cooper, but under the "scientific name" *S. gibbsii* (Girard 1858, p. 333). The fish was noted for having a "moderately lunated tail at its extremity" and heavily spotted fins. Cooper observed this "salmon trout" in the Columbia River basin east of the Cascades. In addition, he observed one caught in Puget Sound in March of 1855. There is a strong likelihood that most of these observations were of steelhead.

In addition to descriptions of presumptive steelhead, there are a number of observations of cutthroat trout. In assessing the historical changes in steelhead/rainbow abundance and habitat use, it is useful to understand the relationship between rainbow/steelhead and cutthroat trout. Girard (1858) identified *Fario stallatus* as the predominant trout in the Lower Columbia River and Puget Sound tributaries. Girard found this trout to be very abundant and distinguished by a patch of vermillion under the chin. This fish is most likely the cutthroat trout, and these observations support the contention that cutthroat trout were the primary resident trout in Puget Sound and the Lower Columbia River. Lord (1866) also noted that *Fario stallatus* "lives in all streams flowing into Puget's Sound and away up the western sides of the Cascades." These observations suggest a complex historical relationship between anadromous and resident *O. mykiss* and *O. clarki*. The presence of large numbers of *O. clarki* in smaller streams likely

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[2] Dolly Varden and bull trout were not recognized as distinct species until 1980 and most historical references only identify Dolly Varden, aka the "red-spotted trout" (Girard 1858).

[3] Gibbs' description generally fits steelhead, although he notes that it has a forked tail and there could be some confusion with spring-run Chinook salmon.

influenced the distribution and abundance of resident *O. mykiss* and to a lesser extent steelhead. In short, although it is clear that steelhead were historically found throughout Puget Sound, there is little basin-specific abundance and distribution information on either anadromous or resident *O. mykiss* to be gleaned from these early accounts.

The taxonomic status of steelhead took on a new importance in the late 1800s when sport and commercial fishers debated whether trout or salmon regulations applied to steelhead caught in freshwater.

> Dr. David Starr Jordan, the renowned piscatorial expert, now at the head of the Stanford Jr. University, has declared that these fish belong to the trout family, but the fishermen, not those who fish for sport, but those who catch fish for a living, have decided that the steelhead is a salmon. Up to 1890 the steelhead was regarded as a salmon, but Dr. Jordan, after an exhaustive research, passed judgment that the public had been in error (San Francisco Call 1895).

Ultimately, this taxonomic distinction would have considerable consequences on the future exploitation of steelhead populations. As a "trout," the steelhead were regulated by many states as a game fish in freshwater fisheries.

Historical Abundance

Analysis of historical abundance can be useful in identifying DIPs, especially where populations have experienced severe declines or been extirpated. Estimates of historical steelhead abundance in Puget Sound have largely been based on catch records, and it was not until the late 1920s that there was an organized effort to survey spawning populations of steelhead in Puget Sound (WDFG 1932). There are a number of considerations that need to be taken into account in estimating historical run sizes, especially from catch data. First, during the late 1800s and early 1900s, Chinook salmon was the preferred species for canning and, whereas there is an extensive database of the cannery packs, the fresh fish markets were not extensively monitored. Second, steelhead have a protracted run timing relative to Chinook salmon and do not tend to travel in large schools, making them less susceptible to harvest in marine waters. Finally, winter-run steelhead return from December through April when conditions in Puget Sound and the rivers that drain to it are not conducive to some commercial gear types. In the absence of standardized fishing effort estimates, it is impossible to report a time series for historical run size estimates with great accuracy and approximate harvest estimates must generally suffice. We have attempted to expand the peak harvest only in order to present an estimate of maximum run size rather than to develop a demographic trend.

Collins (1892) in his review of West Coast fisheries noted that steelhead are found in northern Puget Sound, although they are not as numerous as sockeye salmon (*O. nerka*), and that salmon trout[4] are common in southern Puget Sound, especially near Olympia and Tacoma. In 1888, 23,000 kg (50,600 lb) of fresh "salmon-trout" were marketed in the Puget Sound area. Catch records from 1889 indicate that 41,168 kg (90,570 lb) of steelhead were caught in the Puget Sound District (Rathbun 1900). Rathbun (1900) indicated that steelhead were being targeted by fishermen because the winter run occurred at a time when other salmon fisheries

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[4] It is not clear whether he is referring to steelhead, sea-run cutthroat, or both.

were at seasonal lows and steelhead could command a premium price, up to $0.04 a pound. In converting catch estimates to run size, the PSS TRT used an average fish weight of 4.5 kg, based on the size range 3.6 to 5.5 kg (8 to 12 lb) reported by Rathbun 1900. Based on this average, the 1889 catch (41,118 kg) represents 9,148 steelhead, whereas a more conservative (higher) average weight of 5.5 kg (12 lb) would represent only 7,548 steelhead. These estimates do not allow for unreported commercial catch, sport catch, cleaning, or wastage. Analysis of the commercial catch records from 1889 to 1920 (Figure 4) suggests that the catch peaked at 204,600 steelhead in 1895. Sheppard (1972) reported that commercial catches of steelhead in the contiguous United States began to decline in 1895 after only a few years of intensive harvest. Using a harvest rate range of 30–50%, the estimated peak run size for Puget Sound would range from 409,200 to 682,000 fish (at 4.5 kg average weight). Alternatively, Gayeski et al. (2011) expanded the 1895 harvest data, including estimates of unreported catch and using an average fish size of 3.6 kg to approximate historical abundance. Their estimate ranged (90% posterior distribution) from 485,000 to 930,000 with a mode of 622,000. In either case, it is clear that the historical abundance of steelhead was at least an order or magnitude greater than what is observed currently.

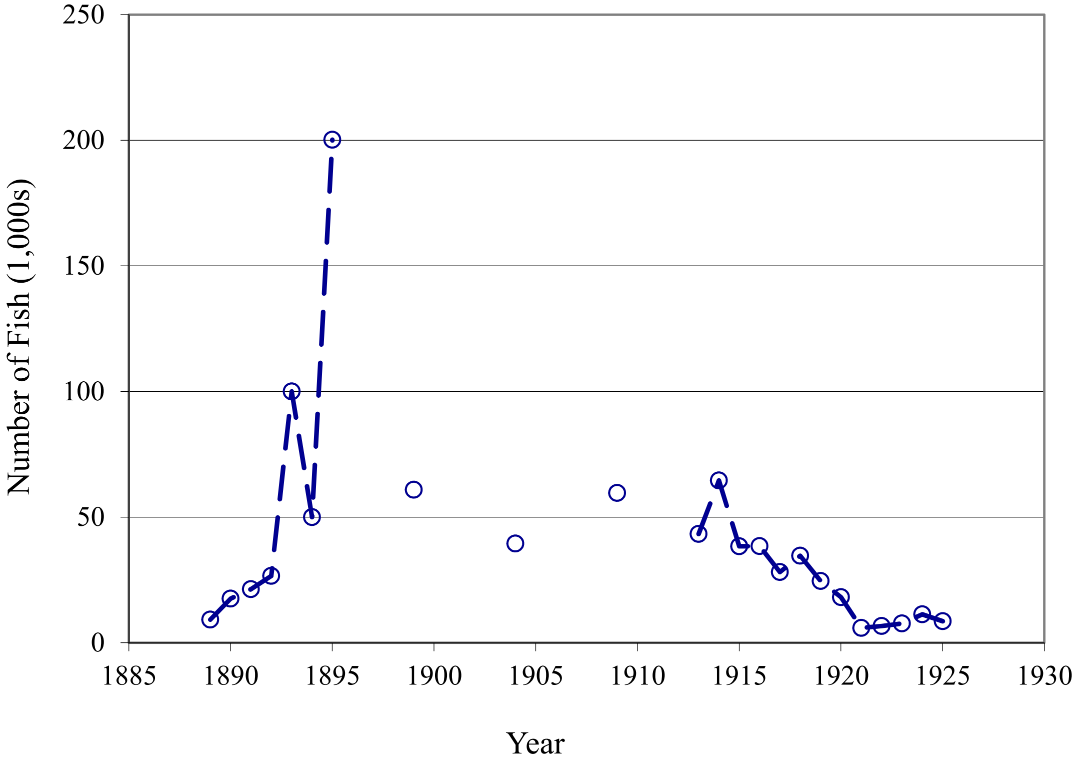

Figure 4. Harvest of steelhead in Puget Sound, 1889–1925. The y-axis is total catch in number of fish. In years without data points, harvest was reported as a combined salmon/steelhead harvest. (Data from Wilcox 1898, Rathbun 1900, WDFG 1902, 1907, 1913, 1916, 1925, Wilcox 1905, and Cobb 1911.)

Rathbun (1900) reported that the steelhead fishery occurred mainly in the winter and the majority of the harvest occurred in the lakes and rivers. Later reports described the majority of the harvest occurring in terminal fisheries (i.e., gill nets or pound nets) in Skagit, Snohomish, King, and Pierce counties (Cobb 1911). The county-by-county analysis suggests that the level of inclusion of Fraser River steelhead in the catch estimates was fairly low and that the majority of steelhead were likely harvested in their natal basins (Appendix F), with the possible exception of Clallam and Whatcom counties, where shore-based fish traps or set nets would have had the potential to intercept Fraser River–bound fish.

Even 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 fifty percent of what it was two or three years ago. Very little has been put towards the protection of this class of salmon” (Little 1898). Catches continued to decline from 1900 through the 1920s (Figure 2). The rapid decline in the Puget Sound steelhead catch after only a few years of intensive fishing is in contrast to other Pacific salmonids that sustained high harvest rates for decades before declining. One explanation suggests that larger, older, repeat spawners were important in maintaining steelhead productivity. High harvest rates would quickly remove existing repeat spawners and reduce the probability that returning females would survive to spawn more than once. Repeat spawner rates of around 30% have been observed in Alaskan (Jones 1976) and British Columbian (Withler 1966) streams, levels that may approach those in historical populations.

The management of steelhead was ultimately transferred to the newly formed WDG in 1921. In 1925 the Washington State Legislature classified steelhead as a game fish, but only upstream of the mouth of any river or stream (WDFG 1928), although by that time the Puget Sound catch was greatly diminished. Commercial harvest of steelhead in Puget Sound had fallen 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 abundance were based on sportfishing catch, tribal catch, and spawning ground surveys.

Pre-1950 abundance: Basin-specific information

Artificial propagation efforts with steelhead began with the first hatchery releases in 1900. Initial hatchery releases were primarily smaller fry and subyearling fish. These releases had varying degrees of success, although in the absence of marking hatchery-reared fish, it is difficult to estimate return rates. Work by Pautzke and Meigs (1941) demonstrated the importance of rearing juveniles for at least 1 year prior to release. In light of the likelihood that hatchery programs prior to 1950 contributed little to adult steelhead returns, we have used pre-1950 abundance levels as estimates of natural productivity. In the early 1970s, artificial propagation programs were expanded in both quantity and geographic scope (Appendix G). After 1970 and until the widespread use of fin clipping to mark hatchery-origin fish, natural and hatchery contributions to spawning escapement cannot be parsed out.

Nooksack River

Wilcox (1898) reported that the fishery for steelhead in the Nooksack River was carried out up to 18 to 20 miles upstream from the mouth. For the 1895 fishery, Wilcox (1898) noted that 300,000 kg (660,000 lb) of steelhead were caught in the Nooksack River alone (most other sources present harvest on a county basis). This would represent 66,000 fish (at 4.5 kg/fish). On a county-wide basis, Whatcom County continued to report a substantial steelhead fishery into the early 1900s. It is unclear to what extent Fraser River steelhead were captured by Whatcom County fishers, although shoreline fish traps at Point Roberts and along Bellingham Bay and Drayton Harbor likely intercepted large numbers of migrating steelhead.

Biological surveys of the North Fork Nooksack River and its tributaries during June and July 1921 noted that steelhead spawned in most of the tributaries (Norgore 1921). Surveys conducted in 1930 identified several "medium-sized" runs in the north, middle, and south forks of the Nooksack River (WDFG 1932). Ernst (1950) reported that railway shipments of dressed steelhead in the past had averaged 230 kg (500 lb) during the 8-week peak of the run. Sport fishery catches in the 1940s and 1950s suggest that abundance had declined considerably and only relatively low numbers of steelhead were present, although glacial sediment in the north and middle forks of the Nooksack River likely limited observation, fishability, and ultimately sport harvest.

Samish River

There is very little information on the early abundance of steelhead in the Samish River and Bellingham Bay tributaries. The Samish River Hatchery was built in 1899, but did not begin intercepting steelhead for broodstock until 1907. There is no record of steelhead being transferred to the hatchery prior to this point, so it is most probable that the original broodstock was native to the basin. The Wenatchee Daily World (1906) reported a sport fisher catching a near-record steelhead in the Samish River in April ("Lands 30-pound trout"). Production levels during the initial years would have required a few hundred female broodstock (Appendix E).

Skagit River

Historical accounts indicate that the run of steelhead in the Skagit River extended from November 15 up to the following spring (Wilcox 1895). Only a "scattering" of steelhead were reported prior to December and a light run continued through the winter (Wilcox 1902). In 1899 steelhead marketed in La Conner, Washington (Skagit River), averaged 5 kg (11 lb). Little (1898) indicated that large numbers of "steel-heads" entered the Baker River and spawned from March to April.

Much of the historical information on steelhead in the Skagit River basin comes from broodstock collection activities in the early 1900s. In 1900 steelhead were first collected at the Baker Lake Hatchery for broodstock. From March 8 to May 9, 81 adults were captured at the base of the lake (Ravenel 1901). Of these, only 14 survived to spawn. The high mortality rate among the adults and subsequent egg lots was ascribed to maturation difficulties in the net pens. It is also possible that if the fish were summer-run steelhead, they would not have matured that first spring. Following construction of the Baker River Dam, returning steelhead arrived at the trap at the base of the dam from March to July (Harisberger 1931). Riseland (1907) reported that the Sauk River Hatchery collected steelhead spawn from the first part of February until June 15, with more than a million eggs collected in 1906. He commented that the collection would have been higher if the hatchery weir gates did not need to continually be raised to allow shingle bolts to pass downstream. The Sauk River was characterized as "an excellent spring Chinook and steelhead stream and the principal spawning stream of the Skagit" (WDFG 1925). Within the Skagit River basin, steelhead eggs were collected from the Baker River, Day Creek, Grandy Creek, Illabot Creek, and Phinney (Finney) Creek during the early 1900s. In most cases, these egg-taking stations intercepted hundreds of steelhead during their initial years of operation (Smith and Anderson 1921a). In 1929 the fish trap at Baker Dam collected 813 steelhead (WDG no date-a). These fish would have represented the last year of returning "pre-dam" steelhead (4-year-olds). Subsequent counts at Baker Dam declined to the tens of fish. In the absence of specific information related to the operation of weirs or hatchery traps, it is impossible to accurately expand the numbers of fish spawned to total escapement.

Stream surveys estimating the extent of natural production were not undertaken until some years after the initiation of the first hatchery programs. Additionally by this time, river clearing, timber harvest (including splash damming), mining, and land development, in general had already severely degraded the productivity of a number of streams. Smith and Anderson (1921a) provided detailed descriptions of the Skagit River and its tributaries. Steelhead were found in "considerable numbers" up to the construction camp for Ross Dam near Nehalem. At that time, they identified Goodell Creek as the farthest branch of the Skagit from the mouth that contained anadromous fish. Smith and Anderson (1921a) also reported steelhead migrating at least as far as Monte Cristo Lake on the Sauk River. It was thought that releases of mining wastes had eliminated fish from the headwaters of the South Fork Sauk River, near the mining town of Monte Cristo. Through interviews with U.S. Forest Service rangers, Smith and Anderson (1921a) also identified a number of tributaries to the Suiattle River that contained runs of steelhead. Although the mainstem Suiattle is normally too ladened with glacial sediment to provide opportunities to observe or fish for steelhead, a number of the tributaries apparently run clear for part of the year. The North Fork Suiattle River, Downey Creek, Buck Creek, and Big Creek were all listed as containing steelhead runs. Stream surveys conducted in 1930 indicated that "large" aggregations of steelhead were found in Finney, Grandy, and Bacon creeks in the mainstem Skagit River and Jordan Creek in the Cascade River (WDFG 1932). Medium abundances were observed in the Baker River, Sauk River, and Cascade River. Mainstem Skagit River surveys were conducted in May of 1930 and in the Baker, Cascade, Sauk, and Suiattle rivers in August of 1930 (WDF 1932). Donaldson (1943) also observed "numerous" steelhead fingerlings in Tenas Creek during a stream survey in August 1943. The presence of steelhead, often in large numbers, throughout the 1920s and 1930s (despite substantial degradation to the freshwater habitat) suggests that the historical (pre-European contact) abundance of steelhead in the Skagit Basin was considerable.

Stillaguamish River

The fishery in the lower Stillaguamish River harvested an estimated 81,820 kg of steelhead in 1895 (18,200 steelhead at 4.5 kg.), although Wilcox (1898) suggests that the total could be considerably higher. WDFG (1916) recommended establishing an egg taking station on Canyon Creek, where "many eggs could be secured in Canyon Creek, particularly those of the steelhead variety, which are very valuable." An article in the Seattle Daily Times (1918a) on September 21 indicated that pools in Canyon Creek contained hundreds of big (7 to 20 pound) steelhead ("Fishing Trips out of Seattle, No. 14, Canyon Creek"). Later surveys underscored the decline of salmon and steelhead runs, especially in Squire, Boulder, and Deer creeks (Smith and Anderson 1921a). Smith and Anderson (1921a) note that the egg-taking station in Canyon Creek spawned 245 steelhead in 1916 and the egg-taking station in Jim Creek spawned 173 steelhead in 1919, the first years for steelhead collection for each site. In 1925 the WDF reported that, "for the past four years the station has been operated by the Game Division for the taking of steelhead spawn. It is understood that the eggs when eyed were transferred to other parts of the state with the result that the steelhead run in Canyon Creek is now about depleted" (WDFG 1925, p. 23). The WDFG surveys in 1929 identified large spawning populations in both the main stems of the North Fork and South Fork Stillaguamish, as well as Deer Creek and Canyon Creek, with medium-sized populations in Boulder, French, Squire, and Jim creeks (WDFG 1932).

Snohomish River

Snohomish River steelhead were reported to return from November 15 and were fished throughout the winter (Wilcox 1898). Steelhead harvest levels were estimated at 182,000 kg (401,000 lb) or 40,444 steelhead from the Snohomish River alone in 1895 (Wilcox 1898). Steelhead were identified as the most plentiful and valuable salmonid (better flesh quality allowed longer transportation times). Hatchery records from the Pilchuck River Hatchery indicate that 397 females were spawned in 1916 (WDFG 1918). Surveys undertaken by the WDFG in 1929 reported large aggregations of steelhead in the Pilchuck, Sultan, Skykomish, and Tolt rivers, and medium aggregations in the North Fork Skykomish, South Fork Skykomish, Wallace, Snoqualmie, and Raging rivers (WDFG 1932). Spawning at the Sultan River U.S. Bureau of Fisheries Hatchery occurred from April 8 to June 4 (Leach 1928). In general, the Snohomish River basin was one of the primary producers of steelhead in Puget Sound.

Green River (Duwamish River)

Interpreting historical abundance estimates is more complicated for the Green River due to its history of headwater transfers. In 1895 there were 45,900 steelhead (based on average weight of 4.5 kg) harvested in King County, with the Duwamish/Green River being the only major river in the county (Wilcox 1898). At this time the Duwamish Basin included the Black, Green, Cedar, and White rivers, in addition to the entire Lake Washington and Lake Sammamish watersheds. In 1906 floodwaters and farmers diverted the White River from the Green River to the Puyallup River. Furthermore, construction of the Headworks Dam (RKM 98.1) in 1911 on the upper Green River eliminated access to 47.9 km of river habitat. During the first 2 years of operation, an egg taking station (White River Eyeing Station) operated by the City of Tacoma collected 6,185,000 eggs in 1911 and 11,260,000 eggs in 1912 (WDFG 1913). There were no species-specific egg takes given, other than the 1911 production was from coho salmon and steelhead and the 1912 production included Chinook salmon and coho salmon in addition to steelhead (WDFG 1913). From 1 April 1912 to 31 March 1913, 1,308 steelhead were intercepted at the Headworks Dam (Grette and Salo 1986, as cited by Kerwin and Nelson 2000). Grette and Salo (1986) further estimated the steelhead escapement above the Headworks Dam ranged from 500 to 2,500, although they did not distinguish between summer-run and winter-run steelhead.

The Lake Washington Ship Canal (first year of operation in 1916) diverted Lake Washington and Lake Sammamish, their tributaries, and the Cedar River directly to Puget Sound. WDFG surveys in 1930, well after the major modifications to the watershed, identified large steelhead populations in the Green River and Soos Creek (WDFG 1932).

Puyallup River

Based on the harvest in 1909, approximately 30,000 steelhead were harvested in rivers in Pierce County (Cobb 1911). The WDFG 1930 survey found large steelhead aggregations in the Puyallup and Carbon rivers and medium sized aggregations in Voights Creek, South Prairie Creek, and the White River (WDFG 1932). In 1942, its second year of operation, nearly 2,000 steelhead were collected below Mud Mountain Dam and transported to the upper watershed. Sport fishery catches for 1946 and 1947 in the Puyallup River averaged 2,846 fish (WDG no date-b), all of which were presumed to be of wild origin. During the 1949/1950 tribal harvest, 2,176 steelhead were caught in the White River during January and February.

Nisqually River

Riseland (1907) described the Nisqually Hatchery as having a steelhead “spawn” that was equal to that of most of our large hatcheries. In 1905, 962,000 steelhead fry were produced at the hatchery, a production level that would have required several hundred female steelhead. Hatchery production continued until 1919, when a flood destroyed the hatchery. At its peak in 1912, the hatchery produced 1,500,000 fry. WDFG (1932) identified the Nisqually and Mashel rivers as having medium-sized spawning aggregations. Annual tribal harvest in the Nisqually River from 1935 to 1945 averaged approximately 1,500 steelhead, and the reported sport catch in the late 1940s varied from a few hundred to a few thousand fish (WDG no date-b).

South Puget Sound tributaries

The presence of steelhead in the South Puget Sound region was noted by Collins (1892): “Salmon trout occur about the head of Puget Sound in the vicinity of Olympia. Off Johnson Point and near Tacoma are noted fishing grounds for them. Considerable quantities are taken for market.” There is relatively little specific quantitative information available on the historical abundance or even presence of steelhead in the small independent tributaries draining into South Puget Sound. Commercial harvest data from 1909 lists steelhead catches for Thurston, Mason, and Kitsap counties that would represent a total escapement of several thousand fish, some of which are likely to have originated in the small South Puget Sound tributaries (Appendix F). Numerous other references to “salmon trout” fishing in the Olympia area were found in the sport literature from the 1800s and early 1900s. For example, an article in the Olympia Record (1909) reported that sportsmen were supporting a bill in the state legislature to prohibit netting in Olympia Harbor in order to protect salmon trout that were returning to local creeks. Sport fishery catch data from the 1940s to 1970s (WDG no date-b) indicate that steelhead catches varied annually from the tens to hundreds of fish in Goldsborough Creek, Mill Creek, Sherwood Creek, and other smaller creeks. Catch numbers within and among streams varied considerably from year to year. It is not clear to what degree this variation is due to true changes in abundance or differences in angler effort.

Skokomish River

Steelhead were historically present in the Skokomish River; Ells (1887) described "salmon-trout" as one of the stable foods of the Twana Tribe. Steelhead were found in both the north and south forks of the Skokomish River, although there is some uncertainty regarding the accessibility of Lake Cushman to anadromous migration. An article in the Daily Olympian newspaper (1897) reported that State Senator McReavey was requesting funds to build a fish ladder 3 miles below Lake Cushman to provide anadromous access to the lake. Although the ladder was never built, McReavey later testified that he had caught salmon in Big Creek, located above the "barrier" falls on the north fork (Olympia Daily Recorder 1921). In 1899 the WDF established an egg-taking station on the north fork of the Skokomish River below Lake Cushman (WDFG 1902). During the first year of operation, the station took an estimated 1,500,000 steelhead eggs (representing 533 females at 2,812 eggs/female[5]). For unexplained reasons, this station was subsequently abandoned 2 years later and the 1899 production figures may be viewed with some skepticism. Tribal harvest for winter-run steelhead averaged 351 fish from the 1934/1935 to 1944/1945 return years, with harvests in the late 1950s averaging more than 2,000 fish, although there is some hatchery contribution to these later catches. During the late 1940s and early 1950s, adjusted punch card–based estimates of the annual sport catch for presumptive wild winter-run steelhead averaged 610 fish, with an additional 88 fish caught annually during the "summer-run" harvest window (WDG no date-b).

Hood Canal, east side tributaries

There is little detailed information on steelhead abundance in creeks draining from the east side of Hood Canal. A number of newspaper accounts from the early 1900s specifically mention good steelhead fishing in the Tahuya River. In 1920 an egg-collecting station was established on the Tahuya River to intercept returning steelhead. In May and June of 1932, the WDF surveyed streams throughout Hood Canal. Of the 26 surveys available for review, all of the larger streams and many smaller creeks were reported to have spawning steelhead from January through March (WDF 1932). Mission Creek and Dewatto Creek were identified as having "good" runs and the Tahuyeh River [sic] contained a small to medium run. Anderson Creek, Union River, and Big Beef Creek were all reported to contain small spawning populations of steelhead. Smaller stream systems, for example Stavis and Rendsland creeks, all supported steelhead spawning, albeit at a low abundance in the 1930s. Additionally, both sea-run and resident cutthroat trout were observed throughout Hood Canal.

Hood Canal, west side tributaries

Records for these west side tributaries to Hood Canal are somewhat limited. At varying times during the early 1900s, the U.S. Bureau of Fisheries operated egg-collecting stations or hatcheries on Quilcene, Dosewallips, and Duckabush rivers. Although the primary objective of these operations was the collection of coho salmon and chum salmon eggs, a number of steelhead eggs were collected, especially from the Duckabush and Quilcene rivers. It was noted that the greater part of the steelhead run ascended by spring high water when the trap could not

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[5] This average steelhead fecundity is based on hatchery averages reported by WDFG (1918).

be operated, and many of the fish collected were "too immature to be retained in ponds" (Leach 1928). Ripe fish were spawned from March 24 to May 1 in 1926.

In the 1932 survey (WDF 1932), the Dosewallips River was specifically mentioned as containing a "large run" of steelhead and the Hamma Hamma was reported to have a small to medium run of saltwater steelhead and cutthroat trout. Of the remaining creeks surveyed, Mission, Little Mission, Dabob, Lilliwaup, Waketickeh, Jorsted, Spencer, Jackson, Finch, and Eagle creeks were all reported to have small spawning populations of steelhead. The steelhead run was observed to begin in January and February, and only a small portion of the steelhead run entered the Little Quilcene River before the hatchery weir was put in place in March. Steelhead were reported spawning during the late winter and early spring. Notably absent were surveys for the Skokomish and Duckabush rivers. Punch card records from the late 1940s to 1960s report catches of tens to hundreds of fish from several west side Hood Canal basins.

Dungeness River

In the 1940s, Pautzke (no date) of the WDF described the winter steelhead fishing in the Dungeness River as being among the best in the state. In 1903, during its second year of operation, the Dungeness Hatchery produced 3,100,840 steelhead. This production represents approximately 2,200 females.[6] Riseland (1907), state fish commissioner, noted that the steelhead catch at the hatchery was the largest of any in the state (output in 1905 was 1,384,000 steelhead), despite of the existence of numerous "irrigation ditches on the Sequin [sic] prairie that destroyed large numbers of young salmon."

Elwha River

Construction of the Elwha Dam in 1912 blocked anadromous access to most of the river. There is little information other than anecdotal accounts of fishing in the river to describe the pre-dam status of steelhead population(s) in the basin. Rathbun (1900) identified the Elwha and Dungeness rivers as supporting both Native American and commercial fisheries. Wilcox (1905) reported only that the commercial catch for Clallam County was 52,000 pounds (23,636 kg). It is unclear whether these fish were caught in terminal fisheries or in the Strait of Juan de Fuca and destined for other basins in the Salish Sea.

Puget Sound Steelhead Life History

Of all the salmonids, *O. mykiss* arguably exhibits the greatest diversity in life history. In part, this diversity is related to the broad geographic range of *O. mykiss* 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. Resident *O. mykiss*, commonly called rainbow trout, complete their life cycle in freshwater. Anadromous *O. mykiss*, steelhead, reside in freshwater for their first 1 to 3 years before emigrating to the ocean for 1 to 3 years before returning to spawn. Also, in contrast to Pacific salmon, *O. mykiss* is iteroparous, capable of repeat spawning.

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[6] This assumes 50% survival from green egg to fry and an average fecundity of 2,812. Also note that these fish would all have been natural origin.

There are two major life history strategies exhibited by anadromous *O. mykiss*. In general, they are primarily distinguished by the degree of sexual maturation at the time of adult freshwater entry (Smith 1969, Burgner et al.1992). Stream-maturing steelhead, or summer-run steelhead, enter freshwater 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 following spring. Ocean-maturing steelhead, or winter-run steelhead, enter freshwater from November to April at an advanced stage of maturation, spawning from February through June. Steelhead are somewhat distinctive in exhibiting multiple run times within the same watershed (Withler 1966).[7]

The winter run of steelhead is the predominant run timing in Puget Sound, in part because there are relatively few basins in the Puget Sound Steelhead DPS with the geomorphological and hydrological characteristics necessary to maintain 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 there are no seasonal migrational barriers.[8]

In 1900 a Smithsonian Institution study reported that Puget Sound steelhead begin returning to freshwater 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 of returning steelhead was 3.6–6.8 kg (8–15 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.

Information on summer-run steelhead in Puget Sound is very limited. In fact, in its 1898 report, the Washington State Fish Commission concluded that 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, that the winter run of steelhead continued from December through the first of May, and overlapping runs of winter and summer steelhead may have been considered a single population. Evermann and Meek (1898) reported that B.A. Alexander examined a number of steelhead caught near Seattle in January 1897 and 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." Returning steelhead were historically harvested from December through February, using in-river fish traps rather than trolling in salt water (Gunther 1927).

Much of the life history information taken early in the 1900s comes from the collection and spawning of steelhead intercepted at hatchery weirs. The U.S. Fish Commission Hatchery at Baker Lake initially collected steelhead returning to Baker Lake using gill nets. Fish were collected from March 9 to May 8, few survived to spawn, and no spawning date was given (USBF 1900). Later attempts to collect fish from Phinney [Finney] and Grandy creeks in March met with limited success; based on a survey of these creeks and the Skagit River, it was

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[7] Other salmonid species, mainly Chinook salmon and to a lesser extent coho salmon, exhibit multiple run times in the same watershed.

[8] D. Rawding, WDFW, Vancouver, WA. Pers. commun., 12 May 2004.

concluded that much of the run entered the rivers in January (Ravenel 1901). During the first years of operation of the Baker Dam, 1929–1931, steelhead were passed above the dam from April to July. Peak entry to the dam trap occurred during April. Although a relatively large number of fish were spawned in May 1931 (51 fish), on 15 June 1931, when spawning operations had ceased, 92 "green" (unripe) fish were passed over the dam (Harisberger 1931). It is unclear whether these fish would have spawned in late June or July, or whether they would have held in freshwater until the next spring (i.e., summer-run steelhead). Riseland (1907) reported that the Sauk River Hatchery collected steelhead spawn from the first part of February until June 15. Steelhead were spawned at the Quilcene National Fish Hatchery in Hood Canal from February 27 to June 7, 1922 (USBF 1923). Stream survey reports for Hood Canal indicated that the steelhead spawn during the late winter and early spring (WDF 1932). It should be noted that this spawning time was only noted for tributaries on the east side of Hood Canal (Dewatto Creek, Tahuyeh [sic] River, Big Beef Creek) or smaller tributaries on the west side of Hood Canal (Jorsted Creek, Little Quilcene River, Little Lilliwaup Creek); larger tributaries were generally too turbid to survey. These larger rivers (primarily Dosewallips and Duckabush) originate in the glacial fields of the Olympic Mountains and it is likely that the temperature and flow regimes in these rivers would produce a different run timing from the lowland, rain-dominated rivers on the east side of Hood Canal.

Pautzke and Meigs (1941) indicated that the 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 is unclear whether these phases were distinct runs or different segments of the same run. In general, summer-run fish run later in the spring than winter-run fish, and the former also tend to be physically smaller than the latter, although historically this may not have been the case. Scale analysis indicates that the majority of first-time spawning summer-run fish have spent only 1 year in the ocean. WDG records from the 1930s indicate a north-south differential in spawn timing (Figure 5), although the timing of egg collection in the hatcheries may not be fully representative of natural spawning timing. The egg collection time for the Dungeness River appears to be especially late. A Seattle Daily Times column (1923) also notes that the Dungeness River steelhead run is much later than those found in Hood Canal. Pautzke (no date) stated that, "During the summer and fall this river [Dungeness] is the conductor of large runs of Chinook and humpback [aka pink, *O. gorbuscha*] salmon, also the steelhead trout." This would suggest the presence of a summer run in the Dungeness River. Pautzke further stated that the winter steelhead fishing in the Dungeness River was one of the best in the state. A Port Angeles resident[9] reported that the Dungeness River produced both winter-run and summer-run steelhead in the 1940s. Summer-run fishing extended up into the Gray Wolf River and there was some overlap between the two run times, with the summer-run fish appearing in May. A Seattle Times article reported summer-run steelhead caught in the Grey Wolf River in August (Bradner 1945). Alternatively, in the southern tributaries to Puget Sound, the steelhead spawning/egg-take data for the Puyallup Hatchery indicated that this stock of fish spawned earlier than those at other hatcheries (Figure 6). In some years, the majority of the spawning took place prior to March 15, the date presently used to distinguish naturally spawning Chambers Creek Hatchery fish from "native" fish. Similarities in spawn timing between the steelhead captured at the Puyallup

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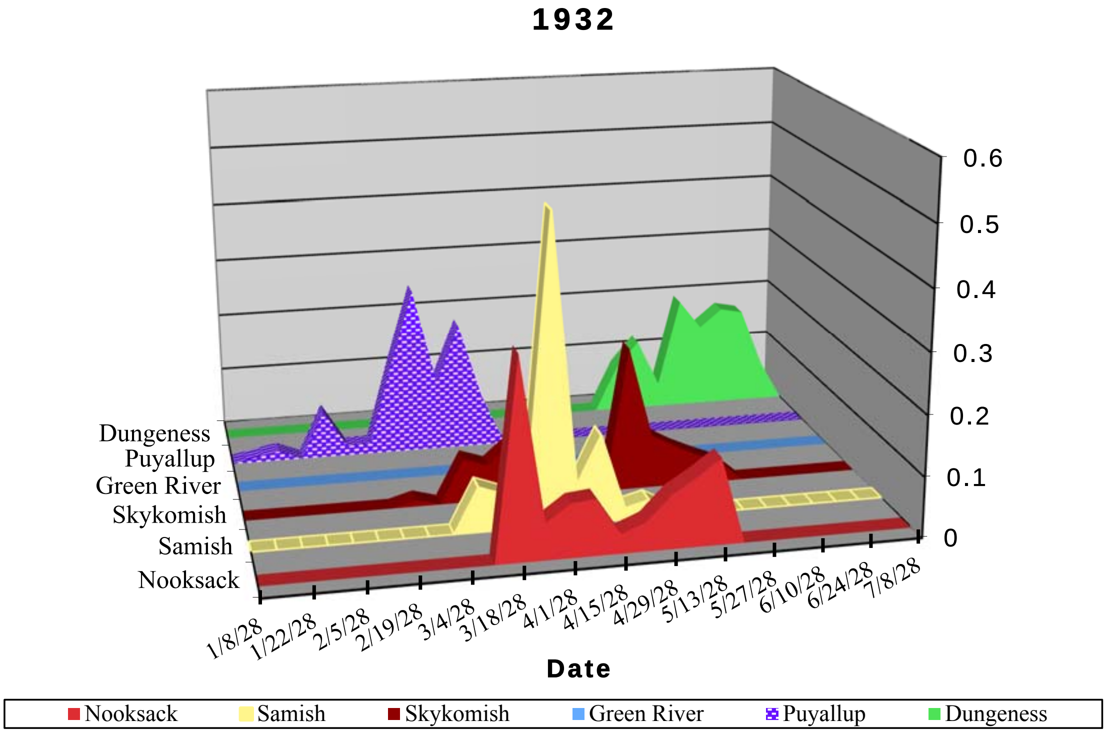
[9] D. Goin, Port Angeles, WA. Pers. commun., 21 November 2011.

Hatchery and the widely used Chambers Creek winter-run hatchery stocks may be related to the close geographic proximity of the two basins.



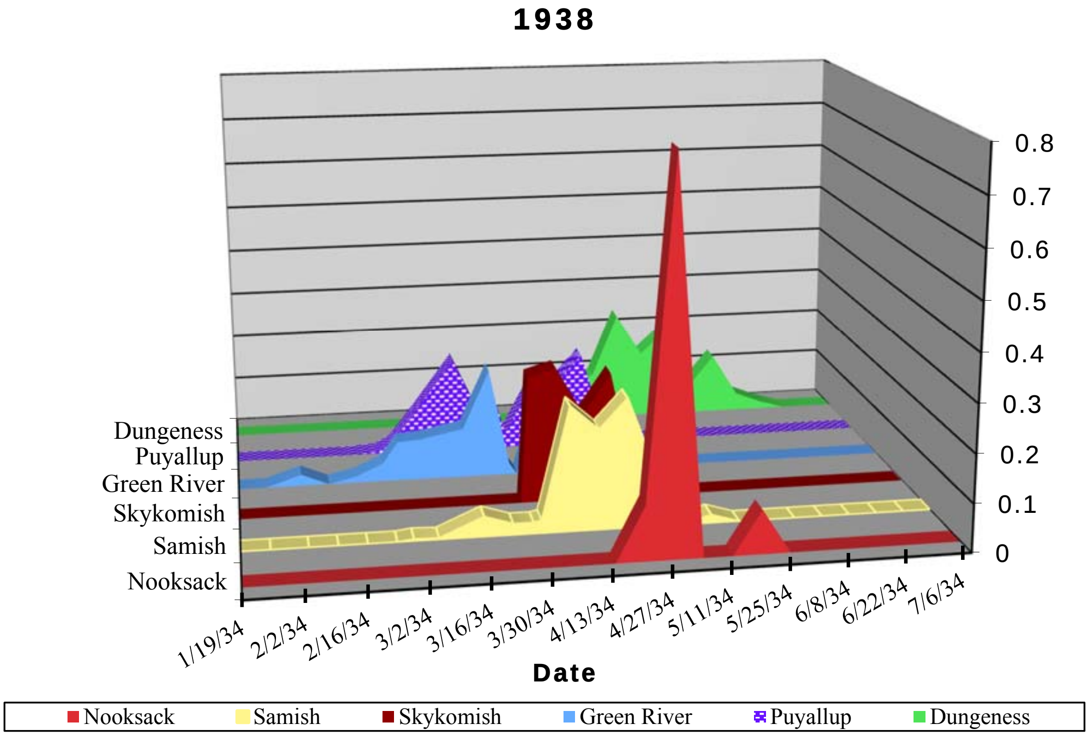


Figure 5. Temporal distribution (proportion of total egg take) of egg collection for steelhead returning to WDG facilities in 1932 and 1938. Egg collection dates may not be representative of natural spawn timing. There was no egg collection at the Green River Hatchery in 1932. (Data from Washington State Archives no date).

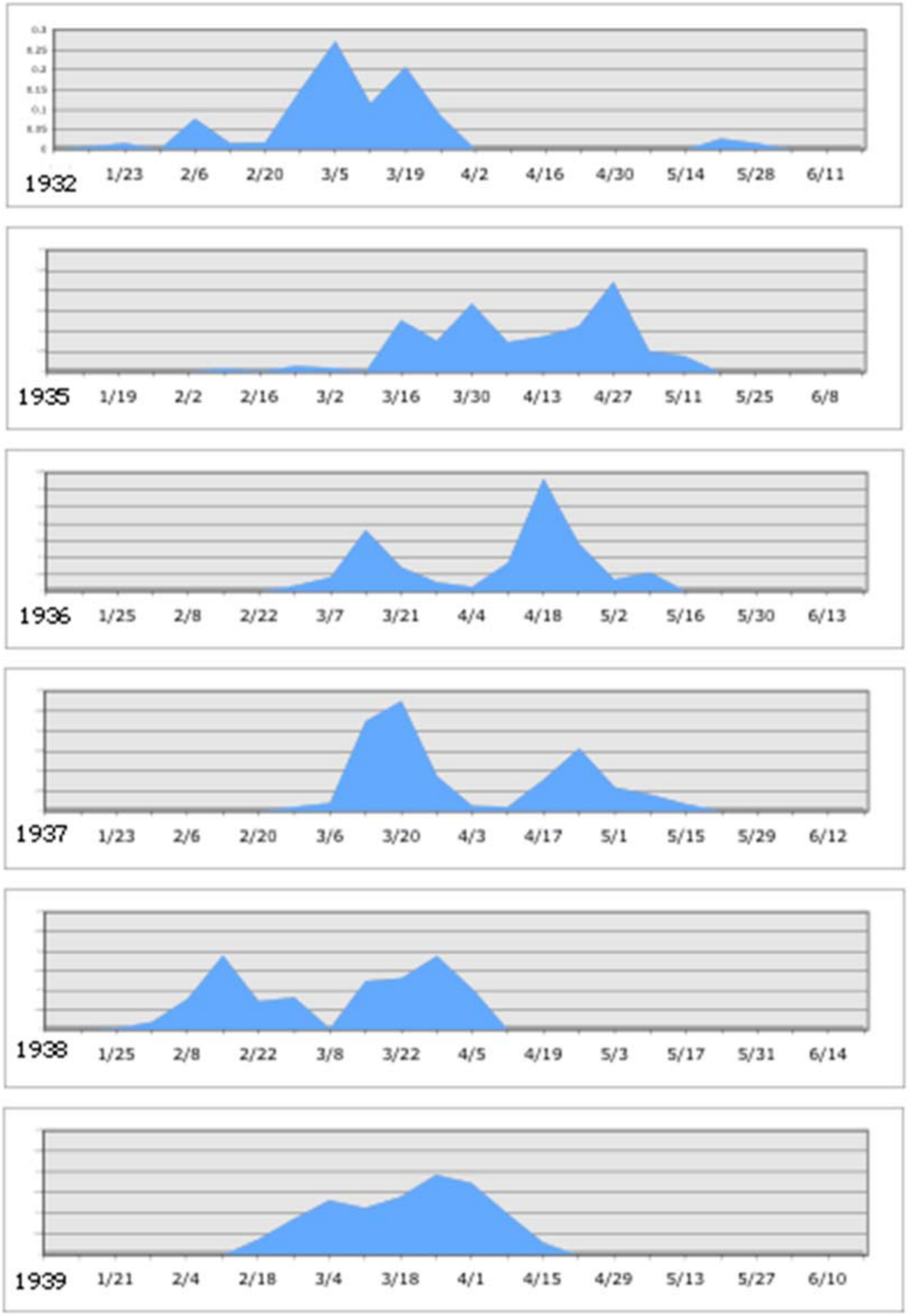


Figure 6. Standardized distribution of steelhead eggs collection at the Puyallup Hatchery from 1932 to 1939, 1933 and 1934 not included. (Data from Washington State Archives no date.)

