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

Final Review Draft

Puget Sound Steelhead Technical Recovery Team Report

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It is apparent then that one of the first requirements of a sound conservation program must be the determination of the extent to which the species to be conserved is broken up into local populations. The defining of specific populations is concerned to a considerable extent with the determination of the geographical limits occupied by each.

—Willis H. Rich, 1939
U.S. Bureau of Fisheries

Dedication

During the development and writing of 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 knowledge of the Skagit River Basin, it was his determination that our process be logical, consistent, and transparent, that ensured our 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 in battling cancer was inspiring. He will be missed by all.

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Executive Summary

The Puget Sound Steelhead Technical Recovery Team (PSS TRT) convened to review information relevant to the identification of historical demographically independent populations (DIPs) of steelhead (*Oncorhynchus mykiss*) within the Puget Sound steelhead distinct population segment (DPS). The TRT identified 3 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- and winter-run migrations. Winter-run steelhead, also known as ocean-maturing steelhead, return to freshwater to spawn 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 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. Winter-run steelhead, presently and historically, 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 and tagging studies have not been undertaken to any great degree.

The TRT reviewed available information on Puget Sound steelhead, which included both 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 (DSS) to identify DIPs. DIPs were, in turn, organized in MPGs. These larger scale units delineate DPS-wide spatial structure. MPGs were identified by the TRT 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 population located on the northeastern corner of the Olympic Peninsula. The DSS relied upon 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 DSS, or gatekeeper model, required that the TRT estimated 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 DSS, 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[1] origin summer run currently in the Green River it is possible that resident *O. mykiss* above Howard Hansen Dam may contain the genetic legacy of a summer run. Within 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 needs to be collected. It is likely

[1] The summer-run steelhead currently released into, and naturally spawning in, the Green River originated from the Skamania Hatchery in the Columbia River Basin.

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.

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). Firstly, we consider historical population structure because the historical template is the only known sustainable configuration for the DPS. Secondly, 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 WDFW (2002) Salmonid Stock Inventory (SaSI) document. 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 viable salmonid population (VSP) document prepared by the National Marine Fisheries Service (NMFS) 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 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, and/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 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- and summer-run fish appear to co-mingle 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 upon. 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, Lawson et al. 2006, Ruckelshaus et al. 2006), 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 upon the work done by the SASSI (WDF et al. 1993) and SaSI (WDFW 2002) steelhead stock inventory processes (Appendix 1). 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 are considerable. 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, coho, and chum salmon 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 estimates of stray rates are particular to the group of fish, season, and streams in which they are made; thus they provide useful information about straying under specific conditions, but should beapplied cautiously as a general estimate. Given the limited monitoring efforts for steelhead it is impossible to estimate the magnitude of among-groups 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 (CWTs) 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. CWTs 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, therefore there has been minimal incentive to tag steelhead other than marking hatchery-origin fish with a fin clip. In addition, steelhead are iteroparous and 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. Finally, 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 hatchery fish are released in. In addition, 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 non-natal 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 present historically. 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 behavior traits, specifically ones with underlying genetic regulation and differences in the DNA coding 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 DNA coding differences can be expressed as allozyme variation or as base-pair coding variation of specific sequences (microsatellite DNA and single nucleotide polymorphism (SNP)) 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 that exhibit different 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 non-equilibrium conditions such as population bottlenecks or genetic drift. Additionally, demographically independent populations 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 non-native 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 non-native summer-run hatchery stock (Columbia Basin-origin) released in the Skykomish River.

Presently, there are a number of steelhead genetics studies 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 3. As appropriate data become available it will be important to re-evaluate 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 system 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 sub-basin). 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 (PDO)) 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 fresh water and shared harvest effects would predominately 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 straight-forward 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 basin). Second, environmental conditions may exert a selective influence on salmonid populations, which in turn may influence the expression of life history characteristics, producing populations that are highly adapted to local conditions. When life history characteristics are especially plastic, perhaps more so with steelhead than other Pacific salmonids, environmental conditions may provide a useful parameter for identifying populations. 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.