Certainly given the variations in spawning times between 1932 and 1938, some caution should be used in associating peak spawning timing at the hatchery with peak timing for natural spawning. Despite the obvious caveats, historical hatchery spawning records provide important information on within-population and between-population differences in spawn timing.

There is only limited documentation on the age structure of Puget Sound steelhead from historical (pre-1950) sources. Work by Pautzke and Meigs (1941) indicated that the majority of steelhead from the Green River emigrated to estuary and marine habitats in their second year (third spring), then remained at sea for 2 years. Scales from returning adults indicated a minority of the fish had been 1-year-old or 3-year-old smolts. Although the historical record is sparse, there appears to be little difference in age structure to first spawning between samples from the 1940s and present day collections (Table 2).

Within the Puget Sound Steelhead DPS, both major steelhead life history strategies are exhibited: summer-run timing (stream maturing) and winter-run timing (ocean maturing). Each strategy includes a suite of associated traits that ultimately provide a high degree of local adaptation to the specific environmental conditions experienced by the population. In some cases, there is a clear geographic distinction between spawning areas containing winter-run or summer-run steelhead; for example, in short, rain-dominated streams or above partially impassable barriers, respectively. In other areas, winter-run and summer-run steelhead can be found utilizing the same holding and spawning habitat, and it may appear that there is a continuum of returning adults. In cases where both runs comingle on spawning grounds, it is unclear whether these two life history types exist as discrete populations, a diverse single population, or a population in transition. Pending further genetic and life history studies, the TRT will treat these populations as single, mixed-run DIPs.

Table 2. Freshwater ages at the time of migration to the ocean. The two populations in italics are representative populations outside the Puget Sound Steelhead DPS. W = winter-run steelhead and S = summer-run steelhead. The frequency in boldface indicates the most common age. (Includes data from Busby et al. 1996).

		Freshwater age at ocean migration				
Population	**Run**	1	2	3	4	**Reference**
Chilliwack River	W	0.02	**0.62**	0.36	<0.01	Maher and Larkin 1955
Skagit River	W	<0.01	**0.82**	0.18	<0.01	WDFW 1994
Skagit River (fishery)	W	<0.01	**0.56**	0.27	0.067	Hayman 2005
Deer Creek	S	—	**0.95**	0.05	—	WDF et al. 1993
Snohomish River	W	0.01	**0.84**	0.15	<0.01	WDFW 1994
Green River	W	0.16	**0.75**	0.09	—	Pautzke and Meigs 1941
Puyallup River	W	0.05	**0.89**	0.06	—	WDFW 1994
White River	W	0.20	**0.72**	0.08	0.00	Smith 2008*
Nisqually River	W	0.19	**0.80**	0.01	—	WDFW 1994
Minter Creek	W	0.03	**0.85**	0.12	—	Gudjonsson 1946
Snow Creek	W	0.09	**0.85**	0.06	—	Johnson and Cooper 1993

Elwha River	W	0.08	**0.77**	0.15	0.00	Morrill 1994
Hoh River	W	0.03	**0.91**	0.06	—	Larson and Ward 1955

* B. Smith, Fisheries, Puyallup Tribe of Indians, Puyallup, WA. Pers. commun., 5 August 2008.

Winter-Run Steelhead

In general, winter-run (ocean maturing) steelhead return as adults to the tributaries of Puget Sound from December to April (WDF et al. 1993). This period of freshwater entry can vary considerably, depending on the characteristics of each specific basin or annual climatic variation in temperature and precipitation. Spawning occurs from January to mid-June, with peak spawning occurring from mid-April through May (Table 3). Prior to spawning, maturing adults reside in pools or in side channels to avoid high winter flows during the relatively short prespawning period.

Steelhead generally spawn in moderate gradient sections of streams. In contrast to semelparous Pacific salmon, steelhead females do not guard their redds, but return to the ocean following spawning, although they may dig several redds in the course of a spawning season (Burgner et al. 1992). Spawned-out fish that return to the sea are referred to as kelts. Adult male steelhead may be relatively less abundant among fish returning to the ocean after spawning, and males usually form a small proportion of repeat (multiyear) spawning fish, based on scale pattern analyses (McGregor 1986, McMillan et al. 2007, Appendix H). If there is lower postspawning survival of winter-run males overall, it may be due to the tendency of males to remain on the spawning ground for longer periods than individual females in an effort to spawn with multiple females, or fighting in defense of prime spawning areas or mates (Withler 1966).

In Puget Sound, winter steelhead are found both in smaller independent streams that drain directly into Puget Sound and the Strait of Juan de Fuca and in larger rivers and their tributaries. The smaller drainages generally experience rain-dominated hydrological and thermal regimes (with the exception of smaller streams draining the Olympic Mountains), while the larger rivers are influenced by rain-and-snow-transitional or snow-dominated hydrological regimes. It is likely that differences in habitat conditions are reflected in the life history characteristics (i.e., migration and spawn timing) of winter steelhead inhabiting these two types of basins. For example, it appears that steelhead spawn earlier in smaller lowland streams where water temperatures are generally warmer than in larger rivers with higher elevation headwaters.

Summer-Run Steelhead

In many cases, the summer migration timing is associated with barrier falls or cascades. These barriers may temporally limit passage in different ways. Some are velocity barriers that prevent passage in the winter during high flows, but are passable during low summer flows, while others are passable only during high flows when plunge pools are full or side channels emerge (Withler 1966). In Puget Sound, winter-run steelhead predominate, in part because there are relatively few basins with the geomorphological (e.g., basalt rock strata) and hydrological characteristics necessary to create the temporal barrier features that establish and sustain the summer-run life history. In general, summer-run steelhead return to freshwater from May or June to October, with spawning taking place from January to April. During the summer-run steelhead's extended freshwater residence prior to spawning, the fish normally hold in deep pools, which exposes the fish to prolonged predation risk and seasonal environmental extremes, likely resulting in higher prespawning mortality relative to winter-run steelhead. This potential survival disadvantage may explain why winter-run steelhead predominate where there are no

Table 3. Puget Sound steelhead freshwater migration and spawning periods.* WR-W = winter run, wild; SR-W = summer run, wild; and WR-H/W = winter run, hatchery/wild. The letter s indicates months of observed spawning and the letter **P** indicates the peak spawning period. Shaded months indicate observed freshwater migration (entry) in recent years.

Run	**Years**	**River, tributary, or area (basin)**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
		<u>Undescribed MPG</u>												
WR-W	1973	Puget Sound tributaries	s	s							s	s	s	s
WR-W	2007	Puget Sound small tributaries										s	s	s
		<u>Northern Cascades MPG</u>												
WR-W	1931–1937	Nooksack River	s											s
WR-W	1937–1938	Nooksack River	s											
WR-W	2007	Nooksack River	**P**	s					▨	▨	▨	s	s	s
WR-W	1931–1940	Samish River	s										s	s
WR-W	2007	Samish River	s	s					▨	▨	▨	s	s	**P**
WR-W	1907	Sauk River (Skagit River)	s	s								s	s	s
WR-W	2007–2013	Skagit River	**P**	s					▨	▨	▨	▨	s	s
WR-W	1931–1932	Skykomish River (Snohomish River)	s	s								s	s	s
WR-W	1935–1940	Skykomish River (Snohomish River)	s											s
WR-W	2007	Snohomish River	s	s					▨	▨	▨	▨	s	P
WR-W	2007	Stillaguamish River	**P**	s					▨	▨	▨	▨	s	s
		<u>Central and South Puget Sound MPG</u>												
WR-W	1897	Central Puget Sound tributaries									s			
WR-W	2007	Lake Washington tributaries	s	s					▨	▨	▨	▨	s	**P**
WR-W	1940	Issaquah Creek (Lake Washington/Lake Sammamish)	s											s
WR-W	1935–1937	Green River											s	s
WR-W	1937–1938	Green River										s	s	s
WR-W	1940	Green River	s											s
WR-W	2007	Green River	s	s					▨	▨	▨	▨	s	**P**
WR-W	1931–1932	Puyallup River									s	s	s	s
WR-W	1935–1936	Puyallup River										s	s	s
WR-W	1936–1938	Puyallup River	s	s							s	s	s	s
WR-W	1940	Puyallup River	s											s
WR-W	2007	Puyallup River	s	s					▨	▨	▨	▨	s	**P**
WR-W	2007	Nisqually River	s	s						▨	▨	▨	s	**P**
WR-W	2007	Deschutes River						▨	▨	▨	s	**P**	s	s
WR-W	2000s	South Puget Sound tributaries							▨	▨	▨	s	**P**	**P**

Table 3 continued. Puget Sound steelhead freshwater migration and spawning periods.* WR-W = winter run, wild; SR-W = summer run, wild; and WR-H/W = winter run, hatchery/wild. The letter s indicates months of observed spawning and the letter P indicates the peak spawning period. Shaded months indicate observed freshwater migration (entry) in recent years.

Run	**Years**	**River, tributary, or area (basin)**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
		<u>Hood Canal and Strait of Juan de Fuca MPG</u>												
WR-W	2007	Skokomish River	s	s					▨	▨	▨	▨ s	▨ s	**P**
WR-W	2007	Tahuya River	s						▨	▨	▨	▨ s	▨ s	**P**
WR-W	2007	Dewatto River	s						▨	▨	▨	▨ s	▨ s	**P**
WR-W	2007	Discovery Bay tributaries	s	s					▨	▨	▨	▨ s	▨ s	**P**
WR-W	2007	Morse Creek	s	s					▨	▨	▨	▨ s	▨ s	**P**
WR-W	1931–1932, 1937, 1940	Dungeness River	s	s	s									s
WR-W	1935–1936	Dungeness River	s	s									s	s
WR-W	1937–1938	Dungeness River	s											s
WR-W	2007	Dungeness River	**P**	s					▨	▨	▨	▨	▨ s	s
WR-W	2012	Elwha River tributaries		s	s	s								
		<u>Northern Cascades MPG</u>												
SR-W	2007	Cascade River (Skagit River)	▨	▨	▨	▨	▨	▨			s	s	s	s
SR-W	2007	Sauk River (Skagit River)	s		▨	▨	▨	▨						s
SR-W	2007	S. F. Stillaguamish River	▨	▨	▨	▨	▨	▨			s	s	s	s
SR-W	2007	Deer Creek (Stillaguamish River)	s	▨	▨	▨	▨	▨					s	s
SR-W	2000s	N. F. Skykomish River (Snohomish River)			▨	▨	▨	▨						
		<u>Northern Cascades MPG</u>												
WR-H/W	2008–2013	Five small Skagit River tributaries	s						▨	▨	▨ s	▨ s	▨ s	▨ s
WR-H/W	2005–2013	Finney Creek (Skagit River)	s	s					▨	▨	▨ s	▨ s	▨ s	▨ s
WR-H/W	2010	Cascade River (Skagit River)	s										s	s
WR-H/W	1997–2011	Upper Skagit River	s	s					▨	▨	▨	▨	▨ s	▨ s
WR-H/W	1998–2008	Sauk River (Skagit River)	s	s	s								s	s
		<u>Hood Canal and Strait of Juan de Fuca MPG</u>												
WR-H/W	1984–1991	Morse Creek	s	s							s	s	s	s

* Data compiled from historical and current literature or raw spawning surveys: Abernethy 1886, Barin 1886, Birtchet and Meekin 1962, WDFW 2002, Pflug et al. 2013, and McMillan unpubl. data.

migrational barriers.[10] In at least two or possibly three Puget Sound river systems lacking obvious migration barriers, the Skagit, Sauk, and Dungeness rivers, there appear to be co-occurring winter-run and summer-run steelhead. The circumstances in each river are somewhat different and further discussion is provided in the specific population descriptions.

The life history of summer-run steelhead is highly adapted to specific environmental conditions. Because these conditions are not commonly found in Puget Sound, the relative incidence of summer-run steelhead populations is substantially less than that for winter-run steelhead. Summer-run steelhead have not been widely monitored, in part because of their small population size and the difficulties in monitoring fish in their headwater holding areas. Much of our general understanding of the summer-run life history comes from studies of Interior Columbia River populations that undergo substantial freshwater migrations to reach their natal streams. Sufficient information exists for only 4 of the 16 Puget Sound summer-run steelhead populations identified in the 2002 SaSI (WDFW 2002) to determine their population status. There is considerable disagreement on the existence of many of the SaSI-designated summer-run steelhead populations. This is due in part to the use of sport and tribal catch data in establishing the presence of summer-run steelhead. Steelhead caught after May were thought to be summer-run fish; however, in many basins with colder, glacial-origin rivers, adult return and spawning times for winter-run fish can extend well into June (e.g., the Dosewallips River). Additionally, kelts may reside in freshwater for several weeks after spawning and appear in catch records through July. In the absence of a substantial database on summer-run steelhead in Puget Sound, considerable reliance was placed on observations by local biologists in substantiating the presence of summer-run steelhead.

In contrast to the classical scenario where summer-run steelhead populations are present only above temporally passable barriers, the PSS TRT considered a number of situations where summer-run and winter-run steelhead were observed holding and spawning in the same river reach, primarily in the Skagit River basin. Based on the information available, there appears to be some temporal separation between the two runs in spawning times, although genetic information is not available to establish whether there is complete reproductive isolation. Furthermore, this occurrence is not sporadic and has occurred regularly each year. It was unclear how the two run times could persist with overlapping niches. One suggestion was that the summer-run fish might represent anadromous progeny from resident *O. mykiss* above nearby impassable barriers and that the summer-run fish are not self-sustaining, but maintained by regular infusions of migrants from above barriers. In the absence of empirical data, such as genetic analysis of winter-run and summer-run steelhead and resident *O. mykiss* to establish whether two co-occurring runs in a basin are indeed DIPs, the TRT opted to include both run times as components of an inclusive DIP. Further investigation is warranted to ensure proper management for these fish.

Juvenile Life History

The majority of naturally produced steelhead juveniles reside in freshwater for 2 years prior to emigrating to marine habitats (Table 2 through Table 5), with limited numbers emigrating as 1-year-old or 3-year-old smolts. Additional age-class distributions are in

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[10] See footnote 8.

Appendix H. Smoltification and seaward migration occurs principally from April to mid-May (WDF et al. 1993). Smolt size varies according to age and location. Wydoski and Whitney (1979) and Burgner et al. (1992) give an average length for 2-year-old naturally produced smolts as 140–160 mm. Alternatively, steelhead smolts from the Keogh River averaged 171 mm in 2002 (McCubbing 2002). Unmarked steelhead smolts from the Dungeness averaged 170 mm with a range of 109–215 mm, and similarly, smolts from the Green River averaged 153 mm with a range of 120–195 mm (Volkhardt et al. 2006). Moore et al. (2010) reported that smolts from Hood Canal streams ranged 159–235 mm. The inshore migration pattern of steelhead in Puget Sound is not well-known, and it was generally thought that steelhead smolts moved offshore within a few weeks (Hartt and Dell 1986). Recent acoustic tagging studies (Moore et al. 2010) have shown that smolts migrate from rivers to the Strait of Juan de Fuca from 1 to 3 weeks.

Ocean Migration

Steelhead oceanic migration patterns are largely unknown. Evidence from tagging and genetic studies indicates that Puget Sound steelhead travel to the central North Pacific Ocean (French et al. 1975, Hartt and Dell 1986, Burgner et al. 1992), although these conclusions are based on a very limited number of recoveries in the open ocean.

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 obtaining weights of 2.3–4.6 kg (Wydoski and Whitney 1979), although notably, Deer Creek summer-run steelhead only spend a single year in the ocean before spawning (Table 4 and Table 5).[11] Tipping (1991) demonstrated that age at maturity (ocean age) was heritable in steelhead. Additionally, the return rate was similar for fish that spent either 2 or 3 years at sea, and Tipping (1991) concluded that the majority of ocean mortality occurred during the first year at sea. Acoustic tagging studies are currently underway to better understand the use of inshore and offshore habitats by steelhead. Additional population age structure distributions are in Appendix H.

Genetics

Previous Studies

Busby et al. (1996) presented a compilation of results from a number of genetic studies that described the population structure of *O. mykiss* throughout the Pacific Northwest. Collectively, these studies provided the genetic evidence for the establishment of the 16 steelhead DPSs that have been identified to date. The following summary focuses on those studies that are relevant to the delineation of the Puget Sound Steelhead DPS.

Work by Allendorf (1975) with allozymes (protein products of genes) identified two major *O. mykiss* lineages in Washington, inland and coastal, that are separated by the Cascade Crest. This pattern also exists in British Columbia (Utter and Allendorf 1977, Okazaki 1984,

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

Reisenbichler et al. 1992). Reisenbichler and Phelps (1989) analyzed genetic variation from nine populations in northwestern Washington using 19 allozyme gene loci. Their analysis indicated that there was relatively little between-basin genetic variability, which they suggested might have been due to the extensive introduction of hatchery steelhead throughout the area. Alternatively, Hatch (1990) suggested that 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.

Table 4. Frequencies of ocean age at the time of first spawning. The two populations in italics are representative of adjacent DPSs. W = winter-run steelhead and S = summer-run steelhead. The frequency in bold indicates the most common age. (Includes data from Busby et al. 1996.)

Population	**Run**	**Ocean age at first spawning**					**Reference**
		0	1	2	3	4	
Chilliwack River	W	—	<0.01	**0.50**	0.49	<0.01	Maher and Larkin 1955
Skagit River	W	—	—	**0.57**	0.42	0.01	WDFW 1994
Deer Creek	S	—	**1.00**	—	—	—	WDF et al. 1993
Snohomish River	W	—	—	**0.57**	0.42	0.01	WDFW 1994
Green River	W	0.02	0.07	**0.66**	0.25	—	Pautzke and Meigs 1941
White River	W	—	0.03	**0.67**	0.30	—	Smith 2008*
Puyallup River	W	—	—	**0.70**	0.30	—	WDFW 1994
Nisqually River	W	—	—	**0.63**	0.36	0.01	WDFW 1994
Elwha River	W	—	0.03	**0.51**	0.46	—	Morrill 1994
Hoh River	W	—	0.02	**0.81**	0.17	—	Larson and Ward 1955

* B. Smith, Fisheries, Puyallup Tribe of Indians, Puyallup, WA. Pers. commun., 5 August 2008.

Table 5. Frequencies of life history patterns. Age structure indicates freshwater age/ocean age. The two populations in italics are representative of adjacent DPSs. (Includes data from Busby et al. 1996.)

Population	**Run**	**Life history (frequency)**				**Reference**
		Primary		Secondary		
Chilliwack River	W	2/2	0.31	2/3	0.31	Maher and Larkin 1955
Skagit River	W	2/2	0.48	2/3	0.33	WDFW 1994
Skagit River (fishery)	W	2/2	0.30	2/3	0.18	Hayman 2005
Deer Creek	S	2/1	0.95	3/1	0.05	WDF et al. 1993
Snohomish River	W	2/2	0.47	2/3	0.36	WDFW 1994
Green River	W	2/2	0.52	2/3	0.17	Pautzke and Meigs 1941
Puyallup River	W	2/2	0.61	2/3	0.28	WDFW 1994
White River	W	2/2	0.50	2/3	0.21	Smith 2008*
Nisqually River	W	2/2	0.51	2/3	0.28	WDFW 1994
Hoh River	W	2/2	0.74	2/3	0.14	Larson and Ward 1955

* B. Smith, Fisheries, Puyallup Tribe of Indians, Puyallup, WA. Pers. commun., 5 August 2008.

The number and morphology of chromosomes in a fish offers an alternative indicator of differences in major lineages. Analysis of chromosomal karyotypes from anadromous and resident *O. mykiss* by Thorgaard (1977, 1983) indicated that fish from Puget Sound and the Strait of Georgia had a distinctive karyotype. In general, *O. mykiss* have 58 chromosomes; however, fish from Puget Sound had 60 chromosomes. Further study by Ostberg and Thorgaard (1994) verified this pattern through more extensive testing of native-origin populations. While suggesting that steelhead populations in Puget Sound share a common founding source, this methodology does not offer much potential for identifying finer scale genetic differences within Puget Sound.

Genetic analysis of Skagit Basin *O. mykiss* in 1980 using allozymes found little distinction between the major subbasins (i.e., lower Skagit, Sauk, and upper Skagit rivers), in part because of the variation between sample sites within each of the subbasins (USFWS and WDG 1981). The Cascade River was specifically identified as being distinct from other samples in the upper Skagit Basin. Although the electrophoretic detection of allozyme variation is not as sensitive to genetic variation as present day microsatellite DNA analysis and only seven loci were analyzed, the report suggested that there was considerable structure within basins (the study sampled *O. mykiss* juveniles at 57 different locations in the Skagit River basin):

> There was a highly significant difference ($P < 0.0001$) between allele frequencies when comparing one stream to another within each sub-area. This statistical difference made by far the greatest contribution to the total genetic difference among steelhead trout samples within the Skagit River drainage. The magnitude of these differences among tributary creeks can be seen by examining Figures 5 through 11 where allele frequencies were plotted for each creek and mainstem sample site (USFWS and WDG 1981, p. 82).

Phelps et al. (1994) and Leider et al. (1995) reported results from an extensive genetic survey of Washington state anadromous and resident *O. mykiss* populations using allozymes. Populations from Puget Sound and the Strait of Juan de Fuca were grouped into three clusters of genetically similar populations: 1) North 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 genetic outliers. Leider et al. (1995) also reported on the relationship between the life history forms of *O. mykiss*. They found a close genetic association between anadromous and resident fish in the Cedar and Elwha rivers. Phelps et al. (1994) indicated that there were substantial genetic similarities between hatchery populations that had exchanged substantial numbers of fish during their operation. Within Puget Sound, hatchery populations of winter-run steelhead in the Skykomish River, Chambers Creek, Tokul River, and Bogachiel River showed a high degree of genetic similarity (Phelps et al. 1994). 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 (Phelps et al. 1994). Because these results were based on juvenile collections, there is some uncertainty regarding the origin of the fish collected at different sites. Specifically, it is unclear whether the sample included naturally produced hatchery fish, hatchery by wild hybrids, migrating juvenile steelhead from another population, or potentially distinct resident *O. mykiss*. Overall, however, there were several distinct, naturally sustained steelhead populations in Puget Sound (Cedar River, Deer Creek, North Fork Skykomish River, and North Fork Stillaguamish River) that appeared to have undergone minimal hatchery introgression (Phelps et al.1994).

A subsequent study by Phelps et al. (1997) with additional population samples found little evidence for hatchery influence in Puget Sound steelhead populations. Among the North Puget Sound populations sampled in that study, four genetic clusters were detected: Nooksack, Skagit (Sauk), Stillaguamish River winter run, and Stillaguamish River summer run, while Tahuya River and Pilchuck River samples were distinct from other geographically proximate steelhead populations (Figure 7). In general, early allozyme studies on Puget Sound *O. mykiss* did provide substantial evidence for population distinctiveness on a large (basin-wide) scale, but did not provide much resolution on finer level population structure.

Recent Studies

There have been a number of genetic studies in the 14 years since the Coast-wide Steelhead Biological Review Team (Busby et al. 1996) reviewed the genetic structure of steelhead populations in Puget Sound. In general, these more recent studies have focused on the analysis of microsatellite DNA variation among populations within specific river basins.

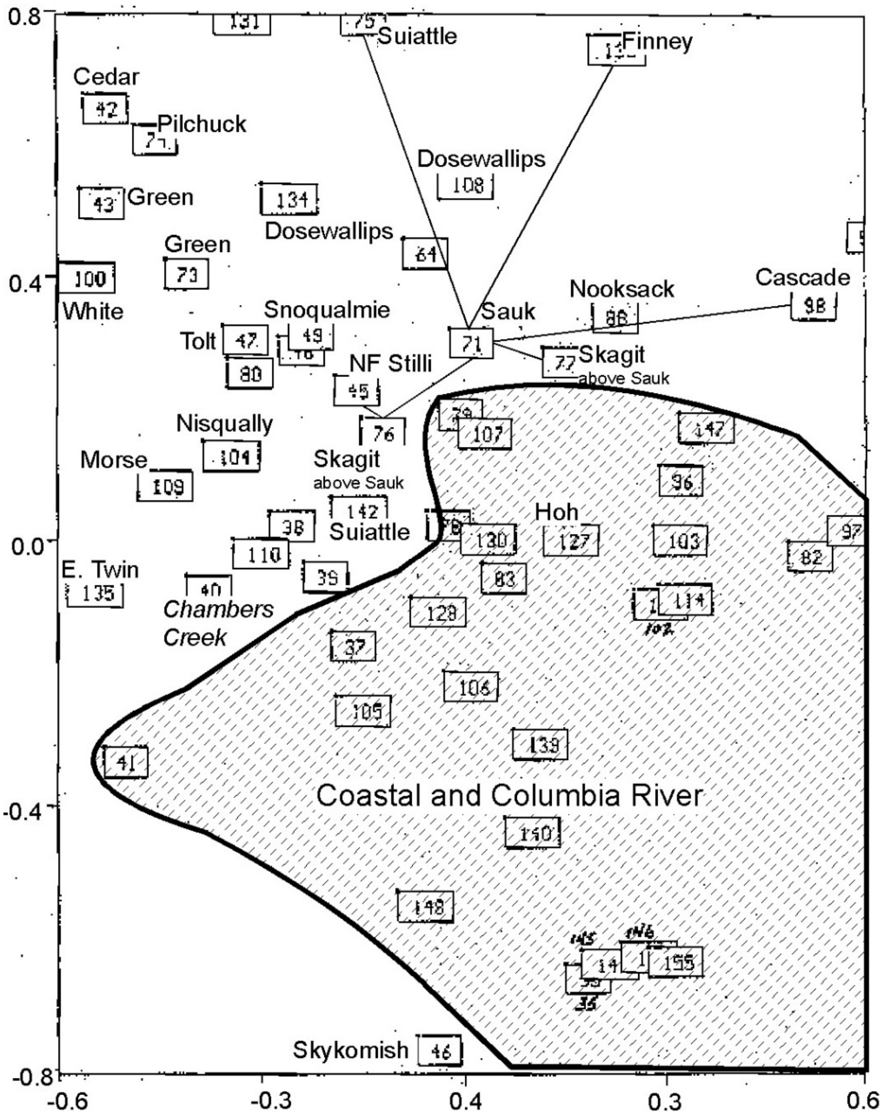

Figure 7. Two-dimensional scaling views, based on allozyme analysis, of coastal Washington steelhead populations. (Reprinted from Phelps et al. 1997.)

Van Doornik et al. (2007) assessed differences between presumptive steelhead populations in the Puyallup River basin. These results indicated that significant genetic differences exist between winter steelhead in the White River and the Puyallup River. Although the White River is a tributary to the Puyallup River, differences between steelhead in these two basins is not surprising, given that the White River formerly flowed into the Green River/Duwamish River basin (Williams et al. 1975). Floodwaters in 1906 diverted the White River into the Puyallup Basin. Additionally, the steelhead sampled from the Puyallup and White rivers were distinct from hatchery-origin fish (derivatives of the Chambers Creek winter steelhead broodstock) that have been released into the Puyallup Basin over the last 50 years (Van Doornik et al. 2007). More importantly, in the 100 years since the White and Puyallup rivers were merged, there has not been sufficient straying between the populations to eliminate genetic differences. This further underscores the presumed homing fidelity of steelhead.

Genetic analysis (microsatellite DNA) of winter steelhead from the Green and Cedar rivers suggested a close affinity between fish from the two basins (Marshall et al. 2006). In contrast to the situation with the White and Puyallup rivers, the Cedar and Green rivers historically flowed together via the Black River, which also drained Lake Washington (Chrastowski 1983). The Cedar River was diverted into Lake Washington initially as a flood control measure in 1912, but this new channel was later expanded to provide adequate flows for the Hiram M. Chittenden Locks in 1916 (Bogue 1911, Williams et al. 1975, Klingle 2005). Furthermore, Marshall et al. (2006) concluded that the Green River and Cedar River steelhead populations were genetically distinct from hatchery-origin winter steelhead (Chambers Creek origin) and summer steelhead (Skamania National Fish Hatchery origin), which have been released in the Green River for many years.

Preliminary results from the genetic analysis of Hood Canal steelhead (Van Doornik and Berejikian 2015) indicated that steelhead from western tributaries, Olympic Peninsula to Hood Canal, are distinct from steelhead in eastern tributaries, Kitsap Peninsula. Tributaries that enter the eastern side of Hood Canal drain lowland hills and are characterized by low to moderate stream gradients, while western Hood Canal tributaries are generally larger, higher gradient rivers that are dominated by snow melt. In general, parr, smolt, and resident *O. mykiss* samples from the same river were genetically more similar to each other than to the same life history stages in other rivers, with the exception of those residents sampled above barriers (Van Doornik et al. 2013, Van Doornik and Berejikian 2015). Hood Canal steelhead were distinct from hatchery (Chambers Creek–origin) winter-run steelhead and resident rainbow trout in area lakes, and were distinct from Snow Creek (Strait of Juan de Fuca tributary) steelhead (Van Doornik et al. 2013).

During the course of the TRT's review of Puget Sound steelhead population information, the preliminary results from a number of genetic studies were released. Microsatellite DNA analyses were carried out by WDFW and NMFS's Northwest Fisheries Science Center. In many cases, the analysis of existing samples was undertaken in response to TRT requests for specific information. This new information was incorporated into the existing Puget Sound steelhead genetic database (Appendix B). Given that this new information for presumptive populations usually includes limited numbers of fish samples taken from a single return year, or in some cases from smolt traps downstream of multiple tributaries, some caution was advised in drawing strong conclusions from the genetic results.

Major Population Groups

The concept of the MPG, a biologically and ecologically based unit that includes one or more DIPs within the DPS or ESU, was developed by previous TRTs (Ruckelshaus et al. 2002, McElhany et al. 2003, Cooney et al. 2007). Rather than simply setting a fixed number or proportion of populations to be fully recovered across the DPS, the TRTs used MPGs to establish guidelines ensuring that populations representative of major life history traits (e.g., summer-run and winter-run steelhead), major genetic lineages, or existing in ecologically or geographically distinct regions, are viable at the time of delisting. Ultimately, if a DPS contains viable populations in each MPG, it will have a relatively lower extinction risk from catastrophic events, correlated environmental effects, and loss of diversity (McElhany et al. 2003). Good et al. (2008) demonstrated that recovered populations dispersed across multiple MPGs in the Puget

Sound Chinook Salmon ESU were less susceptible to catastrophic risks than populations randomly dispersed (Appendix I). The linkage between sustainable MPGs (strata) and DPS viability was further underscored in Waples et al. (2007), who suggest that MPGs are useful elements for evaluating whether a species is threatened or endangered under the "significant portion of its range" consideration in the U.S. Endangered Species Act. Therefore, MPGs should be designated based on the premise that the loss of any one MPG within a DPS may put the entire DPS at a heightened risk of extinction. Establishing guidelines for population assignment into MPGs has generally been done in the viability documents produced by the TRTs; however, because the basis for designating MPGs is biologically based, it was convenient to simultaneously identify MPGs and DIPs for the Puget Sound Steelhead DPS within this document.

Major Population Grouping Determinations for Other DPSs and ESUs

For steelhead in the Lower Columbia River Steelhead DPS, two major life history types were recognized by the Lower Columbia River TRT: winter run and summer run (McElhany et al. 2003). Additionally, the TRT recognized that there was substantial ecological diversity within the DPS. Within the Lower Columbia River, the TRT recognized three ecological zones from the mouth of the Columbia River to the historical location of Celilo Falls. The Lower Columbia River Steelhead DPS included two of these three ecological zones: Cascade and Gorge. These ecological zones were based on the EPA's Level III ecoregions (Omernik 1987) and the Pacific Northwest River Basins Commission physiographic provinces (PNRBC 1969). The TRT designated the ecologically based MPGs as follows (McElhany et al. 2003).

MPG	Ecological zone	Run timing	Historical populations
1	Cascade	Summer	4
2	Cascade	Winter	14
3	Columbia Gorge	Summer	2
4	Columbia Gorge	Winter	3

They reflect the homing fidelity exhibited by steelhead and the likely degree to which populations will be locally adapted to marine and nearshore migratory corridors and freshwater spawning and rearing conditions. These MPGs are intended to assist in coordinating watershed planning, ensuring that recovery efforts are spread adequately across the distribution of distinct life history and ecological diversity categories.

The Interior Columbia TRT also established MPGs for ESUs and DPSs within their recovery domain (Cooney et al. 2007). The determination of MPGs was primarily established using geographic and ecological criteria. Interior populations of salmonids do not exhibit the same range of life history traits within an ESU or DPS as is observed among coastal populations. Within the Snake River Steelhead DPS, six MPGs were identified, each associated with a major tributary or mainstem section. Similarly, four MPGs were identified within the Middle Columbia River Steelhead DPS, but only one MPG in the Upper Columbia River Steelhead DPS. The situation in the Upper Columbia River Steelhead DPS was complicated by the loss of spawning habitat due to the construction of the Grand Coulee and Chief Joseph dams and the potential influence of the Grand Coulee Fish Maintenance Project on contemporary steelhead population structure (Cooney et al. 2007).

The North-Central California Coast TRT identified both historical populations and diversity MPGs for steelhead (Bjorkstadt et al. 2005). Geographically, the situation along the California coast is somewhat similar to that of Puget Sound. River basins drain separately into marine waters, providing geographic and environmental isolation (nonmigratory juveniles are restricted to their natal basin for an extended period). Based on observed genetic differences between populations in the river basins, coastal geography (e.g., coastal headlands), ecology, and life history differences, the North-Central California Coast TRT recognized seven diversity MPGs (two summer run and five winter run) within the North California Steelhead DPS and five diversity MPGs (winter run only) within the Central California Coast Steelhead DPS (Bjorkstedt et al. 2005).

The Puget Sound Chinook Salmon TRT established five "geographic regions" (Figure 8) within the ESU (Ruckelshaus et al. 2002). These geographic regions were established to provide population spatial distribution "based on similarities in hydrographic, biogeographic, and geologic characteristics of the Puget Sound basin and freshwater catchments, which also correspond to regions where groups of populations could be affected similarly by catastrophes (volcanic events, earthquakes, oil spills, etc.) and regions where groups of populations have evolved in common" (Ruckelshaus et al. 2002). In doing so, the TRT created de facto MPG subdivisions by requiring for future viability that one of each life history type (e.g., spring run and fall run) be represented in each geographic region where they currently exist.

Puget Sound Steelhead MPG Determinations

The geographic region template developed for Puget Sound Chinook salmon (Figure 8) provided a foundation for developing the configuration of steelhead MPGs. In contrast to Chinook salmon that spawn predominately in the main stem and major tributaries of most river basins in Puget Sound, steelhead utilize a variety of stream types, from the larger streams (similar to Chinook salmon) to smaller tributaries and drainages (more similar to coho salmon). In addition, resident *O. mykiss* occupy a variety of small tributaries in anadromous zones. The TRT identified a number of major basins that contain multiple habitat types, all of them containing *O. mykiss*. Although the TRT considered that freshwater habitat was an important factor in establishing steelhead life history phenotypes, larger scale geographic factors were identified as the primary factor in establishing substructuring within the DPS (i.e., MPGs).

Figure 8. Geographic regions for Chinook salmon as developed by the Puget Sound Chinook Salmon TRT (Ruckelshaus et al. 2002).

Geomorphology was evaluated as a structuring factor because of its influence on stream morphology, streambed composition, precipitation, stream hydrology, and water temperature. In Puget Sound, unconsolidated glacial deposits dominate much of the lowland habitat (Appendix J). The geologic composition of the upper basins of Puget Sound streams varied from volcanic depositions along western Hood Canal, the Strait of Juan de Fuca, and Mt. Rainier to a mix of sedimentary, metamorphic, and igneous formations in the North Cascades. The presence of erosion-resilient basalt formations in the North Cascades was often associated with waterfalls or cascades and the potential conditions for a summer-run steelhead life history strategy. The geomorphology of marine areas in association with land masses was also considered in identifying MPGs boundaries. Submarine sills, terminal moraines from glacial recession, may provide oceanographic substructure in Puget Sound. For example, there is a sill at Admiralty Inlet separating central Puget Sound from the Strait of Juan de Fuca and Strait of Georgia, and an additional sill at the entrance to Hood Canal. A sill at the Tacoma Narrows was considered a potential biogeographic barrier dividing south Puget Sound from northern areas.

The EPA ecoregion designations were useful in identifying ecologically distinct areas in Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Portions of four Level III ecoregions are found within the Puget Sound DPS (Figure 2): the Coast Range (covering the western side of the Hood Canal), the Puget Lowlands, the Cascades (covering the headwater regions of the Cedar River and south), and the North Cascades (encompassing the higher elevation areas of the Olympic Mountains and the Cascades north of the Cedar River).

The North Cascades Ecoregion differs from the Cascades Ecoregion in geology and glacial coverage. Currently the North Cascades Ecoregion contains the highest concentration of glacial coverage in the continuous United States. Glacially influenced streams exhibit an "inverse" hydrology relative to the precipitation-driven flow patterns observed in lowland streams (Appendix K). River flows in glacial-source streams peak during warmer summer months and stream temperatures are universally cooler in glacially driven relative to rain-driven streams. As a result, the timing of most major steelhead life history events is different in glacial/snow-dominated vs. rain-dominated systems. Substantial differences in the timing of stream flow events provide a strong isolating mechanism via spawn timing differences or through some fitness/selection mechanism in the timing of development, hatch, emigration, and adult return migration.

Seasonal stream flow differences were also evident among rain-driven streams, with smaller lowland streams having summer low flows that were less than 10% of the peak winter flows, while larger rain-driven streams have more sustained groundwater-driven summer flows, normally 20–40% of winter peak flows. Summer flows in turn likely have a strong influence on the life history of juvenile *O. mykiss*. Thus major hydrological differences between basins provide a useful proxy for steelhead life history diversity and the delineation of both DIPs and MPGs when life history data are not available.

Life history and genetic characteristics, ecological diversity, and geographic distribution were important factors influencing the designation of MPGs. Although, many TRT members emphasized the importance of freshwater hydrology and ecology, it was recognized that a wide range of conditions exist across subbasins within individual basins. Ultimately, rather than divide basins or create of patchwork of populations within an MPG, it was decided that MPGs would be primarily based on geographic proximity, marine migrational corridors, and genetics (Figure 9). Finally, genetic analysis of steelhead populations suggested a clustering of populations similar to some of the geographic regions developed by the Puget Sound Chinook Salmon TRT (Appendix B). Genetic analysis suggested a further split in the Northern Cascades, with Drayton Harbor, Nooksack Basin, and Samish River as a possible MPG; however, the ecological and geographic characteristics were not considered distinct enough. In contrast, the placement of the Snohomish Basin was based solely on ecological data in the absence of genetic data (other than South Fork Tolt River summer-run fish). Using these criteria to establish MPGs ensures that there would be broad spatial and genetic representation in the DPS that is ultimately recovered. Each MPG in turn contains populations with a variety of habitats and associated life history traits. It is the TRT's intention to create viability criteria for each MPG to ensure that among-population diversity and spatial structure is preserved.

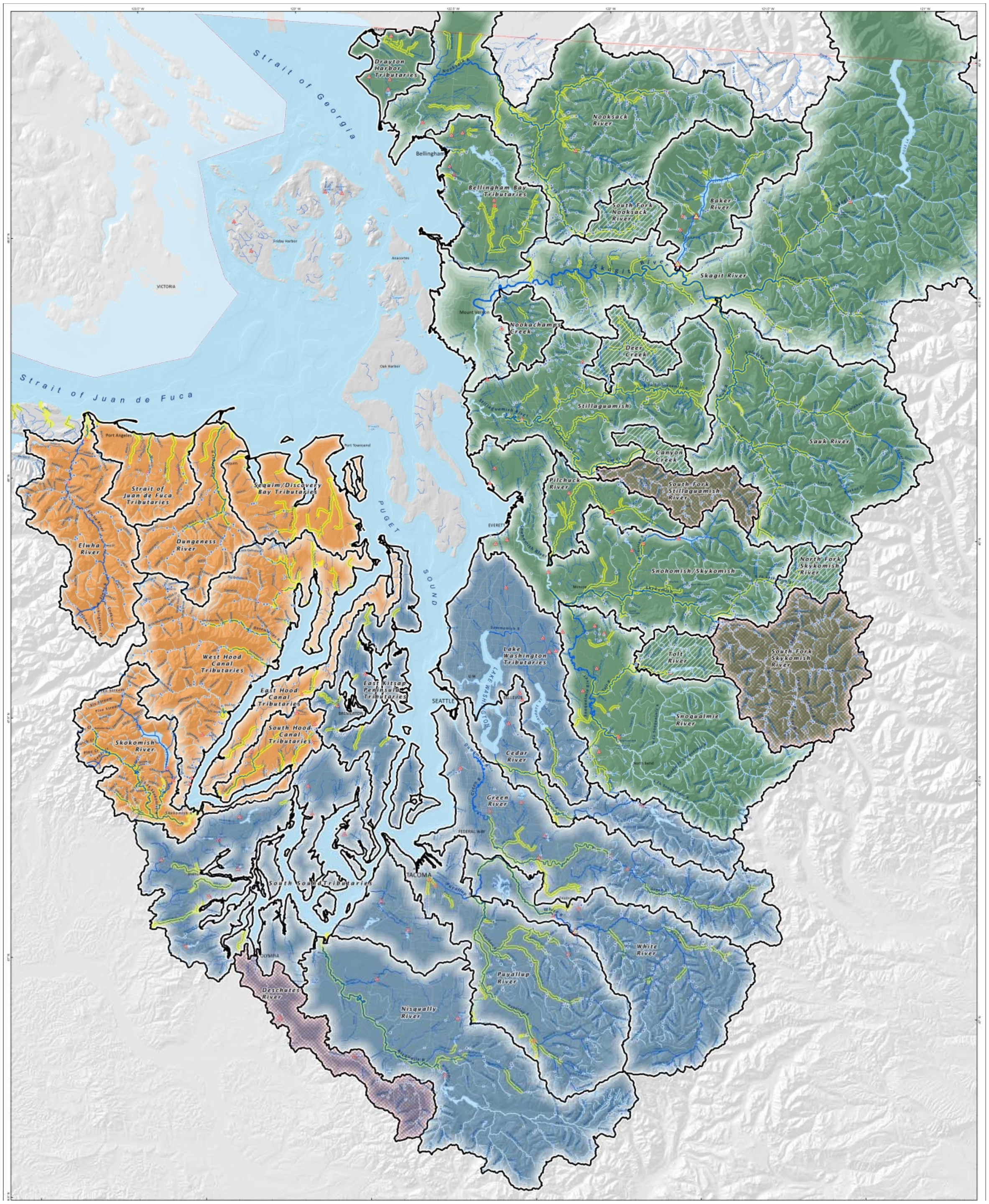

Figure 9. Major population groupings for the Puget Sound Steelhead DPS: Northern Cascades, Central and South Puget Sound, and Hood Canal and Strait of Juan de Fuca MPGs. Note that the Deschutes, South Fork Stillaguamish, and South Fork Skykomish River basins are not included in the DPS and have not been assigned to DIPs. We are unaware of historical or current information on steelhead presence in the islands in North Puget Sound (Whidbey, San Juan, etc.) and these areas remain unassigned.

Historical Demographically Independent Populations

The PSS TRT ultimately utilized two parallel methodologies to identify DIPs. An expert panel system was employed, with each TRT member evaluating the likelihood that presumptive populations met the criteria for being DIPs. The process focused on several data categories, including: genetic distance, geographic distance (Appendix L), basin size, abundance, life history, habitat type, hydrology, demographic trends, and spawn timing. These categories were selected for their relevance to the question of sustainability and independence and the quantity and quality of the data for most populations. TRT members evaluated the information categories for each population and determined whether the information for that category was a factor "contributing to independence," a factor "contributing to amalgamating," or "not informative." The TRT then reviewed the combined category scores and any additional information not specifically covered by the categories before deciding the status of the presumptive DIP.

In a parallel effort, the TRT employed a number of decision support systems to identify DIPs. The decision support system provides a more quantitative and transparent methodology than the panel system, although the selection of categories and thresholds are still assigned by the TRT via an expert panel system. Most of the decision support systems reviewed by the TRT required a considerable amount of information on each population or utilized default values that introduced considerable uncertainty into the system conclusions. Ultimately, the TRT developed a simplified linear decision model that used independence threshold values derived in part from the truth membership functions generated by the TRT. Discussion of this model and the truth membership functions it relied on is in Appendix B. The linear decision (aka gatekeeper) model identified a set of provisional DIPs that was nearly identical to that arrived at via the expert panel system. Where the two systems differed, the TRT debated the specifics of the DIP, but generally endorsed the outcome of the gatekeeper model.

The following subsections list the MPGs and DIPs identified by the TRT and provide some detail on those factors that were especially relevant in that determination. Where appropriate, we have noted where there were substantial uncertainties among the TRT members in the DIP determination.

Northern Cascades (South Salish Sea) MPG

Overview

The Northern Cascades MPG includes populations of steelhead from the Canadian border to and including the Snohomish River basin (Table 6). This MPG was established based on the geologic distinctiveness, ecological differences, geographic separation between it and the MPGs to the south and west, and genetic relatedness of populations within the MPG boundary. The

Table 6. DIPs within the Northern Cascades MPG and their respective categorization by state and tribal agencies. WRIA = Water Resource Inventory Area and SASSI/SaSI = Salmon and Steelhead Stock Inventory/Salmonid Stock Inventory.

WRIA	1992 SASSI/2002 SaSI	TRT DIP
1	Dakota Creek winter	1. Drayton Harbor Tributaries Winter Run
1	N. F. Nooksack River winter	2. Nooksack River Winter Run
1	M. F. Nooksack River winter	
1	S. F. Nooksack River summer S. F. Nooksack River winter	3. S. F. Nooksack River Summer Run
3	Samish River winter	4. Samish R. and Bellingham Bay Winter Run
4	Mainstem Skagit River winter	5. Skagit River Summer Run and Winter Run
4	Finney Creek summer	
4	Cascade River summer Cascade River winter	
4	—	6. Nookachamps Creek Winter Run
4	—	7. Baker River Summer Run and Winter Run
4	Sauk River summer Sauk River winter	8. Sauk River Summer Run and Winter Run
5	Stillaguamish River winter	9. Stillaguamish River Winter Run
5	Deer Creek summer	10. Deer Creek Summer Run
5	S. F. Stillaguamish River summer	Out of DPS
5	Canyon Creek summer	11. Canyon Creek Summer Run
7	Snohomish/Skykomish R. winter	12. Snohomish/Skykomish Rivers Winter Run
7	Pilchuck River winter	13. Pilchuck River Winter Run
7	S. F. Skykomish River summer	Out of DPS
7	N. F. Skykomish River summer	14. N. F. Skykomish River Summer Run
7	Snoqualmie River winter	15. Snoqualmie River Winter Run
7	Tolt River summer	16. Tolt River Summer Run

boundary between this MPG and the South Central Cascades MPG to the south largely corresponds with the ecoregion boundary between the North Cascades and Cascades ecoregions in headwater areas. Glaciers dominate many of the mountain areas. In some areas the rock substrate is highly erosible, while in others it is relatively stable, resulting in a number of cascades and falls that may serve as isolating mechanisms for steelhead run times (Appendix J).

This geology is likely responsible for the relatively large number of summer-run populations. In fact, this MPG currently contains the majority of existing steelhead summer runs, although there is some uncertainty about the historical presence or present day persistence of summer-run steelhead in rivers elsewhere in the DPS. The Snohomish River, the most southern population in this MPG, is geographically separated from the nearest populations in the other MPGs by 50–100 km. A recent microsatellite analyses indicated that populations in the North Cascades MPG represented a major genetic cluster, although it should be noted that samples from the Snohomish Basin were unavailable.[12] Alternatively, Phelps et al. (1997), using allozyme genetic analysis, indicated that the genetic diversity unit boundary between major genetic groups lies between the Stillaguamish and Snohomish basins, farther to the north. Notwithstanding concerns about the samples used in the Phelps et al. (1997) study, all agreed that further steelhead genetic studies were necessary to address these critical uncertainties.

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[12] Additional genetic analyses have been made of Snohomish River basin populations, but have not been integrated into the DPS-wide database at the time of this publication.

The Puget Sound Chinook Salmon TRT (Ruckleshaus et al. 2006) identified a similar MPG (originally termed a "geographic region"), although within the boundaries of the steelhead Northern Cascades MPG, they also identified the Nooksack River basin as a major geographic unit. Based on available information, primarily limited genetic analysis, and life history information, the PSS TRT concluded that the Nooksack River basin steelhead populations did not constitute a distinct MPG.

Proposed DIPs within the MPG

1. Drayton Harbor Tributaries Winter Run

This population includes steelhead that spawn in tributaries from the Canadian border to Sandy Point, Washington, primarily in Dakota and California creeks (Smith 2002). It was identified based on geographic isolation from the Nooksack and Fraser rivers, the most proximate steelhead populations. Although genetic analysis is unavailable for this population, it is thought that it is sufficiently geographically isolated from the nearby larger basins, Nooksack and Fraser. Spawning and rearing habitat in these smaller, low-gradient, rain-dominated systems is very different from the glacially influenced conditions in the North Fork Nooksack River. Dakota Creek steelhead have an earlier spawn timing than fish in the Fraser or Nooksack rivers and are morphologically distinct, being generally smaller and looking "more like cutthroat" than Nooksack River fish.[13]

The tributaries supporting this population are wholly contained within the EPA Level III Puget Lowlands Ecoregion, with 89 m maximum elevation in the basin. The basin size for Dakota Creek is 139 km^2, although this does not include some other minor tributaries (e.g., Terrell Creek). Historical information indicates that this population was of medium abundance; however, observations were only reported in Dakota Creek and not California or Terrill creeks (WDFG 1932). Habitat-based IP run size was estimated to be 2,426–4,930 fish[14] (Appendix D). Sportfishing punch card records indicate a maximum catch (adjusted)[15] of 67 fish in 1957, with an average catch of 18 fish annually from 1946 to 1970. Steelhead and presumptive steelhead redds have been observed recently, but in low numbers, although monitoring is intermittent.

2. Nooksack River Winter Run

This population includes winter-run steelhead in the north, middle, and south forks of the Nooksack River. While the entire TRT agreed that winter-run steelhead in the Nooksack constituted at least one DIP, some members suggested the presence of multiple winter-run DIPs within the basin, including making each of the three forks a DIP. SaSI (WDFW 2002) reported that the Middle Fork Nooksack River may have supported a summer run of steelhead prior to the construction of the impassable diversion dam at RKM 11. Genetic analysis (based on allozymes) indicated that North Fork and South Fork Nooksack rivers steelhead were genetically distinct (Phelps et al. 1997), although the south fork samples may have included some summer-run fish. Preliminary microsatellite DNA analysis indicated that: 1) Nooksack River steelhead were

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[13] B. Barkdull, WDFW, La Conner, WA. Pers. commun., October 2008.

[14] IP estimates of basin capacity are presented as a range using smolt survivals varying from 10 to 20%.

[15] Sport catch estimates were adjusted by 0.60 from numbers published in WDG (no date-b), based on a personal communication (P. K. Hahn, WDFW, Olympia, WA. Pers. commun., 18 November 2009).

distinct from Samish River winter-run steelhead and 2) genetic differences among samples within the Nooksack River basin did not suggest a high degree of differentiation (although sample sizes were relatively small).

Winter-run steelhead from the north, middle, and south forks of the Nooksack River were combined based on the geographic proximity of the basins and the apparent continuum of spawning grounds. The lower reaches of the mainstem Nooksack River are located in the Puget Lowlands Ecoregion and upstream tributary areas are located in the North Cascades Ecoregion. Currently, there is considerable spawning area in low elevation, low gradient tributaries, such as Fishtrap and Bertrand creeks.[16] There is considerable ecological variability among the major tributaries. The North Fork Nooksack River has a glacial, snowmelt-driven hydrology, the Middle Fork Nooksack River has a rain and snow–driven hydrology, and the South Fork Nooksack River is a lower gradient, primarily rain-driven river. Conditions specifically related to glacial sediment in the North Fork and Middle Fork Nooksack rivers prevent visual estimation of escapement (e.g., redd counts) or life history characteristics (e.g., spawn timing). Local biologists for the state and tribes suggested that winter-run steelhead spawning has a continuous distribution throughout the basin, with little opportunity for spatial or temporal isolation.[17]

Historical estimates from in-river harvest suggest that there was a substantial run (10,000s) of steelhead into the Nooksack Basin in the early 1900s. The habitat-based IP capacity estimate was 22,045–44,091 steelhead. Spawner surveys of the North Fork and Middle Fork Nooksack rivers in 1930 identified a number of tributaries that supported steelhead. Ernst (1950) reported that the South Fork Nooksack River was the major producer in the basin, and that most of these fish spawned in the main stem. Adjusted punch card catch estimates (1946–1972) peaked in 1953 at 2,114 winter-run steelhead. Additionally, there are reports of summer-run steelhead present in the North Fork and Middle Fork Nooksack rivers; however, it was unclear whether these were fish from the South Fork Nooksack Summer-Run DIP, a distinct North Fork or Middle Fork Nooksack River summer run, or a diversity component within this population. The TRT recommends that further genetic sampling be carried out in order to verify the proposed DIP boundaries.

3. South Fork Nooksack River Summer Run

The TRT identified a DIP in the upper portion of the South Fork Nooksack River based in part on geographic separation between winter-run and summer-run steelhead in the Nooksack Basin. According to WDFW (2002), summer-run steelhead spawn in the mainstem South Fork Nooksack above the series of cascades and falls at RKM 40 and in upper watershed tributaries, Hutchinson and Wanlick creeks (RKM 16.3 and 54.9, respectively). Smith (2002) suggested that the summer run of steelhead in the South Fork Nooksack has always been relatively small compared to the winter run, although the potential run size, based on habitat above the cascades (IP range), was estimated at 1,137–2,273 steelhead. WDFW (2002) suggested that summer-run spawning extends from February to April, while winter-run steelhead exhibit a more protracted spawning interval, mid-February to mid-June. Genetic analysis by Phelps et al. (1997) indicated that winter-run and summer-run steelhead were significantly different from each other in the

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[16] N. Currence, Nooksack Tribe, Natural Resource Department, Deming, WA. Pers. commun., October 2008.

[17] See footnote 16.

South Fork Nooksack River. Preliminary microsatellite DNA analysis of steelhead from there did not suggest the presence of multiple populations, although the sample size was relatively small. Additional sampling, especially of adults in the holding pools below the falls at RKM 40 or above the falls, was identified by the TRT as a priority for future sampling.

The South Fork Nooksack River basin above the falls covers 480 km^2 and lies within the EPA Level III North Cascades Ecoregion. The South Fork Nooksack River is categorized hydrologically as a rain and snow–driven system and experiences relatively high late summer water temperatures in the lower reaches (>20°C). Under these conditions, summer-run steelhead holding habitat in the lower river would be limited by the availability of cold water seeps, deep resting holes, or access to headwater areas. Surveys during 1930 identified steelhead spawning aggregations in Hutchinson and Skookum creeks (WDFG 1932), although no distinction was made between winter-run and summer-run fish in these surveys. Ernst (1950) reported that steelhead migrated as far as 5.6 km above Howard Creek.

4. Samish River and Bellingham Bay Tributaries Winter Run

This DIP exists in a series of independent tributaries to Puget Sound; the Samish River and associated nearby creeks drain into Samish and Bellingham bays. In contrast to the adjacent DIP areas, the Samish River exhibits a largely rain-dominated flow pattern. The entire basin is located within the Puget Lowlands Ecoregion with relatively low elevation headwaters. Average elevation in the basin is only 192 m. Only winter-run steelhead are present in this basin, with the majority of spawning occurring in Friday Creek and the Samish River from mid-February to mid-June (WDFW 2002). This run was noted as being especially early relative to other populations in the area (Seattle Daily Times 1923). The present day run has maintained that early timing.[18] The Samish River Hatchery was originally constructed in 1899 primarily as a coho salmon hatchery, but substantial numbers of steelhead eggs were obtained, 2.1 million eggs in 1910 (Cobb 1911, WDFG 1913). Although the basin is relatively small, the basin averaged 617 steelhead over the most recent 5-year period.[19] Peak catch based on adjusted punch cards was 1,934 winter-run steelhead in 1951. The IP-based estimated range of capacity for the Samish Basin was 3,193–6,386 steelhead (Appendix D). Furthermore, while the adjacent Nooksack River and Skagit River steelhead populations appear to be steadily declining, the Samish River steelhead escapement trend has been stable or increasing at times during recent years, indicating that it is demographically independent of the other populations.

Genetic analysis using microsatellite DNA indicated samples from the Samish River winter run are more closely related to Nooksack River fish than to Skagit River or Stillaguamish River steelhead. There was a general consensus among the TRT members that genetically the Samish and Nooksack steelhead were part of a larger MPG that included rivers to the south.

The TRT included in the Samish River DIP a number of independent tributaries draining into Bellingham Bay: Squalicum, Whatcom, Padden, Chuckanut, Oyster, and Colony creeks. Smith (2002) reported steelhead spawning in these creeks. Punch card records (WDG no date-b) indicate a peak catch of 23 fish in Chuckanut Creek (1958), 8 in Squalicum Creek (1970), and 34

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[18] B. Barkdull, WDFW, La Conner, WA. Pers. commun., August 2012.

[19] Data from B. Leland, WDFW, Olympia, WA. Pers. commun., 14 February 2012.

in Whatcom Creek (1953). The IP estimate indicates that annual production would be 185 fish annually for Chuckanut Creek alone. These creeks are lowland, rain-driven systems, very distinct from the nearby, glacially influenced Nooksack River. Although there was some discussion that these creeks might constitute a DIP, the distances between these streams and both the Nooksack and Samish rivers were not considered large enough to warrant independence. The TRT concluded that ecological conditions in these creeks were more similar to those in the Samish River than in the Nooksack River and supported grouping them with Samish steelhead to form a DIP.

5. Skagit River Summer Run and Winter Run

There was considerable discussion by the TRT on the structure of populations within the Skagit River basin. Abundance, life history, and genetic information were limited, especially at the subbasin level. At the time of this review, an extensive genetics sampling program was being undertaken in the Skagit River basin. Results from the analysis of the first 2 years of sampling (2010 and 2011) did not provide evidence for much divergence among fish sampled in anadromous zones within the basin, but did show high divergence between steelhead and *O. mykiss* that resided upstream of anadromous barriers. Given the recent decline in steelhead abundance in the Skagit River, especially in the tributaries, it is unclear how informative contemporary genetic sampling will be regarding the potential historical population structure of the basin. As with all DIP determinations, information may become available that initiates a review of one or more DIPs. In the case of the Skagit River basin, there is a clear timeline for the availability of new genetic information.

The Skagit River Summer-Run and Winter-Run DIP includes all steelhead spawning in the mainstem Skagit River and its tributaries, excluding the Baker and Sauk rivers, from the mouth to the historical location of a series of cascades located near the Gorge Dam (Smith and Anderson 1921b). Based on abundance, Skagit River steelhead represent one of the predominant steelhead populations in Puget Sound, accounting annually for several thousand spawning steelhead. WDFW (2002) notes that, although they consider winter-run steelhead in the main stem and tributaries to be distinct stocks, there is no apparent break in the spawning distribution between the Skagit, Sauk, and Cascade rivers. In the recent genetic analysis (Appendix B), the Cascade River and Goodell Creek juvenile samples from the anadromous zone accessible reaches were distinct from some of the other Skagit Basin samples. In the case of the Cascade River juvenile fish sampled that did not genetically resemble resident *O. mykiss* from above a series of inaccessible falls, it is still unclear whether they represent the progeny of anadromous steelhead. The population status of the Cascade River steelhead and steelhead from other tributaries may need to be reassessed as new information becomes available.

Winter-run steelhead predominate in the main stem and lower tributaries, with summer-run steelhead reported in Day and Finney creeks and the Cascade River (Donaldson 1943, WDG no date-a). In the case of these three summer-run steelhead–bearing tributaries, cascades or falls may present a migrational barrier to winter-run fish but not summer-run fish. Some members of the TRT concluded that these barriers were sufficient to maintain independent summer runs in each of these tributaries, while others were unsure whether there was sufficient habitat above the barriers to sustain a population. Of these summer-run aggregates, the Cascade River came the closest to meeting DIP criteria, although there was limited information available. For example, peak adjusted punch card catch was 58 summer-run fish in 1970 (WDG no date-b), although accessibility to fishers likely limited the sport catch. Further sampling efforts in these basins were recommended. At a minimum, winter-run and summer-run life histories are somewhat reproductively isolated (temporal separation) from each other; however, it is unclear whether any of these summer-run aggregates was historically large enough to persist as a DIP. In evaluating the viability of this DIP, both life histories were recognized as important diversity components.

In a previous genetic analysis, samples from the Skagit, Sauk, and North Fork Stillaguamish rivers formed a cluster within the greater Puget Sound grouping (Phelps et al. 1997) (Figure 7). Steelhead samples (possibly containing summer-run fish) from Finney Creek and the Cascade River clustered with samples from Deer Creek and the Nooksack River (Phelps et al. 1997), although the number of fish sampled from Finney Creek was relatively small. Interestingly, the headwaters of Deer Creek (Stillaguamish River) and Finney Creek (Skagit River) are adjacent to each other. While there is considerable information that summer-run steelhead existed in the Skagit River tributaries, recent surveys suggest that the summer-run component is at a critically low level. While the abundance of winter-run steelhead is also depressed, there is not as marked a decline as with the summer-run steelhead. Given the large size of this DIP relative to other populations, there is the potential for considerable within-population ecological, spatial, and genetic (life history) diversity. Preliminary results from the recent genetic analysis indicated that Skagit River steelhead have remained relatively distinct from steelhead broodstock (Chambers Creek–origin) used at Marblemount Hatchery,[20] near the confluence of the Cascade and Skagit rivers.

This DIP includes the entire Skagit River except for the Sauk and Baker river subbasins. In total, this DIP covers 3,327 km^2, the largest of the DIPs within the DPS. Estimated historical capacity, based on IP estimates, ranges from 64,775 to 129,551 steelhead (Appendix D). Spawning occurs from early March to early June. The majority of this population spawns within the North Cascades Ecoregion. Given the size of the DIP, it is not surprising that tributaries exhibit a variety of hydrologies, from lowland rain-driven to snowmelt-dominated streams, many with heavy glacial sediment loads. Landslides and volcanic activity pose some of the greatest catastrophic risks.

6. Nookachamps Creek Winter Run

Nookachamps Creek, was identified as a potential DIP for winter-run steelhead. This basin met the criteria for basin size and IP production. In contrast to much of the Skagit Basin, this lowland subbasin exhibits a rain-driven hydrology, with peak flows in December and January and low flows in August and September. Given the lowland ecology, it is thought that Nookachamps Creek only supported winter-run steelhead and that there may have been a difference in run timing between these steelhead and other steelhead returning to snow-dominated tributaries higher in the Skagit Basin, similar to the situation between the Drayton Harbor Tributaries Winter-Run DIP and the Nooksack River Winter-Run DIP. However, it was unclear how geographically separated spawning areas in Nookachamps Creek would be from

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[20] T. Kassler, WDFW, Olympia. Pers. commun., 26 May 2010.

other Skagit tributaries. In the absence of specific information on steelhead characteristics, ecological information provided the majority of information for designating a DIP.

WDF (1932) identified steelhead as being "very scarce," while notations on the 1940 steelhead map of the Skagit River basin (WDG no date-a) suggested that a fair number of fish spawned in Lake Creek up to the swamps below Lake McMurray. Additionally, a fairly extensive run was noted in East Fork Nookachamps Creek. Given the lowland nature of this subbasin and its proximity to Mt. Vernon, Washington, it is thought that significant habitat alterations had likely occurred by the time of the 1932 and 1940 surveys. Juvenile *O. mykiss*, presumptive steelhead, were sampled from both forks of Nookachamps Creek and from Lake Creek in 1980 (USFWS and WDG 1981). Juvenile surveys in the 1980s observed some of the highest juvenile densities in the Skagit River basin in Nookachamps Creek (Phillips et al. 1981).

There was little information available on the characteristics of historical or contemporary steelhead in the Nookachamps Creek basin. Potential abundance was estimated at 1,231 to 2,462 using the IP method. Although identifying this as a historical DIP, the TRT agreed that additional information and monitoring was needed to address critical uncertainties.

7. Baker River Summer Run and Winter Run

Historically, the Baker River was likely a major contributor to Skagit River basin steelhead runs. The Baker River is the second largest tributary to the Skagit River, with a basin size of 771 km^2. The Baker Lake Hatchery began operation in 1896, initially managed by the State of Washington and subsequently transferred to the U.S. Bureau of Commercial Fisheries. Steelhead were not the primary species cultured (only a few thousand eggs were taken annually) and the number of spawned fish recorded might have been limited by the available incubation space. Hatchery reports strongly suggest that this population included a summer-run life history element. In any event, the construction of the lower Baker Dam in 1927 eliminated access to nearly all of the Baker River and necessitated the initiation of a trap and haul program. During the first year of operation (1929), 830 steelhead were transported to the upper basin from April to July. Upper Baker Dam, constructed in 1958, inundated the lower reaches of the upper Baker River tributaries. During those years when adults were transported to the upper Baker River (the practice was terminated some years ago) the origin of steelhead collected was unknown. Recent analysis of genetics samples from Baker Lake resident *O. mykiss* showed that they were genetically similar to Skagit River anadromous steelhead; however, it is unclear whether *O. mykiss* currently spawning in Baker Lake/River retain any genetic association with the historical population.[21] Many of the TRT members and reviewers considered the Baker River Summer-Run and Winter-Run DIP to have been extirpated, although resident *O. mykiss* in the Baker River basin may retain some of the historical genetic legacy of this population. In the absence of anadromous adults being transported above the dams, the resident *O. mykiss* population continues to produce smolts, with a few hundred collected in the bypass system annually. Marking outmigrating smolts to see if there is any contribution to returning adults would be informative. Finally, while it is clear that steelhead historically occupied the Baker River basin, there is considerable uncertainty regarding the characteristics of that population.

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[21] Presentation by D. Pflug, Seattle City Light, to the PSS TRT, Seattle, WA., 25 January 2012.

The majority of this population historically spawned within the North Cascades Ecoregion and the river exhibits a glacial snowmelt–dominated hydrograph. Habitat-based abundance estimates (IP) suggest a capacity of 5,028 to 10,056 steelhead (Appendix D). Historically, canyon areas in the lower river below Baker Lake (corresponding with the present locations of Lower Baker and Upper Baker dams) may have represented migrational barriers normally corresponding to the presence of summer-run fish. This basin is one of the highest elevation DIPs in the DPS, with an average elevation of 1,014 m, and drains the slopes of Mt. Baker. Landslides and volcanic activity pose some of the greatest catastrophic risks.

8. Sauk River Summer Run and Winter Run

The identification of this DIP followed extensive discussions by the TRT. These discussions focused on the separation of Sauk River steelhead from those in the mainstem Skagit River and the distinctiveness of diversity components within the Sauk River basin itself. Summer-run and winter-run steelhead are present in the Sauk River, but they were not assigned to separate DIPs. No migrational barriers (falls or cascades) have been identified that would provide a reproductive isolating mechanism between the two run times, yet they likely maintain some reproductive isolation through spawn timing differences (WDF et al. 1993). Current abundance of summer-run fish is relatively low and is thought to have historically been a minor contributor to total abundance (WDFW 2002). Historical surveys suggest that the winter run of steelhead in the Sauk River basin was significantly earlier than that in the mainstem Skagit River, specifically in the Suiattle River: “Of considerable biological importance is the persistent report that the early run of steelhead in the Skagit River system proceed up the Sauk River” (WDG no date-a). It was suggested that the early run timing allowed fish to access spawning grounds while stream conditions were good and prior to the spring glacial runoff. During 1906, the WDFG hatchery on the Sauk River collected more than a million steelhead eggs from early February to June 15 (WDFG 1907). The wide temporal window for collecting eggs suggests that they were collected from both summer and winter runs. For summer-run and winter-run steelhead in the Sauk River basin, there does not appear to be any geographic separation on the spawning grounds. WDFW (2002) reported that summer-run fish spawn from mid-April to early June and winter-run fish spawn from mid-March to mid-July.

Samples from Sauk River steelhead were genetically similar to winter-run steelhead sampled from the mainstem Skagit River, especially those downstream of the Skagit/Sauk River confluence (Phelps et al. 1997). Steelhead from the Suiattle River were distinct from mainstem Skagit River steelhead and Sauk River steelhead (Figure 8 in Phelps et al. 1997). Sauk River flows are strongly influenced by snow melt and, as mentioned earlier, are subject to considerable glacial turbidity for most of the year (except during winter low flow periods), depending on the tributary. The Suiattle and Whitechuck rivers were specifically noted as containing high levels of glacial debris (WDG no date-a). There was some discussion regarding additional populations within the Sauk River. However, although many tributaries to the Sauk are capable of sustaining independent populations (based solely on basin size), there was little information available to support such a conclusion. Genetic sampling efforts are underway in the Skagit River basin. Preliminary results from recent genetic sampling indicated that *O. mykiss* from anadromous-accessible areas of the Skagit Basin were genetically similar, with samples from the Suiattle River and Goodell Creek being slightly more distinct, and those from the Cascade River being considerably more distinct (Figure 2 through Figure 5 and Appendix B). Pooling samples within the Upper Skagit and Lower Skagit basins and Sauk Basin reduces the genetic distance between the Skagit and Sauk sample aggregates, but this may be because of variability within subbasins. As more genetic information becomes available, it may be necessary to revisit the TRT's DIP conclusions.

The entire Sauk River basin is contained within the North Cascades Ecoregion. Given the large size of the Sauk River basin, 1,898 km^2, and the number of larger tributaries within the basin, it is possible that other DIPs exist within the basin. Recent escapement (2006) to the Sauk River was estimated to be 3,068. The IP estimate of basin capacity ranged from 23,230 to 46,460 steelhead (Appendix D). At a minimum, there is likely to be some population substructure that should be considered in maintaining within-population diversity.

9. Stillaguamish River Winter Run

Winter-run steelhead spawn in the mainstem north and south forks of the Stillaguamish River and in numerous tributaries. Winter-run steelhead were identified by the TRT as distinct from summer-run steelhead in Deer Creek and Canyon Creek because of the likely geographic and temporal separation of spawners. Nonnative summer-run fish (Skamania Hatchery, Columbia River origin) and their progeny spawning above Granite Falls (South Fork Stillaguamish River) are not part of the DPS and were not considered. It is not known whether any native steelhead spawn above the falls (an area historically inaccessible prior to the construction of a fish ladder). Genetic analysis indicated that there was some reproductive isolation between the native winter-run (North Fork Stillaguamish River) and summer-run (Deer Creek) spawners (Phelps et al.1997). Stillaguamish River winter-run steelhead clustered with winter-run and summer-run Sauk River steelhead and other Skagit River steelhead (Phelps et al. 1997). Recent genetic analysis using microsatellite loci also indicated a close affinity between the Stillaguamish River steelhead and Sauk/Suiattle River steelhead collections (Appendix B). This genetic relationship is thought to be related to the Sauk River's historical drainage to the North Fork Stillaguamish River prior to a series of lahars (volcanic mudflows) diverting the flow of the Upper Sauk River to the Skagit River more than 10,000 years BP. WDFW (2002) reported that winter-run steelhead spawn from mid-March to mid-June, and summer-run fish spawn from early April to early June in Deer Creek and February to April in Canyon Creek.

The Stillaguamish River basin, not including the Deer Creek and Canyon Creek Summer-Run DIPs, covers 1,282 km^2. The IP-based capacity ranged from 19,118 to 38,236 steelhead (Appendix D). There are no basin-wide estimates of escapements. Current escapement surveys only cover index areas and these estimates have averaged in the low hundreds of adult fish in recent years.

The lower Stillaguamish River is located in the Puget Lowlands Ecoregion and the upper North Fork and South Fork Stillaguamish are located in the North Cascades Ecoregion. Historically, the Sauk River flowed into the North Fork Stillaguamish River and, as a result, the North Fork Stillaguamish River valley is much broader than might be expected based on current river size and flow. Flow in the Stillaguamish River is considered rain-and-snow transitional. The river is subject to moderate risks from volcanic, landslide, and earthquake events.

10. Deer Creek Summer Run

The Deer Creek summer-run steelhead population spawns and rears in the upper portion of Deer Creek. Steep canyons and cascades from RKM 2.5 to 8 may present a temporal barrier to winter-run fish, but Deer Creek is accessible to summer-run steelhead up to approximately RKM 32. Deer Creek summer-run steelhead were most famously observed by Zane Grey in August 1918, during a fishing trip (Grey 1928). Smith and Anderson (1921a) surveyed the basin in August 1921, but observed only summer-run coho salmon and reported that a few steelhead run in the stream. Even under pristine conditions, the steelhead run into Deer Creek may not have been very large, potentially 1,000 to 2,000 adults (WSCC 1999), although the 1929 survey classified Deer Creek as a large population (WDFG 1932). The IP estimate range for Deer Creek is 1,572 to 3,144 adults (Appendix D). There are no recent estimates of escapement; the last adult census was conducted in October 1994 and resulted in an estimate of 460 steelhead (Kraemer 1994). The supporting basin is relatively small, 172 km^2, and freshwater productivity varied from 0.059 to 0.609 parr/m^2 (Kraemer 1994).

Deer Creek steelhead were genetically distinct from winter-run fish in the Stillaguamish River and Skagit River (Phelps et al. 1997). Reanalysis of one of the same Deer Creek samples from 1995 using microsatellite DNA variation indicated that Deer Creek steelhead were outliers, loosely clustering with the South Fork Tolt River steelhead and steelhead derived from Skamania Hatchery broodstock in dendrogram presentations; however, principal component analysis placed the Deer Creek collection more closely with collections from the Skagit and Stillaguamish rivers (Appendix B). In general, this analysis supports the contention that the summer-run life history has evolved independently in different basins, as initially described by Phelps et al. (1997). Deer Creek steelhead also have distinct 2/1 age structure (2 years in fresh water and 1 year in the ocean before returning to spawn) (Kraemer 1994), although the writings and photographs of Zane Grey would suggest that previously larger, likely repeat spawners were more common (Grey 1928). Deer Creek is located in the North Cascades Ecoregion and is categorized as a rain-and-snow transitional river.

11. Canyon Creek Summer Run

There is relatively little information available on the present-day summer run of steelhead in the Canyon Creek basin. Information provided by local biologists indicates that a summer run is still present in the basin. Historically, Canyon Creek was identified as having a relatively good-sized run of steelhead. Newspaper accounts listed Canyon Creek as a good summer-run steelhead stream (Seattle Daily Times 1935). There is no genetic information available on this run. A series of cascades and falls at RKM 2 is thought to be a partial temporal barrier to most adult salmon (Williams et al. 1975) and may provide a barrier to separate winter-run and summer-run steelhead. Above the cascades, there are approximately 26 km of accessible mainstem and tributary habitat (Appendix D). These conditions may provide a sufficiently strong isolating mechanism to justify designating this population as a DIP. Similar to Deer Creek, the Canyon Creek basin is small, 163 km^2, with an IP-based capacity of 121 to 243; this low estimate highlights the likely use of higher gradient stream reaches by summer-run steelhead (a factor not currently included in the model). Alternatively, summer-run steelhead may rear in the lower reaches of the basin, below the cascades that demark the winter-run and summer-run spawning habitat. The upper reaches of Canyon Creek lie in the North Cascades Ecoregion.

12. Snohomish/Skykomish Rivers Winter Run

This population includes winter-run steelhead in the mainstem Snohomish, Sultan, and Wallace rivers, and in the North Fork Skykomish River below Bear Creek Falls and the South Fork Skykomish River below Sunset Falls. WDFW (2002) identified three winter-run populations in the Snohomish Basin based on geographic discreteness. There is no recent genetic information available (e.g., microsatellite DNA analysis). Based on the work of Phelps et al. (1997), winter-run steelhead in the Tolt, Skykomish, and Snoqualmie rivers were most similar genetically, forming a cluster along with winter-run steelhead from the Green River. Spawn timing for winter-run steelhead through the Snohomish Basin extends from early-March to mid-June, similar to neighboring steelhead populations.

Historically, a number of mainstem and tributary areas of this population were identified as supporting medium and large “populations” of steelhead that may have constituted some of the most productive in Puget Sound (WDFG 1932). Furthermore, harvests recorded for Snohomish County in the late 1800s and early 1900s indicated that runs likely exceeded 100,000 fish (Appendix D). Basin area is 2,185 km^2 and the IP estimates suggest a run size of approximately 21,389 to 42,779 fish (Appendix D).

The lower reaches of the Snohomish River are in the Puget Lowlands Ecoregion, while the upper portions of the Skykomish and Snoqualmie rivers are in the Northern Cascades Ecoregion. The boundary between the Northern Cascades and Cascades ecoregions lies between the Snohomish River and the Lake Washington basin. The Pilchuck River is predominantly a rainfall-driven system, whereas the Snohomish, Snoqualmie, and Skykomish rivers are classified as rain-and-snow transitional. The Snohomish River is subject to relatively high earthquake catastrophic risks, but low volcanic risks.

13. Pilchuck River Winter Run

In 1876 Ranche provided the following description: “The Pill Chuck (or red water as it means in English)—the water is always clear and cold as any mountain spring. In salmon season it abounds with these delicious fish, also trout” (Ranche 1876). The Pilchuck River flows through the Northern Cascades and Puget Lowlands ecoregions. The basin is relatively low gradient and low altitude and has a rainfall-dominated flow pattern. There is sufficient habitat (366 km^2) to support a population as defined by the TRT. The IP-based estimate of capacity is 5,193 to 10,386 steelhead (Appendix D). The last escapement estimate (2011) was 552 steelhead. The Pilchuck River was historically reported to be a good producer of winter-run steelhead (WDFG 1932) and an egg collecting station was operated on the Pilchuck for a number of years in the early 1900s. The Pilchuck River is mentioned in numerous newspaper articles on steelhead fishing, including a notable catch of two steelhead, each weighing 10 kg (Seattle Daily Times 1918b). Although genetic samples from Pilchuck River steelhead were most similar to those from other Snohomish Basin samples, the Pilchuck River was an outlier from other Snohomish River and central Puget Sound samples (Phelps et al. 1997). More recent genetic sampling indicated that there were significant differences between steelhead from the Pilchuck River and other samples; however, the sample size was small (<25) and no other Snohomish River basin samples were available. In identifying steelhead from the Pilchuck River as a DIP, the TRT deviated from the findings of the gatekeeper model. In this case, the TRT considered additional information not included in the model. Pilchuck River steelhead have an earlier run timing than other Snohomish River basin winter-run steelhead, and there appears to a discontinuous spawning distribution between the lower Pilchuck River and mainstem Snohomish River.[22] WDF et al. (1993) reported that the Pilchuck River age structure may include a higher proportion of 3-year ocean fish than found in other Snohomish Basin populations.

14. North Fork Skykomish River Summer Run

Summer-run steelhead in the North Fork Skykomish River primarily spawn upstream of Bear Creek Falls (RKM 21) (WDFW 2002). There is limited spawning habitat above these falls, and accessible habitat may terminate at RKM 31 (Williams et al. 1975). Falls and cascades may provide some level of reproductive isolation from winter-run steelhead in the Skykomish River, but probably also limit population abundance. The basin size above the falls is relatively small, 381 km^2, but still large enough to sustain an estimated 663 to 1,325 fish, based on the IP estimate (Appendix D). Again, the IP estimate appears to underestimate the summer-run population’s possible abundance. Genetic analysis by Phelps et al. (1997) indicated that a North Fork Skykomish River sample, presumably summer-run fish, was very distinct from winter-run fish in the Snohomish Basin and from summer-run fish in the Tolt River; however, the fact that the north fork sample clustered with Columbia River steelhead may be indicative of some introgression or natural spawning by introduced Skamania Hatchery summer-run steelhead. Alternatively, the analysis by Phelps et al. (1997) relied on juvenile samples collected in 1993 and 1994 and may have contained both winter-run and summer-run fish, as well as the progeny of feral hatchery fish. More recent analysis by Kassler et al. (2008) suggested that North Fork Skykomish River summer-run steelhead are distinct from Skamania Hatchery summer-run steelhead, although some introgression appears to have occurred. The Kassler et al. (2008) study did not include samples from other Puget Sound basins, so no comparisons could be made among North Fork Skykomish River summer-run steelhead and other summer-run steelhead.

The North Fork Skykomish River is located in the North Cascades Ecoregion. Geologically, much of the North Fork Basin consists of volcanic and igneous rock formations. Hydrologically, the river exhibits more of a snow-dominated pattern than the rest of the Skykomish River.

15. Snoqualmie River Winter Run

This DIP includes steelhead in the mainstem Snoqualmie River and those in its tributaries, particularly the Tolt River, Raging River, and Tokul Creek. There are numerous historical references indicating that this basin sustained large runs of steelhead. The lower Snoqualmie River, downstream of the Tolt River, is rarely used by steelhead as a spawning area and provides some geographic separation from other Snohomish Basin areas. Similarly, a series of falls and cascades creates temporal migrational barriers on the North Fork Tolt and South Fork Tolt rivers. Genetic analysis by Phelps et al. (1997) indicated that Snoqualmie River winter-run steelhead generally clustered with other central Puget Sound steelhead, but were most closely associated with Green River winter-run rather than steelhead from the Tolt or Skykomish rivers. The presence of offspring from hatchery-origin fish may have confounded the analysis.

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[22] G. Pess, NWFSC, Seattle, WA. Field observation, October 2008.

The Snohomish River basin is one of the largest basins in Puget Sound that have yet to be comprehensively assessed using microsatellite DNA analysis. Kassler and Bell (2011) analyzed genetic variation in juvenile *O. mykiss* from the lower South Fork Tolt River and found that these fish most closely resembled unmarked winter-run steelhead from the Skagit River, rather than presumptive summer-run steelhead from the upper South Fork Tolt River.

The Snoqualmie River Winter-Run DIP includes nearly 1,100 km of stream in a relatively large basin, 1,534 km^2. The IP-based historical capacity is estimated in the range of 16,740 to 33,479 steelhead (Appendix D). In contrast, the most recent escapement estimate (2010) for the Snoqualmie River is 732 steelhead. Much of the accessible portion of the Snoqualmie River is contained within the Puget Lowlands Ecoregion, although stream flows are heavily influenced by flows from inaccessible headwater subbasins in the Cascades Ecoregion, primarily above Snoqualmie Falls. As a result, the Snoqualmie River exhibits a rain/snow hydrograph with relatively sustained summer flows.

16. Tolt River Summer Run

The majority of the TRT concluded that summer-run steelhead in the Tolt River basin constituted a DIP. Summer-run steelhead are found in the North Fork Tolt and South Fork Tolt rivers. Both forks are typical of summer-run steelhead habitat and contain a number of falls and cascades, although the North Fork Tolt is higher gradient with steeply sloped canyon walls (Williams et al. 1975). Genetically, Tolt River steelhead were similar to other Snohomish Basin steelhead samples (Phelps et al. 1997), but the samples were comprised of juveniles, and the progeny of naturally spawning native, hatchery, or native-by-hatchery hybrid winter-run or summer-run steelhead would not be phenotypically distinguished (the possibility of resident juvenile *O. mykiss* being included would further confuse the issue). Thus genetic relationships among Tolt River summer-run steelhead and other populations are not clear. Recent genetic analysis identifies the South Fork Tolt River fish as being distinct, but most closely associated with Skamania Hatchery–derived summer-run steelhead (Appendix B). This association may be related to introgression by Skamania-origin fish released into the Tolt River summer-run population; because of the distinct (Columbia River origin) genetic composition of Skamania Hatchery steelhead, even low levels of introgression would influence clustering outcomes. Principal component analysis suggested that the South Fork Tolt River collection is intermediate between Skamania Hatchery and populations from the western Cascades (no other Snohomish Basin collections were available). Spawn timing for Tolt River summer-run fish is from January to May, somewhat earlier than other summer-run steelhead populations in Puget Sound (Campbell et al. 2008). Additionally, there appear to be two peaks in spawning activity, one in February and the other in mid-April, the earlier peak possibly representing hatchery-origin fish (Campbell et al. 2008).

The Tolt River basin is similar to other Puget Sound basins supporting summer-run steelhead; it is relatively small, 255 km^2, and contains geologic formations (basalt shelves) that create falls which act as temporal migratory barriers. The IP-based estimate of capacity ranges from 321 to 641 steelhead (Appendix D), while the most recent (2010) escapement estimate was 116 steelhead. Much of the Tolt Basin contains glacial sediments, with the exception of harder volcanic formations in the canyons (Haring 2002). The basin straddles the Puget Lowlands and North Cascades ecoregions. Tolt River flows are generally rain-and-snow transitional.

Central and South Puget Sound MPG

Overview

The Central and South Puget Sound MPG includes populations in the Lake Washington and Cedar River basins, in the Green, Puyallup, and Nisqually rivers, and in South Puget Sound and East Kitsap Peninsula tributaries (Table 7). This MPG includes portions of the Cascades (higher elevation) and Puget Lowlands ecoregions. The TRT identified this MPG based on the geographic discreteness of central and south Puget Sound from the other MPGs. There is a geographic break of 50 to 100 km between the nearest populations in the three MPGs. Genetic information was quite extensive for steelhead in the major basins draining the Cascades, but there is little information on neighboring smaller, lowland rivers. Recent genetic analysis indicates that sampled populations in this MPG clustered together on a scale similar to those in the other MPGs. This MPG contains only winter-run steelhead populations, although there is some anecdotal information that summer-run steelhead populations may have existed in headwater areas of some rivers. Geologically, the headwater areas of this region are different from those in the Northern Cascades (South Salish Sea) MPG. Although the large river systems have their headwaters in higher elevation areas, most of these river basins also have extensive alluvial plains that are ecologically similar to smaller lowland steams. Geographically, this MPG is identical to a Chinook salmon MPG established by the Puget Sound Chinook Salmon TRT.