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, that 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 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 the viability analysis document.

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 2) 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. But 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, 1895). 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. The TRT concluded, based in part on recommendations in Allendorf et al. (1997), 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. There was some disagreement voiced by a number of TRT members 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 could be directly established through an inter-population migration estimate using genetic information or physical tags. 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 were employed to gauge the degree of demographic independence. These indirect (Tier 2) criteria included:

a. basin size and stream characteristics (length and wetted area)

b. temporal isolation (different run or spawn timing),

c. geographic isolation (migration distance between populations[2]),

   i. relative population size – where population size differentials exist, small migration rates from large populations into small populations could preclude independence of the small population

d. basin-specific information (e.g., barrier falls or cascades),

e. ecological distinctiveness

   i. Ecoregion – geology, rainfall, temperature, elevation

   ii. hydrology – rain or snow driven, timing and magnitude of peak and low flows

   iii. streambed characteristics (gradient, confined, etc)

   iv. 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 which 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- 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 component 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 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.

[2] 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 as a conservative measure of the distance.

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. Tributary basins, if large enough, may provide ecologically distinctive habitats and characteristic homing (olfactory) cues that reinforce the establishment of independent populations. At a minimum, differences in ecology may minimize the "attractiveness" of a non-natal 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 northeast 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 (km) separating spawning areas were defined as the shortest nautical distance separating river mouths (Appendix 4). This measure was considered a conservative estimate of the minimum distance between presumptive populations.

Distances were calculated using network routing tools in ESRI's ArcMap and 100k scale NHD (National Hydrography Dataset) streams. The "starting" and "ending" locations (such as river mouths) were used to create a network from the NHD 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.

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

After reviewing existing run sizes and basin areas, the TRTconcluded 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 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 Figure 2) criteria was probably not a definitive threshold, but minimized the likelihood of a 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 Systems (GIS) model) and for accessible portions of each basin for Puget Sound streams using both known natural and manmade barriers (Williams et al. 1975, Streamnet 2009). In large watersheds, such as the Skagit River, which contain major tributaries (Appendix 4), 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 on using 100 m reaches. To estimate historical capacity, these data were integrated into an intrinsic potential (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 two stream gradient classes, more or less than 4% gradient, and three stream widths: 0-3 m, 3-50 m, and >50m (Figure 2). Stream habitat was initially classified as having low, medium, and high productivity (Figure 2).

Stream Habitat Rating Matrix (below natural barriers)				
		Stream Width (bankful)		
		0-3 m	3-50 m	> 50 m
Stream	0.0 – 4.0%	Moderate	High	Moderate
Gradient	> 4.0%	Low	Low	Low

Figure 2. Stream habitat intrinsic potential (productivity) rating for Puget Sound Steelhead. Stream size and gradient categories were assigned by TRT members based on expert opinion. The TRT used these basin characteristics to calculate total intrinsic potential (IP) of basins in order to establish whether a large enough population could be sustained into the foreseeable future.

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[3]). Similarly, USACE (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 greater than 4% were not included in the estimate of potential parr numbers. There was also considerable discussion on the productivity of large rivers (> 50m wide), because much of the bankfull area in larger rivers in 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 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 pre-contact 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 to 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 4). 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

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[3] Gibbons (1986) revised the average Puget Sound parr production estimate from 0.0717 to 0.0771 parr/m^2 and the parr to spawner rate from 0.0265 to 0.0277 spawner/parr. A net increase of 12.5% in estimated escapement.

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 3) based on soil content, topography, climate, potential vegetation, and land use (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 4.