Table 7. DIPs within the Central and South Puget Sound MPG and their respective categorization by state and tribal agencies. WRIA = Water Resource Inventory Area and SASSI/SaSI = Salmon and Steelhead Stock Inventory/Salmonid Stock Inventory.

WRIA	1992 SASSI/2002 SaSI	TRT DIP
8	Lake Washington winter	17. Cedar River Winter Run 18. North Lake Washington and Lake Sammamish Winter Run
9	Green River summer[a] Green River winter	19. Green River Winter Run
10	Mainstem Puyallup R. winter	20. Puyallup/Carbon Rivers Winter Run
10	Carbon River winter	
10	White River winter	21. White River Winter Run
11	Nisqually River winter	22. Nisqually River Winter Run
13	Deschutes River winter[b]	23. South Puget Sound Tributaries Winter Run
13,14	Eld Inlet winter	
14	Totten Inlet winter	
14	Hammersley Inlet winter	
14,15	Case/Carr Inlet winter	
15	East Kitsap winter	24. East Kitsap Peninsula Tributaries Winter Run

[a] The existing Green River summer-run steelhead population is descended from nonnative summer-run steelhead (Skamania Hatchery origin) and any native historical population (anadromous component) was likely extirpated, but may persist above Howard Hanson Dam in a resident life history form.

[b] Historically, Tumwater Falls on the Deschutes River was impassable; therefore, the Deschutes River was not included as part of the Puget Sound DPS.

Areas of South Puget Sound and Kitsap Peninsula contain predominately smaller, rain-dominated, low-elevation tributaries. Little is known of the steelhead populations that existed or exist in these basins. The Nisqually River basin is the only large river system in the southern portion of this MPG with a historically documented steelhead run (or runs). The Deschutes River was historically impassable to anadromous fish at Tumwater Falls.

Proposed DIPs within the MPG

17. Cedar River Winter Run

This DIP includes the Cedar River basin and major tributaries to the southern portion of Lake Washington, primarily Kelsey Creek, May Creek, and Coal Creek. Dramatic changes in the Lake Washington/Green River basin in the early 1900s resulted in the Cedar River being artificially rerouted from the Green/Black River confluence into Lake Washington. The concurrent construction of the Lake Washington ship canal established a new outflow for the Cedar River watershed into Puget Sound rather than through the Black River. Although the current Cedar River/Lake Washington relationship does not reflect historical conditions, it is unlikely that there will be a return to a prior-to-ship-canal environment, thus the TRT evaluated the contemporary hydrological/biological unit. Winter-run steelhead in the Cedar River adapted to the changes in their migration routes, but in turn increased their level of isolation from steelhead in the Green River. The historical relationship between the Cedar River and Lake Washington has been influenced by alterations in the course of the Cedar River, which has alternatively drained to Lake Washington or the Black River for various lengths of time following the last glacial recession (≈10,000 years BP). Recent data may be influenced by the numerous attempts by state and county agencies to establish steelhead runs in the creeks draining into Lake Washington and Lake Sammamish. A substantial resident *O. mykiss* population exists in the Cedar River. The relationship between the existing resident population and the historical anadromous population remains unclear, and underscores the complexities of interactions between rainbow trout and steelhead. Marshall et al. (2006) provide a genetic analysis of contemporary Cedar River smolts, and nonanadromous *O. mykiss* downstream and upstream of Landsburg Dam, which until 2003 was impassable to anadromous fish.

Genetically, Cedar River steelhead are very similar to native Green River winter-run steelhead (Phelps et al. 1997, Marshall et al. 2004). Based on spawning ground surveys currently conducted in the Cedar river and previous fish ladder counts, the abundance of steelhead has been critically low for at least a decade, with some years when few or no fish were observed at the Hiram M. Chittenden (aka Ballard) Locks fish ladder (although fish can pass undetected through the locks). The IP estimate of abundance ranges from 5,949 to 11,899 steelhead (Appendix D). The Lake Washington basin is mostly contained in the Puget Lowlands Ecoregion, with the headwaters of the Cedar River and Issaquah Creek extending into the Cascades Ecoregion. The Cedar River has a rain-and-snow-transitional flow pattern, which is very distinct from most of the tributaries to Lake Washington, although flows have been modified by Seattle Public Utilities municipal water withdrawals. Earthquake and flood events constitute the most likely catastrophic risks.

18. North Lake Washington and Lake Sammamish Winter Run

This DIP includes tributaries draining the northern end of Lake Washington (approximately north of Lake Union and Evergreen Point) and the Sammamish River/Lake Sammamish basin. Dramatic changes in the Lake Washington/Green River basin in the early 1900s resulted in the lowering of Lake Washington and the dewatering of the Black River, the historical outlet of Lake Washington. The concurrent construction of the Lake Washington ship canal established a new outflow for the Lake Washington/Cedar River watershed into Puget Sound. Although the current Cedar River/Lake Washington relationship does not reflect historical conditions, it is unlikely that there will be a return to a prior-to-ship-canal environment; therefore, the TRT evaluated the existing hydrological/biological unit. Winter-run steelhead adapted to the changes in their migration routes, but in turn increased their level of isolation from steelhead in the Green River. It is not clear to what degree steelhead historically utilized tributaries other than the Cedar River in the Lake Washington basin. Evermann and Meek (1898) suggested that small numbers of steelhead migrated up the Sammamish River into Lake Sammamish, although they did not observe any in their sampling. Analysis of recent data may be influenced by the numerous attempts by state and county agencies to establish steelhead runs in the creeks draining into Lake Washington and Lake Sammamish. WDFW (2002) listed a number of tributaries (e.g., Swamp Creek, Bear Creek, Issaquah Creek) to Lake Washington and Lake Sammamish as supporting steelhead, although given the very low steelhead counts at the Chittenden Locks, it is unlikely that there is much of a current steelhead presence in these tributaries. Cutthroat trout appear to be the predominant resident species in many of the smaller Lake Washington tributaries. In recent years the abundance of cutthroat trout exhibiting an anadromous life history has dramatically declined, but it is not clear whether *O. mykiss* in Lake Washington tributaries have undergone a similar shift in life history expression. The relationship between the existing resident population and the historical anadromous population remains unclear, and underscore the complexities of interactions between rainbow trout and steelhead.

Steelhead passing through the Chittenden Locks fish ladder are destined for either of two DIPs (Lake Washington or the Cedar River). Based on fish ladder counts, the abundance of steelhead has been critically low for at least a decade, with several years when few or no fish were observed at the fish ladder (although fish can pass undetected through the locks). The Lake Washington basin is mostly contained in the Puget Lowlands Ecoregion, with the headwaters of Issaquah Creek extending into the Cascades Ecoregion. Tributaries to Lake Washington exhibit rain-dominated flow patterns (high fall and winter flows with low summer flows), which distinguishes them from the Cedar River, whose flow is more snowmelt dominated. The IP-estimated range is 5,268 to 10,536 steelhead (Appendix D). Earthquake and flood events constitute the most likely catastrophic risks.

19. Green River Winter Run

The TRT determined that a single winter-run DIP is present in the Green River basin. Winter-run steelhead were historically present in considerable numbers in the Green River, although until the early 1900s, the current population existed as part of a larger metapopulation that included steelhead in the Cedar, Black, and White rivers. Genetic analysis (Phelps et al. 1997, Marshall et al. 2006) confirms the close genetic affinity that these populations have with one another. WDFW (2002) reports that winter-run steelhead spawn from mid-March through early June. The presence of early returning, hatchery-origin, winter-run steelhead (Chambers Creek stock) may confound the identification of early spawning (February to March) native steelhead. Kerwin and Nelson (2000) suggest that a native summer-run steelhead existed in the Green River, likely passing upstream of the Headworks Diversion Dam (RKM 98.1). This dam blocked migratory access to the upper basin in 1913.

A minority of TRT members indicated that a native steelhead summer run likely occurred in the Green River in upstream basin areas. A 1907 newspaper article (Seattle Daily Times) describes how a man nearly drowned landing a 4.5 kg steelhead in the Green River above Auburn in July. The upper basin of the Green River is characteristic of summer-run steelhead habitat, with numerous cascades and falls. Major tributaries such as the North Fork Green River, May Creek, and Sunday Creek would have provided additional spawning and rearing habitat. A historical summer run in the Green River should not be confused with the existing Skamania Hatchery–origin, summer-run steelhead. Native *O. mykiss* currently exist above Howard Hanson Dam and it is unclear to what degree these fish represent some portion of the historical anadromous population. The majority of the TRT concluded that a summer-run life history should not be considered a diversity component of the Green River steelhead DIP.

Native-origin winter-run steelhead currently spawn throughout the Green River up to the Headworks Diversion Dam, although historically steelhead could have had access up to RKM 149. Efforts are underway to provide passage via a trap and haul program to the upper river.

The Green River basin covers 1,191 km^2, with Soos and Newaukum creeks constituting the major tributaries. The lower portion of the Green River is in the Puget Lowlands Ecoregion, while the upper basin is in the Cascades Ecoregion. The IP-estimated range for this DIP is 19,768 to 39,537 steelhead (Appendix D); however, the recent 5-year average has only been 770 fish. Much of the lower portion of this basin has been highly modified through channelization and land development. Flow gauge information indicates that the Green River is a rain-dominated system, although this may be due to the effects of Howard Hanson Dam (RKM 104), a flood control dam. Historically, it is more likely that the Green River was a rain-and-snow-transitional system.

20. Puyallup/Carbon Rivers Winter Run

This population includes winter-run steelhead in the Puyallup River and one of its major tributaries, the Carbon River. Steelhead in the Puyallup Basin's other major tributary, the White River, were designated in a separate DIP. The TRT determined that the mainstem Puyallup River below the confluence of the Puyallup and White rivers was more closely associated with the Carbon River than with the White River. Historically, the White River drained to the Green River rather than the Puyallup River and the Puyallup/Carbon was a separate basin. The Puyallup/Carbon River DIP covers 1,277 km^2 and, although recent escapements have averaged 410 steelhead (between 2007 and 2011), the IP-based capacity estimate is 14,716 to 29,432 steelhead (Appendix D). There is little life history information available on these stocks other than spawn timing, which extends from early March to mid-June (WDFW 2002). Phelps et al. (1997) reported that steelhead genetic samples from the Green, White, and Puyallup rivers clustered together, with Puyallup River steelhead being slightly more distinct. Van Doornik et al. (2007) found that samples from the White and Carbon rivers were genetically significantly different from each other, although genetic divergence (F_{ST}) between samples from the two locations was only 0.015, a relatively low degree of differentiation.

The Puyallup River drains the slopes of Mt. Rainer and exhibits a generally transitional hydrograph, although the Carbon River is not as glacially influenced (i.e., glacial flour) as the White River. Much of the basin is located in the Cascades Ecoregion. The dominance of Mt. Rainer in this basin greatly increases the risk of a catastrophic event, especially from volcanic, earthquake, and flood sources.

21. White River Winter Run

The TRT determined the White River steelhead population begins at the confluence of the White and Puyallup rivers. Differences in the hydrologies of the White and Puyallup/Carbon rivers were cited as distinguishing ecological factors between the two basins. It also appears that steelhead returning to the White River have a somewhat later migration and spawning time than those in the Carbon River, in part due to the colder stream temperatures in the White River. There is no evidence that native summer-run steelhead exist or existed in the White River basin. Phelps et al. (1997) reported that steelhead genetic samples from the Green, White, and Puyallup rivers clustered together, with Puyallup River steelhead being slightly more distinct. Genetic analysis found that samples from the White and Carbon rivers were statistically different from each other, with the genetic distance (Cavalli-Sforza and Edwards chord distance, a measure of genetic distinction) between samples of 0.23, above the 0.20 threshold set by the TRT. The course of the White River has changed considerably over time; in the 1800s, the White River drained to the Green River rather than the Puyallup River, which likely explains some of the underlying genetic differences among steelhead in the existing Puyallup Basin.

The basin is located in the Cascades Ecoregion and covers 1,287 km^2. Recent run size was 516 winter-run steelhead fish in 2011 (based on Mud Mountain Dam counts); however the IP estimate is considerably higher at 17,490 to 34,981 fish (Appendix D). The dominance of Mt. Rainer in this basin greatly increases the risk of a catastrophic event, especially from volcanic, earthquake, and flood sources.

22. Nisqually River Winter Run

Winter-run steelhead in the Nisqually River are presently restricted to the lower gradient reaches, with the exception of the Mashel River. The LaGrande and Alder dams (RKM 63.5 and 66.0, respectively) have eliminated access to higher gradient reaches in the mainstem Nisqually River and numerous tributaries that drain the southern slopes of Mt. Rainier. These areas may have also historically supported summer runs of steelhead, although the information on summer-run steelhead presence is less definitive. Historically a series of cascades near the present site of the La Grande and Alder dams may have been a seasonal barrier, but also could have been a complete barrier to fish passage. Based on topography and river morphology, it is possible that a summer run of steelhead historically existed in the upper basin of the Nisqually River. There is little documentation to reconstruct the characteristics of this population.

Presently, winter-run steelhead spawn from mid-March to early June (WDFW 2002), although as mentioned in earlier subsections, the harvest targeting early returning hatchery-origin fish may have truncated the early portion of the native-origin spawn timing range. Phelps et al. (1997) reported that Nisqually River steelhead did not cluster genetically with steelhead in nearby rivers such as the Puyallup or Green rivers, but instead clustered with steelhead in small rivers draining to the Strait of Juan de Fuca. More recently, microsatellite DNA analysis suggested that the Nisqually River steelhead are somewhat distinct from other central Puget Sound populations, including the steelhead originating from the adjacent Chambers Creek basin (Appendix B), and they are more closely associated with north and south Puget Sound steelhead than with steelhead from Hood Canal and the Olympic Peninsula. There are few data regarding relationships among steelhead in the Nisqually River and those in the smaller watersheds throughout southern Puget Sound south of the Tacoma Narrows.

Much of the accessible river habitat is located in the Puget Lowlands Ecoregion, while the upper basin (above the existing dams) is located in the Cascades Ecoregion. The basin covers 1,842 km^2, making it one of the largest DIPs in Puget Sound. Although much of the accessible habitat is in the lowlands, the highest identified potential spawning habitat is at 749 m. The IP estimate ranges from 15,330 to 30,660 steelhead (Appendix D). In the late 1980s, run size estimates for "wild" Nisqually River steelhead were in excess of 6,000 fish, although recent estimates (2007–2011) have averaged only 402 steelhead. Currently, the Nisqually River exhibits a rain-dominated flow pattern, which is most likely heavily influenced by the two dams present that moderate snowmelt and rain runoff from Mt. Rainier. This population is most likely at risk from catastrophic volcanic, earthquake, and flood events.

23. South Puget Sound Tributaries Winter Run

This population includes winter-run steelhead in rivers and streams that drain to Eld Inlet, Totten Inlet, Hammersley Inlet and Case/Carr Inlet—effectively all of the lowland tributaries entering South Puget Sound (south of the Tacoma Narrows). There is little definitive information on their abundance, life history characteristics, or genetic variation. Commercial harvest data from the early 1900s indicates that several thousand steelhead were caught in Thurston County (Cobb 1911), which effectively covers much of the South Puget Sound. Sport fishery catch records (punch cards) indicate that steelhead were caught in a number of independent tributaries to the South Puget Sound area: Coulter, Goldsborough, Kennedy, Mill, Percival, and Sherwood creeks. The average reported sport harvest was 85 steelhead through the 1950 and 1960s (WDG no date-b). Overall, while some streams have long histories of hatchery introductions, others would appear to represent natural production. The Chambers Creek basin historically supported winter steelhead, although presently steelhead are no longer thought to be present in the basin. There is little historical information available on the abundance of steelhead in the basin. Beginning in 1935, steelhead returning to Chambers Creek were used to establish a hatchery stock that was subsequently released throughout much of western Washington and the Lower Columbia River (Crawford 1979).

In total, this DIP covers 1,914 km^2. There is no one dominant stream in this DIP and demographic connectivity is likely through a "stepping stone" interaction process. The tributaries all lie within the Puget Lowlands Ecoregion and are generally rain-dominated short river systems, with the exception of the Deschutes River, which was not historically accessible to steelhead above Tumwater Falls (RKM 3.2). The only South Puget Sound sample available for genetic analysis (other than Chambers Creek Hatchery origin broodstocks) was from Minter

Creek, although this sample included only 13 fish. In general, the Minter Creek collection was closely related to, but still distinct from, the Chambers Creek Hatchery samples and the Nisqually River samples (Appendix B). The IP-estimated range is 9,854–19,709 steelhead (Appendix D). There are no recent estimates of escapement and no genetic samples are available for analysis. There has been no concerted effort to survey streams in this area and, until these are undertaken, this DIP is something of a placeholder for the one or more populations it may contain. StreamNet (no date) distribution maps do, however, indicate steelhead spawning in a number of tributaries throughout the DIP.

This DIP has been the subject of considerable discussion by the TRT. A plurality of TRT members proposed the DIP structure described above, and alternate variations included distinct Chamber's Creek, and Case/Carr Inlet DIPs in addition to a combined Eld, Totten, and Hammersley Inlet (southwest Puget Sound) DIP. Much of the uncertainty in DIP structure was related to historical abundances in the streams throughout the DIP and whether those numbers were sufficient to sustain one or more DIPs. Some TRT members were concerned that the DIP straddles the Nisqually River DIP; however, stark differences in hydrology and water quality between the lowland stream tributaries and the rain-and-snow-fed Nisqually River likely produced historical differences in life history traits between steelhead in the two DIPs and provided some level of isolation.

24. East Kitsap Peninsula Tributaries Winter Run

This population includes small independent tributaries on the east side of the Kitsap Peninsula. There is limited information, other than presence, for East Kitsap steelhead with the exception of Curley Creek, which had an average annual sport catch of 15.4 fish (range 0–68) from 1959 to 1970 (WDG no date-b). Numerous other smaller tributaries have been identified as containing spawning steelhead via redd surveys in the 1980s, although there are no specific estimates of production. Redds were observed in various streams from February to April (Zischke 2011). IP estimates for this DIP are relatively low, 1,557 to 3,115 steelhead, especially given the relatively large basin size of 678 km^2 (Appendix D). The streams in this DIP all display rain-dominated flow patterns. Currently, many streams have critically low summer flows, although this may be an artifact of land use patterns over the last century. There is no one dominant stream in this DIP and demographic connectivity is through a "stepping stone" interaction process. Marine biogeographic barriers at Point No Point and the Tacoma Narrows may influence the demographic isolation of this DIP.

Spawn timing extends from February to mid-June, with some slight differences between river systems (WDFW 2002). The entire population lies within the Puget Lowlands Ecoregion, with headwater areas that drain low hills. Although some TRT members were concerned that the estimated historical abundance within this DIP was relatively low for sustainability, a majority of the TRT considered that the geographic isolation of this area was complete enough to ensure demographic independence.

Hood Canal and Strait of Juan de Fuca MPG

Overview

This MPG includes steelhead from rivers draining into the Strait of Juan de Fuca, either directly or via Hood Canal (Table 8). Larger rivers share a common headwater source in the Olympic Mountain Range and are largely glacially influenced. With the exception of streams in Sequim and Discovery bays, most of these systems are dominated by relatively constrained, high-gradient reaches. In addition, there are numerous small tributaries and those draining lowland areas are rain dominated or rely on groundwater.

Winter-run steelhead currently are and historically were the predominant run in this MPG. There is some uncertainty regarding the historical or current presence of summer-run steelhead in a number of rivers, although if present, none of these summer-run populations (subpopulations) was thought to be very large. There is considerable genetic information available for many of the populations in this MPG. In general, genetic analysis indicates that the steelhead populations from this MPG cluster together, with three genetic subgroups: eastern Hood Canal, western Hood Canal, and the Strait of Juan de Fuca. The TRT was influenced in its designation by the geographic discreteness of this region. From the eastern-most edge (Foulweather Bluff) to the nearest population in either of the other MPGs, there was substantial separation (more than 50 km) between major spawning regions. The Puget Lowlands and

Table 8. DIPs within the Hood Canal and Strait of Juan de Fuca MPG and their respective categorization by state and tribal agencies. WRIA = Water Resource Inventory Area and SASSI/SaSI = Salmon and Steelhead Stock Inventory/Salmonid Stock Inventory.

WRIA	1992 SASSI/2002 SaSI	TRT DIP
15	Dewatto River winter	25. East Hood Canal Tributaries Winter Run
15	Tahuya River winter	26. South Hood Canal Tributaries Winter Run
15	Union River winter	
16	Skokomish River summer Skokomish River winter	27. Skokomish River Winter Run
16	Hamma Hamma River winter	28. West Hood Canal Tributaries Winter Run
16	Duckabush River summer Duckabush River winter	
16	Dosewallips River summer Dosewallips River winter	
17	Quilcene/Dabob Bays winter	
17	Discovery Bay winter	29. Sequim/Discovery Bays Tributaries Winter Run
17	Sequim Bay winter	
18	Dungeness River summer Dungeness River winter	30. Dungeness River Summer Run and Winter Run
18	Morse Creek winter	31. Strait of Juan de Fuca Tributaries Winter Run
18	Elwha River summer Elwha River winter	32. Elwha River Winter Run (summer)*

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

Coastal Range ecoregions dominate the low elevation areas of the MPG, while high elevation areas are located in the North Cascades Ecoregion. This MPG corresponds to the amalgamation of the Puget Sound Chinook Salmon TRT's Strait of Juan de Fuca and Hood Canal geographic regions (MPGs).

Proposed DIPs within the MPG

25. East Hood Canal Tributaries Winter Run

This DIP includes winter-run steelhead spawning in small independent tributaries on the west side of the Kitsap Peninsula (eastern shore of Hood Canal) from Foulweather Bluff to the Great Bend of southern Hood Canal. The primary tributaries in this DIP include: Big Beef Creek, Anderson Creek, and the Dewatto River. Stream surveys conducted in 1932 provide very general estimates of abundance; small runs of steelhead were identified in Anderson, Big Beef, and Stavis creeks, with larger runs in the Dewatto River (WDFG 1932). Maximum harvest (adjusted) in the Dewatto was 232 steelhead in 1952 and 242 in 1963 in Big Beef Creek (WDG no date-b). Historical and contemporary estimates of abundance for this DIP underscore the significant contribution of smaller lowland streams to overall DPS abundance. The IP estimate ranges from 1,270 to 2,540 steelhead (Appendix D).

The streams in this DIP share a Puget Sound lowland ecology with rain-dominated flow patterns. Elevations are relatively low throughout the DIP. Currently, many streams have high winter flows and critically low summer flows, although this may be an artifact of land development and water withdrawals.

There was considerable discussion regarding the composition of this DIP, with a minority considering the East Hood Canal and South Hood Canal DIPs as one unit. There were numerous other variations, each grouping four main components (northwest Kitsap Peninsula, Dewatto River, Tahuya River, and Union River) into different combinations. Although many of these components exhibited abundance and habitat characteristics above the population thresholds, the proximity of the streams to one another was thought to allow a higher rate of exchange than is generally considered for a demographically independent population. However, genetic data indicated that, despite their relative proximity, steelhead populations in the Dewatto, Tahuya, and Union rivers were genetically distinct, although these differences were smaller than those observed in comparisons between the East Hood Canal and West Hood Canal DIPs (Appendix B). Ongoing research on steelhead populations in Hood Canal should provide additional information on the rate of straying and further boundary adjustments may be necessary.

26. South Hood Canal Tributaries Winter Run

This DIP includes winter-run steelhead spawning in independent tributaries on the southwest side of the Kitsap Peninsula (eastern shore of Hood Canal) that drain into the "hook" of southern Hood Canal. The streams in this DIP include the Tahuya and Union rivers (the primary streams) and streams to the southern end of Hood Canal (including Alderbrook and Twanoh creeks). Stream surveys conducted in 1932 give very general estimates of abundance, with larger runs of steelhead in the Tahuya and Union rivers (WDFG 1932). Maximum harvest (adjusted) was 640 steelhead in 1952 (WDG no date-b). Overall, the IP estimate ranges from

2,985 to 5,970 fish (Appendix D), which is somewhat high for the basin size, 641 km^2, relative to adjacent DIPs.

The streams in this DIP share a Puget Sound lowland ecology with rain-dominated flow patterns. Elevations are relatively low throughout the DIP. Currently, many streams have critically low summer flows, although this may be an artifact of land use patterns over the last century. There is no one dominant stream in this DIP and demographic connectivity is likely maintained through a “stepping stone” process. Genetically, there was very good coverage of steelhead spawning aggregations throughout Hood Canal. In general, samples from within this DIP clustered together relative to samples from the Skokomish and west side of Hood Canal.

While there was considerable disagreement regarding the composition of this DIP, a plurality of members considered it as a single unit. There were numerous other variations, grouping four main components (northwest Kitsap Peninsula, Dewatto River, Tahuya River, and Union River) in different arrangements. Although many of these components exhibited abundance and habitat characteristics above the population thresholds, the proximity of the streams to one another (<20 km) was thought to allow a higher rate of exchange than is allowable for a DIP. Ongoing research on steelhead populations in Hood Canal should provide further information on the rate of straying and life history characteristics, and further adjustments may be necessary.

27. Skokomish River Winter Run

This population contains native winter-run steelhead in the north fork and south fork of the Skokomish River. Much of the North Fork Skokomish River is currently inaccessible beyond Cushman Dam No. 2 (RKM 27.8). There has been considerable debate as to whether winter-run steelhead had access beyond the series of falls in the lower North Fork Skokomish River; steelhead may have had access at least to the Staircase Rapids, RKM 48.1 (Williams et al. 1975). In all, the Skokomish River basin occupies 635 km^2. Currently, winter-run steelhead spawn in the mainstem Skokomish, the South Fork Skokomish, and the lower North Fork Skokomish rivers from mid-February to mid-June (WDFW 2002). Genetically, Skokomish River steelhead are distinct from other populations in the region, but most similar to other West Hood Canal steelhead populations (Phelps et al. 1997, Van Doornik and Berejikian 2015).

A summer run of steelhead was identified in SaSI (WDFW 2002), but there is no information on this presumptive population. WDFW (2002) reported that summer-run steelhead spawn in the upper reaches of the South Fork Skokomish River from February to April. Anadromous access may extend as far as Steel Creek (RKM 36.8) and the upper 10 km is characterized by very high-gradient reaches that would be suitable for summer-run steelhead (Williams et al. 1975, Correa 2003). No genetic analysis has been specifically done for Skokomish River summer-run steelhead, although juvenile samples collected in the river’s winter-run section (n = 23) may include summer-run steelhead. Fish classified as summer run based on harvest after May 30 were caught in the sport fishery from 2000 to 2004, with 50 fish recorded in 2003 (WDFW et al. 2004). Based on available information, the TRT was unable to establish whether a self-sustaining run was historically or is currently present. Furthermore, additional monitoring would be needed to assess any differences among winter-run steelhead in the North Fork Skokomish and South Fork Skokomish rivers.

The Skokomish River exhibits a rain-dominated flow regime, although this may be because the majority of the flow from the more mountainous north fork is diverted for hydropower and discharges directly into Hood Canal. The entire basin covers approximately 628 km^2, with the north fork and south fork basins roughly equal size. The habitat-based IP estimate for this basin is 10,030 to 20,060 steelhead (Appendix D). The Skokomish River basin lies in the Coast Range and Puget Lowlands ecoregions. Earthquake, landslide, and flood events pose a relatively high catastrophic risk to the Skokomish River basin.

28. West Hood Canal Tributaries Winter Run

This population combines winter-run steelhead from four former SaSI stocks (WDFW 2002): Hamma Hamma, Duckabush, and Dosewallips rivers, and QuilceneRiver/Dabob Bay. WDFW (2002) identified these as distinct stocks based on their geographic separation. However, resident, parr, and smolt *O. mykiss* from the Duckabush and Dosewallips rivers clustered together genetically relative to steelhead populations on the east side of Hood Canal (Van Doornik and Berejikian 2015). In an initial genetic analysis, Hamma Hamma River *O. mykiss* samples were genetic outliers relative to samples from other rivers in this DIP, although that appears to be related to the small total spawning escapement (less than 20 fish in some recent years) and a potentially biased sample in one year. In any event, a Hamma Hamma River population would not be large enough to be sustainable (and thus not independent). Spawn timing for winter-run steelhead in these rivers is similar, occurring from mid-February to mid-June. This population lies mostly in the Coast Range Ecoregion, with the exception of headwater areas that lie in the North Cascades Ecoregion and parts of Dabob Bay that lie in the Puget Lowlands Ecoregion. Much of the area is in the rain shadow of the Olympic Mountain Range. River flows in the Dosewallips River are strongly influenced by glacial runoff, while the Duckabush, Hamma Hamma and Quilcene rivers exhibit more transitional rain-and-snow-dominated flow patterns. Although SaSI identified summer-run steelhead in the Dosewallips and Duckabush rivers, the TRT did not find any evidence to establish that native summer-run steelhead existed. SaSI designations may have been based on run timing indicated by punch card catch records. Summer-run steelhead harvest (based on fish caught after May 30) from 2000 to 2004 has been at or near zero in the Duckabush, Dosewallips, and Quilcene rivers (WDFW et al. 2004). It was thought that the glacially influenced (e.g., colder) rivers in this DIP may have a much later winter-run timing, resulting in fish being misclassified as summer run.

Total watershed area is 1,423 km^2, although the topography of the area creates impassable barrier falls on a number of the streams. The IP estimate in this DIP ranges from 3,608 to 7,217 fish (Appendix D). Stream surveys conducted in 1932 identified a “large” run of steelhead on the Dosewallips River, with steelhead runs reported in almost every stream (WDFG 1932). Punch card records indicate a maximum (adjusted) catch of 982 fish in 1952, although this estimate does include some hatchery returns. In recent years, stream surveys have been intermittent on many of the rivers. Overall, total escapement to this DIP likely consists of a few hundred fish, with the most recent (2011) estimate of 227 adults.[23]

There was considerable discussion among the TRT members regarding this DIP; based on basin size and IP estimates, some members reasoned that this DIP should be split into

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[23] See footnote 19.

multiple DIPs. Alternatively, because the two largest steelhead rivers (Dosewallips and Duckabush) in this area are so geographically close to one another (12 km), and are highly similar environmentally to one another, they should be considered demographically linked. The other rivers along the western shore of the Hood Canal were too small to exist as DIPs, so they were included in a single DIP. These considerations, in addition to the general clustering of steelhead genetic samples from western Hood Canal streams, resulted in a majority of the TRT concluding that there was a single west Hood Canal population.

29. Sequim/Discovery Bays Tributaries Winter Run

This population combines two former SaSI stocks, Sequim Bay and Discovery Bay, and includes winter-run steelhead that occupy streams in the Quimper Peninsula (Port Townsend) that were not included in the WDFW (2002) stock list. The entire population is located within the Puget Lowlands Ecoregion. Stream flows are rain dominated with many streams lacking surface flow during summer. Although the 802 km^2 basin size for this DIP is well above the minimum, the majority of the area contains relatively small, independent streams. Steelhead in one tributary, Snow Creek, have been intensively monitored since 1976; they provided most of the abundance and life history data available for this DIP and provided the TRT with an understanding of the potential productivity of small, independent steelhead populations. Steelhead in this DIP spawn from early-February to mid-May, with the majority of smolts emigrating as 2-year-olds. Combined recorded sport catch for these tributaries averaged more than 60 steelhead annually during the 1950s and 1960s, with an adjusted peak catch of 200 steelhead in 1962 (WDG no date-b). The IP estimate is 512 to 1,024 steelhead (Appendix D). Genetically, Snow Creek steelhead are distinct from neighboring Dungeness River and Hood Canal steelhead. Many streams in the western portion of this DIP are relatively near the Dungeness River. However, substantial differences in basin character and river hydrology (glacial vs. rain driven) were thought to produce differences in run timing and thus provide an isolating mechanism to minimize interpopulation migration.

30. Dungeness River Summer Run and Winter Run

This population includes steelhead spawning in the mainstem Dungeness and Greywolf rivers. Winter-run steelhead in the Dungeness River spawn from mid-March to early June (WDFW 2002). Haring (1999) and Goin[24] indicate that summer-run steelhead were present in the early 1940s, prior to the introduction of Skamania Hatchery steelhead. It is unclear whether native summer-run steelhead are still present in the basin. The Dungeness River is accessible to RKM 30, where a waterfall above Gold Creek prevents passage. Greywolf River, the major tributary to the Dungeness River, is accessible to RKM 15.5, above where the three forks of the Greywolf River meet. River conditions in the glacially influenced Dungeness River were thought to be different enough from the rain-driven, lower elevation streams in the adjacent DIPs to provide some level of demographic isolation between the DIPs.

The Dungeness River basin area is approximately 560 km^2, with headwaters in the Olympic Mountains. The upper basin is glacially influenced and the flow regime in the Dungeness River is snowmelt dominated. Geologically, the basin consists of volcanic bedrock

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[24] See footnote 9.

and unstable glacial deposits that produce a high sediment load (Haring 1999). Genetically, the Dungeness River steelhead most closely cluster with other collections from the Strait of Juan de Fuca, Snow Creek (Sequim/Discovery Bays Tributaries DIP) and the Elwha River, but are also part of a large clusters of populations belonging to rivers draining the Olympic Peninsula (Appendix B). Each year a few hundred steelhead spawn in the Dungeness River, although high flows, particularly during the spring snowmelt, limits the accuracy of redd surveys. The last escapement estimate for the year 2000/2001 was 183 steelhead based on index area counts. Punch card returns from sport harvest (adjusted) averaged 348 steelhead from 1946 to 1953 prior to the introduction of large numbers of hatchery fish. The IP estimate is 2,465 to 4,930 steelhead (Appendix D).

A majority of the TRT agreed that a winter-run population existed as a DIP in the Dungeness River basin. A minority of the TRT concluded that summer-run steelhead likely existed in the upper accessible reaches of the mainstem Dungeness and Greywolf rivers. The relatively late timing of winter steelhead in the Dungeness River may have resulted in identifying some winter-run steelhead as summer-run fish, as likely occurred in the Dosewallips and Duckabush rivers. Historically, Native Americans harvested steelhead using fish traps or lines (Gunther 1927) from December through February, although in-river conditions may not have been amenable for harvesting summer-run fish. Haring (1999) indicated that summer-run fish were present, although conditions in the river limited direct observation. The TRT strongly encourages further monitoring to establish whether native summer-run fish are still present and, if so, determine whether they are part of a combined summer/winter DIP or represent an independent population.

31. Strait of Juan de Fuca Tributaries Winter Run

This population consists of steelhead spawning in independent tributaries to the Strait of Juan de Fuca between the Dungeness and Elwha rivers, including: Ennis, White, Morse, Siebert, and McDonald creeks. Each of the tributaries is relatively small and collectively the creeks contain a 410 km^2 watershed. Sports catch (punch card) data for Morse, Siebert, and McDonald creeks indicate that well over 100 wild fish were caught annually through the 1950s and 1960s, with a peak catch of 258 in 1958 (WDG no date-b). The IP estimate is 728 to 1,456 fish (Appendix D), with the most recent (2010) abundance estimate, 245 steelhead, based on index counts in just Morse and McDonald creeks. The headwaters of these creeks extend into the Olympic Mountains and flows can be considerable, especially following lowland rain events (Haring 1999). Summer-run steelhead have been reported caught in Morse Creek, although it is unclear whether these fish were native or strays from the Elwha or Dungeness rivers (Haring 1999). Further investigation is warranted to confirm the presence and identify the source of summer-run fish in Morse Creek (as well as in the Dungeness River and Elwha River DIPs).

The TRT concluded that it was unlikely that any one of the streams within this DIP was large enough to persist as a DIP. In any case, their proximity to one another in addition to their environmental similarity limited the likelihood of their demographic independence. Distances between streams in this DIP and the Dungeness and Elwha rivers to the east and west, respectively, were at their closest less than 20 km. The TRT concluded that while the distances between the Elwha and Dungeness rivers and the smaller independent tributaries were somewhat small for a DIP, ecological differences between the smaller creeks and larger river systems would reduce the likelihood of interaction between these DIPs, while not limiting demographic connectivity between Ennis, McDonald, Morse, Siebert, and White creeks.

32. Elwha River Winter Run

Winter-run steelhead were historically present in the Elwha River basin, although little is known of their life history diversity prior to the construction of the two Elwha River dams in the early 1900s. Currently, there are two known populations of winter-run steelhead in Elwha River, one presumptive native, late-winter run and one early winter, hatchery-origin run (Chambers Creek origin). Natural spawning occurs throughout the main stem and tributaries below the (former, now removed) Elwha Dam (RKM 7.9), with early returning steelhead spawning prior to mid-March and late returning steelhead spawning from April to June. Genetic analysis indicated that the early timed portion of the steelhead run is largely derived from Chambers Creek Hatchery stock, while the later returning component is significantly different from the early, hatchery-origin, component, but also different from some collections of resident *O. mykiss* in the upper Elwha River (Winans et al. 2008). However, Phelps et al. (2001) suggested that some residualized populations (above the dams) of *O. mykiss* were similar to anadromous steelhead below the dam. It is unclear whether existing resident *O. mykiss* populations contain an anadromous legacy. If so, it may take several years following the removal of the (former, now removed) Elwha and Glines Canyon dams for these populations to reestablish themselves as anadromous and reach some equilibrium with steelhead that are currently spawning below the Elwha Dam site. Additionally, it is unclear whether summer-run steelhead were historically present and still persist, either as anadromous fish below the dams or above the dams as resident *O. mykiss*.

The Elwha River basin is 832 km^2 with its headwaters in the Olympic Mountains. Much of the upper basin is in the North Cascades Ecoregion with the lower reaches in the Puget Lowlands Ecoregion. The Elwha River exhibits a rain-and-snow-transitional flow pattern. Historically, the mainstem Elwha River was accessible to RKM 62.8, with additional habitat in tributaries in the lower and middle reaches. The IP estimate for steelhead abundance in the Elwha River is 7,116–14,231 (Appendix D), based on unrestricted access to the basin (without the dams). Estimates of native-origin spawner escapement have not been done on a comprehensive basis in recent years. For the last complete year, 1996/1997, escapement was only 153 fish (anadromous access was limited to the lower river).

Historically, a summer run may have been present in the Elwha River; however, it is possible that the run was extirpated or residualized when the Elwha and Glines Canyon dams were constructed in the early 1900s at RKM 7.9 and RKM 21.6, respectively. Although summer-run steelhead have been observed in the pools below the Elwha Dam in recent years, it is most probable that these fish are the product of nonnative, Skamania Hatchery, summer-run steelhead releases into the Elwha River (see Appendix G for summer-run releases). Summer temperatures in the lower Elwha River, in addition to frequent outbreaks of *Dermocystidium*, greatly reduce survival of returning adult salmonids. Thus it is likely that the native summer steelhead run was (or runs were) extirpated follow the construction of the Elwha River dams. Alternatively, summer or winter steelhead runs may have residualized in tributaries to the Elwha River above the dams. The historical distribution of summer-run steelhead in the Elwha River is unknown, but it is possible that rapids and cascades in canyon areas may have provided an isolating mechanism for migrating winter-run and summer-run steelhead (especially during high spring flows). Alternatively, the two run times could have occupied similar spawning habitat with temporal isolation in spawning. Although there was general agreement regarding the presence of winter-run steelhead in the Elwha River DIP, there was no consensus regarding the historical existence of summer-run steelhead in the Elwha River. At present, the majority conclusion was that summer-run steelhead were absent. Further study is required to establish whether there is any legacy of a native summer run above or below the recently removed dams.

Puget Sound Steelhead DPS Population Considerations

The TRT conclusions presented are based on available information. Responses to reviewer comments are in Appendix M. It is likely that in the future (during the course of subsequent monitoring efforts, historical document review, etc.) new information will become available that may support the need for reconsidering the DIPs identified in this document, including the addition, deletion, or redelineation of DIPs. Where possible, we have identified areas where there was uncertainty in the designation of DIPs to stimulate further research and assessment. As with any biological unit, DIPs represent part of a continuum of population structure and there is some potential for between-TRT-member differences in the criteria for DIPs and MPGs. For example, the process of identifying components for truth membership functions in the decision support system was very informative in identifying variation in DIP thresholds among the individual members within the TRT. We have utilized both the conclusions of the TRT members and the results of the gatekeeper model to identify the historical DIPs and MPGs within the Puget Sound Steelhead DPS. In developing our reconstruction of the structure of the historical DIPs of steelhead in Puget Sound, we are providing a general template for the restoration of a sustainable DPS. Our descriptions of the individual populations and major population groups are intended to convey a sense of the diversity and dispersal of demographic units and their environment. It is the restoration of these essential elements that will ensure the sustainability of this DPS into the foreseeable future. A companionate technical memorandum (Hard et al. in press) focuses on viability criteria for this DPS.

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Appendix A: Comparison of Populations and Management Units

Table A-1. Steelhead (*Oncorhynchus mykiss*) populations listed under the 1930 survey were identified as being medium to large abundance (WDFG 1932). Genetic analysis indicates populations in genetic diversity units (GDUs) (Phelps et al. 1997). State and tribal comanagers identified populations in their 1992 SASSI (WDF et al. 1993) and 2002 SaSI (WDFW 2002) steelhead inventories.

1930 survey	Genetic analysis 1997	1992 SASSI / 2002 SaSI	WRIA[a]
Dakota Creek		Dakota Creek winter	1
Nooksack River			1
North Fork	North Puget Sound GDU 8	N. F. Nooksack River winter	1
Middle Fork	North Puget Sound GDU 8	M. F. Nooksack River winter	1
South Fork		S. F. Nooksack River summer S. F. Nooksack River winter	1
		Samish River winter	3
Skagit River	North Puget Sound GDU 8	Mainstem Skagit River winter	4
Finney Creek	North Puget Sound GDU 8	Finney Creek summer	4
Grandy Creek			4
Bacon Creek			4
Baker River			4
Cascade River	North Puget Sound GDU 8	Cascade River summer Cascade River winter	4
Sauk River	North Puget Sound GDU 8	Sauk River summer Sauk River winter	4
Dan Creek			4
Stillaguamish River		Stillaguamish River winter	5
N. F. Stillaguamish	North Puget Sound GDU 8		5
Pilchuck River	North Puget Sound GDU 8		5
Deer Creek	North Puget Sound GDU 8	Deer Creek summer	5
Boulder Creek			5
French Creek			5
Squire Creek			5
S. F. Stillaguamish		S. F. Stillaguamish R. summer[b]	5
Jim Creek			5
Canyon Creek		Canyon Creek summer	5
Snohomish River		Snohomish River winter	7
Pilchuck River	South Puget Sound GDU 2	Pilchuck River winter	7
Skykomish River	South Puget Sound GDU 2		7
Woods Creek			7
Elwell Creek			7
Wallace River			7
S. F. Skykomish R.		S. F. Skykomish River summer[c]	7

Table A-1 continued. Steelhead populations listed under the 1930 survey were identified as being medium to large abundance (WDFG 1932). Genetic analysis indicates populations in genetic diversity units (GDUs) (Phelps et al. 1997). State and tribal comanagers identified populations in their 1992 SASSI (WDF et al. 1993) and 2002 SaSI (WDFW 2002) steelhead inventories.

1930 survey	Genetic analysis 1997	1992 SASSI / 2002 SaSI	WRIA[a]
N. F. Skykomish R.	South Puget Sound GDU 2	N. F. Skykomish River summer	7
Snoqualmie River		Snoqualmie River winter	7
Tolt River	South Puget Sound GDU 2	Tolt River summer	7
Raging River	South Puget Sound GDU 2		7
Cedar River[d]	South Puget Sound GDU 2	Lake Washington winter	8
Duwamish River			9
Green River	South Puget Sound GDU 2	Green River summer[e] Green River winter	9
Soos Creek			9
Puyallup River	South Puget Sound GDU 2	Mainstem Puyallup River winter	10
Carbon River		Carbon River winter	10
Voight Creek			10
S. Prairie Creek			10
White River	South Puget Sound GDU 2	White River winter	10
Nisqually River	South Puget Sound GDU 2	Nisqually River winter	11
Mashel River			11
Not Surveyed		Deschutes River winter	13
Not Surveyed		Eld Inlet winter	13,14
Not Surveyed		Totten Inlet winter	14
Not Surveyed		Hammersley Inlet winter	14
Not Surveyed		Case/Carr Inlet winter	14,15
Not Surveyed		East Kitsap winter	15
Not Surveyed		Dewatto River winter	15
Not Surveyed	South Puget Sound GDU 2	Tahuya River winter	15
Not Surveyed		Union River winter	15
Not Surveyed	South Puget Sound GDU 2	Skokomish River summer Skokomish River winter	16
Not Surveyed	South Puget Sound GDU 2	Hamma Hamma River winter	16
Not Surveyed		Duckabush River summer Duckabush River winter	16
Not Surveyed	South Puget Sound GDU 2	Dosewallips River summer Dosewallips River winter	16
Not Surveyed		Quilcene/Dabob bays winter	17
Not Surveyed	South Puget Sound GDU 2	Discovery Bay winter	17
Not Surveyed		Sequim Bay winter	17
Not Surveyed	South Puget Sound GDU 2	Dungeness River summer Dungeness River winter	18
Not Surveyed	South Puget Sound GDU 2	Morse Creek winter	18
Not Surveyed	North Coast GDU 9	Elwha River summer Elwha River winter	18

[a] WRIA = Water Resource Inventory Area.

[b] South Fork Stillaguamish River steelhead were considered nonnative.

[c] South Fork Skykomish River steelhead were considered nonnative.

[d] Cedar River steelhead were considered “scarce.”

[e] Green River summer-run steelhead were considered nonnative (the historical population was extirpated).

Appendix B: Genetic Analysis of Steelhead from Puget Sound

A number of studies have analyzed genetic variation among steelhead (*Oncorhynchus mykiss*) populations in Puget Sound; however, the majority of these have focused on specific river basins or geographic areas within the Puget Sound distinct population segment (DPS). The last comprehensive genetic assessment of Puget Sound steelhead was undertaken by Phelps et al. (1997). This appendix reports on microsatellite DNA variation for 21 of the 32 proposed demographically independent populations (DIPs) within the Puget Sound Steelhead DPS (Table B-1).

Samples representing all three major population groups (MPGs) and the majority of DIPs within those MPGs were obtained on an as available basis (Table B-1). Data were analyzed for 13 microsatellite DNA loci for 4,563 fish from 39 collections available from published and unpublished sources (Table B-2). Collections generally consisted of more than 48 fish. The Minter Creek collection was the smallest (n = 13), but was retained in the analysis as a distinct sample because it was thought to be representative of South Puget Sound steelhead and distinct from the Nisqually River collection. The majority of the samples were acquired subsequent to the study by Phelps et al. (1997). Laboratory conditions are given in Winans et al. (2008).

We evaluated Hardy-Weinberg equilibrium with FSTAT version 2.9.3.[25] The significance of F_{IS} estimates was determined with permutation over alleles by 468,000 randomizations. Differences among collections were illustrated in a dendrogram using the Cavalli-Sforza and Edwards chord metric (Cavalli-Sforza and Edwards 1967) calculated with Populations version 1.2.30.[26] Precision of branching patterns was evaluated by bootstrapping over loci 1,000 times. The tree was printed with TreeView.[27] An additional independent assessment of among-collection variability was done using a factorial correspondence analysis (FCA) with GENETIX 4.05.2.[28] It was believed that some collections (e.g., Snow Creek and Samish River) contained fish with Chambers Creek ancestry. To identify these fish and eliminate them from the subsequent analyses, we implemented Structure 2.2[29] (burn-in of 50,000 iterations and a run of 500,000 iterations) (Pritchard et al. 2000), using the selected collections and two Chambers Creek stocks—Soos Creek Hatchery (adults, 2008) and Lower Elwha Klallam Hatchery (juveniles, 2005 and 2006). Fish assigned a Chambers Creek contribution to genetic composition of more than 50% were removed from further analyses.

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[25] A software program developed by Jerome Goudet to estimate and test gene diversities and fixation indices, online at http://www2.unil.ch/popgen/softwares/fstat.htm.

[26] A population genetics software program (individuals or population distance, phylogenetic trees) developed by Olivier Langella, online at http://bioinformatics.org/~tryphon/populations.

[27] A tree drawing software program, online at http://rana.lbl.gov/EisenSoftware.htm and http://www.treeview.net/tv /download.asp.

[28] Population genetics software, online at http://kimura.univ-montp2.fr/genetix.

[29] The program implements a model-based clustering method for inferring population structure, online at http://pritchardlab.stanford.edu/software/structure2_2.html.

Of the 4,363 samples analyzed, five fish from Snow Creek and five from the Samish River were identified with substantial Chambers Creek ancestry. A total of 4,353 fish were used in the remaining analyses. Significant departures from Hardy-Weinberg equilibrium were detected at Duckabush, Skokomish, and Green River samples where F_{IS} values were significantly positive in each case (indicating heterozygote deficiency, Table B-2). Heterozygote deficiency (Wahlund effect) may indicate a pooling of dissimilar gene pools.

In the 39-collection dendrogram (Cavalli-Sforza and Edwards chord metric and neighbor joining clustering, Figure B-1), seven groups are apparent:

- Samish and Nooksack River collections,
- Skagit River and tributaries collections (six Skagit River samples and Stillaguamish, Sauk, and Suiattle rivers),
- East Hood Canal collections (Big Beef Creek and Dewatto River) that are joined by Tahuya River,
- Four Chambers Creek–based hatcheries that are joined by Minter Creek,
- Three Olympic Peninsula collections (Elwha and Dungeness rivers and Snow Creek) that join to the Skokomish River and three West Hood Canal collections (Hamma Hamma, Duckabush, and Dosewallips rivers),
- Five collections from South Puget Sound and Central Puget Sound, and
- Skamania stock joined with South Fork Tolt River and loosely with Deer Creek.

In a Cavalli-Sforza and Edwards chord tree with unweighted pair group method with arithmetic mean clustering (Table B-3 and Figure B-2), several collections or collection groups are distinctive: Minter, Deer, East Hood Canal, Tahuya, Nooksack, and Skamania-Tolt. Two broad groups are seen, the Chambers Creek collections, Samish, West Hood Canal, and Olympic Peninsula populations, and the South/Central Puget Sound, Stillaguamish, and Skagit collections. The Puyallup River sample is distinctive.

The first three FCA components explained 30.6% of the total variance in the 39-collection data set. Along the first axis, the East Hood Canal and West Hood Canal, Chambers Creek stocks, and Olympic Peninsula collections (including single locales Tahuya River and Minter Creek) were broadly different from Nooksack/Samish, Skagit, and Stillaguamish rivers, in addition to summer-run fish (Skamania Hatchery, South Fork Tolt River, and Deer Creek), and South/Central Puget Sound collections (except Minter Creek, Figure B-3). Along FCA1 and FCA2, collections grouped by DIP. Noticeably similar are Skagit and Nooksack/Samish rivers, and particularly distinctive are Tahuya and Skokomish rivers. Along FCA3, the Skagit collections are more different from Nooksack/Samish River collections, as are the summer-run fish compared to their variability along FCA1 and FCA2. Nisqually is distinctive from the other South/Central Puget Sound collections along FCA3 (Figure B-4). Collections from Big Beef Creek and Dewatto River are highly divergent along FCA3.

In general, there was a close correspondence between geographic proximity and genetic similarity. From a Puget Sound–wide prospective, it was surprising that collections from Hood Canal accounted for considerable between-collection variability (Figure B-5 and Figure B-6). Of the summer-run samples, FCA results suggested a closer affinity of Deer Creek steelhead with winter-run steelhead in the Stillaguamish River basin. In contrast, the close affinity of South Fork Tolt River summer-run steelhead to Skamania Hatchery summer-run steelhead is likely the result of the presence of offspring from hatchery strays or introgression between native and introduced fish in the Tolt River basin. The Skamania Hatchery steelhead that originated from the Columbia River are genetically distinctive; it is safe to say that populations in the Puget Sound that are genetically similar have probably experienced introgression with the nonnative summer-run fish. In contrast, because Chambers Creek Hatchery winter-run steelhead were developed from native South Puget Sound fish, there is likely some level of statistically inferred Chambers Creek Hatchery introgression that is simply the result of shared alleles between Puget Sound–origin populations.

Table B-1. Geographic distribution of steelhead genetic samples from the Puget Sound Steelhead DPS analyzed for DNA microsatellite variation at 13 loci. Additional sample information can be found in subsequent tables.

TRT MPG	TRT DIP	Genetics sample(s)

		25 sample no.	**39 sample no.**
North Cascades	Drayton Harbor Tributaries Winter Run	—	—
	Nooksack River Winter Run	1, 2 (3, 4?)	1, 2, 5 (3, 4?)
	South Fork Nooksack River Summer Run	(3, 4?)	(3, 4?)
	Samish River and Bellingham Bay Tributaries Winter Run	5	6,7
	Skagit River Summer Run and Winter Run	6	8, 9, 10, 13, 15, 16
	Nookachamps Creek Winter Run	—	—
	Baker River Summer Run and Winter Run	—	—
	Sauk River Summer Run and Winter Run	7	11, 12
	Stillaguamish River Winter Run	8	18
	Deer Creek Summer Run	9	17
	Canyon Creek Summer Run	—	—
	Snohomish/Skykomish Rivers Winter Run	—	—
	Pilchuck River Winter Run	—	—
	North Fork Skykomish River Summer Run	—	—
	Snoqualmie River Winter Run	—	—
	Tolt River Summer Run	10	21
Central and South Puget Sound	Cedar River Winter Run	11	22
	North Lake Washington and Lake Sammamish Winter Run	—	—
	Green River Winter Run	12	24
	Puyallup/Carbon Rivers Winter Run	14	26
	White River Winter Run	12	25
	Nisqually River Winter Run	15	27
	South Puget Sound Tributaries Winter Run	16	28
	East Kitsap Peninsula Tributaries Winter Run	—	—
Olympic Peninsula	East Hood Canal Tributaries Winter Run	17	29, 30
	South Hood Canal Tributaries Winter Run	18	31
	Skokomish River Winter Run	19	32
	West Hood Canal Tributaries Winter Run	20	33, 34, 35
	Sequim/Discovery Bays Tributaries Winter Run	21	36
	Dungeness River Summer Run and Winter Run	22	37
	Strait of Juan de Fuca Tributaries Winter Run	—	—
	Elwha River Winter Run	23	39

Table B-2. Information for collections of steelhead used in the genetic analyses. A significant positive value for F_{IS} within samples indicates a significant departure from Hardy-Weinberg. Based on 468,000 randomizations, the adjusted nominal level of *P* (5%) for F_{IS} is 0.00011.

Pop	Sample	Source	Fish sampled	N	F_{IS}	***P*** **values**
1	Nooksack R. 1	NMFS/Nooksack Tribe	Mix, 2008–2009	25	0.086	0.0020
2	Nooksack R. 2	NMFS	Not available	37	0.045	0.0210
3	S.F. Nooksack A	WDFW unpublished	Adults, 2007–2010	38	0.040	0.0310
4	S.F. Nooksack J	WDFW unpublished	Juveniles, 2009	26	0.018	0.2340
5	Main Nooksack	WDFW unpublished	Juveniles, 2009	47	0.020	0.1510
6	Samish R. 2009	WDFW unpublished	Adults, 2009	37	0.025	0.1410
7	Samish R. 2008	WDFW unpublished	Adults, 2008	41	0.000	0.4800
8	Skagit/Manser	WDFW unpublished	Parr, 2007	235	0.019	0.0090
9	Upper Skagit R.	WDFW unpublished	Adults, 2008–2011	81	0.014	0.1590
10	Cascade River	WDFW unpublished	Juveniles, 2009–10	98	0.006	0.3270
11	Suiattle River	WDFW unpublished	Adults, 2010–2011	51	0.010	0.2790
12	Sauk River	WDFW unpublished	Adults, 2008–2011	81	0.021	0.0720
13	Finney Creek	WDFW unpublished	Juveniles, 2009–10	105	0.000	0.5110
14	Marblemount H.	WDFW unpublished	Adults, 2008–2010	151	0.020	0.0240
15	Mid Skagit R.	WDFW unpublished	Adults, 2009–2010	42	0.035	0.0340
16	Goodell Creek	WDFW unpublished	Juveniles, 2010–11	88	0.008	0.2800
17	Deer Creek	WDFW unpublished	Juveniles, 1995	31	0.020	0.2050
18	Stillaguamish R.	WDFW unpublished	Smolts, 2006	109	0.036	0.0010
19	Tokul Creek H.	WDFW unpublished	Adults, 2001	95	−0.008	0.7391
20	Skamania H.	WDFW unpublished	N/A, 2008	95	−0.033	0.9900
21	S.F. Tolt (above)	WDFW unpublished	Juveniles, 2010	75	0.005	0.3820
22	Cedar River	Marshall et al. 2004	Mix, 2007	144	0.033	0.0010
23	Soos Creek H.	Winans et al. 2010	Adults, 2008	48	0.038	0.0211
24	Green River	Winans et al. 2010	Adults, 2006	43	0.076	0.0000
25	White River	Van Doornik et al. 2007	Mix, 2002, 2004–06	438	0.015	0.0060
26	Pulyallup River	Van Doornik et al. 2007	Mix, 2002, 2004–06	70	0.008	0.2870
27	Nisqually River	NMFS-NWFSC	Juv., 2006–2008	151	0.018	0.0480
28	Minter Creek	WDFW unpublished	Mix, 2006–2007	13	0.039	0.1600
29	Big Beef Creek	NWFSC-Manchester	Mix, 2006–2007	264	0.023	0.0020
30	Dewatto River	NWFSC-Manchester	Parr, smolts, 2006–7	295	0.000	0.5100
31	Tahuya River	NWFSC-Manchester	Smolts, 2006–2007	179	0.014	0.0720
32	Skokomish R.	NWFSC-Manchester	Parr, smolts, 2006–7	299	0.041	0.0000
33	Hamma Hamma	NWFSC-Manchester	Smolts, 2006, 2007	64	0.049	0.0010
34	Duckabush R.	NWFSC-Manchester	Parr, smolts, 2006–7	228	0.040	0.0000
35	Dosewallips R.	NWFSC-Manchester	Parr, smolts, 2006–7	169	0.033	0.0000
36	Snow Creek	NWFSC-Manchest./WDFW	Smolts, 2006–2007	129	0.011	0.1710
37	Dungeness River	WDFW unpublished	Parr, smolts, 2006–7	251	0.017	0.0130
38	L. Elwha Kla. H.	Winans et al. 2008	Juv., 2005–2006	142	0.029	0.0070
39	Elwha River	Winans et al. 2008	Juveniles, 2005	48	0.032	0.9690
			Total:	4563		

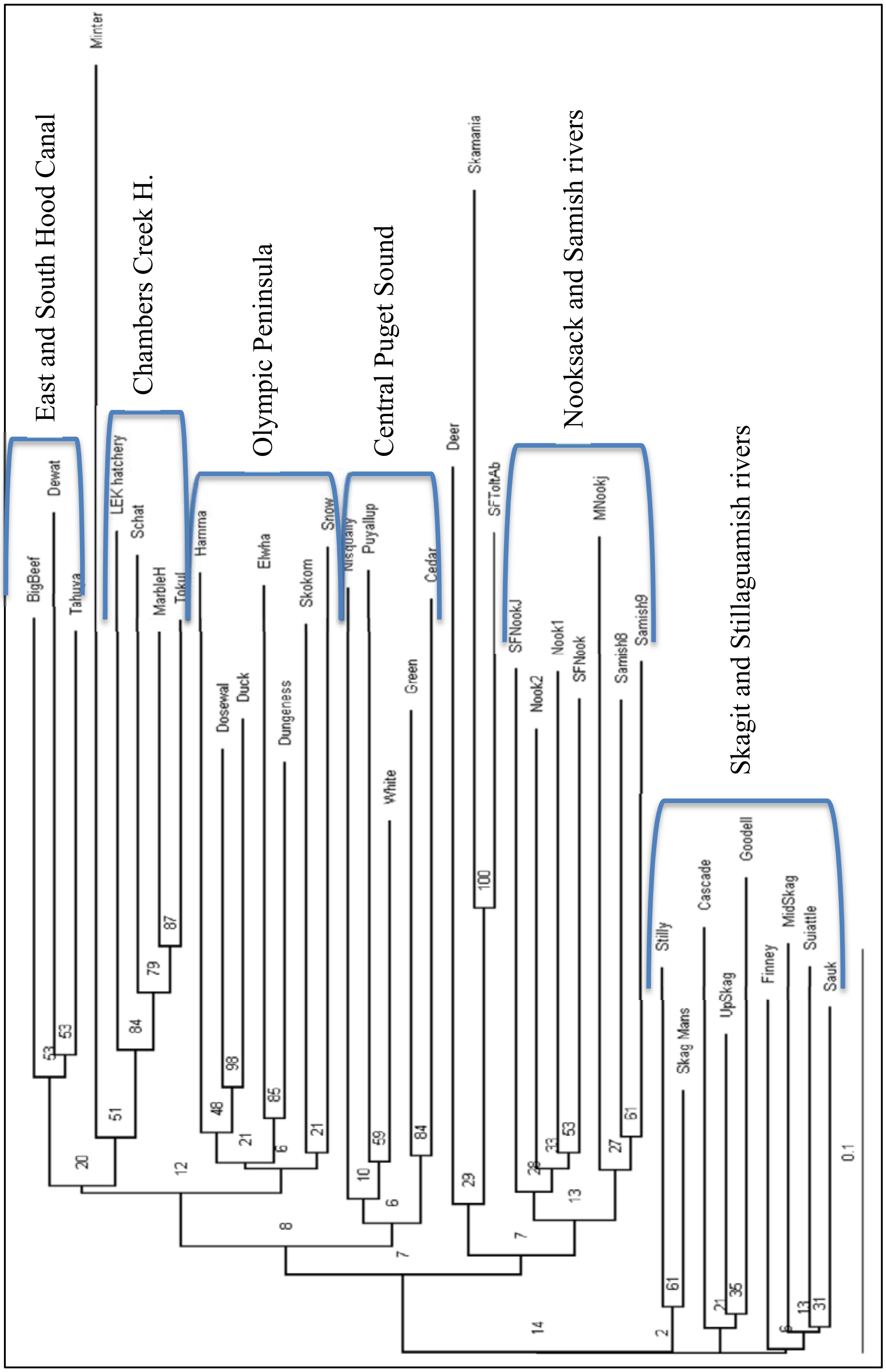

Figure B-1. Dendrogram of 39 Puget Sound steelhead collections analyzed for 13 microsatellite DNA loci and displayed using Cavalli-Sforza and Edwards chord metric and neighbor joining clustering. Numbers at the branches of the tree are representative of bootstrap values (percent).

Table B-3. Cavalli-Sforza and Edwards chord distances for 39 steelhead collections from Puget Sound. The gatekeeper model (Appendix C) used a Cavalli-Sforza and Edwards chord distance of 0.200 as a threshold for population independence. Numbers shaded in gray have distances less than 0.20. Numbers framed within lined boxes represent intra-Skagit River basin collections.

		Population number							
Population	**Pop. no.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Big Beef	**1**	**0**	0.262116	0.241455	0.262637	0.279043	0.290157	0.214851	0.332614
Dewatto	**2**	0.262116	**0**	0.286243	0.293168	0.315803	0.318019	0.239286	0.359593
Dosewallips	**3**	0.241455	0.286243	**0**	0.175085	0.228511	0.268656	0.243821	0.293635
Duckabush	**4**	0.262637	0.293168	0.175085	**0**	0.237968	0.266607	0.258463	0.301843
Skokomish	**5**	0.279043	0.315803	0.228511	0.237968	**0**	0.281614	0.282103	0.303785
Snow	**6**	0.290157	0.318019	0.268656	0.266607	0.281614	**0**	0.282242	0.345242
Tahuya	**7**	0.214851	0.239286	0.243821	0.258463	0.282103	0.282242	**0**	0.341022
Puyallup	**8**	0.332614	0.359593	0.293635	0.301843	0.303785	0.345242	0.341022	**0**
White	**9**	0.265447	0.307553	0.227053	0.236120	0.258416	0.283369	0.270277	0.230843
Nisqually	**10**	0.287926	0.325270	0.265088	0.274664	0.313629	0.321052	0.286171	0.294474
Elwha	**11**	0.297039	0.316219	0.236469	0.266258	0.285213	0.291876	0.291943	0.319542
Green	**12**	0.299120	0.325930	0.258079	0.261443	0.294091	0.319159	0.299414	0.289932
Skamania H.	**13**	0.409008	0.445069	0.380190	0.378980	0.394588	0.446388	0.437625	0.408210
Dungeness	**14**	0.260616	0.289429	0.191793	0.195368	0.249072	0.251927	0.239008	0.285152
Minter	**15**	0.421685	0.441543	0.406143	0.400416	0.436430	0.438207	0.431098	0.455574
Cedar	**16**	0.333143	0.352983	0.293839	0.289460	0.316655	0.334837	0.318299	0.295857
Stillaguamish	**17**	0.262464	0.291450	0.214412	0.222831	0.259532	0.281870	0.270271	0.276437
Skagit Manser	**18**	0.257255	0.284414	0.209617	0.215832	0.261767	0.272643	0.255704	0.274446
Nooksack 1	**19**	0.336913	0.341797	0.308496	0.318860	0.343484	0.354178	0.325958	0.343759
Nooksack 2	**20**	0.311230	0.324536	0.290164	0.293473	0.319683	0.334226	0.301917	0.342053
Upper Skagit	**21**	0.270676	0.294632	0.224910	0.228140	0.263425	0.289793	0.255529	0.289025
Mid Skagit	**22**	0.276755	0.314458	0.247853	0.257809	0.280300	0.288480	0.276764	0.307629
Cascade	**23**	0.288620	0.312604	0.259065	0.263651	0.270060	0.302447	0.287364	0.302185
Suiattle	**24**	0.286295	0.301935	0.255646	0.267996	0.283659	0.301296	0.283013	0.291080
Sauk	**25**	0.270891	0.307891	0.243761	0.254745	0.267928	0.284099	0.266308	0.294726
Finney	**26**	0.270903	0.299876	0.236840	0.236662	0.261582	0.293311	0.265983	0.296803
Goodell	**27**	0.293439	0.301672	0.279179	0.291768	0.302318	0.321544	0.279469	0.329600
Marblemount H.	**28**	0.268846	0.293805	0.242732	0.259085	0.305934	0.293909	0.259775	0.333254
Deer	**29**	0.370476	0.366557	0.345459	0.364302	0.370736	0.396580	0.364632	0.363295
S. F. Tolt	**30**	0.324545	0.364875	0.291886	0.289282	0.319169	0.346591	0.343278	0.331715
S. F. Nooksack	**31**	0.314759	0.344220	0.300838	0.309086	0.324501	0.346640	0.322223	0.336414
S. F. Nooksack j	**32**	0.337109	0.351399	0.293936	0.311733	0.334160	0.353473	0.331402	0.341541
Mainstem N'sack	**33**	0.336429	0.369378	0.322172	0.325020	0.338686	0.358526	0.336260	0.360462
Samish 08	**34**	0.292386	0.314068	0.248982	0.261353	0.298857	0.310697	0.281388	0.337938
Samish 09	**35**	0.297191	0.332507	0.286921	0.284363	0.303490	0.315319	0.298967	0.350057
Lower Elwha H.	**36**	0.307446	0.315650	0.277532	0.283882	0.304858	0.296743	0.282911	0.358379
Tokul Hatchery	**37**	0.279919	0.296422	0.247468	0.260761	0.307233	0.282423	0.267917	0.331927
Hamma Hamma	**38**	0.299071	0.342052	0.233147	0.241947	0.278394	0.300938	0.295151	0.335092
Soos Creek H.	**39**	0.296569	0.313922	0.276336	0.288313	0.317479	0.302252	0.291281	0.337560

Table B-3 continued horizontally. Cavalli-Sforza and Edwards chord distances for 39 steelhead collections from Puget Sound. The gatekeeper model (Appendix C) used a Cavalli-Sforza and Edwards chord distance of 0.200 as a threshold for population independence. Numbers shaded in gray have distances less than 0.20. Numbers framed within lined boxes represent intra-Skagit River basin collections.

		Population number							
Population	**Pop. no.**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Big Beef	**1**	0.265447	0.287926	0.297039	0.299120	0.409008	0.260616	0.421685	0.333143
Dewatto	**2**	0.307553	0.325270	0.316219	0.325930	0.445069	0.289429	0.441543	0.352983
Dosewallips	**3**	0.227053	0.265088	0.236469	0.258079	0.380190	0.191793	0.406143	0.293839
Duckabush	**4**	0.236120	0.274664	0.266258	0.261443	0.378980	0.195368	0.400416	0.289460
Skokomish	**5**	0.258416	0.313629	0.285213	0.294091	0.394588	0.249072	0.436430	0.316655
Snow	**6**	0.283369	0.321052	0.291876	0.319159	0.446388	0.251927	0.438207	0.334837
Tahuya	**7**	0.270277	0.286171	0.291943	0.299414	0.437625	0.239008	0.431098	0.318299
Puyallup	**8**	0.230843	0.294474	0.319542	0.289932	0.408210	0.285152	0.455574	0.295857
White	**9**	**0**	0.258035	0.286888	0.216689	0.382943	0.228604	0.424696	0.243325
Nisqually	**10**	0.258035	**0**	0.306498	0.297183	0.399713	0.274427	0.443317	0.320326
Elwha	**11**	0.286888	0.306498	**0**	0.308999	0.418636	0.220238	0.428818	0.334763
Green	**12**	0.216689	0.297183	0.308999	**0**	0.416368	0.264104	0.448291	0.248451
Skamania H.	**13**	0.382943	0.399713	0.418636	0.416368	**0**	0.389832	0.501450	0.439181
Dungeness	**14**	0.228604	0.274427	0.220238	0.264104	0.389832	**0**	0.397546	0.286452
Minter	**15**	0.424696	0.443317	0.428818	0.448291	0.501450	0.397546	**0**	0.445248
Cedar	**16**	0.243325	0.320326	0.334763	0.248451	0.439181	0.286452	0.445248	**0**
Stillaguamish	**17**	0.197018	0.272815	0.258143	0.242932	0.346478	0.207397	0.410468	0.284919
Skagit Manser	**18**	0.180758	0.267719	0.264860	0.221565	0.381906	0.195191	0.405612	0.262210
Nooksack 1	**19**	0.269087	0.329307	0.342332	0.306815	0.404724	0.304009	0.441800	0.328132
Nooksack 2	**20**	0.271969	0.316956	0.319534	0.297634	0.398205	0.270711	0.423518	0.317118
Upper Skagit	**21**	0.202947	0.278837	0.276714	0.236125	0.404531	0.217505	0.409157	0.284095
Mid Skagit	**22**	0.210108	0.296812	0.300449	0.245891	0.398347	0.242066	0.412304	0.291643
Cascade	**23**	0.238197	0.308837	0.308239	0.263302	0.381994	0.260985	0.423223	0.294278
Suiattle	**24**	0.195495	0.284790	0.294026	0.234859	0.401148	0.248012	0.432298	0.270615
Sauk	**25**	0.209449	0.288656	0.284461	0.240422	0.408236	0.229248	0.420127	0.282860
Finney	**26**	0.205955	0.277488	0.284488	0.241039	0.390311	0.232278	0.420708	0.283001
Goodell	**27**	0.251493	0.310393	0.311858	0.274439	0.414342	0.275331	0.421917	0.300480
Marblemount H.	**28**	0.270701	0.285184	0.284894	0.291091	0.418600	0.225636	0.400976	0.312430
Deer	**29**	0.348754	0.381735	0.358883	0.330676	0.420397	0.354510	0.506952	0.374539
S. F. Tolt	**30**	0.282519	0.321114	0.324569	0.303572	0.270701	0.302472	0.466584	0.333043
S. F. Nooksack	**31**	0.285603	0.331376	0.322516	0.313397	0.395930	0.280491	0.425616	0.334013
S. F. Nooksack j	**32**	0.299376	0.322761	0.331165	0.327285	0.391858	0.291844	0.431605	0.341644
Mainstem N'sack	**33**	0.313057	0.347254	0.329620	0.321460	0.434785	0.311412	0.442822	0.342884
Samish 08	**34**	0.269045	0.288837	0.283959	0.305436	0.402356	0.240810	0.421185	0.315321
Samish 09	**35**	0.296533	0.324683	0.306425	0.315900	0.402566	0.252417	0.403525	0.340730
Lower Elwha H.	**36**	0.304343	0.323565	0.323403	0.317216	0.446427	0.265550	0.413726	0.333218
Tokul Hatchery	**37**	0.269091	0.278677	0.301051	0.288881	0.428447	0.238966	0.405815	0.313088
Hamma Hamma	**38**	0.284766	0.297010	0.301290	0.303257	0.399595	0.244495	0.421153	0.335307
Soos Creek H.	**39**	0.267050	0.281003	0.321389	0.296117	0.418930	0.260958	0.402961	0.326066

Table B-3 continued horizontally. Cavalli-Sforza and Edwards chord distances for 39 steelhead collections from Puget Sound. The gatekeeper model (Appendix C) used a Cavalli-Sforza and Edwards chord distance of 0.200 as a threshold for population independence. Numbers shaded in gray have distances less than 0.20. Numbers framed within lined boxes represent intra-Skagit River basin collections.

		Population number							
Population	**Pop. no.**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Big Beef	**1**	0.262464	0.257255	0.336913	0.311230	0.270676	0.276755	0.288620	0.286295
Dewatto	**2**	0.291450	0.284414	0.341797	0.324536	0.294632	0.314458	0.312604	0.301935
Dosewallips	**3**	0.214412	0.209617	0.308496	0.290164	0.224910	0.247853	0.259065	0.255646
Duckabush	**4**	0.222831	0.215832	0.318860	0.293473	0.228140	0.257809	0.263651	0.267996
Skokomish	**5**	0.259532	0.261767	0.343484	0.319683	0.263425	0.280300	0.270060	0.283659
Snow	**6**	0.281870	0.272643	0.354178	0.334226	0.289793	0.288480	0.302447	0.301296
Tahuya	**7**	0.270271	0.255704	0.325958	0.301917	0.255529	0.276764	0.287364	0.283013
Puyallup	**8**	0.276437	0.274446	0.343759	0.342053	0.289025	0.307629	0.302185	0.291080
White	**9**	0.197018	0.180758	0.269087	0.271969	0.202947	0.210108	0.238197	0.195495
Nisqually	**10**	0.272815	0.267719	0.329307	0.316956	0.278837	0.296812	0.308837	0.284790
Elwha	**11**	0.258143	0.264860	0.342332	0.319534	0.276714	0.300449	0.308239	0.294026
Green	**12**	0.242932	0.221565	0.306815	0.297634	0.236125	0.245891	0.263302	0.234859
Skamania H.	**13**	0.346478	0.381906	0.404724	0.398205	0.404531	0.398347	0.381994	0.401148
Dungeness	**14**	0.207397	0.195191	0.304009	0.270711	0.217505	0.242066	0.260985	0.248012
Minter	**15**	0.410468	0.405612	0.441800	0.423518	0.409157	0.412304	0.423223	0.432298
Cedar	**16**	0.284919	0.262210	0.328132	0.317118	0.284095	0.291643	0.294278	0.270615
Stillaguamish	**17**	**0**	0.137383	0.264259	0.252405	0.170106	0.204741	0.203564	0.191996
Skagit Manser	**18**	0.137383	**0**	0.252524	0.227307	0.131883	0.165032	0.174665	0.153392
Nooksack 1	**19**	0.264259	0.252524	**0**	0.232230	0.246735	0.252575	0.283602	0.252331
Nooksack 2	**20**	0.252405	0.227307	0.232230	**0**	0.240708	0.254176	0.250281	0.249163
Upper Skagit	**21**	0.170106	0.131883	0.246735	0.240708	**0**	0.184463	0.176769	0.172175
Mid Skagit	**22**	0.204741	0.165032	0.252575	0.254176	0.184463	**0**	0.209389	0.189032
Cascade	**23**	0.203564	0.174665	0.283602	0.250281	0.176769	0.209389	**0**	0.206946
Suiattle	**24**	0.191996	0.153392	0.252331	0.249163	0.172175	0.189032	0.206946	**0**
Sauk	**25**	0.187856	0.150035	0.257765	0.257406	0.154893	0.174744	0.178446	0.168374
Finney	**26**	0.180195	0.152284	0.252271	0.252109	0.163960	0.186015	0.193578	0.183244
Goodell	**27**	0.216016	0.188604	0.273522	0.241893	0.177206	0.219964	0.205820	0.208057
Marblemount H.	**28**	0.259171	0.251124	0.313982	0.313714	0.260332	0.276910	0.298777	0.281571
Deer	**29**	0.306421	0.303290	0.335933	0.310287	0.314434	0.317836	0.304327	0.310301
S. F. Tolt	**30**	0.255692	0.284347	0.334152	0.333401	0.300263	0.302139	0.295647	0.303513
S. F. Nooksack	**31**	0.262809	0.242951	0.231305	0.225257	0.247637	0.256454	0.262545	0.256778
S. F. Nooksack j	**32**	0.270677	0.241158	0.258098	0.244985	0.254225	0.264854	0.260629	0.255716
Mainstem N'sack	**33**	0.298489	0.284110	0.282598	0.273990	0.299856	0.295220	0.330380	0.300496
Samish 08	**34**	0.245746	0.236540	0.276470	0.257450	0.243389	0.263980	0.275314	0.263400
Samish 09	**35**	0.252544	0.253471	0.274514	0.258904	0.250606	0.263898	0.290250	0.275237
Lower Elwha H.	**36**	0.292708	0.278425	0.349498	0.327139	0.291563	0.302241	0.313606	0.318323
Tokul Hatchery	**37**	0.271132	0.256791	0.324349	0.317552	0.268008	0.281089	0.292854	0.282040
Hamma Hamma	**38**	0.271388	0.268114	0.323223	0.311459	0.283746	0.305176	0.301793	0.301037
Soos Creek H.	**39**	0.274657	0.279389	0.333105	0.326814	0.291879	0.295808	0.304853	0.297502

Table B-3 continued horizontally. Cavalli-Sforza and Edwards chord distances for 39 steelhead collections from Puget Sound. The gatekeeper model (Appendix C) used a Cavalli-Sforza and Edwards chord distance of 0.200 as a threshold for population independence. Numbers shaded in gray have distances less than 0.20. Numbers framed within lined boxes represent intra-Skagit River basin collections.

		Population number							
Population	**Pop. no.**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Big Beef	**1**	0.270891	0.270903	0.293439	0.268846	0.370476	0.324545	0.314759	0.337109
Dewatto	**2**	0.307891	0.299876	0.301672	0.293805	0.366557	0.364875	0.344220	0.351399
Dosewallips	**3**	0.243761	0.236840	0.279179	0.242732	0.345459	0.291886	0.300838	0.293936
Duckabush	**4**	0.254745	0.236662	0.291768	0.259085	0.364302	0.289282	0.309086	0.311733
Skokomish	**5**	0.267928	0.261582	0.302318	0.305934	0.370736	0.319169	0.324501	0.334160
Snow	**6**	0.284099	0.293311	0.321544	0.293909	0.396580	0.346591	0.346640	0.353473
Tahuya	**7**	0.266308	0.265983	0.279469	0.259775	0.364632	0.343278	0.322223	0.331402
Puyallup	**8**	0.294726	0.296803	0.329600	0.333254	0.363295	0.331715	0.336414	0.341541
White	**9**	0.209449	0.205955	0.251493	0.270701	0.348754	0.282519	0.285603	0.299376
Nisqually	**10**	0.288656	0.277488	0.310393	0.285184	0.381735	0.321114	0.331376	0.322761
Elwha	**11**	0.284461	0.284488	0.311858	0.284894	0.358883	0.324569	0.322516	0.331165
Green	**12**	0.240422	0.241039	0.274439	0.291091	0.330676	0.303572	0.313397	0.327285
Skamania H.	**13**	0.408236	0.390311	0.414342	0.418600	0.420397	0.270701	0.395930	0.391858
Dungeness	**14**	0.229248	0.232278	0.275331	0.225636	0.354510	0.302472	0.280491	0.291844
Minter	**15**	0.420127	0.420708	0.421917	0.400976	0.506952	0.466584	0.425616	0.431605
Cedar	**16**	0.282860	0.283001	0.300480	0.312430	0.374539	0.333043	0.334013	0.341644
Stillaguamish	**17**	0.187856	0.180195	0.216016	0.259171	0.306421	0.255692	0.262809	0.270677
Skagit Manser	**18**	0.150035	0.152284	0.188604	0.251124	0.303290	0.284347	0.242951	0.241158
Nooksack 1	**19**	0.257765	0.252271	0.273522	0.313982	0.335933	0.334152	0.231305	0.258098
Nooksack 2	**20**	0.257406	0.252109	0.241893	0.313714	0.310287	0.333401	0.225257	0.244985
Upper Skagit	**21**	0.154893	0.163960	0.177206	0.260332	0.314434	0.300263	0.247637	0.254225
Mid Skagit	**22**	0.174744	0.186015	0.219964	0.276910	0.317836	0.302139	0.256454	0.264854
Cascade	**23**	0.178446	0.193578	0.205820	0.298777	0.304327	0.295647	0.262545	0.260629
Suiattle	**24**	0.168374	0.183244	0.208057	0.281571	0.310301	0.303513	0.256778	0.255716
Sauk	**25**	**0**	0.171487	0.206453	0.275394	0.307677	0.303311	0.249819	0.249106
Finney	**26**	0.171487	**0**	0.212237	0.267714	0.308050	0.283384	0.248863	0.252053
Goodell	**27**	0.206453	0.212237	**0**	0.302677	0.313351	0.328118	0.262411	0.267763
Marblemount H.	**28**	0.275394	0.267714	0.302677	**0**	0.371994	0.336912	0.318152	0.331069
Deer	**29**	0.307677	0.308050	0.313351	0.371994	**0**	0.362203	0.317951	0.323598
S. F. Tolt	**30**	0.303311	0.283384	0.328118	0.336912	0.362203	**0**	0.330266	0.330302
S. F. Nooksack	**31**	0.249819	0.248863	0.262411	0.318152	0.317951	0.330266	**0**	0.251182
S. F. Nooksack j	**32**	0.249106	0.252053	0.267763	0.331069	0.323598	0.330302	0.251182	**0**
Mainstem N'sack	**33**	0.293090	0.287072	0.295110	0.315008	0.376250	0.365296	0.273840	0.313267
Samish 08	**34**	0.249145	0.255524	0.283847	0.262116	0.359234	0.325833	0.261897	0.274127
Samish 09	**35**	0.261353	0.254635	0.277195	0.295466	0.355830	0.332953	0.264236	0.286343
Lower Elwha H.	**36**	0.301161	0.285637	0.317065	0.231527	0.387189	0.359809	0.340588	0.351923
Tokul Hatchery	**37**	0.276532	0.262379	0.313843	0.159131	0.374250	0.337070	0.320555	0.335666
Hamma Hamma	**38**	0.292387	0.285257	0.319196	0.284200	0.388456	0.314794	0.320264	0.334894
Soos Creek H.	**39**	0.297475	0.299291	0.327031	0.209113	0.395013	0.334958	0.334033	0.341975

Table B-3 continued horizontally. Cavalli-Sforza and Edwards chord distances for 39 steelhead collections from Puget Sound. The gatekeeper model (Appendix C) used a Cavalli-Sforza and Edwards chord distance of 0.200 as a threshold for population independence. Numbers shaded in gray have distances less than 0.20. Numbers framed within lined boxes represent intra-Skagit River basin collections.