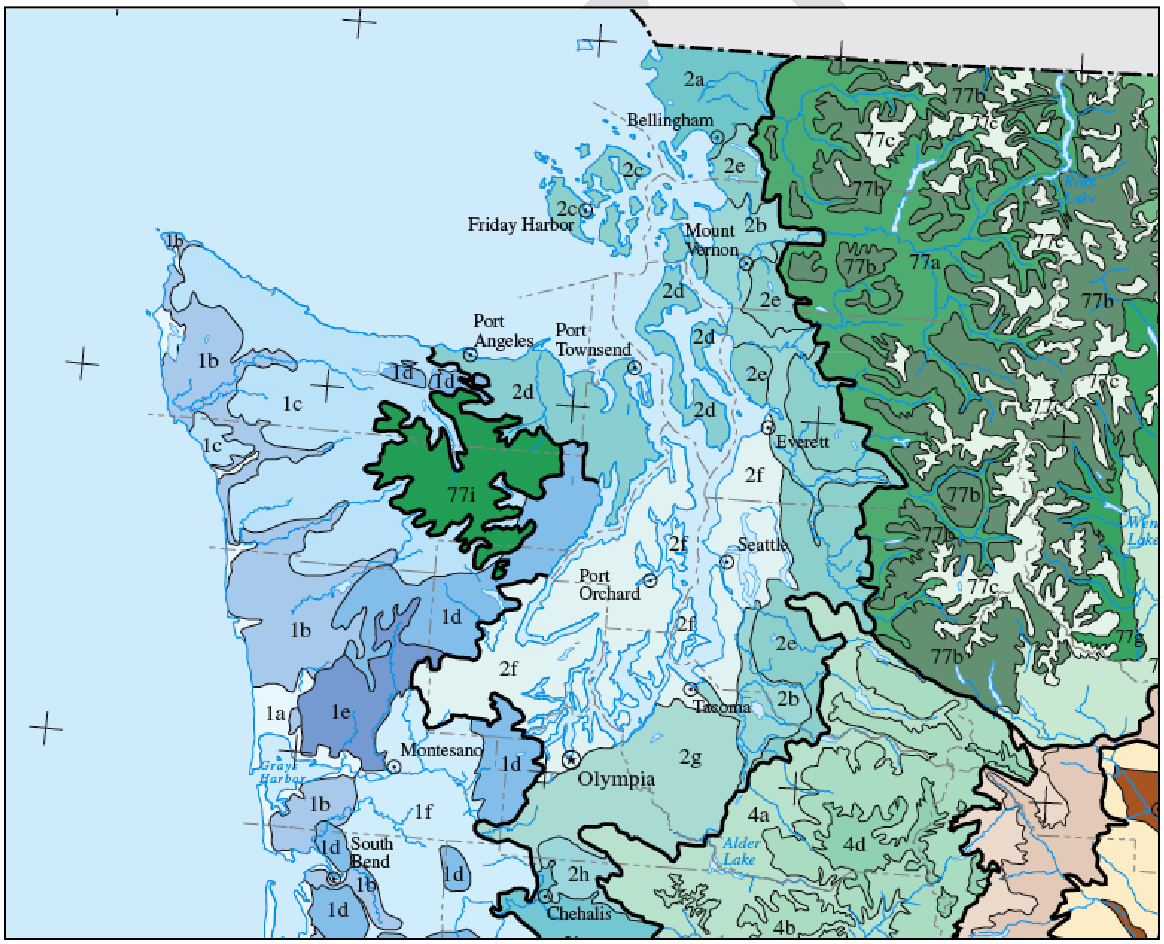


Figure 3. Level III and IV Ecoregions of the Northwestern United States map was compiled primarily at a scale of 1:250,000; it depicts revisions and subdivisions of earlier level III Ecoregions that were originally compiled at a smaller scale (Omernik 1987, U.S. EPA 1999). Level III Ecoregions are indicated by a numeric code 1 – Coast Range, 2 – Puget Lowland, 4 – Cascades, 77 - North Cascades. Level IV Ecoregions are indicated by a

lower case letter suffix. Map and supporting documentation available from: http://www.epa.gov/wed/pages/ecoregions/level_iv.htm.