		Population number						
Population	**Pop. no.**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
Big Beef	**1**	0.336429	0.292386	0.297191	0.307446	0.279919	0.299071	0.296569
Dewatto	**2**	0.369378	0.314068	0.332507	0.315650	0.296422	0.342052	0.313922
Dosewallips	**3**	0.322172	0.248982	0.286921	0.277532	0.247468	0.233147	0.276336
Duckabush	**4**	0.325020	0.261353	0.284363	0.283882	0.260761	0.241947	0.288313
Skokomish	**5**	0.338686	0.298857	0.303490	0.304858	0.307233	0.278394	0.317479
Snow	**6**	0.358526	0.310697	0.315319	0.296743	0.282423	0.300938	0.302252
Tahuya	**7**	0.336260	0.281388	0.298967	0.282911	0.267917	0.295151	0.291281
Puyallup	**8**	0.360462	0.337938	0.350057	0.358379	0.331927	0.335092	0.337560
White	**9**	0.313057	0.269045	0.296533	0.304343	0.269091	0.284766	0.267050
Nisqually	**10**	0.347254	0.288837	0.324683	0.323565	0.278677	0.297010	0.281003
Elwha	**11**	0.329620	0.283959	0.306425	0.323403	0.301051	0.301290	0.321389
Green	**12**	0.321460	0.305436	0.315900	0.317216	0.288881	0.303257	0.296117
Skamania H.	**13**	0.434785	0.402356	0.402566	0.446427	0.428447	0.399595	0.418930
Dungeness	**14**	0.311412	0.240810	0.252417	0.265550	0.238966	0.244495	0.260958
Minter	**15**	0.442822	0.421185	0.403525	0.413726	0.405815	0.421153	0.402961
Cedar	**16**	0.342884	0.315321	0.340730	0.333218	0.313088	0.335307	0.326066
Stillaguamish	**17**	0.298489	0.245746	0.252544	0.292708	0.271132	0.271388	0.274657
Skagit Manser	**18**	0.284110	0.236540	0.253471	0.278425	0.256791	0.268114	0.279389
Nooksack 1	**19**	0.282598	0.276470	0.274514	0.349498	0.324349	0.323223	0.333105
Nooksack 2	**20**	0.273990	0.257450	0.258904	0.327139	0.317552	0.311459	0.326814
Upper Skagit	**21**	0.299856	0.243389	0.250606	0.291563	0.268008	0.283746	0.291879
Mid Skagit	**22**	0.295220	0.263980	0.263898	0.302241	0.281089	0.305176	0.295808
Cascade	**23**	0.330380	0.275314	0.290250	0.313606	0.292854	0.301793	0.304853
Suiattle	**24**	0.300496	0.263400	0.275237	0.318323	0.282040	0.301037	0.297502
Sauk	**25**	0.293090	0.249145	0.261353	0.301161	0.276532	0.292387	0.297475
Finney	**26**	0.287072	0.255524	0.254635	0.285637	0.262379	0.285257	0.299291
Goodell	**27**	0.295110	0.283847	0.277195	0.317065	0.313843	0.319196	0.327031
Marblemount H.	**28**	0.315008	0.262116	0.295466	0.231527	0.159131	0.284200	0.209113
Deer	**29**	0.376250	0.359234	0.355830	0.387189	0.374250	0.388456	0.395013
S. F. Tolt	**30**	0.365296	0.325833	0.332953	0.359809	0.337070	0.314794	0.334958
S. F. Nooksack	**31**	0.273840	0.261897	0.264236	0.340588	0.320555	0.320264	0.334033
S. F. Nooksack j	**32**	0.313267	0.274127	0.286343	0.351923	0.335666	0.334894	0.341975
Mainstem N'sack	**33**	**0**	0.286991	0.268826	0.344762	0.330004	0.336249	0.361875
Samish 08	**34**	0.286991	**0**	0.225735	0.303091	0.275504	0.304365	0.291041
Samish 09	**35**	0.268826	0.225735	**0**	0.307622	0.304091	0.312427	0.320300
Lower Elwha H.	**36**	0.344762	0.303091	0.307622	**0**	0.215918	0.318801	0.261522
Tokul Hatchery	**37**	0.330004	0.275504	0.304091	0.215918	**0**	0.293326	0.189651
Hamma Hamma	**38**	0.336249	0.304365	0.312427	0.318801	0.293326	**0**	0.301092
Soos Creek H.	**39**	0.361875	0.291041	0.320300	0.261522	0.189651	0.301092	**0**

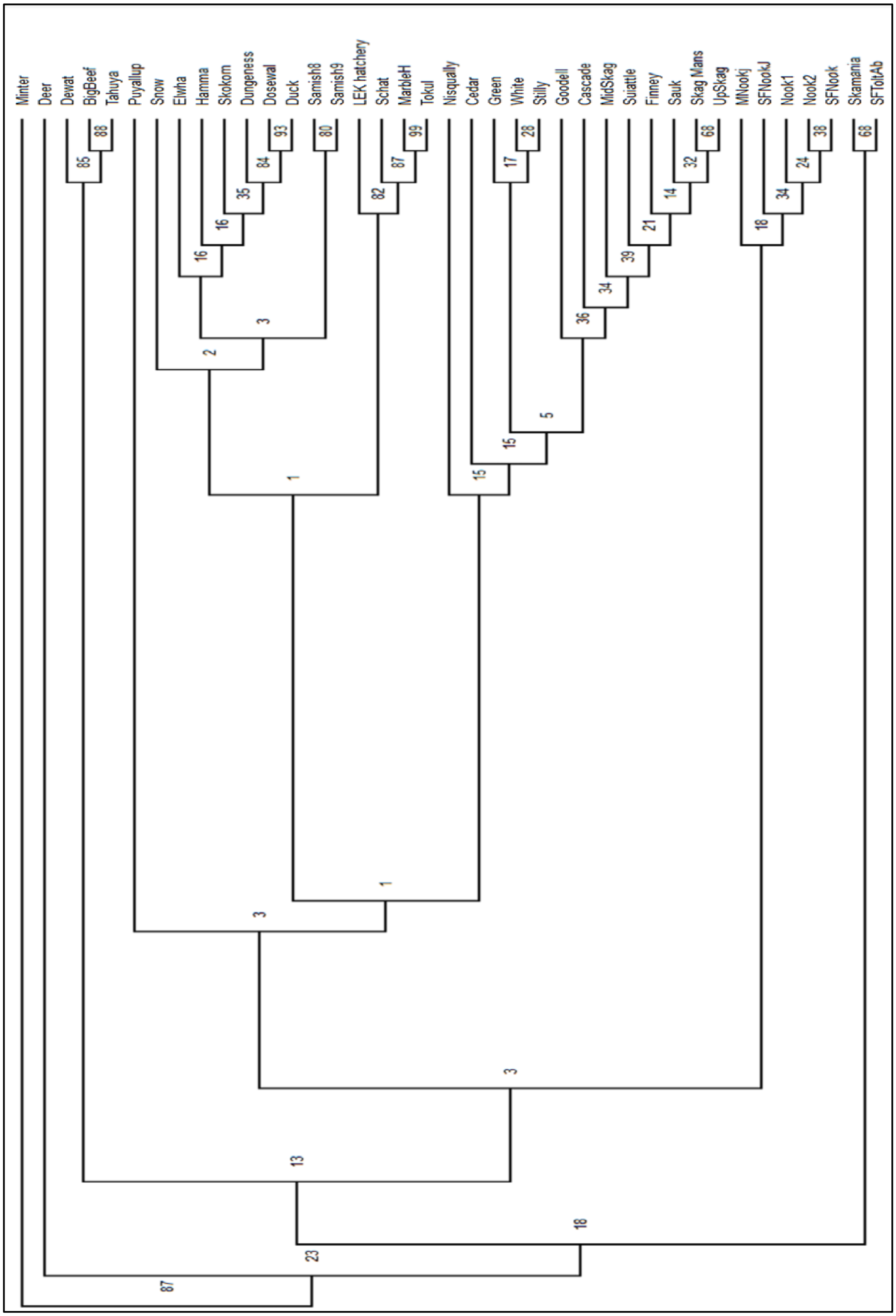

Figure B-2. Dendrogram of 39 Puget Sound steelhead collections analyzed for 13 microsatellite DNA loci and displayed using Cavalli-Sforza and Edwards chord tree with unweighted pair group method with arithmetic averages clustering. Numbers at the branches of the tree are representative of bootstrap values (percent).

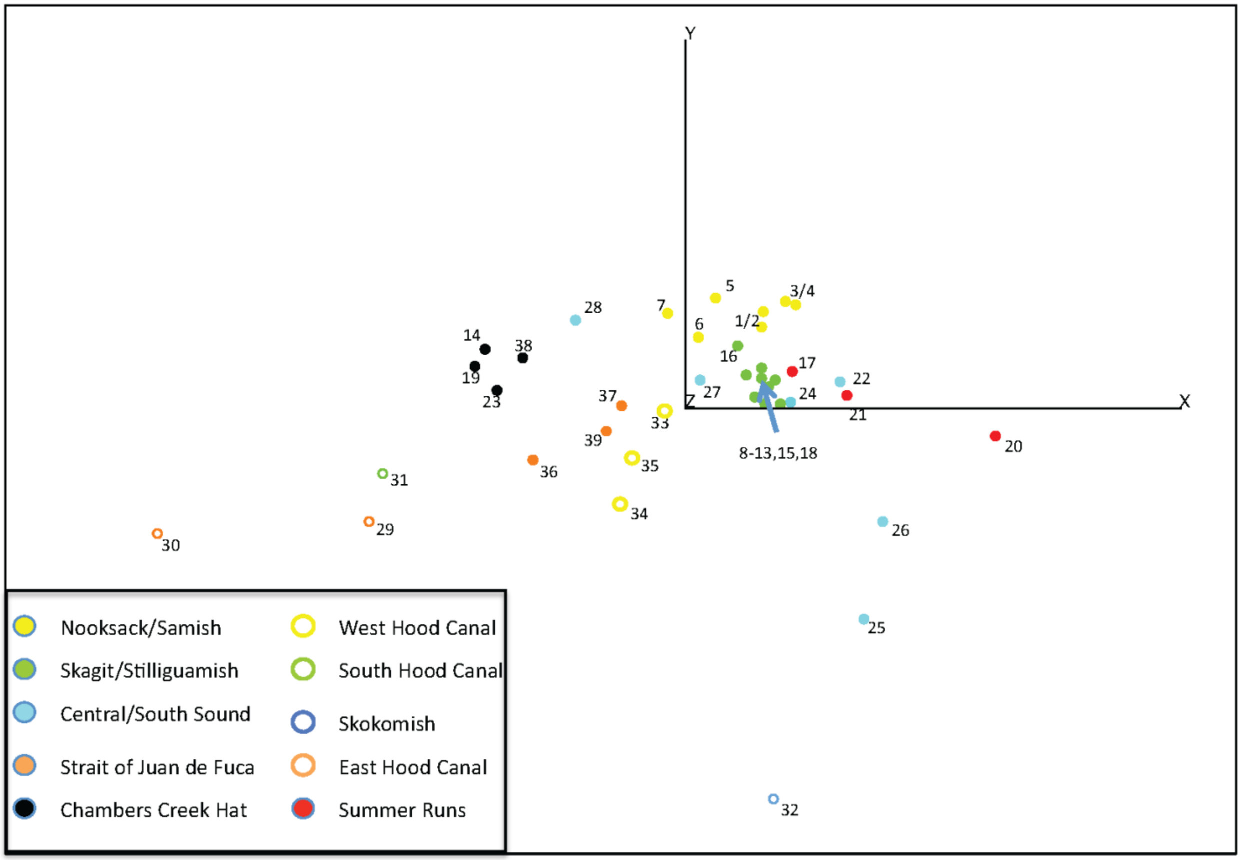

Figure B-3. Relationships between 39 steelhead population samples from Puget Sound based on 13 microsatellite DNA loci. The x-axis corresponds to the primary principal component variable (FCA1) and the y-axis corresponds to the secondary principal component variable (FCA2). Numbers correspond to samples listed in Table B-2. Colors indicate the general geographic location of the samples.

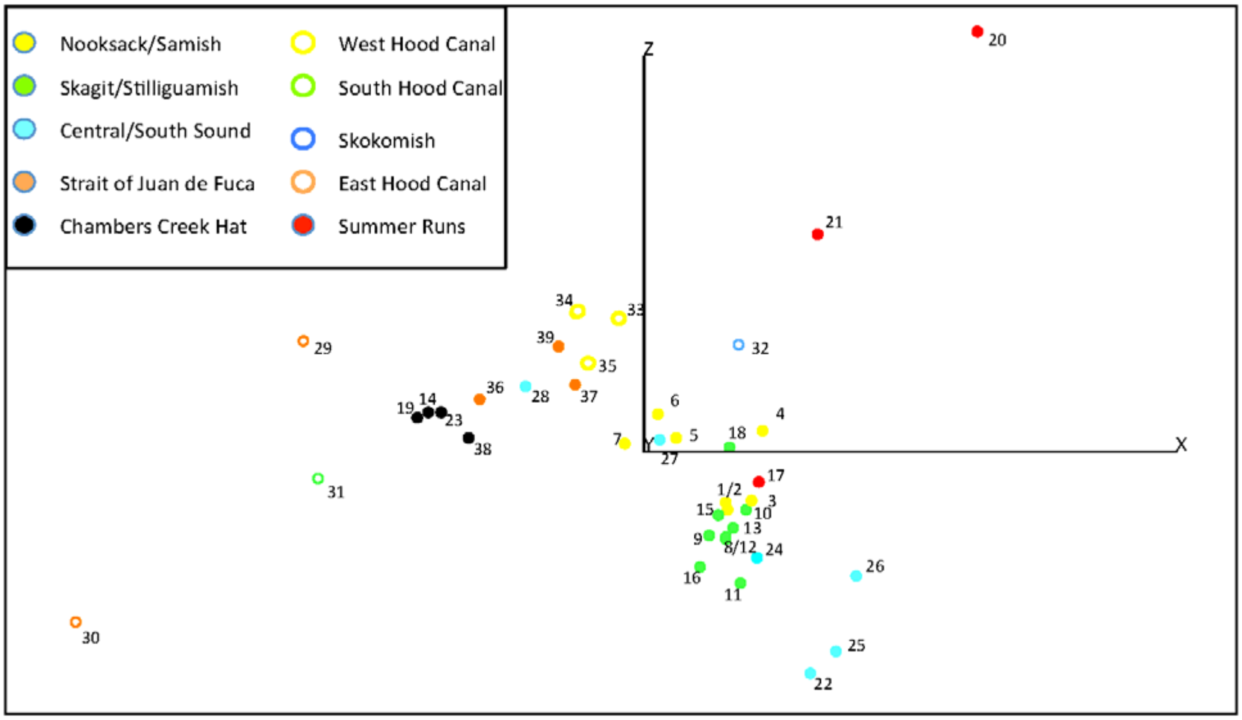

Figure B-4. Relationships between 39 steelhead population samples from Puget Sound based on 13 microsatellite DNA loci. The x-axis corresponds to the primary principal component variable (FCA1) and the z-axis corresponds to the tertiary principal component variable (FCA3). Numbers correspond to samples listed in Table B-2. Colors indicate the general geographic location of the samples.

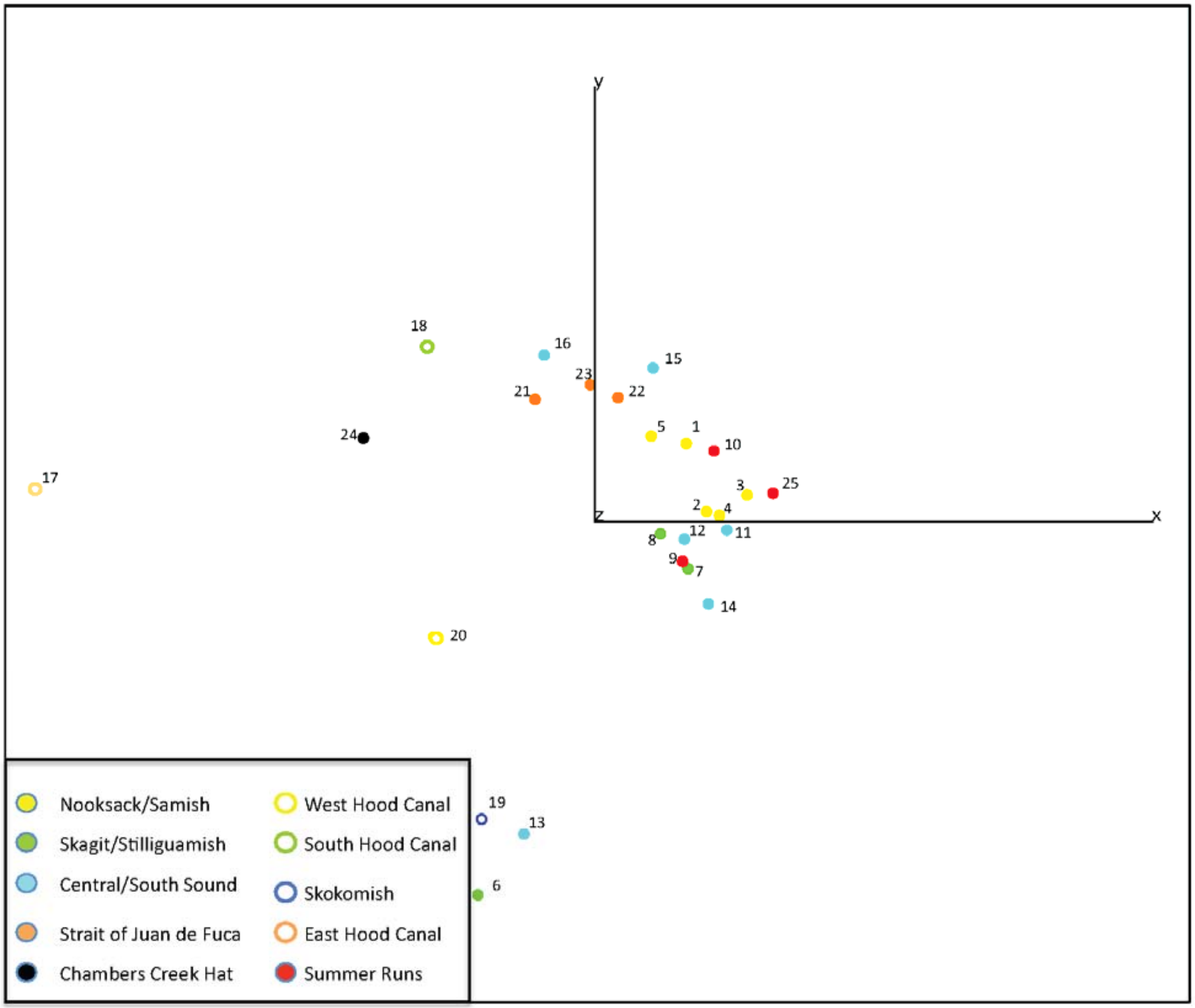

Figure B-5. Relationships between 25 steelhead population samples from Puget Sound based on 13 microsatellite DNA loci. The x-axis corresponds to the primary principal component variable (FCA1) and the y-axis corresponds to the secondary principal component variable (FCA2). Numbers correspond to samples listed in Table B-4. Colors indicate the general geographic location of the samples.

Table B-4. Information for collections of steelhead used in the genetic analyses. Presumptive populations were created by pooling samples from Table B-2 by basin, with the exception of the Nooksack River basin samples.

Pop	Sample	Fish sampled	N	Sample no. from Table B-2
1	Main Nooksack	Juveniles, 2009	47	5
2	Nooksack1 and 2	Mix, 2008–2009	62	1 and 2
3	S. F. Nooksack A	Adults, 2007–2010	38	3
4	S. F. Nooksack J	Juveniles, 2009	26	4
5	Samish River	Adults, 2008–2009	78	6 and 7
6	Skagit River	Mix, 2008–2011	551	8, 9, 10, 13, 15, and 16
7	Sauk River	Adults, 2008–2011	132	11 and 12
8	Stillaguamish River	Smolts, 2006	109	18
9	Deer Creek	Juveniles, 1995	31	17
10	S. F. Tolt (above falls)	Juveniles, 2010	75	21
11	Cedar River	Mix, 2007	144	22
12	Green River	Adults, 2006	43	24
13	White River	Mix, 2002, 2004–2006	438	25
14	Puyallup River	Mix, 2002, 2004–2006	70	26
15	Nisqually River	Juv., 2006–2008	151	27
16	Minter Creek	Mix, 2006–2007	13	28
17	East Hood Canal	Mix, 2006–2007	558	29 and 30
18	Tahuya/South Hood Canal	Smolts, 2006–2007	179	31
19	Skokomish River	Parr, smolts, 2006–2007	299	32
20	West Hood Canal	Smolts, 2006, 2007	461	33, 34, and 35
21	Snow Creek	Smolts, 2006–2007	129	36
22	Dungeness River	Parr, smolts, 2006–2007	251	37
23	Elwha River	Juveniles, 2005	48	39
24	Chambers Creek Hatcheries	Juveniles, 2005, 2006	436	14, 19, 23, and 38
25	Skamania Hatchery	Not available, 2008	95	20
		Total:	4,563	

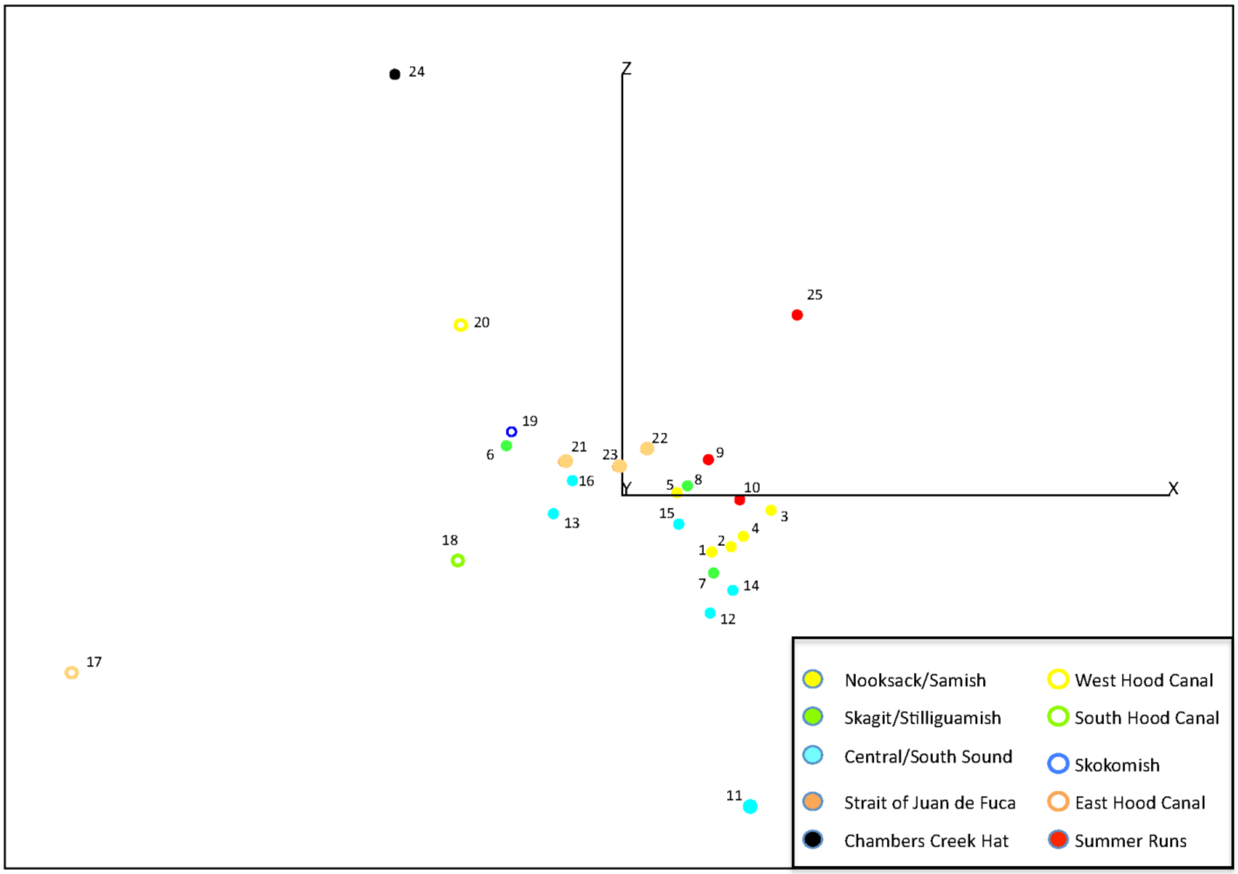

Figure B-6. Relationships between 25 steelhead population samples from Puget Sound based on 13 microsatellites DNA loci. The x- axis corresponds to the primary principal component variable (FCA1) and the z-axis corresponds to the tertiary principal component variable (FCA3). Numbers correspond to samples listed in Table B-4. Colors indicate the general geographic location of the samples.

Appendix C: Puget Sound Steelhead TRT Checklist and Gatekeeper Model for Identifying DIPs

Demographically Independent Population Checklist

The Puget Sound Steelhead Technical Recovery Team (PSS TRT) developed a layered checklist (Table C-1) to assist in identification of historical demographically independent populations (DIPs). This checklist provided a conceptual framework for establishing prospective DIPs and identifying the supporting evidence available and level of certainty for each DIP. Essentially, if one can show that a presumptive population was historically present and sufficient evidence exists that the population is (or was) large enough to be sustainable and is not substantially demographically influenced by other populations (via migration), it qualifies as a DIP. There was some discussion regarding how large is large enough. Work by Allendorf et al. (1997) suggests that an "effective population size, N_e," of 500 or more would be sufficient to ensure a less than 5% risk of extinction in the near future (100 years). Converting N_e to a census population size (N) is somewhat challenging. Waples suggests that N_e/N is 0.2–0.25 for Chinook salmon (*Oncorhynchus tshawytscha*); this number should be somewhat larger (approximately 0.50) for iteroparous steelhead (*O. mykiss*), giving a target N of possibly 1,000 spawners per generation (this adjusted N_e/N ratio roughly accounts for an unknown number of resident fish contributing to the anadromous DPS and the presence of a small proportion of repeat spawners), or about 250 spawners annually (at a mean generation length of 4 years). Demographic independence was most clearly demonstrated when the abundance trajectory of a presumptive population is clearly distinct from its neighboring populations. The PSS TRT also considered empirical evidence for identifying DIPs. Specifically, the TRT selected the smallest independent spawning aggregation for which a long-term data set exists (establishing sustainability); for Puget Sound steelhead this was Snow Creek. Historical abundance was estimated using historical estimates, harvest expansions, or a habitat-based intrinsic potential (IP) model, with the amount of habitat in each presumptive DIP compared to that in Snow Creek.

Tier 1 Checklist

☐ Historically present

☐ Abundance (actual or IP-estimated)

☐ Demographic independence

If all three conditions are met, the presumptive population is considered a DIP; for that population, the only further discussion necessary is to discern whether there are additional DIPs within the population in question.

For Puget Sound steelhead, it is more likely that there will be insufficient information to establish whether the conditions in the first box or third box are met. In these cases it will become necessary to use proxies, more indirect measures of abundance and demographic independence. As stated earlier, the habitat-based IP model was used as the abundance proxy for historical abundance. For the demographic independence measure, there are a number of possible proxies, all of which provide some indicator of the degree of isolation.

For the Tier 2 Checklist, geographic isolation is the distance between presumptive population spawning locations. Isolation barriers normally are falls and cascades, velocity barriers that may provide temporal windows to upstream access. Genetic distinctiveness, a measure of genetic differences, indicates the degree to which populations interbreed (gene flow rates and time of isolation). Ecological differences are differences between natal streams that may result in local adaptation by presumptive populations. Strong freshwater adaptation would reinforce homing fidelity. Temporal isolation indicates that run timing differences may result in fish spawning in the same or nearby stream reaches, but at different times of the year with minimum chance for introgression.

Tier 2 Checklist

☐ Abundance proxy—IP or other habitat-based estimate of potential productivity

☐ Basin size—a very simple proxy for abundance (potential productivity)
Drainage area (80 km^2)—adjusted for gradient

☐ Geographic isolation—beyond 50 km independent, bays and shoreline morphology

☐ Genetic distance (FST)

☐ Barriers—physical (seasonal, flow [high or low], substrate)

☐ Temporal isolation—run or spawn timing

While there is no minimum number of Tier 2 boxes that need to be checked, it is assumed that meeting just one of the above conditions would not necessarily be sufficient to establish a DIP. There are also gradations to many of the check boxes; for example, where temporal isolation is considered as a factor, it is possible that the spawn timing of presumptive populations is separated by days, weeks, or months.

Where there is a marginal degree of support for designating a presumptive population as a DIP, it may be useful to identify additional measures within the Tier 3 Checklist. Essentially, it utilizes a number of the categories from Tier 2, but the information is related to population independence by an additional level of inference.

Tier 3 Checklist

☐ Ecological separation (geology, flow regime, elevation, ecoregion)—in the absence of life history information, the TRT concluded that ecological differences between basins would result in life history differences in the steelhead that reared and spawned in those basins.

Table C-1. Data available for DIP evaluation. A check mark indicates that information was available for consideration by the TRT. A star indicates that information was available and that it was definitive in identifying the DIP.

	DIP criteria		
	——Tier 1——	**——Tier 2 and Tier 3——**	**VSP data**

Population name	Historical presence	Sustainability (abundance)	Demographic independence	Basin size (IP)	Temporal isolation	Geographic isolation	Life history (except run type)	Genetics	Habitat type	Abundance*	Genetics	Age	Punch card
Baker River	✔	✔	—	✔	—	—	—	—	—	—	✔	—	—
Canyon Creek	✔	—	—	—	★	—	—	—	—	—	—	—	✔
Cedar River	✔	—	—	✔	—	★	—	—	★	✔	✔	—	✔
Deer Creek	✔	✔	—	✔	★	—	—	✔	—	—	✔	✔	✔
Drayton Harbor Tributaries	✔	—	—	✔	—	★	✔	—	★	—	—	—	✔
Dungeness River	✔	—	—	✔	—	—	—	★	★	—	✔	—	✔
East Hood Canal Tributaries	✔	—	✔	✔	—	—	—	★	★	✔	✔	—	✔
East Kitsap Peninsula Tributaries	✔	—	—	✔	—	—	—	—	✔	—	—	—	✔
Elwha River	✔	—	—	✔	—	—	—	✔	—	✔	✔	—	✔
Green River	✔	✔	—	✔	—	★	—	✔	—	✔	✔	✔	✔
Nisqually River	✔	—	—	✔	—	—	—	★	★	✔	✔	✔	✔
Nookachamps Creek	✔	—	—	✔	—	—	—	—	★	—	—	—	—
Nooksack River	✔	✔	—	✔	—	—	—	★	★	—	✔	✔	✔
North Fork Skykomish River	✔	—	—	✔	★	—	—	★	—	—	✔	—	✔
N. Lake Wash. & Lake Sammam.	✔	—	—	✔	—	★	—	—	★	—	—	—	—
Pilchuck River	✔	✔	—	✔	—	—	★	—	✔	✔	—	✔	✔
Puyallup/Carbon Rivers	✔	—	—	✔	—	—	—	★	—	✔	✔	✔	✔
Samish R.&Bellingham Bay Tribs.	✔	✔	★	✔	—	—	—	★	★	✔	✔	—	✔
Sauk River	✔	✔	—	✔	—	—	★	✔	—	—	✔	✔	✔
Sequim/Discovery Bays Tribs.	—	—	—	✔	—	—	—	✔	★	✔	✔	✔	✔
Skagit River	✔	✔	—	✔	—	—	—	✔	✔	✔	✔	✔	✔
Skokomish River	✔	✔	—	✔	—	—	—	✔	★	✔	✔	—	✔
Snohomish/Skykomish Rivers	✔	✔	—	✔	—	—	—	—	—	✔	—	✔	✔
Snoqualmie River	✔	✔	—	✔	★	★	—	—	—	✔	—	✔	✔
South Fork Nooksack River	✔	—	—	✔	★	—	—	—	—	—	—	—	✔
South Hood Canal Tributaries	✔	✔	✔	✔	—	—	—	★	✔	✔	✔	—	✔
South Puget Sound Tributaries	✔	—	—	✔	—	★	—	✔	★	—	—	—	✔
Stillaguamish River	✔	✔	—	✔	★	—	—	—	—	✔	✔	✔	✔
Strait of Juan de Fuca Tributaries	✔	—	—	✔	—	—	—	✔	★	✔	✔	—	✔
Tolt River	✔	—	—	—	★	—	—	✔	—	✔	✔	—	✔
West Hood Canal Tributaries	✔	—	—	✔	—	—	—	★	✔	✔	✔	—	✔
White River	✔	✔	—	✔	—	—	—	★	—	✔	✔	—	✔

* Abundance information available for 5 of the last 10 years.

Gatekeeper Model

In an effort to develop a simplified methodology for identifying historical DIPs, the PSS TRT established a number of DIP threshold values related to the biological and geographic characteristics of the provisional population (Figure C-1). These threshold values were set such that if any pair-wise comparison of DIPs exceeded the value, there was a very high degree of certainty that the two populations were independent. Because information on many provisional DIPs was limited or lacking, the number of characteristics considered was constrained to only those that were available for nearly all populations.

The initial set of candidate populations was established by identifying those hydrological units or combinations of hydrological units with IP production levels greater than that estimated for Snow Creek in the Strait of Juan de Fuca. Snow Creek was selected as a minimum size for consideration because long-term monitoring of juvenile and adult steelhead suggests that this natural population is self-sustaining.

Presumptive DIPs were compared in a pair-wise manner according to five characteristic categories: geographic distance, presence of a temporal barrier, genetic distance (Cavalli-Sforza and Edwards chord distance), run timing/life history, and river flow hydrographs (standardized across months). For geographic distance, a river mouth to river mouth distance of 50 km was established as a threshold, beyond which the TRT concluded it was highly unlikely for there to be demographic interaction between populations. The presence of a substantial temporal barrier (low flow or velocity) was considered to provide a mechanism for reproductively isolating two populations. A Cavalli-Sforza and Edwards chord distance of 0.20, based on the microsatellite DNA analysis of contemporary Puget Sound steelhead populations, was considered to be representative of a significant genetic (reproductive) isolation between populations. Where substantial life history differences exist or existed, the populations were considered to be reproductively isolated. These life history characteristics most commonly included run timing, spawn timing, and age structure. Since variation in these traits is partially influenced by genetic effects, differences in trait expression indicate genetic differences and some degree of reproductive isolation. Lastly, where the annual hydrographs for two populations were substantially different (primarily distinguishing between snow-dominated and rain-dominated systems), it was inferred that the major life history characteristics would be adapted to local conditions and parallel these differences. In the case of river hydrology, flow types were distinguished via cluster analysis, based on the Gower similarity coefficient (Gower 1971) (Figure C-2). A substantial difference in river hydrograph was inferred by differences in clustering based solely on the first bifurcation (a distinction that accounted for the majority of the variability).

In the gatekeeper model, each population characteristic is evaluated independently of the others. Therefore, neither order nor missing data affected the outcome of the analysis.

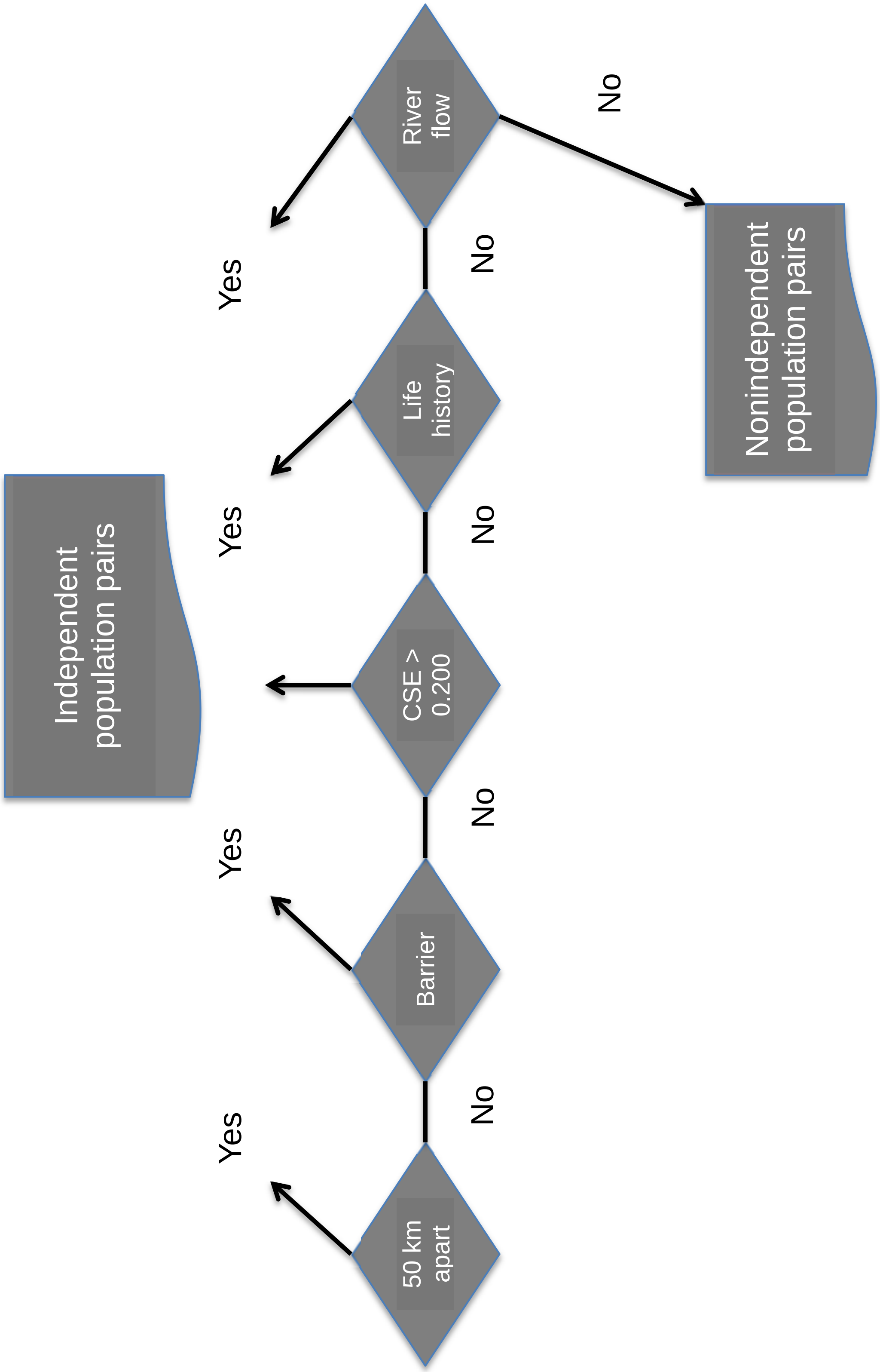

Figure C-1. Schematic of the gatekeeper model used to identify historical DIPs. If differences between presumptive populations exceeded the threshold for any of the gatekeeper criteria, those populations were considered independent of each other.

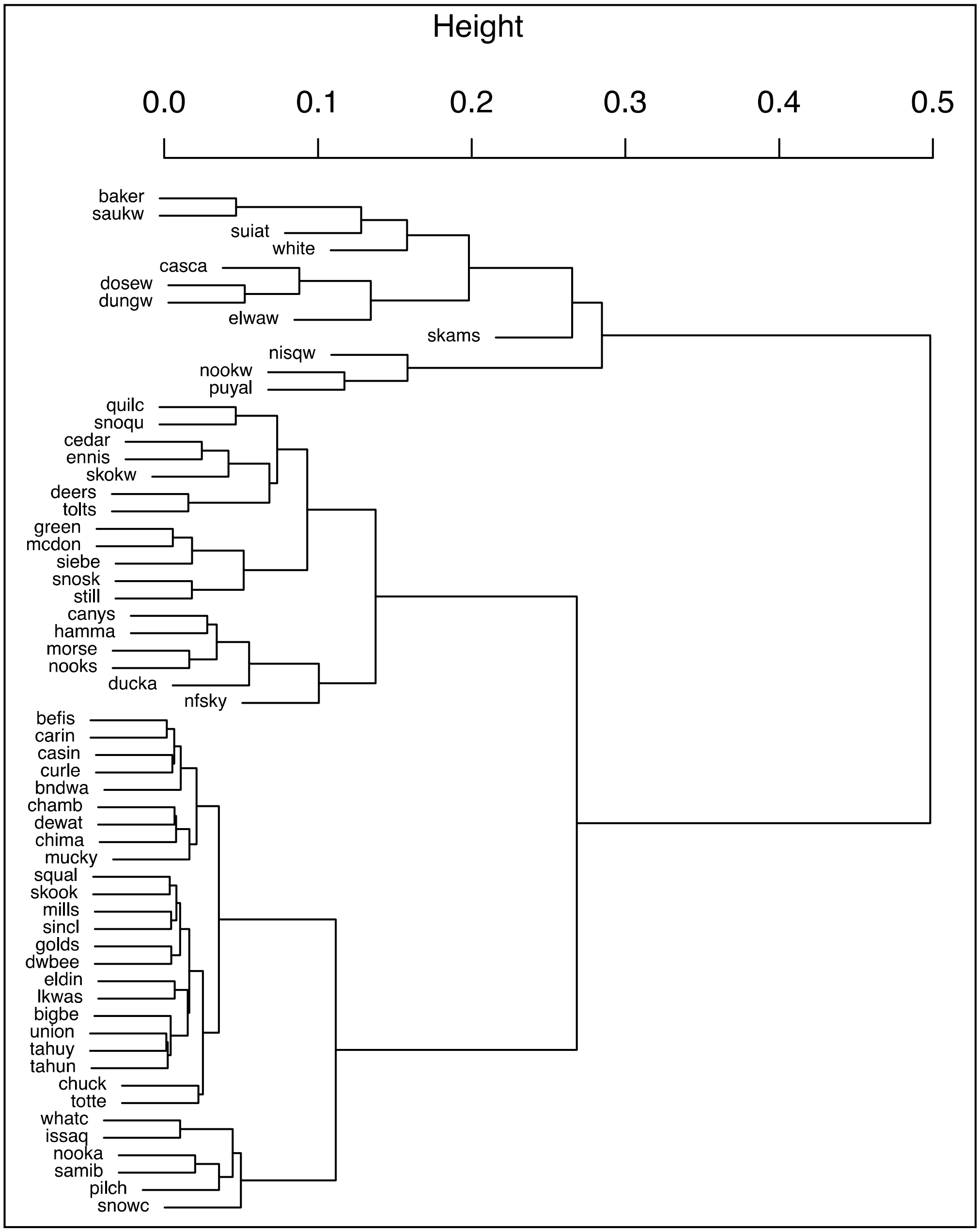

Figure C-2. Gower chart of candidate DIP ecological parameters used to distinguish habitat characteristics in each basin. The Gower index (Gower 1971) includes information on permanent snow cover, elevation, and basin size. Groups that clustered below the 0.2 height thresholds were considered to have similar habitat types.

Appendix D: Basin Characteristics and Estimates of Spawners

This appendix contains a two-page table, continued horizontally.

Table D-1. Basin geographic, hydrologic, and ecological characteristics with intrinsic potential (IP) estimates of spawners using two smolt-to-adult survival (SAS) rates. Capacity is the number of returning adults.