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 would be similarly affected, perhaps more so because of the longer freshwater residency of steelhead relative to Chinook salmon. In independently 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 and Lower Columbia River Domain ESUs and DPSs, higher level ecological differences were ultimately used in the process for identifying MPGs.

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 (a.k.a. straying) are largely unavailable for steelhead in Puget Sound. Interpopulation migration rates are most commonly estimated for salmonid species using CWT-marked fish releases (primarily from hatcheries). In general, neither natural-origin nor hatchery-origin steelhead have been marked with CWT 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 non-natal 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 4). 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), Washington Department of Fisheries and Washington Department of Game (later Washington Department of Fish and Wildlife), 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 they were intended to contribute to.

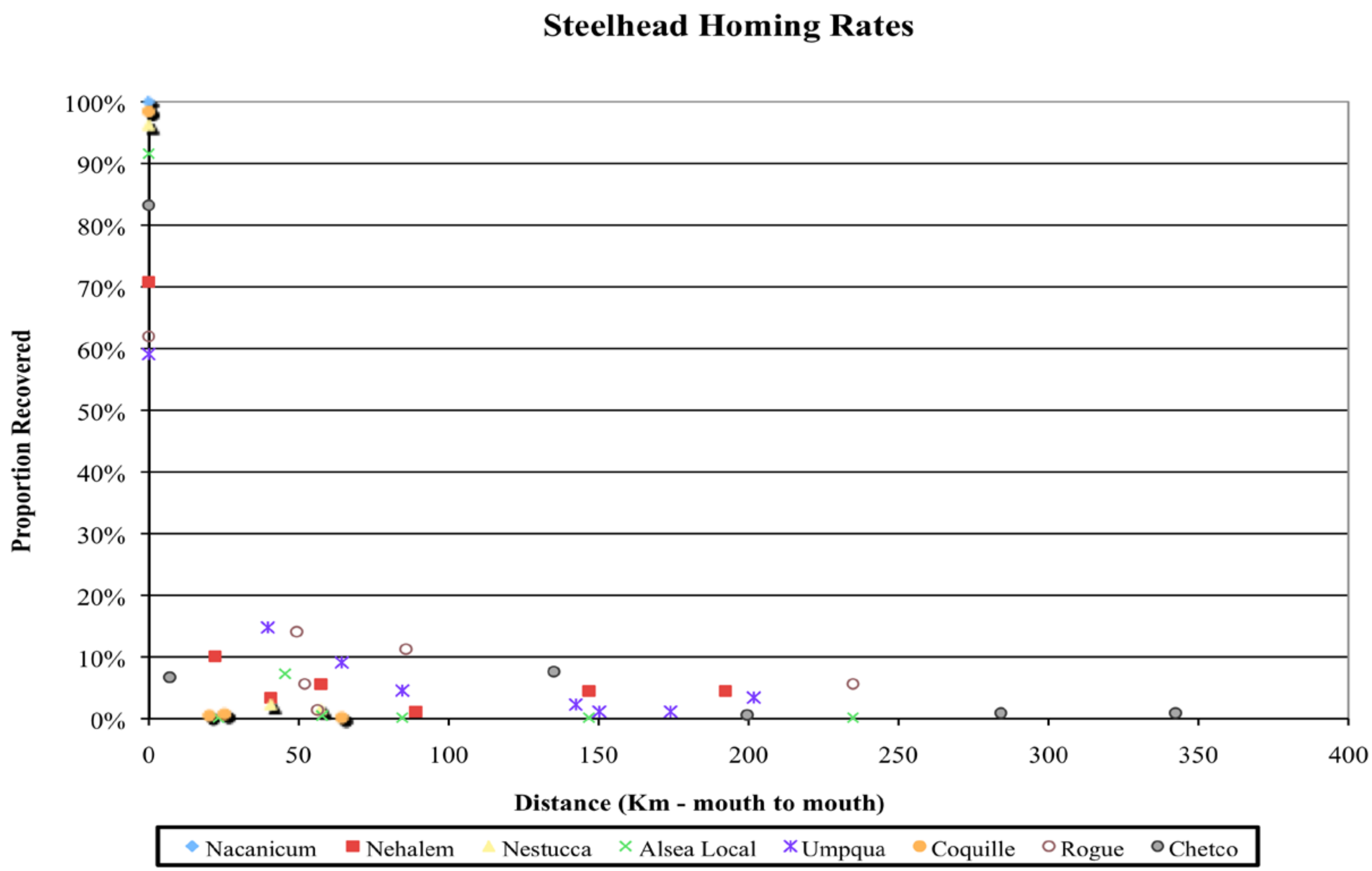


Figure 4. Distance from point of juvenile release (river mouth to river mouth) for returning adult steelhead. Proportion recovered is calculated separately for each river release group. Recovery data from Schroeder et al. (2001).

The Pacific Fisherman article on "Rearing and Feeding Salmon Fry," summarized this practice (Pacific Fisherman, June 1914 page 23):

> 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 one to three 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 superintendant 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 pay roll." 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 5). More recent genetic studies by Phelps et al. (1994) and Phelps et al. (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 (for example: 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 where there is 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 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 un-occupied 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 (also know as the U.S. Exploring Surveys) conducted during the 1850s, provided the first widely available descriptions of fish species in the Pacific Northwest, although Johann Walbaum, a naturalists 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: Dr. Charles Girard and Dr. George Suckley, compiled species descriptions from their observations or from a number of other sources. Their efforts would later attract considerable criticism. Dr. David Starr Jordan would later comment that, "Girard indeed did all a man could do to make it difficult to determine the trout (Jordan 1931, pg. 157)." Jordan's opinion of Dr. 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, pg. 157). In the Appendices to the Pacific Railroad surveys, Girard (1858) describes at least four species that could have represented the anadromous and/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 char Bull Trout (*Salvelinus confluentus*) or Dolly Varden[1] (*Salvelinus malma*). For the Puget Sound region, Bull Trout would be the predominant of the two 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, pg 326-327) quotes George Gibbs describing a "salmon" that enters the Puyallup at the end of December, holds in the river until the snows begin melting (spring) and 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[2]. 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 anther 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 in mid-June to August, a run timing that