	Basin dimensions			**Basin climate**											
				Mean max. temp.		Mean min. temp.		Mean precipitation (mm)			Hydrograph type (%)				
Population name	Area (km^2)	Mean elev. (m)	Total stream len. (m)	Jan.	July	Jan.	July	Jan.	July	Year	High-land	Low-land	Rain domi-nated	R/S domi-nated	Snow domi-nated
Baker River	770.68	999	421,859	186	2,041	-457	817	408	80	3,017	0.46	0.00	0.19	0.12	0.22
Canyon Creek	99.84	864	47,716	311	2,054	-271	937	527	106	3,610	0.10	0.00	0.10	0.36	0.44
Cedar River	649.93	461	402,349	472	2,252	-112	1,001	263	49	1,867	0.06	0.48	0.15	0.13	0.17
Deer Creek	180.44	761	105,313	367	2,129	-246	939	472	91	3,322	0.06	0.00	0.21	0.28	0.44
Drayton Harbor Tributaries	223.07	37	206,057	569	2,238	-35	1,102	150	41	1,168	0.00	1.00	0.00	0.00	0.00
Dungeness River	564.16	978	306,740	311	1,912	-309	855	218	34	1,493	0.16	0.20	0.12	0.33	0.20
East Hood Canal Tributaries	341.99	99	174,736	694	2,412	85	1,132	207	25	1,446	0.00	1.00	0.00	0.00	0.00
East Kitsap Peninsula Tributaries	703.00	75	259,413	723	2,384	132	1,175	169	23	1,194	0.00	0.99	0.01	0.00	0.00
Elwha River	832.87	1,021	472,871	309	1,899	-301	850	380	41	2,574	0.11	0.05	0.09	0.36	0.39
Green River	1,443.92	463	834,472	470	2,280	-135	989	227	41	1,621	0.06	0.51	0.10	0.17	0.17
Nisqually River	1,991.50	524	1,030,771	528	2,306	-147	952	228	38	1,610	0.08	0.47	0.13	0.16	0.15
Nookachamps Creek	182.95	252	159,503	556	2,264	-52	1,048	185	57	1,553	0.00	0.45	0.40	0.09	0.06
Nooksack River	1,982.16	619	1,257,480	362	2,164	-266	956	278	64	2,133	0.22	0.31	0.15	0.15	0.17
North Fork Skykomish River	156.19	1,195	117,602	-17	2,124	-636	768	432	63	2,825	0.61	0.00	0.01	0.12	0.27
N. Lake Wash. & Lake Sammam.	977.61	119	441,887	677	2,360	79	1,142	152	31	1,151	0.00	0.90	0.07	0.02	0.00
Pilchuck River	355.62	253	242,383	567	2,314	-21	1,068	246	51	1,863	0.00	0.56	0.35	0.06	0.03
Puyallup River	1,394.77	672	803,817	459	2,194	-216	904	218	49	1,635	0.20	0.35	0.16	0.16	0.12
Samish R. and Bellingham Bay	661.49	203	453,694	561	2,290	-58	1,083	191	52	1,500	0.00	0.50	0.41	0.08	0.02
Sauk River	1,896.68	1,132	1,079,263	42	2,083	-611	822	406	63	2,758	0.54	0.00	0.13	0.12	0.21
Sequim/Discovery Bays Tribs.	557.46	197	234,042	628	2,237	48	1,102	98	28	771	0.00	0.74	0.17	0.08	0.00
Skagit River	5,542.66	1,098	2,815,113	98	2,052	-567	810	311	57	2,148	0.47	0.12	0.10	0.13	0.18
Skokomish River	634.47	570	411,699	485	2,192	-120	1,000	428	46	2,969	0.02	0.21	0.25	0.40	0.12
Snohomish/Skykomish Rivers	1,595.49	420	1,021,690	481	2,249	-112	1,026	308	60	2,222	0.09	0.45	0.21	0.13	0.12
Snoqualmie River	1,615.45	620	1,134,038	358	2,195	-210	924	334	65	2,408	0.18	0.24	0.28	0.14	0.16
South Fork Nooksack River	172.44	926	99,347	324	2,059	-339	903	499	86	3,516	0.30	0.00	0.06	0.23	0.41
South Hood Canal Tributaries	294.73	126	216,935	683	2,473	56	1,117	238	27	1,649	0.00	0.92	0.08	0.00	0.00
South Puget Sound Tributaries	1,859.99	84	582,451	702	2,454	66	1,107	205	24	1,432	0.00	0.98	0.02	0.00	0.00
Stillaguamish River	1,230.17	398	927,234	508	2,248	-96	1,038	303	62	2,201	0.05	0.33	0.35	0.14	0.13
Strait of Juan de Fuca Tributaries	403.06	611	246,441	431	2,081	-130	1,007	196	24	1,300	0.04	0.37	0.24	0.23	0.12
Tolt River	181.79	784	117,732	264	2,094	-268	882	419	91	3,055	0.12	0.00	0.26	0.31	0.31
West Hood Canal Tributaries	1,433.45	715	842,382	417	2,075	-193	962	276	37	1,986	0.09	0.31	0.13	0.31	0.16
White River	1,284.83	1,061	863,251	173	2,035	-447	751	262	43	1,767	0.41	0.15	0.07	0.15	0.23

Table D-1 continued horizontally. Basin geographic, hydrologic, and ecological characteristics with intrinsic potential (IP) estimates of spawners using two smolt-to-adult survival (SAS) rates. Capacity is the number of returning adults.

Population name	**Low IP**		**Moderate IP**		**High IP**		**Total IP area**	**Total IP length**	**10% SAS**	**20% SAS**
	Area (m^2)	Length (m)	Area (m^2)	Length (m)	Area (m^2)	Length (m)				
Baker River	664,185	33,456	756,160	13,600	1,429,939	48,977	2,850,284	96,033	5,028	10,056
Canyon Creek	38,897	1,198	0	0	52,800	1,600	91,697	2,798	121	243
Cedar River	194,567	19,704	26,506	12,431	2,560,148	98,155	2,781,221	130,290	5,949	11,899
Deer Creek	892,062	29,791	0	0	683,535	19,998	1,575,597	49,789	1,572	3,144
Drayton Harbor Tributaries	27,173	4,712	1,108	426	1,053,755	144,565	1,082,036	149,703	2,426	4,852
Dungeness River	377,935	16,488	17,732	27,031	1,053,909	25,799	1,449,576	69,318	2,465	4,930
East Hood Canal Tributaries	316,861	48,602	13,725	21,355	538,539	61,704	869,125	131,661	1,270	2,540
East Kitsap Peninsula Tributaries	137,480	40,273	63,470	41,482	613,683	105,698	814,633	187,453	1,557	3,115
Elwha River	821,470	26,380	1,609,610	29,113	1,484,141	44,188	3,915,221	99,681	7,116	14,231
Green River	1,575,485	105,150	5,378,593	142,598	3,216,399	195,118	10,170,477	442,866	19,768	39,537
Nisqually River	403,936	22,106	4,666,086	97,995	1,999,147	185,214	7,069,169	305,315	15,330	30,660
Nookachamps Creek	335,222	38,171	16,113	7,896	519,131	42,745	870,466	88,812	1,231	2,462
Nooksack River	1,049,951	62,533	5,066,204	125,680	4,518,781	263,717	10,634,936	451,930	22,045	44,091
North Fork Skykomish River	126,531	3,798	0	0	288,151	7,598	414,682	11,396	663	1,325
N. Lake Wash. & Lake Sammam.	314,181	60,580	71,368	44,554	2,219,024	196,643	2,604,573	301,777	5,268	10,536
Pilchuck River	188,570	16,504	37,520	16,026	2,220,396	144,372	2,446,486	176,902	5,193	10,386
Puyallup River	1,381,684	64,725	2,092,459	60,899	4,305,737	179,856	7,779,880	305,480	14,716	29,432
Samish R. & Bellingham Bay	227,796	27,173	64,002	29,465	1,324,222	128,158	1,616,020	184,796	3,193	6,386
Sauk River	2,768,556	93,608	7,235,046	101,598	2,864,886	94,149	12,868,488	289,355	23,230	46,460
Sequim/Discovery Bays Tribs.	112,707	36,528	12,661	41,573	209,957	27,463	335,325	105,564	512	1,024
Skagit River	1,875,151	99,753	24,639,163	168,235	3,524,068	185,443	30,038,382	453,431	64,775	129,551
Skokomish River	1,680,590	47,530	535,705	8,616	3,825,158	94,030	6,041,453	150,176	10,030	20,060
Snohomish/Skykomish Rivers	1,875,442	88,275	4,921,478	94,072	4,378,288	257,393	11,175,208	439,740	21,389	42,779
Snoqualmie River	460,438	34,104	5,335,600	62,000	1,942,496	142,803	7,738,534	238,907	16,740	33,479
South Fork Nooksack River	301,160	13,085	0	0	494,222	18,399	795,382	31,484	1,137	2,273
South Hood Canal Tributaries	277,401	34,043	0	0	1,297,905	117,841	1,575,306	151,884	2,985	5,970
South Puget Sound Tributaries	622,873	61,652	15,051	6,153	4,269,429	390,014	4,907,353	457,819	9,854	19,709
Stillaguamish River	1,502,178	93,530	4,207,466	103,583	4,104,756	229,107	9,814,400	426,220	19,118	38,236
Strait of Juan de Fuca Tributaries	351,837	45,542	11,281	7,669	305,255	20,930	668,373	74,141	728	1,456
Tolt River	92,503	3,799	0	0	139,380	5,600	231,883	9,399	321	641
West Hood Canal Tributaries	487,392	57,002	48,234	51,748	1,520,652	61,586	2,056,278	170,336	3,608	7,217
White River	1,465,480	77,561	4,784,282	71,150	2,820,242	126,362	9,070,004	275,073	17,490	34,981

Appendix E: Puget Sound Steelhead Hatchery Production from 1900 to 1945

This appendix contains a five-page table, continued horizontally by year.

Table E-1. Puget Sound steelhead (*Oncorhynchus mykiss*) hatchery production from 1900 to 1945. Release numbers represent fry or fingerlings (subyearlings). E = egg production (in addition to fish listed) and out = transfers of eggs or fish from the hatchery. Data for 1900–1911 are incomplete.

Basin	**Hatchery**	**1900**	**1901**	**1902**	**1903**	**1904**	**1905**	**1906**	**1907**	**1908**	**1909**
Nooksack	Kendall	—	—	—	—	—	—	55,000 E			
	Kendall (out)										
Samish	Samish										
	Samish (out)										
Skagit	Baker	26,000	—	110,000*	80,000 E 663,815	255,000 E 70,000	—	103,000 E 540,000			
	Birdsview	—	—	—	—	—	400,000 E				
	Birdsview (out)										
	Darrington										
	Day Creek										
	Illabott Creek										
	Sauk River	—	—	—	—	—	—	1,027,000 E			
	Skagit River										
Stillaguamish	Stillaguamish										
Snohomish	Snohomish	—	—	—	369,000 E	—	435,000	577,820 E			
	Pilchuck										
	Pichuck (out)										
	Skykomish (Startup)										
	Skykomish (out)										
	Sultan										
Green	Green/White	—	—	—	96,800 E	—	84,426	417,000			
	Green/White (out)										
Puyallup	Puyallup										
	Puyallup (out)										
South Sound	Chambers Creek										
	Chambers Creek (out)										
Nisqually	Nisqually	—	—	—	265,000 E	—	962,000	218,000 E			
Hood Canal	Skokomish	1,500,000									
	Tahuya Station										
	Dungeness (Brinnon)										
	Duckabush										
	Quilcene										
Dungeness	Dungeness	—	—	1,500,000	3,100,000 E	—	1,384,000	1,168,000			
Elwha	Elwha										
	Elwha (out)										
WDF est.:		—	—	—	—	2,395,150	2,886,926	3,463,970	4,429,575	3,681,450	4,855,000
USBF est.:	Fry	1,572,560	1,398,476	2,591,371	3,107,891	3,518,476	1,329,940	3,162,174	3,964,308	4,566,491	4,499,141
Total:	Fingerling	—	—	—	218,200	—	—	15,000			

* Egg-collection source was Finney Creek and Grandy Creek.

Table E-1 continued horizontally. Puget Sound steelhead hatchery production from 1900 to 1945. Release numbers represent subyearlings. E = egg production (in addition to fish listed) and out = transfers of eggs or fish from the hatchery. Data for 1900–1911 are incomplete.

Basin	**Hatchery**	**1910**	**1911**	**1912**	**1913**	**1914**	**1915**	**1916**	**1917**	**1918**	**1919**
Nooksack	Kendall	—	—	50,000	203,400	98,705	74,176	—	52,826	—	61,000
	Kendall (out)	—	—	—	—	—	—	—	—	40,000	
Samish	Samish	—	—	2,310,000	994,000	1,406,252	1,311,149	—	1,639,777	980,600	129,700
	Samish (out)										
Skagit	Baker	1,368,000	—	—	12,400						
	Birdsview	—	—	733,000 E 2,001,650	780,000 E 409,000	579,000 E 752,225	1,848,365	529,000 E 1,207,000	240,000	1,589,500	198,865
	Birdsview (out)	—	—	125,000 E	350,000 E	150,000 E	125,000 E				
	Darrington	—	—	—	114,000						
	Day Creek	769,000	—	—	—	—	47,500	—	—	43,000	
	Illabott Creek	—	—	255,665	347,500	187,755	60,000	277,000	451,000		
	Sauk River										
	Skagit River	—	—	95,000 E	38,920	27,849					
Stillaguamish	Stillaguamish	—	—	205,400	20,600 E	29,575	577,570	—	139,765		
Snohomish	Snohomish	—	—	—	—	66,740	119,225				
	Pilchuck	—	—	—	—	—	—	—	644,100	480,000	838,000
	Pichuck (out)	—	—	—	—	—	—	—	—	—	100,000
	Skykomish (Startup)	—	—	524,000 E	578,685	232,046	182,712	—	395,540	227,490	359,200
	Skykomish (out)										
	Sultan	—	—	—	486,700	112,000	292,425	34,000	—	50,000 E 60,000	92,500
Green	Green/White	—	—	315,200	516,500	505,150	558,750	—	198,600	42,600	277,500
	Green/White (out)										
Puyallup	Puyallup	—	—	—	—	—	—	—	—	390,200	153,200
	Puyallup (out)										
South Sound	Chambers Creek	—	—	—	—	—	—	—	119,300	395,000	160,000
	Chambers Creek (out)	—	—	—	—	—	—	—	—	—	10,000
Nisqually	Nisqually			1,500,000	740,365	305,932	981,402		123,220	112,200	Floods
Hood Canal	Skokomish	—	—	—	—	—	—	—	—	114,825	56,560
	Tahuya Station										
	Dungeness (Brinnon)	—	—	—	—	—	35,000 E	100,000	—	129,000	
	Duckabush	—	—	—	200,00 E 258,000	603,000	—	91,000	689,700	446,840	
	Quilcene	—	—	47,000 E 27,000	34,000	37,700	101,400	—	626,500	284,000	50,000 E 170,000
Dungeness	Dungeness	—	—	912,456	—	—	589,850	—	633,000	189,537	784,800
Elwha	Elwha	—	—	—	—	—	—	—	395,200	38,000	24,600
	Elwha (out)										
WDF est.:		5,234,240	5,912,656	11,059,000	3,462,639	4,975,460	5,545,652	5,545,653	567,625	3,551,830	3,764,450
USBF est.:	Fry	6,292,338	4,841,330	3,732,805	9,731,400	4,444,271	4,922,555	5,102,566	1,979,010	4,851,092	3,152,452
Total:	Fingerling	—	—	1,000	—	—	—	891,000	1,420,500	352,420	

Table E-1 continued horizontally. Puget Sound steelhead (*Oncorhynchus mykiss*) hatchery production from 1900 to 1945. Release numbers represent fry or fingerlings (subyearlings). E = egg production (in addition to fish listed) and out = transfers of eggs or fish from the hatchery. Data for 1900–1911 are incomplete.

Basin	**Hatchery**	**1920**	**1921**	**1922**	**1923**	**1924**	**1925**	**1926**	**1927**	**1928**	**1929**
Nooksack	Kendall	80,200	19,425	—	—	—	122,500	105,600	—	141,775	122,250
	Kendall (out)	—	—	—	—	—	—	—	122,975		
Samish	Samish	9,575	661,783	273,955	271,316	1,789,790	141,655	842,100	963,550	499,905	923,840
	Samish (out)	—	279,500	667,000 E 167,000	751,000	250,000	—	800,000	400,000	375,000	400,000
Skagit	Baker										
	Birdsview	255,000	128,250	78,000	93,305	550,000	418,000	346,500	200,000 E 715,600	1,585,000	750,000
	Birdsview (out)	—	85,000	55,000	—	—	100,000	—	—	25,000	
	Darrington										
	Day Creek										
	Illabott Creek										
	Sauk River										
	Skagit River										
Stillaguamish	Stillaguamish										
Snohomish	Snohomish										
	Pilchuck	229,900	335,200	—	—	—	—	—	—	—	2,071,000
	Pichuck (out)	100,000	200,000	—	—	—	—	—	—	—	600,000
	Skykomish (Startup)	151,200	264,855	287,509	486,408	609,730	348,915	334,390	482,950	684,760	664,894
	Skykomish (out)	—	100,000	25,000	250,000	50,000	—	250,000	200,000	100,000	200,000
	Sultan	92,000	76,800	104,400	207,800	216,000	83,000	64,000		474,500	247,500
Green	Green/White	70,100	41,300	32,000	—	450,500	204,500	65,000	50,000	221,000	335,000
	Green/White (out)	490,000	44,000 E 226,000	—	—	20,000	—	283,000			
Puyallup	Puyallup	273,237	—	—	—	—	—	—	—	—	138,250
	Puyallup (out)										
South Sound	Chambers Creek	273,000	385,000								
	Chambers Creek (out)	105,000	109,600								
Nisqually	Nisqually										
Hood Canal	Skokomish										
	Tahuya Station	2,000									
	Dungeness (Brinnon)	—	100,000								
	Duckabush	405,000	1,095,000	90,300	139,445	209,110	90,400	34,200	60,100		
	Quilcene	460,000	303,500	83,400	545,555	658,400	50,000	100,000	44,000	190,500	540,000
Dungeness	Dungeness	1,068,100	144,350	253,000	939,000	839,000	223,000	470,000	331,000	—	304,000
Elwha	Elwha	150,500	121,000								
	Elwha (out)	—	—	22,000							
WDF est.:		3,784,050									
USBF est.:	Fry										
Total:	Fingerling										

Table E-1 continued horizontally. Puget Sound steelhead (*Oncorhynchus mykiss*) hatchery production from 1900 to 1945. Release numbers represent fry or fingerlings (subyearlings). E = egg production (in addition to fish listed) and out = transfers of eggs or fish from the hatchery. Data for 1900–1911 are incomplete.

Basin	**Hatchery**	**1930**	**1931**	**1932**	**1933**	**1934**	**1935**	**1936**	**1937**	**1938**	**1939**
Nooksack	Kendall	65,175	—	—	—	—	—	268,500	128,000	88,000	36,579
	Kendall (out)	250,000									
Samish	Samish	1,040,170	—	—	—	—	1,116,900	2,725,700	1,392,800	2,196,100	799,511
	Samish (out)	50,000									
Skagit	Baker										
	Birdsview	535,000 E 462,000	90,000 E 281,680	616,000	113,000 E 672,000	1,145,000	603,000	289,000	184,000	666,500	813,700
	Birdsview (out)	—	—	143,000	—	110,000	—	—	375,000	—	35,000
	Darrington										
	Day Creek										
	Illabott Creek										
	Sauk River										
	Skagit River										
Stillaguamish	Stillaguamish										
Snohomish	Snohomish										
	Pilchuck	984,700									
	Pichuck (out)										
	Skykomish (Startup)	848,500	—	—	—	—	50,000	71,500	93,000	60,000	51,110
	Skykomish (out)										
	Sultan	431,000	73,800	270,660							
Green	Green/White	87,000	—	—	—	—	5,000	40,000	48,000	107,000	95,197
	Green/White (out)										
Puyallup	Puyallup	430,000	—	—	—	—	674,000	585,000	628,000	597,000	86,670
	Puyallup (out)	33,827									
South Sound	Chambers Creek										
	Chambers Creek (out)										
Nisqually	Nisqually										
Hood Canal	Skokomish										
	Tahuya Station										
	Dungeness (Brinnon)										
	Duckabush	206,000	—	19,000	108,000	53,500					
	Quilcene	578,000	50,000 E 204,000	50,000 E 380,000	283,319	290,500	185,500	153,000	259,115	322,305	39,020
Dungeness	Dungeness	771,000	683,000	394,000	968,500	806,500	1,265,000	1,080,000	978,000	712,000	995,414
Elwha	Elwha										
	Elwha (out)										
WDF est.:		—	—	413,000	1,076,500	860,000	3,105,900	4,462,200	3,091,800	3,565,100	1,932,705
USBF est.:	Fry										
Total:	Fingerling	—	—	996,000	955,319	1,435,500	788,500	442,000	443,115	988,805	852,720

Table E-1 continued horizontally. Puget Sound steelhead (*Oncorhynchus mykiss*) hatchery production from 1900 to 1945. Release numbers represent fry or fingerlings (subyearlings). E = egg production (in addition to fish listed) and out = transfers of eggs or fish from the hatchery. Data for 1900–1911 are incomplete.

Basin	**Hatchery**	**1940**	**1941**	**1942**	**1943**	**1944**	**1945**
Nooksack	Kendall						
	Kendall (out)						
Samish	Samish	456,24	555,485	486,267	219,152	118,315	502,947
	Samish (out)						
Skagit	Baker						
	Birdsview	810,000					
	Birdsview (out)	38,500					
	Darrington						
	Day Creek						
	Illabott Creek						
	Sauk River						
	Skagit River						
Stillaguamish	Stillaguamish						
Snohomish	Snohomish						
	Pilchuck						
	Pichuck (out)						
	Skykomish (Startup)	10,814					
	Skykomish (out)						
	Sultan						
Green	Green/White	25,488					
	Green/White (out)						
Puyallup	Puyallup	167,223					
	Puyallup (out)						
South Sound	Chambers Creek						
	Chambers Creek (out)						
Nisqually	Nisqually						
Hood Canal	Skokomish						
	Tahuya Station						
	Dungeness (Brinnon)						
	Duckabush						
	Quilcene	509,285					
Dungeness	Dungeness	405,701	189,050	1,014,568	—	221,763	121,659
Elwha	Elwha						
	Elwha (out)						
WDF est.:		1,039,986	744,535	1,500,835	219,152	340,078	624,606
USBF est.:	Fry						
Total:	Fingerling	1,319,285					

Appendix F: Puget Sound Steelhead Fisheries Reported Harvest for Years 1895, 1904, and 1909

Table F-1. Steelhead (*Oncorhynchus mykiss*) fisheries reported harvest by county for 1895 (Wilcox 1898).

County	**Gear (catch kg)** Gill net	Seine net	**Total (kg)**	**Count (@ 4.5 kg)**	**Run (40% harvest)**
Clallam	—	—	0	0	0
Jefferson	—	—	0	0	0
Pierce	—	—	0	0	0
King	204,704	—	204,704	45,490	113,725
Snohomish	264,372	—	264,372	58,749	146,873
Skagit	93,268	—	93,268	20,726	51.815
Whatcom	347,856	10,503	358,359	79,635	199,088
		Total:	**920,703**	**204,600**	**511,500**

Table F-2. Steelhead fisheries reported harvest by county for 1904 (Wilcox 1905).

County	**River**	**Total (kg)**	**Count (@ 4.5 kg)**	**Run (40% harvest)**
Clallam	Hoh, Elwha	23,636	5,253	13,132
Jefferson	Coast/Hood Canal	11,363	2,525	6,313
Kitsap	—	11,363	2,525	6,313
Mason	Skokomish	11,363	2,525	6313
Thurston	—	0	0	0
Pierce	—	0	0	0
King	Green	82,020	18,237	45,566
Snohomish	Snohomish	53,409	11,868	29,671
Skagit	Skagit	18,181	4,040	10,100
Whatcom	Nooksack	130,754	29,056	72,641
	Total:	**342,089**	**76,029**	**190,049**

Table F-3. Steelhead fisheries reported harvest by county for 1909 (Cobb 1911).

County	River	Total (kg)	Count (@ 4.5 kg)	Run (40% harvest)
Clallam	Hoh, Elwha	21,470	4,771	11,927
Jefferson	Coast/Hood Canal	6,334	1,408	3,520
Kitsap	—	11,036	2,453	6,133
Mason	Skokomish	3,455	768	1,920
Thurston	South Sound	13,818	3,070	7,675
Pierce	Puyallup/Nisqually	50,182	11,152	27,880
King	Green	99,591	22,131	55,327
Snohomish	Snohomish	76,929	17,095	74,178
Skagit	Skagit	60,285	27,402	68,505
Whatcom	Nooksack	3,181	707	1,768
	Total:	**346,281**	**90,957**	**258,833**

Appendix G: Steelhead Smolt Releases into Puget Sound Tributaries from 1965 to 2008

This appendix contains a four-page table for winter-run steelhead (*Oncorhynchus mykiss*) and a four-page table for summer-run steelhead. Both are continued horizontally by year.

Table G-1. Releases of winter-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**
Dakota Creek	—	—	—	—	—	—	—	10,000					
Nooksack River	—	—	—	—	—	—	—	35,261	62,600	34,219	10,000	20,019	87,680
Whatcom Creek/Squalicum	—	—	—	—	—	—	—	—	—	8,650	—	10,075	9,702
Samish River	42,900	48,667	38,604	43,151	55,440	62,708	60,642	41,960	43,477	24,492	40,013	77,860	75,375
Skagit River System	183,669	250,297	201,308	278,327	360,963	307,107	349,579	155,202	289,608	147,503	124,710	261,943	358,839
Skagit River main stem	143,570	179,454	113,659	187,370	270,761	227,079	297,050	125,600	214,309	86,889	66,075	145,780	328,521
Nookachamps/Big Lake	—	—	—	—	—	—	—	—	—	20,900	—	55,120	
Baker River													
Sauk River	40,099	68,893	75,786	58,863	59,712	47,022	52,529	29,602	64,695	29,120	38,235	45,300	30,318
Cascade River	—	1,950	11,863	32,094	30,490	33,006	—	—	10,604	10,594	20,400	15,743	
Stillaguamish River System	87,416	116,946	107,190	126,580	141,569	105,405	100,989	115,728	110,630	87,808	106,009	217,296	139,513
Stillaguamish main stem	—	—	—	—	36,000	—	—	—	—	—	—	89,202	
Canyon Creek	—	—	—	—	—	18,058	5,468	—	—	—	—	10,123	12,104
Pilchuck Creek (Still.)	17,440	19,970	18,240	20,055	15,218	16,664	2,895	14,532	8,105	9,606	10,547	28,769	33,564
North Fork	69,976	68,080	88,950	55,475	67,873	50,748	70,991	71,047	72,480	58,937	70,188	68,915	72,536
South Fork	—	28,896	—	51,050	22,478	19,935	21,635	30,149	30,045	19,265	25,274	20,287	21,309
Snohomish River System	303,073	252,032	212,53	266,588	469,136	332,843	332,428	364,406	389,579	417,714	345,894	583,717	664,396
Skykomish River	64,635	58,411	19,920	55,045	100,202	54,717	37,790	58,768	65,230	59,245	60,951	89,139	149,148
Pilchuck River (Snoho.)	19,500	28,162	25,691	25,060	42,826	23,486	44,538	35,260	36,362	47,191	40,002	40,247	34,797
Snoqualmie River	44,000	42,240	31,006	51,334	59,993	47,886	59,903	60,242	65,152	52,298	41,786	133,948	139,691
Tolt River	42,712	20,000	10,005	19,710	34,163	26,985	16,733	17,221	20,084	26,968	24,535	32,190	41,540
Raging River													
Sultan River	—	—	—	—	—	—	15,062	10,001	10,160	25,010	13,206	—	21,063
Wallace River	10,000	8,260	16,920	20,005	15,578	—	15,132	9,976	—	25,024	—	20,138	15,010
N. F. Skykomish River	26,200	—	9,867	9,992	20,076	60,224	—	25,652	14,956	15,000	15,272	30,437	
Lake Wash. System	28,696	15,120	22,975	—	41,393	19,964	30,047	20,261	24,216	91,920	59,800	56,610	62,191
Green River (King Co.)	67,330	79,839	76,151	85,442	154,905	99,581	113,223	127,025	153,419	75,058	90,342	181,008	200,956
Puyallup River System	65,129	99,803	66,516	99,617	127,676	167,271	122,418	107,441	105,449	91,338	145,630	38,682	113,422
Puyallup River	65,129	81,804	66,516	87,536	101,909	137,133	101,767	89,314	75,419	71,618	125,454	15,330	83,310
White (Stuck) River	—	17,999	—	12,081	25,767	30,138	20,651	18,127	30,030	19,720	20,176	23,352	30,112
Carbon River (Voight Cr.)	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.	w/Puyall.
Nisqually River	—	26,334	20,312	19,630	30,492	17,170	26,547	24,841	23,136	14,974	16,030	10,000	9,950
Deschutes River	10,200	24,480	20,131	7,800	40,435	14,779	12,175	39,661	38,721	29,055	24,868	39,592	41,400
Kennedy Creek	—	—	—	—	—	—	—	—	—	10,001	10,200	10,000	15,005
Burley Creek	—	—	—	—	—	—	—	—	—	—	—	—	10,025
Goldsborough Creek	5,082	4,290	—	4,410	—	11,872	—	—	5,025	14,649	5,100	10,165	15,000
Curley Creek/Kitsap	—	—	—	—	—	—	—	—	—	—	—	—	5,025
Dewatto River	—	—	—	—	10,020	3,600	—	10,060	8,640	10,014	10,013	10,000	
Tahuyha River	—	4,971	5,055	5,022	9,860	9,967	10,107	10,229	10,328	1,003	10,040	10,295	10,000
Union River	—	5,012	—	5,084	10,330	9,998	10,112	10,126	10,068	10,000	9,993	17,850	10,066
Skokomish River	14,730	21,000	5,257	15,431	39,389	43,640	20,022	20,010	15,090	13,847	18,775	—	35,759
Hamma Hamma													
Duckabush River	—	—	—	—	—	19,987	19,017	20,010	19,825	20,119	15,000	35,477	20,005
Dosewallips River	—	—	—	—	—	20,160	20,025	20,015	19,800	20,007	44,180	25,033	40,046
Quilcene River	—	—	—	—	—	10,260	10,350	10,356	10,046	20,849	10,547	15,000	15,080
Dungeness River	12,535	15,017	14,125	10,516	25,841	24,300	20,355	17,680	13,942	25,137	20,050	30,004	40,067
Morse Creek	3,544	—	—	—	—	—	—	—	—	—	—	4,174	10,032
Elwha River	24,000	15,000	14,694	12,306	38,998	15,022	15,347	17,180	20,076	20,100	20,075	20,02	30,374
Total for year:	0.85	0.98	0.80	0.98	1.56	1.30	1.27	1.17	1.37	1.19	1.14	1.68	2.00

Table G-1 continued horizontally. Releases of winter-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
Dakota Creek													
Nooksack River	69,572	57,759	55,795	70,470	65,900	81,485	130,900	110,100	123,800	131,000	111,000	109,400	100,100
Whatcom Creek/Squalicum	10,032	9,900	8,000	103,000	7,000	10,000	10,000	14,300	7,600	6,400	6,600	11,200	13,500
Samish River	80,200	80,007	90,600	41,100	40,100	46,951	45,138	30,100	27,800	29,900	40,900	39,000	50,100
Skagit River System	275,847	372,227	283,417	171,700	236,700	237,300	258,200	336,400	298,400	136,000	228,300	286,800	172,200
Skagit River main stem	244,467	273,385	166,678	5,247	—	167,100	197,000	276,000	269,200	112,400	203,300	251,800	163,000
Nookachamps/Big Lake													
Baker River													
Sauk River	31,380	98,842	78,758	20,953	30,278	20,700	61,200	60,400	29,200	16,100	25,000	35,000	9,200
Cascade River	—	—	37,981	27,192	25,471	49,500							
Stillaguamish River System	103,726	56,881	83,897	111,554	91,241	127,542	110,000	114,600	117,500	128,900	116,100	145,300	122,000
Stillaguamish main stem	—	—	—	—	29,498	33,944							
Canyon Creek	9,983	—	—	7,498	6,300	11,998	12,300	12,700	10,100	9,300	11,900	10,600	9,800
Pilchuck Creek (Still.)	—	13,159	31,842	29,068	25,172	10,000	15,500	10,000	10,300	5,000	15,000	15,000	10,100
North Fork	77,659	20,494	26,851	52,466	20,248	49,600	64,900	71,800	77,100	90,800	63,800	101,200	102,100
South Fork	16,084	23,228	25,204	22,522	10,023	22,000	17,300	20,100	20,000	23,800	25,400	18,500	
Snohomish River System	593,274	481,599	501,886	521,995	437,934	335,200	227,300	359,900	353,100	230,000	436,800	424,900	350,200
Skykomish River	141,801	108,873	118,522	84,796	80,496	170,500	29,600	125,800	151,100	90,200	155,200	159,600	139,100
Pilchuck River (Snoho.)	39,915	—	—	—	—	21,000	19,600	28,800	24,300	19,100	26,700	30,400	5,700
Snoqualmie River	94,265	99,539	91,299	105,002	100,650	65,200	89,800	119,400	93,600	62,000	129,700	122,500	117,400
Tolt River	37,915	6,666	40,714	28,400	16,664	16,700	20,000	20,100	14,800	10,900	47,600	35,000	40,900
Raging River	—	—	—	—	—	12,000	14,600	15,000	16,000	9,800	13,900	10,200	10,300
Sultan River	18,239	17,727	16,927	38,451	20,000	15,300	20,300	10,500	10,500	10,800	23,000	19,800	15,400
Wallace River	7,840	20,894	20,224	20,246	15,024	20,000	20,400	20,100	20,700	12,100	7,800	25,000	
N. F. Skykomish River	25,199	—	—	—	—	14,500	13,000	20,200	22,100	15,100	32,900	22,400	21,400
Lake Wash. System	33,600	39,200	52,600	56,800	38,500	45,000	64,900	66,400	50,300	75,200	76,800	48,900	50,160
Green River (King Co.)	194,500	188,700	161,600	188,300	166,600	164,600	221,100	223,500	151,100	140,000	186,100	231,300	225,800
Puyallup River System	174,449	67,265	92,516	88,605	86,213	106,844	149,800	167,100	186,078	132,517	165,800	138,700	169,400
Puyallup River	101,449	54,265	92,516	73,539	81,171	85,900	139,800	157,100	176,100	132,500	140,700	123,500	149,400
White (Stuck) River	73,000	13,000	—	15,066	5,042	10,444							
Carbon River (Voight Cr.)	w/Puyall.	14,000	—	6,270	17,228	10,500	10,000	10,000	10,000	—	25,100	15,200	20,000
Nisqually River	10,000	10,000	30,200	10,000	35,400								
Deschutes River	40,800	32,600	40,300	30,000	19,100	32,100	32,000	24,500	25,100	9,500	35,000	49,300	22,300
Kennedy Creek	15,000	15,000	10,100	15,200	6,400	18,000	18,100	11,300	15,000	4,900	15,500	15,000	10,000
Burley Creek	10,080												
Goldsborough Creek	17,400	15,000	15,200	15,000	3,100	13,000	13,000	4,900	10,100	5,200	10,100	15,000	10,100
Curley Creek/Kitsap	10,080												
Dewatto River	10,000	10,010	10,254	12,400	9,996	12,000	12,000	11,000	9,900	3,000	10,100	14,800	10,000
Tahuyha River	9,900	10,100	10,500	10,700	8,400	15,100	10,300	10,000	10,000	10,000	10,000	15,000	
Union River	10,000	10,100	10,300	9,900	10,010	10,000	10,000	9,400	10,000	10,000	15,000	14,850	10,035
Skokomish River	18,700	10,500	17,000	27,200	14,800	27,082	29,600	23,100	20,900	20,000	44,800	39,975	39,000
Hamma Hamma													
Duckabush River	26,400	15,100	15,000	17,800	18,100	20,000	20,000	20,100	22,300	5,000	20,000	20,000	15,000
Dosewallips River	30,000	25,200	23,200	23,700	18,200	20,000	25,100	20,800	19,600	15,000	25,400	25,000	15,100
Quilcene River	15,000	15,300	9,585	15,043	13,060	11,900	10,300	10,200	10,200	5,300	5,100	10,160	10,100
Dungeness River	30,300	24,800	20,000	20,100	17,000	18,600	14,800	15,900	15,400	15,545	20,100	20,123	20,300
Morse Creek	15,000	12,900	12,300	18,000	15,400	16,400	15,500	15,900	18,800	15,200	15,000	15,514	10,100
Elwha River	45,200	60,400	51,000	66,400	63,600	86,300	95,600	90,000	118,800	73,600	88,200	118,600	46,100
Total for year:	1.83	1.62	1.61	1.67	1.43	1.46	1.52	1.69	1.62	1.20	1.68	1.81	1.47

Table G-1 continued horizontally. Releases of winter-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Dakota Creek													
Nooksack River	55,000	47,400	81,800	70,500	75,900	89,300	43,300	63,900	33,900	35,000	56,500	34,800	160,000
Whatcom Creek/Squalicum	10,000	7,200	5,500	6,500	5,100	9,700	5,400	20,000	20,100	—	5,000	—	5,370
Samish River	13,900	27,000	19,600	6,600	32,100	31,200	22,900	47,900	12,100	25,000	31,000		
Skagit River System	205,800	166,300	364,200	446,400	354,100	289,000	328,400	562,700	414,400	417,600	463,500	241,200	513,330
Skagit River main stem	183,100	145,900	332,600	415,800	239,200	202,900	194,300	400,600	238,300	214,300	242,000	20,000	225,000
Nookachamps/Big Lake													
Baker River	—	—	—	—	—	—	—	—	49,000	60,000	93,000	—	68,000
Sauk River	22,700	20,400	31,600	30,600	30,200	25,900	21,600	30,800	26,800	20,900	21,800	21,200	20,000
Cascade River	—	—	—	—	84,700	60,200	112,500	131,300	100,300	122,400	106,700	200,000	200,330
Stillaguamish River System	137,900	106,800	133,200	140,600	122,900	130,900	100,175	162,700	106,500	98,600	129,800	138,600	161,662
Stillaguamish main stem	—	19,100	—	—	—	—	—	8,000	—	—	—	15,700	
Canyon Creek	10,100	10,000	10,200	10,300	5,000	15,000	9,975	10,200	9,100	10,000	—	4,700	15,225
Pilchuck Creek (Still.)	15,800	4,700	10,000	4,000	4,900	10,700	—	10,000					
North Fork	96,000	73,000	113,000	119,200	113,000	105,200	90,200	132,500	97,400	88,600	121,400	118,200	146,437
South Fork	16,000	—	—	7,100	—	—	—	2,000	—	—	8,400		
Snohomish River System	345,000	343,200	436,200	326,600	288,600	414,900	196,200	474,000	442,700	402,300	418,000	418,650	433,552
Skykomish River	128,300	129,100	161,000	110,200	111,300	173,000	44,200	132,600	161,200	119,700	112,600	133,400	143,584
Pilchuck River (Snoho.)	21,400	14,900	28,400	7,500	25,000	21,900	14,800	20,700	31,200	34,200	29,000	25,500	35,295
Snoqualmie River	114,000	153,500	150,000	113,800	100,300	117,200	93,400	184,400	151,900	145,400	180,900	165,500	161,661
Tolt River	23,400	10,700	39,300	35,700	17,400	35,300	9,100	30,900	24,800	20,900	21,200	20,000	20,017
Raging River	4,000	4,100	10,900	8,600	10,100	14,900	9,000	14,100	10,000	10,400	11,700	10,000	11,795
Sultan River	16,200	5,800	8,500	20,300	12,400	17,200	7,700	43,600	45,000	35,900	17,700	29,100	24,575
Wallace River	19,100	15,000	18,800	20,200	12,100	20,200	13,000	5,200	14,800	15,800	20,000	20,000	19,700
N. F. Skykomish River	18,600	10,100	19,300	10,300	—	15,200	5,000	42,500	3,800	20,000	24,900	15,150	16,925
Lake Wash. System	38,000	—	—	—	—	—	—	—	12,400	14,300			
Green River (King Co.)	212,400	137,000	197,400	231,200	237,700	210,900	262,300	220,100	285,800	274,600	280,000	102,200	155,432
Puyallup River System	182,800	123,600	336,500	317,000	221,500	252,900	235,550	223,500	240,300	305,600	207,300	211,300	200,000
Puyallup River	162,900	98,500	287,700	238,600	152,300	179,300	157,700	14,800	42,100	107,000	10,000		
White (Stuck) River	—	41,300	24,900	19,700	24,900	24,000	18,600	19,600	18,200	20,000	21,000	20,000	
Carbon River (Voight Cr.)	19,900	25,100	23,900	58,700	44,300	49,600	59,250	189,100	180,000	178,600	176,300	191,300	200,000
Nisqually River													
Deschutes River	10,100	15,000	20,000	15,600	—	95,900	18,000	29,400	26,900	—	24,400	25,000	27,000
Kennedy Creek	5,000	10,200	7,900	7,000	—	10,000							
Burley Creek													
Goldsborough Creek	5,000	9,300	9,100	14,200									
Curley Creek/Kitsap													
Dewatto River													
Tahuyha River	—	—	9,800	14,976									
Union River	5,000	10,000	11,500	15,028									
Skokomish River	19,900	28,500	20,000	39,130	39,296	53,684	14,688	53,495	46,700	62,300	63,000	68,400	55,803
Hamma Hamma	—	—	—	—	—	—	—	—	1,524	1,336	489	1,454	877
Duckabush River		15,100	17,000	15,142	5,000	10,080	—	10,032	10,638	10,200	10,000	10,000	10,032
Dosewallips River	5,600	15,000	20,100	14,742	5,000	12,648	—	12,500	12,300	12,500	12,600	12,500	12,533
Quilcene River													
Dungeness River	15,000	15,100	15,300	18,800	9,900	10,000	9,800	9,000	11,000	10,500	12,200	10,250	13,715
Morse Creek	14,700	15,200	15,400	15,338	15,029	5,100	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Elwha River	91,000	83,500	229,100	92,400	94,000	170,100	59,600	61,300	182,200	225,200	120,000	151,700	99,600
Total for year:	1.37	1.18	1.95	1.81	1.51	1.80	1.30	1.96	1.86	1.90	1.84	1.43	1.85

Table G-1 continued horizontally. Releases of winter-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**2004**	**2005**	**2006**	**2007**	**2008**	**21-yr avg**	**10-yr avg**
Dakota Creek							
Nooksack River	—	—	—	—	—	83,099	66,310
Whatcom Creek/Squalicum	—	—	—	—	—	8,546	7,717
Samish River	—	—	—	—	—	27,580	20,880
Skagit River System	529,821	466,100	517,000	511,560	235,010	329,561	403,063
Skagit River main stem	243,500	200,000	210,000	185,000	20,000	223,514	239,240
Nookachamps/Big Lake							
Baker River	70,000	30,000	30,000	30,000	30,000	12,857	27,000
Sauk River	20,000	20,000	30,000	30,000	10	27,681	24,980
Cascade River	196,321	216,100	247,000	266,560	185,000	55,973	111,843
Stillaguamish River System	150,027	152,427	148,760	153,937	145,734	127,378	129,244
Stillaguamish main stem	—	—	—	—	—	4,039	2,633
Canyon Creek	—	—	—	—	—	9,928	8,950
Pilchuck Creek (Still.)	5,226	10,000	10,004	10,018	1,080	7,190	2,960
North Fork	144,801	142,427	138,756	143,919	144,654	96,926	113,214
South Fork	—	—	—	—	—	8,600	1,750
Snohomish River System	442,790	444,677	442,308	436,224	439,326	368,186	381,550
Skykomish River	173,500	160,025	184,324	181,536	150,740	127,680	124,178
Pilchuck River (Snoho.)	33,314	25,108	28,014	35,025	25,314	23,114	24,510
Snoqualmie River	156,333	188,573	160,437	177,712	166,585	125,312	141,446
Tolt River	22,160	—	—	—	24,970	24,510	23,532
Raging River	4,650	15,117	20,273	—	24,998	11,019	11,060
Sultan River	19,906	20,270	15,660	15,073	25,014	19,504	25,348
Wallace River	18,500	22,000	22,000	26,878	21,705	16,190	16,100
N. F. Skykomish River	14,427	13,584	11,600	—	—	17,304	15,378
Lake Wash. System	—	—	—	—	—	25,827	2,670
Green River (King Co.)	76,895	253,318	243,246	254,669	281,430	207,168	226,023
Puyallup River System	231,859	207,400	211,900	128,000	218,353	203,031	241,495
Puyallup River	—	—	—	—	—	134,521	112,725
White (Stuck) River	—	—	—	—	56,378	21,887	20,667
Carbon River (Voight Cr.)	231,859	207,400	211,900	128,000	161,975	74,843	132,715
Nisqually River							
Deschutes River	30,400	24,550	—	—	—	28,268	32,775
Kennedy Creek	—	—	—	—	—	11,377	8,500
Burley Creek							
Goldsborough Creek	—	—	—	—	—	9,917	14,200
Curley Creek/Kitsap							
Dewatto River	—	—	—	—	—	10,350	
Tahuyha River	—	—	—	—	—	11,686	14,976
Union River	—	—	—	—	—	10,901	15,028
Skokomish River	49,946	—	—	—	4,091	38,541	49,650
Hamma Hamma		965	—	—	131	1,136	1,136
Duckabush River	—	—	—	—	—	13,980	10,125
Dosewallips River	—	—	—	—	—	15,701	11,925
Quilcene River	—	—	—	—	—	9,158	
Dungeness River	10,500	—	10,900	10,700	10,200	14,349	11,517
Morse Creek	5,000	—	—	—	—	11,342	7,047
Elwha River	59,500	—	38,850	29,150	267,899	113,186	125,610
Total for year:	1.59	1.55	1.61	1.52	1.60	1.63	1.73