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

corresponds to existing summer-run steelhead or possibly early returning (spring- or summer-run) Chinook. 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 Dr. J.G. Cooper, but under the "scientific name" *S. gibbsii* (Girard 1858, pg 333). The fish was noted for having a "moderately lunated tail at its extremity" and a heavily spotted fins. Dr 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 probability 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 stellatus [sic]* … "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 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 fresh water.

> 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 demographically independent populations, 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. Firstly, 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. Secondly, 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, approximate harvest estimates must generally suffice. We have only attempted to expand the peak harvest only in years in order to present an estimate of maximum run size.

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[3] are common in Southern Puget Sound, especially near Olympia and Tacoma. In 1888, 23,000 kg (50,600 lbs) of fresh "salmon-trout" were marketed in the Puget Sound area. Catch records from 1889 indicate that 41,168 kg (90,570 lbs) 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 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 TRT used an average fish weight of 4.5 kg, based on the size range 3.6 to 5.5 kg (8 to 12 lbs) 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 non-reported commercial catch, sport catch, cleaning or wastage. Analysis of the commercial catch records from 1889 to 1920 (Figure 5) 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 409,200–682,000 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.

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

Rathbun (1900) reports that the steelhead fishery occurred mainly in the winter and the majority of the harvest occurred in the lakes and rivers. Later reports describe 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 7), 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 3). 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 historical populations.

The management of steelhead was ultimately transferred to the newly formed Washington Department of Game in 1921. In 1925, the Washington State Legislature classified steelhead has 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 fell to levels generally below 10,000 fish. In 1932, the newly formed Washington State Game Commission prohibited the commercial catch, possession, or sale of steelhead (Crawford 1979). After 1932, estimates of Puget Sound steelhead abundance were based on sportfisher catch, tribal catch, and spawning ground surveys.