Table G-2. Releases of summer-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**
Nooksack River	—	—	—	—	—	—	—	—	—	—	20,028	
Whatcom Creek												
Skagit River System												
Skagit River main stem	—	—	—	—	—	—	132,726	141,503	92,187	69,432	50,413	36,470
Sauk River												
Cascade River	—	—	—	—	—	—	48,815	—	11,380	30,656	26,775	15,369
Stillaguamish R. System												
Stillag. main stem												
Canyon Creek	—	—	—	—	—	—	—	—	26,678	11,358	9,900	12,815
South Fork	12,462	—	43,000	28,170	26,164	21,627	17,139	20,934	24,610	52,732	21,466	17,034
North Fork	26,902	33,050	32,020	33,240	36,264	91,944	46,288	44,981	48,888	55,893	43,902	28,169
Snohomish River System												
Skykomish River	24,350	11,520	35,110	—	—	—	—	9,240	—	—	76,374	74,975
Pilchuck River (Snoho.)												
Snohomish River												
Snoqualmie River	—	—	20,005	31,967	—	—	23,088	25,622	19,764	30,854	41,300	20,988
Tolt River	22,200	14,130	—	—	—	43,505	25,787	15,886	35,993	47,901	34,799	17,297
Raging River												
Sultan River												
Wallace River												
N. F. Skykomish River	9,900	39,635	32,860	40,005	39,322	5,783	37,183	18,518	57,045	66,720	20,662	10,923
S. F. Skykomish River											11,121	10,278
Green River (King Co.)	—	—	—	—	—	49,713	64,440	58,532	68,921	58,328	94,477	63,840
Puyallup River System												
White (Stuck) River												
Carbon R. (Voight Cr.)												
Nisqually River												
Deschutes River												
East Hood Canal	—	—	—	—	—	17,450						
Skokomish River	—	—	—	—	—	—	—	20,130	20,430	21,588	20,085	
West Hood Canal												
Dungeness River	—	—	—	—	—	—	—	—	—	20,025	20,136	19,430
Morse Creek												
Elwha River	—	—	—	20,127	22,747	21,180	20,940	20,010	20,195	20,080	30,600	19,926
Total for year:	120,814	138,335	192,995	178,593	124,497	289,227	427,456	382,265	453,071	514,995	551,248	347,514

Table G-2 continued horizontally. Releases of summer-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**
Nooksack River	—	63,000	—	3,078	10,818							
Whatcom Creek												
Skagit River System	—	—	—	—	—	—	—	—	—	—	0	30,900
Skagit River main stem	63,962	59,731	23,306	53,559	73,322	—	30,958	—	10,022	10,089		
Sauk River	—	—	—	—	7,463							
Cascade River	15,930	22,345	60,966	16,279	29,081	—	—	34,897	10,104	25,030	—	30,900
Stillaguamish R. System	—	—	—	—	—	—	—	—	—	—	73,111	82,800
Stillag. main stem	—	—	—	—	—	—	—	—	—	—	3,500	
Canyon Creek	13,616	12,699	—	5,121	5,217	—	—	2,475	10,877	10,243	9,711	9,700
South Fork	24,097	24,236	25,018	—	33,071	—	—	34,143	15,806	26,342	—	18,500
North Fork	47,260	53,413	53,184	121,543	39,160	27,704	24,530	42,167	33,014	63,172	59,900	54,600
Snohomish River System	—	—	—	—	—	—	—	—	—	—	63,100	233,000
Skykomish River	62,629	64,307	61,478	59,409	24,960	54,598	65,760	112,063	36,744	95,235	63,100	76,400
Pilchuck River (Snoho.)												
Snohomish River												
Snoqualmie River	35,956	16,951	16,951	17,955	7,655	16,650	—	16,650	27,376	68,381	—	72,700
Tolt River	37,055	30,337	11,598	32,498	23,651	15,952	11,763	7,854	11,013	14,175	—	15,800
Raging River	—	—	—	—	—	—	—	5,050	5,785	5,600	—	4,100
Sultan River	7,623	—	—	—	—	—	—	18,677	20,378	9,800	—	19,400
Wallace River												
N. F. Skykomish River	42,460	35,530	32,500	41,290	—	13,342	19,147	26,935	16,322	18,092	—	24,700
S. F. Skykomish River	10,236	4,930	52,833	18,469	25,485	15,000	8,165	32,132	11,665	20,287	—	19,900
Green River (King Co.)	93,872	90,016	140,044	118,666	54,096	76,633	76,398	72,208	69,304	114,085	—	74,800
Puyallup River System	—	—	—	—	—	—	—	—	—	—	0	0
White (Stuck) River												
Carbon R. (Voight Cr.)												
Nisqually River	29,120	19,500	47,640	19,355	11,250	20,243	34,390	42,646	19,952	26,028	—	22,200
Deschutes River	689	—	—	—	—	—	—	—	—	—	115,011	
East Hood Canal												
Skokomish River	—	—	20,215	17,010	10,107							
West Hood Canal	—	—	—	—	15,043							
Dungeness River	19,530	18,300	20,025	10,010	5,141	4,530	4,150	5,000	10,371	5,150	10,200	10,100
Morse Creek												
Elwha River	20,776	27,100	20,007	20,020	26,115	17,820	15,175	20,285	20,747	18,949	19,800	25,400
Total for year:	524,811	542,395	585,765	554,262	401,635	262,472	290,436	473,182	329,480	530,658	281,222	479,200

Table G-2 continued horizontally. Releases of summer-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Nooksack River												
Whatcom Creek												
Skagit River System	0	24,100	18,700	19,800	32,300	27,000	25,200	25,000	0	21,000	0	0
Skagit River main stem	—	24,100	18,700	19,800	27,300	27,000	25,200	25,000	—	21,000		
Sauk River	—	—	—	—	5,000							
Cascade River												
Stillaguamish R. System	59,500	100,000	80,600	85,100	81,300	87,100	74,000	85,100	38,600	74,700	17,600	70,000
Stillag. main stem	—	—	—	—	—	—	—	—	—	31,300	17,600	21,800
Canyon Creek	—	7,500	9,200	9,600	7,900	9,700	5,300	13,500				
South Fork	—	23,300	8,100	15,500	15,300	18,500	20,100	21,000				
North Fork	59,500	69,200	63,300	60,000	58,100	58,900	48,600	50,600	38,600	43,400	—	48,200
Snohomish River System	137,700	184,300	179,900	235,100	127,100	230,500	180,900	226,400	168,631	265,300	266,300	167,200
Skykomish River	101,600	91,800	104,500	111,500	72,800	146,200	120,000	127,400	93,700	175,000	185,700	117,400
Pilchuck River (Snoho.)												
Snohomish River	—	—	—	26,900	0	0	0	0	0	0	0	0
Snoqualmie River	30,800	38,300	44,900	46,200	30,500	56,500	48,700	73,500	45,221	41,600	27,800	22,000
Tolt River	5,300	8,700	0	0	8,000	0	0	0	0	0	0	0
Raging River	—	—	—	—	—	—	—	—	—	—	21,700	9,200
Sultan River	—	15,000	0	10,100	8,200	8,200	5,500	9,700	15,100	15,400	13,300	14,000
Wallace River												
N. F. Skykomish River	—	14,600	15,300	20,400	7,600	19,600	6,700	15,800	14,610	33,300	17,800	4,600
S. F. Skykomish River	—	15,900	15,200	20,000	0	0	0	0	0	0	0	0
Green River (King Co.)	5,200	71,300	23,700	79,600	83,700	81,300	83,600	100,100	36,000	86,300	67,300	65,300
Puyallup River System	0	0	0	0	0	0	0	0	0	0	0	0
White (Stuck) River												
Carbon R. (Voight Cr.)												
Nisqually River	—	13,400	0	24,800	23,700	12,800						
Deschutes River	—	—	3,300	3,000								
East Hood Canal												
Skokomish River												
West Hood Canal												
Dungeness River	10,100	6,100	0	15,100	16,100	10,500						
Morse Creek												
Elwha River	19,800	15,000	0	23,600	25,100	0	25,100	20,200	10,000	10,000	10,100	10,000
Total for year:	232,300	414,200	306,200	486,100	389,300	449,200	388,800	456,800	253,231	457,300	361,300	312,500

Table G-2 continued horizontally. Releases of summer-run steelhead smolts into Puget Sound tributaries from 1965 to 2008

Name of stream	2001	2002	2003	2004	2005	2006	2007	2008	10-yr avg
Nooksack River									
Whatcom Creek									
Skagit River System	0	0	0	0	0	0	0	0	0
Skagit River main stem									
Sauk River									
Cascade River									
Stillaguamish R. System	106,900	90,600	45,633	77,776	73,633	105,575	97,000	96,858	78,158
Stillag. main stem	—	61,800	—	—	—	—	—	—	33,733
Canyon Creek	—	—	—	—	—	—	7,020	5,100	6,060
South Fork	46,900	28,800	—	—	—	29,321	13,052	15,330	26,681
North Fork	60,000	—	45,633	77,776	73,633	76,254	76,928	76,428	66,857
Snohomish River System	223,400	221,200	177,849	248,268	261,770	234,006	245,057	271,686	231,674
Skykomish River	136,500	0	107,217	165,000	168,800	149,440	160,135	178,361	136,855
Pilchuck River (Snoho.)									
Snohomish River	0	0	0						
Snoqualmie River	28,300	0	44,901	18,885	52,470	50,838	28,840	62,763	33,680
Tolt River	0	0	0						
Raging River	21,700	51,500	0	23,786	—	—	27,720	—	22,229
Sultan River	20,600	14,900	10,449	20,447	20,340	20,330	28,362	30,562	19,329
Wallace River									
N. F. Skykomish River	16,300	154,800	15,282	20,150	20,160	13,398	—	—	32,811
S. F. Skykomish River	0	0	0	—	—	—	—	—	0
Green River (King Co.)	39,600	101,100	59,833	74,605	164,463	96,841	96,564	54,400	82,001
Puyallup River System	0	0	0	0	0	0	0	0	0
White (Stuck) River									
Carbon R. (Voight Cr.)									
Nisqually River									
Deschutes River									
East Hood Canal									
Skokomish River									
West Hood Canal									
Dungeness River									
Morse Creek									
Elwha River	—	—	—	—	—	—	—	—	10,050
Total for year:	369,900	412,900	283,315	400,649	499,866	436,422	438,621	422,944	393,842

Appendix H: Steelhead Adult Age-Classes by Sex (Table H-1) and Age Structure by Broodyear (Table H-2)

Table H-1. Distribution of steelhead (*Oncorhynchus mykiss*) adult age-classes (including multiple spawner information) by sex for winter-run steehead captured in sport and tribal fisheries for selected Puget Sound rivers. All fish were identified as naturally produced based on scale growth patterns. The letter S indicates a "spawn check" in the scale growth pattern (e.g., repeat spawner). (Data from R. F. Leland, Fish Program, WDFW, Olympia. Pers. commun., 16 April 2009.)

River basin		**1.1+**		**1.2+**		**2.1+**		**2.2+**		**2.3+**		**2.1+S+**		**2.1+S+S**		**2.2+S+**		**2.3+S+**		**3.1+**		**3.2+**		**3.1+S+**	
(all tribs.)	**Year**	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Stillaguamish	1982/83	0	1	0	0	11	8	14	34	0	0	3	11	0	3	0	3	0	1	0	0	0	0	0	0
Green	1982/83	0	1	0	2	9	4	10	18	1	0	1	1	0	0	0	1	0	0	1	2	0	0	0	0
Skagit	1984/85	0	0	0	0	51	51	11	30	0	0	2	7	0	1	0	3	0	0	11	6	1	0	0	1
Skagit	1982/83	0	0	0	0	11	9	14	23	0	0	1	8	0	0	1	4	0	0	3	1	0	0	0	3
Puyallup	1983/84	2	1	10	6	0	0	3	2	0	0	0	0	0	1	0	3	0	0	0	1	0	0	0	1
Puyallup	1979/80	3	1	0	1	24	24	2	11	0	0	0	5	0	0	0	0	0	0	4	5	0	0	0	0
Puyallup	1978/79	1	2	0	1	18	16	7	14	0	0	0	1	0	1	0	1	0	0	0	1	0	1	0	1

Table H-2. Steelhead age structure by broodyear for selected Puget Sound rivers. Age structure (freshwater/ salt water) is based on scales collected from steelhead captured in tribal net fisheries and sport fisheries (sp). All fish were identified as naturally produced based on scale growth patterns. The notation “all” indicates that samples came from all fisheries. Skykomish numbers 1 and 2 indicate management zones. Decimal numbers are percentages and numbers in bold indicate the most common age-class. (Data from R. F. Leland, Fish Program, WDFW, Olympia. Pers. commun., 16 April 2009.)

River	**Broodyear**	**1.1+**	**1.2+**	**2.1+**	**1.3+**	**2.2+**	**3.1+**	**2.3+**	**3.2+**	**4.1+**
Nooksack	1978/80	0.00	0.00	**78.72**	0.00	13.18	7.09	0.00	1.01	0.00
Skagit	1979/86	0.29	0.06	45.85	0.00	30.42	13.60	1.06	8.57	0.15
Sauk	1983	0.00	0.00	29.47	0.00	43.16	5.26	0.00	22.11	0.00
Snohomish (all)	1978/86	1.07	0.27	47.40	0.00	37.27	5.69	0.84	7.46	0.00
Snohomish (sp)	1980/86	0.86	0.32	48.82	0.00	31.69	8.40	0.92	9.00	0.00
Pilchuck	1983/85	1.90	0.68	46.70	0.00	36.60	8.19	3.49	2.44	0.00
Skykomish (1)	1985/86	0.36	1.49	**62.22**	0.00	34.19	0.00	0.00	1.74	0.00
Skykomish (sp) (1+2)	1979/81	0.58	0.00	**61.39**	0.00	27.96	2.16	1.24	6.67	0.00
Tolt	1984	0.00	48.98	0.00	0.00	**51.02**	0.00	0.00	0.00	0.00
Snoqualmie	1979/85	0.61	0.90	**58.33**	0.00	36.04	1.60	0.00	2.51	0.00
Green	1981/86	6.14	2.37	42.82	0.00	40.72	3.52	1.90	2.53	0.00
Puyallup	1976/77	7.57	0.58	**62.98**	0.00	20.57	8.31	0.00	0.00	0.00
Nisqually	1978/80	10.49	3.86	**66.61**	0.00	17.41	1.49	0.05	0.08	0.00

Appendix I: Catastrophic Risk Categories for Puget Sound Chinook Salmon

Table I-1. Scores for catastrophic risk categories for Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*). (Modified from Good et al. 2008.)

		Risk source							
Geo-region	**Basin/population**	**Vol-cano**[a]	**Earth-quake**[b]	**Land-slide**[c]	**Flood**[d]	**Toxic leak**[e]	**Toxic spill**[f]	**Hatch-ery**[g]	**Dam breach**[h]
NE	N. F. Nooksack	70.6	34.9	18.8	20	0.20	0.19	0.0	0.0
NE	S. F. Nooksack	4.2	33.6	20.2	20	0.04	0.14	0.0	0.0
CE	Lower Skagit	70.3	34.8	20.6	20	0.20	0.15	0.0	55.8
CE	Upper Skagit	3.5	20.7	32.2	20	0.10	0.61	11.6	51.5
CE	Cascade	0.0	20.0	34.0	20	0.10	0.00	0.0	0.0
CE	Lower Sauk	98.9	30.0	19.4	22	0.10	0.25	0.0	6.8
CE	Upper Sauk	100	29.9	31.0	25	0.00	0.00	0.0	0.0
CE	Suiattle	99.2	25.7	31.0	23	0.01	0.03	0.0	0.0
CE	N. F. Stillaguamish	79.7	34.0	21.3	25	0.02	0.26	9.0	0.0
CE	S. F. Stillaguamish	52.5	40.0	16.5	25	0.20	0.28	0.0	25.2
CE	Skykomish	0.0	40.0	19.7	26	0.30	0.39	3.0	17.9
CE	Snoqualmie	0.0	48.3	19.8	33	0.20	0.28	0.0	25.2
S	Sammamish	0.0	51.4	4.5	31	1.60	0.62	12.2	0.0
S	Cedar	0.0	52.3	10.7	33	0.80	0.74	0.0	45.0
S	Green	37.3	45.5	9.2	33	0.90	0.39	14.6	42.2
S	White	92.1	39.9	14.4	27	0.30	0.28	1.9	31.2
S	Puyallup	98.6	44.6	10.4	25	0.20	0.31	8.4	7.0
S	Nisqually	92.9	42.3	5.1	28	0.10	0.16	33.1	52.9
CW	Skokomish	0.0	50.0	23.3	25	0.03	0.08	28.0	35.5
CW	Mid-Hood Canal	0.0	50.0	32.2	21	0.10	0.06	5.4	0.0
NW	Dungeness	0.0	50.0	30.2	14	0.10	0.02	41.1	0.0
NW	Elwha	0.0	50.0	36.6	15	0.04	0.16	46.8	20.4

[a] Chinook salmon distribution overlapping with volcanic hazard zones (%).

[b] Chinook salmon distribution falling under earthquake risk; weighted mean amount of the distribution under each contour value (%).

[c] Chinook salmon distribution under high landslide risk (%)

[d] Mean chance of annual flood occurrence (%).

[e] Potential point source pollution facilities per kilometer of Chinook salmon reaches (no./km).

[f] Major transportation routes per kilometer of Chinook salmon reaches (km/km).

[g] Releases of hatchery Chinook salmon per kilometer of Chinook salmon reaches (no./km).

[h] Chinook salmon distribution impacted by unplanned dam breaches (%).

Appendix J: Geologic Regions of Washington State

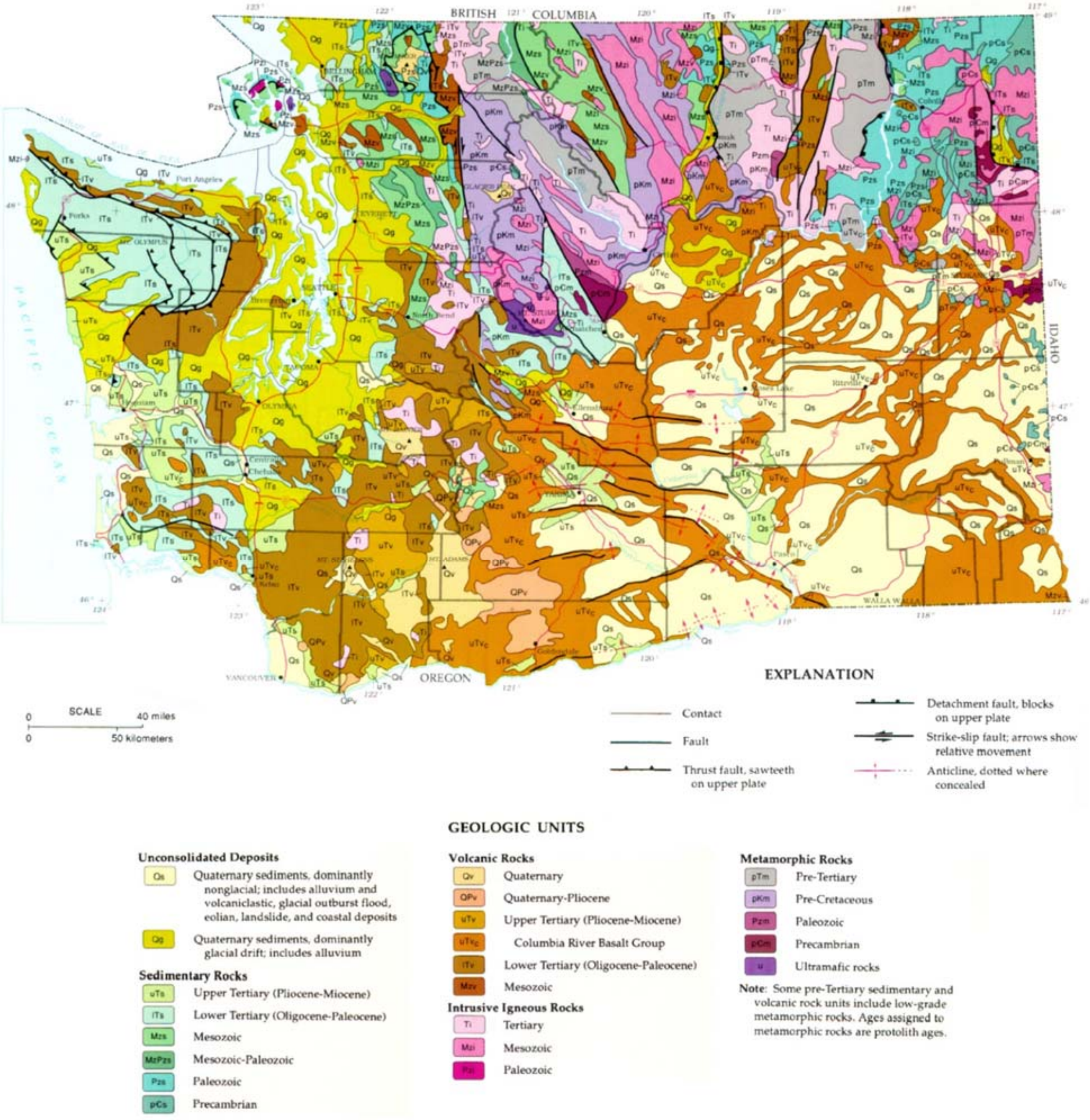

Figure J-1. Geologic map GM-53 of Washington State. (Reprinted from Schuster 2005.)

Appendix K: Average Monthly Flows for Puget Sound Streams

Table K-1. Normalized average monthly flows for Puget Sound streams. Peak monthly flows for each river are set to 100 in boldface.

River	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Baker River Concrete	1990–2006	79.8	68.9	52.0	48.5	62.0	81.1	69.9	56.9	50.0	65.8	**100.0**	74.5
Big Beef Creek	1990–2006	**100.0**	73.1	53.8	28.6	14.3	8.4	4.9	3.5	3.8	12.6	39.5	84.9
Cascade River Marblemount	1990–2006	32.5	29.1	27.6	39.4	76.0	**100.0**	78.8	42.6	31.0	34.0	40.2	38.7
Cedar River Landsberg	1990–2006	**100.0**	91.9	74.1	72.8	61.1	57.4	41.0	31.9	31.9	45.9	86.1	98.5
Duckabush River	1990–2006	**100.0**	71.8	65.4	63.5	76.2	73.4	43.8	24.6	17.4	38.4	84.0	94.4
Dungeness River	1990–2006	79.7	65.0	53.0	54.5	82.5	**100.0**	70.9	39.8	24.1	32.2	67.0	73.9
Elwha River (above Mills)	1994–2007	**100.0**	75.8	62.1	52.5	76.7	73.1	48.9	23.2	19.2	34.3	76.3	93.6
Green River Auburn	1990–2006	**100.0**	92.6	71.3	71.3	61.7	43.0	22.3	12.6	15.0	30.3	79.6	87.8
Hoko River	1962–2007	**100.0**	70.1	61.9	36.2	18.6	11.6	8.7	4.8	8.0	33.9	87.8	92.7
Huge Creek (Kitsap)	1990–2006	**100.0**	84.0	64.0	44.0	29.2	24.0	19.6	17.6	17.2	22.8	44.0	76.0
Issaquah Creek	1990–2006	**100.0**	82.0	71.2	56.0	36.8	29.6	17.6	10.8	10.8	21.6	69.2	87.2
Leach Creek	1990–2006	**100.0**	71.0	62.0	55.0	38.0	35.0	27.0	29.0	31.0	55.0	91.0	87.0
Mercer Creek	1990–2006	**100.0**	76.2	66.7	54.8	38.1	31.0	22.6	22.4	26.2	47.6	85.7	90.5
M. Fork Snoqualmie Tanner	1990–2006	84.8	66.0	56.5	71.2	88.5	83.2	41.6	18.4	21.8	53.4	**100.0**	75.9
N. Fork Snoqualmie near falls	1990–2006	90.6	68.1	59.7	72.1	78.4	68.6	33.5	14.7	23.1	56.0	**100.0**	80.2
Nisqually McKenna	1990–2006	97.8	93.8	66.4	57.5	46.9	36.8	28.5	21.9	24.6	32.7	65.0	100.0
Nooksack River main stem	1990–2006	95.9	76.4	67.2	69.5	76.4	79.8	58.0	37.8	31.7	54.1	**100.0**	92.6
North Fork Nooksack River	1990–2006	46.4	37.1	34.1	45.6	76.6	**100.0**	86.9	55.2	37.9	49.1	61.1	45.9
South Fork Nooksack River	1990–2006	93.8	55.8	64.3	68.2	71.7	57.9	29.5	15.7	18.8	51.2	**100.0**	82.9
Pilchuck River	1992–2007	**100.0**	76.3	76.5	60.3	43.3	31.3	18.1	10.8	12.9	36.1	80.0	98.5
Puyallup River Boise	1990–2006	**100.0**	93.0	75.4	66.7	52.6	45.6	26.3	16.5	14.9	26.3	77.2	86.0
Puyallup/Carbon rivers	1990–2006	91.8	71.6	57.4	64.4	92.8	**100.0**	73.4	51.4	40.4	55.3	92.3	88.0
Puyallup River Electron Dam	1990–2006	85.4	67.6	57.9	66.7	88.0	**100.0**	91.6	78.1	57.5	58.3	88.6	82.1
Puyallup R. Greenwater River	1990–2006	73.9	70.1	55.8	74.5	**100.0**	79.9	33.8	16.5	12.4	20.1	52.2	65.1
Puyallup River main stem	1990–2006	**100.0**	92.6	73.6	75.7	78.8	89.0	64.2	44.8	34.0	46.2	83.1	95.5
South Prairie Creek	1990–2006	**100.0**	89.4	72.0	71.2	66.7	53.7	28.0	15.9	15.6	31.0	78.8	88.1
Samish River	1990–2006	**100.0**	71.9	68.9	54.5	32.8	24.7	14.0	8.0	8.5	27.5	73.2	88.8
Sauk River Whitechuck	1990–2006	66.3	54.4	47.7	62.4	95.0	**100.0**	63.0	27.9	21.3	48.7	83.4	61.3

Table K-1 continued. Normalized average monthly flows for Puget Sound streams. Peak monthly flows for each river are set to 100 in boldface.

River	**Year**	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
South Fork Tolt	1990–2006	**100.0**	85.1	64.5	58.9	67.4	64.5	46.1	42.6	42.6	45.4	83.7	90.1
Skagit River Marblemount	1990–2006	92.8	90.9	78.1	73.4	78.5	83.9	89.6	59.5	48.2	60.9	**100.0**	75.7
Skagit River Mount Vernon	1990–2006	93.0	84.2	71.6	71.6	86.5	96.3	81.9	52.6	42.1	59.1	**100.0**	86.0
Skokomish River	1990–2006	**100.0**	74.8	57.2	41.4	25.3	18.0	11.2	9.6	9.9	27.8	77.2	97.9
Skykomish River Gold Bar	1990–2006	80.8	64.9	57.7	74.4	**100.0**	92.2	46.6	18.9	18.4	49.3	99.2	72.5
Snohomish River Monroe	1990–2006	95.1	78.2	66.3	75.4	85.2	78.2	41.2	19.5	20.6	49.6	**100.0**	88.0
Snoqualmie River Tolt River	1990–2006	**100.0**	78.2	66.4	67.6	63.8	53.5	31.0	19.9	22.5	44.5	88.7	90.9
Stillaguamish River Arlington	1990–2006	98.4	75.5	68.0	64.0	57.5	44.7	21.7	13.6	17.6	49.1	**100.0**	94.4
Stillaguamish R. Granite Falls	1990–2006	87.4	71.4	62.9	61.7	78.3	64.6	36.9	21.0	30.6	50.4	79.4	**100.0**
Tulalip Creek	2000–2006	**100.0**	88.9	88.9	88.9	55.0	41.1	30.6	29.4	32.2	49.4	61.1	83.3

Appendix L: Distances between Adjacent Puget Sound River Mouths

Table L-1. Summary of distances to nearest neighbor spawning grounds. Distances are determined by water-based migration.

Spawning area	Nearest neighbor(s)	Distance (km)	Next nearest	Distance (km)
Boundary tributaries	Mainstem Nooksack	25.5[c]	Samish	39.8
Mainstem Nooksack	North Fork, Middle Fork, and South Fork Nooksack	0.0[a]	Boundary tributaries	25.5
North Fork Nooksack	Mainstem and Middle Fork Nooksack	0.0[a]	South Fork Nooksack	5.6
Middle Fork Nooksack	Mainstem and North Fork Nooksack	0.0[a]	South Fork Nooksack	5.6
South Fork Nooksack	Mainstem Nooksack	0.0[a]	N. Fork and Middle Fork Nooksack	5.6
Samish	Boundary tributaries	39.8[d]	Mainstem Nooksack	61.3
Lower Skagit	Middle Skagit and Finney and Sauk	0.0[a]	Baker	26.1
Middle Skagit	Lower Skagit and Cascade and Sauk	0.0[a]	Finney	14.5
Sauk	Middle Skagit	0.0[a]	Lower Skagit	19.1
Skagit–Finney	Lower Skagit	0.0[a]	Middle Skagit	14.5
Skagit–Baker River	Lower Skagit	26.1[c]	Finney	40.5
Skagit–Cascade	Middle Skagit	0.0[a]	Sauk	19.5
Stillaguamish	North Fork and South Fork Stillaguamish	0.0[a]	Deer Creek	37.6
North Fork Stillaguamish	Stillaguamish and South Fork Stillaguamish	0.0[a]	Deer Creek	14.7
South Fork Stillaguamish	Stillaguamish and North Fork Stillaguamish	0.0[a]	Deer Creek	37.7
Stillaguamish–Deer Cr.	North Fork Stillaguamish	14.7[b]	Stillaguamish	37.6
Snohomish	Skykomish	1.2[a]	Snoqualmie	4.2
Snohomish–Pilchuck R.	Snohomish	8.3[a]	Skykomish	11.4
North Fork Skykomish	Skykomish	0.0[a]	Snohomish	47.6
N. F. and S. F. Skykomish	North Fork Skykomish	0.0[a]	Snohomish	1.2
Snoqualmie	Skykomish	3.6[a]	Tolt	3.9
Snoqualmie–Tolt River	Snoqualmie	3.9[a]	Skykomish	39.5
Sammamish	Cedar	68.3[d]	East Kitsap	81.2
Cedar River	East Kitsap	51.0[d]	Sammamish	68.3
Green River	East Kitsap	66.3[d]	Cedar	89.0

Table L-1 continued. Summary of distances to nearest neighbor spawning grounds. Distances are determined by water-based migration.

Spawning area	Nearest neighbor(s)	Distance (km)	Next nearest	Distance (km)
Puyallup–entire basin	Carbon	0.0[a]	White	7.5
Puyallup–White	Puyallup	7.5[a]	Carbon	19.6
Puyallup–Carbon	Puyallup	0.0[a]	White	19.6
Nisqually	South Sound inlets	35.7[d]	Puyallup	61.0
South Sound inlets	Nisqually	35.7[d]	East Kitsap	79.5
Kitsap–East/Curley	Cedar	51.0[d]	Puyallup	56.2
Hood Canal East	Dosewallips	13.2[b]	Hamma Hamma	15.8
Tahuya	Skokomish	10.1[b]	East Hood Canal	18.9
Skokomish–entire basin	N. F. and S. F. Skokomish	0.0[a]	Tahuya	10.1
North Fork Skokomish	Skokomish and South Fork Skokomish	0.0[a]	Tahuya	24.1
South Fork Skokomish	Skokomish and North Fork Skokomish	0.0[a]	Tahuya	24.1
Hamma Hamma	East Hood Canal	15.8[b]	Duckabush	18.8
Duckabush	Dosewallips	12.0[b]	Hamma Hamma	18.8
Dosewallips	Duckabush	12.0[b]	Hamma Hamma	24.7
Big Quilcene	Dabob Bay	20.9[b]	Dosewallips	27.5
Sequim/Discovery/ Dabob bays	Big Quilcene	20.9[b]	Dungeness	21.8
Dungeness	Strait of Juan de Fuca tributaries	21.6[b]	Sequim/Discovery/ Dabob bays	21.8
Strait of J. de Fuca tribs.	Elwha	18.5[b]	Dungeness	21.6
Elwha	Strait of J.. de Fuca tribs.	18.5[b]	Dungeness	44.7

[a] Separation <10 km.
[b] Separation 10 to 25 km.
[c] Separation 25 to 35 km.
[d] Separation >35 km.

Appendix M: Responses to Reviewer Comments

This appendix includes comments and concerns provided by two peer reviewers as well as by other interested parties. Not included here are editorial comments; we have addressed those issues directly in the text. There have been a number of requests for comments. Comanagers and interested parties were contacted by letter (17 October 2011), and electronic and paper copies of a draft document were provided prior to a 30 May 2013 workshop at NOAA's Western Regional Office (7600 Sand Point Way Northeast, Seattle) that discussed both this population identification document and the viability criteria document (Hard et al. in press) for the Puget Sound steelhead (*Oncorhynchus mykiss*) distinct population segment (DPS). Following the workshop, a revised population identification document was made electronically available for review.

Peer Reviewer 1

Review

The reviewer was concerned about "a lack of clarity about the nature of phenotypic variation," and specifically how that variation or lack thereof would be used in the identification of demographically independent populations (DIPs).

Response

The reviewer correctly identified a section on local adaptation and plasticity that did not clearly discuss their application to identifying populations. Where ecological conditions differ, there is a potential for selection in life history or morphological traits. Over time this selection will confer a fitness advantage to "native" individuals over strays from other populations and increase the level of genetic isolation between populations. Alternatively, where these traits are highly plastic, allowing for a wide range of phenotypic expression, the selective advantage of "native" fish is decreased and the potential for genetic introgression between populations increases.

Interestingly, in the case of steelhead populations in the Puget Sound DPS and elsewhere, there is little phenotypic or life history variation on a regional basis other than in run timing (winter run or summer run); yet we find there is genetic differentiation between proximate populations. This may indicate a strong homing fidelity or the presence of locally adapted traits that are not readily detectable.

Review

The reviewer also commented that the P value for Hardy-Weinberg was especially stringent. In the case of Table 3-2 (appendix Table B-2 herein), the threshold was $F_{IS} = 0.00011$ for an overall experiment-wise error of $P = 0.05$.

Response

The large number of total individuals sampled generates a very low F_{IS} threshold for an experiment-wise error rate of $P = 0.05$; however, the values in the table reflect within sample (population level) deviations from Hardy-Weinberg. In most cases where there was a significant deviation, the F_{IS} value was positive, indicating a deficiency of heterozygotes and the possibility that multiple populations were represented, or where populations are numerically small this deviation can be due to family effects within a population.

Peer Reviewer 2

Review

The reviewer suggested that in those cases where both summer-run and winter-run steelhead were found to hold and spawn in the same river reaches (i.e., mainstem Skagit River) a more conservative approach would have been to designate the two run times as independent populations.

Response

In identifying criteria for establishing DIPs, the Puget Sound Steelhead Technical Recovery Team (PSS TRT) focused on widely accepted factors influencing the degree of reproductive isolation between populations. In contrast to summer-run steelhead in Deer Creek or the North Fork Skykomish River, summer-run steelhead in the mainstem Skagit and Sauk rivers are not separated by obvious migration barriers, but spawn in the same river reaches without a clear temporal separation. In the case of Finney Creek (Skagit River), comanagers argued that the summer-run spawning aggregation was too small to be a DIP and was likely extirpated. In addition, some reviewers suggest that these presumptive summer-run fish were resident fish from nearby tributaries. In the absence of genetic information on summer-run and winter-run steelhead to establish reproductive isolation (and thereby demographic independence) in the rivers in question, the PSS TRT decided that making a DIP distinction was too tenuous. A further consideration in not identifying distinct DIPs was the absence of abundance information indicating that historical and present abundance was sufficient for a sustainable summer-run population. The TRT did not discount the potential presence of summer-run populations co-occurring with winter-run steelhead, but suggested that data were currently lacking to support such a conclusion. In the case of the Dungeness, Elwha, and Green rivers, there were potential migration barriers, but historical and current documentation was deficient. The TRT strongly encourages the comanagers to undertake the necessary studies to resolve this issue.

Additional Reviewer Comments

Review

One of the concerns put forward was that the 50 km distance threshold for demographically independent populations was not clearly defined; specifically questioning whether it focused on the distance mouth-to-mouth for tributaries or between spawning sites, etc.

Specific examples were provided of hatchery-run steelhead straying from the Stillaguamish River to the Skagit River.

Response

The TRT took a conservative approach and established the 50 km distance as mouth-to-mouth. There was some discussion that the distance could be measured between spawning areas; however, there were insufficient data to attempt this calculation for most rivers. Additionally, much of the steelhead straying data analyzed was presented using the mouth-to-mouth distance.

The examples provide by the commentator underscore a number of issues. Firstly, under the criteria establish by the TRT, the mouth-to-mouth distance would be less than 50 km. Secondly, the return migration of summer-run steelhead often includes extended freshwater holding periods in nonnatal stream, making it difficult to distinguish between true strays and "dip ins." Thirdly, they highlight the potential for hatchery fish to stray more widely than their naturally born counterparts. Straying may be further affected by rearing and release strategies, specifically off-site releases.

Review

There was considerable concern that the level of gene flow between the populations identified by the TRT was more substantial than the 10% level set forth in defining DIPs. The commentator interpreted the relatively low (below threshold) genetic distances between several populations as being indicative of a much higher gene flow. Creating such artificial populations, it was argued, would limit the efficacy of any management actions.

Response

It is important to consider that demographic independence is different from reproductive independence. The level of demographic influence from other populations (straying) is thought to be about 10% and still maintain independence. Reproductive independence is related to the proportion of straying individuals that successfully reproduce. Therefore, the level of reproductive independence will be lower than the level of demographic independence.

The threshold set for independence based on genetic differences, Cavalli-Sforza and Edwards chord distances, was set large enough that there was a very high level of certainty for independence. This reflects the TRT's desire for multiple types of evidence to establish independence. In addition, analysis of the genetic data suggests a deviation from Hardy-Weinberg proposing that there may be some mixing of populations in the sample. This mixing may not necessarily be between the two populations in question, but could suggest additional populations may be present within a sample. If multiple populations were included in a presumptive single population sample, the increase in variation could reduce the between-population Cavalli-Sforza and Edwards chord distances presented in Figure 3-7 (appendix Table B-3 herein).

Review

There were a number of comments from biologists with the comanaging agencies that questioned the inclusion of collections of several smaller independent streams or smaller tributaries as DIPs; for example, the Nookachamps Basin (small tributary to the Skagit River), several clusters of independent tributaries in Hood Canal, and independent tributaries in South Puget Sound and the East Kitsap Peninsula. Another area that generated a number of comments was the Strait of Juan de Fuca and variations of combinations of smaller independent tributaries with the two large rivers, Dungeness and Elwha.

Commentators questioned whether some of these provisional DIPs ever historically contained sufficient numbers of steelhead to be considered self-sustaining, and if they did historically, they had been effectively extirpated in the recent past. In other cases, there was a preference voiced to combine smaller independent tributaries with geographically proximate larger rivers.

Response

Firstly, it is important to remember that a primary criterion for establishing DIPs is evidence of historical presence, and therefore even if fish were no long present in large numbers, the capacity of the basin may be sufficient to support a DIP. There was sufficient historical data (primarily historical catch records from the 1940s and 1950s) to establish that steelhead were naturally produced in the streams in question. This information comported with intrinsic potential (IP) estimates of steelhead productivity. Secondly, analysis of steelhead populations in Hood Canal, one the most data-rich regions in Puget Sound, validated the premise that genetically distinct populations of steelhead can be sustained in close geographic proximity to one another. This geographic template was very useful in areas where information was much more limiting, especially in the South Puget Sound area. Finally, regarding the combination of smaller independent tributaries with larger rivers, it was observed that the run and spawn timing for winter steelhead in smaller, rain-driven tributaries was much earlier than in the larger, colder, snow-driven rivers. This provided some temporal spawning separation between steelhead in the two stream types.

The TRT debated a number of scenarios for South Puget Sound, with as many as six DIPs being present. In addition to the Nisqually River, where there is considerable historical and contemporary information available, historical catch records indicate that there were winter-run steelhead in a number of independent tributaries throughout the area. Also, the rain-driven hydrology of these tributaries was distinct from the larger, snowmelt-driven Nisqually River. Furthermore, these smaller tributaries were distributed across a large geographic area, providing the potential for geographic isolation. Ultimately, the majority of the TRT agreed that the minor tributaries constituted one or more DIPs, but were unable to agree upon an exact number, nor identify where the boundaries might lie. In creating one South Sound DIP, the TRT confirmed the historic importance of this region, but left further subdivision to the acquisition of additional information.

In contrast to the comments received disputing the inclusion of small independent tributaries in DIPs, the TRT received a number of responses that included redd counts and adult sightings from many of the tributaries being discussed (especially in Bellingham Bay and the East Kitsap Peninsula). These responses reinforced the TRT’s understanding that steelhead utilized a wide range of stream habitats and that many spawning aggregations thought to be extirpated continued to persist at low abundance levels. It also underscored the need for more extensive monitoring to more accurately evaluate the status of steelhead populations.

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126 **Russell, S., and M.S. Ruff. 2014.** The U.S. whale watching industry of Greater Puget Sound: A description and baseline analysis. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-126, 171 p. NTIS number PB2014-105939.

125 **Sloan, C.A., B.F. Anulacion, K.A. Baugh, J.L. Bolton, D. Boyd, R.H. Boyer, D.G. Burrows, D.P. Herman, R.W. Pearce, and G.M. Ylitalo. 2014.** Northwest Fisheries Science Center's analyses of tissue, sediment, and water samples for organic contaminants by gas chromatography/mass spectrometry and analyses of tissue for lipid classes by thin layer chromatography/flame ionization detection. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-125, 61 p. NTIS number PB2014-104055.

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