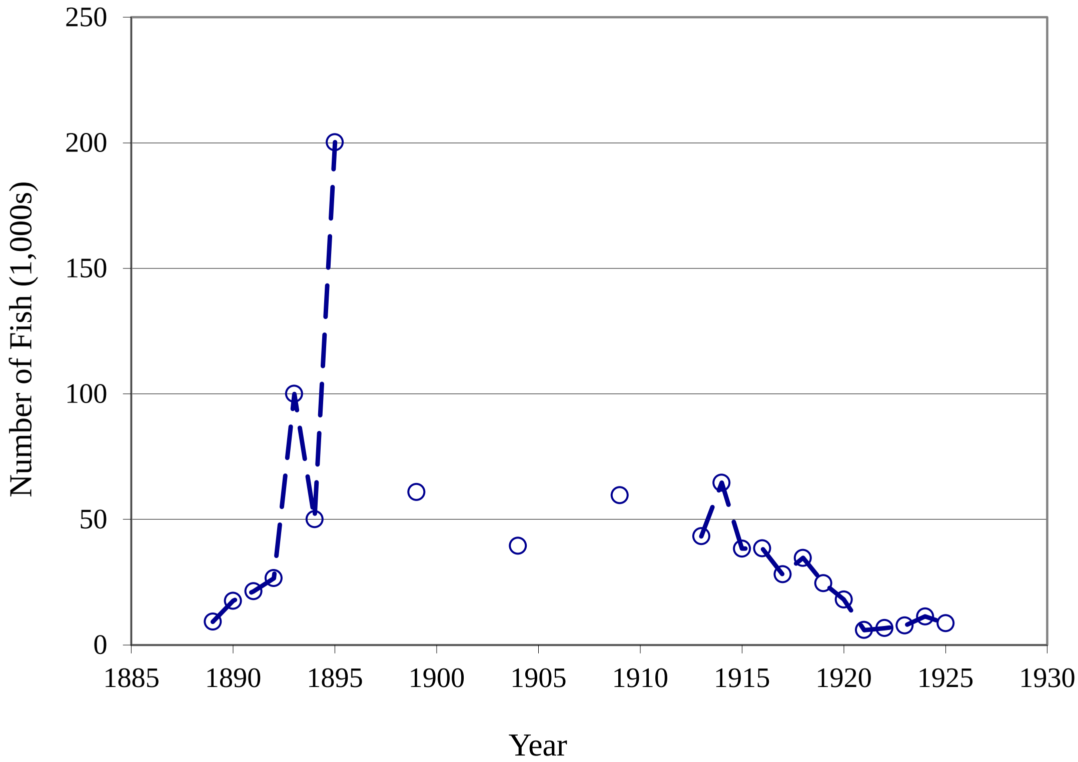


Figure 5. Harvest of steelhead in Puget Sound (1889-1925). The y-axis is total catch in number of fish. In years without data points harvest was reported as a combined salmon/steelhead harvest. Data from Washington Department of Fisheries Annual/Biannual Reports (1890-1920), Wilcox (1898), Rathbun (1900), Wilcox (1905), and Cobb (1911).

Pre-1950 Abundance: Basin Specific Information

Artificial propagation efforts with steelhead began with the first releases in 1900. Hatchery releases were initially primarily of smaller fry and subyearling fish with varying degrees of success. Work by Pautzke and Meigs (1941) was critical in beginning the transition to yearling releases from hatcheries. For this reason, we have focused on descriptions of abundance pre-1950s as indicators of natural production. In the early 1970s artificial propagation programs were expanded in both quantity and geographic scope (Appendix 6). Abundance estimates from before that period are thought to provide a more accurate estimate of natural productivity and abundance.

Nooksack River

Wilcox (1898) reports 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) notes that 300,000 kg (660,000 lbs) 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 during June and July 1921 of the North Fork Nooksack River and its tributaries 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 Fork Nooksack rivers (WDFG 1932). Ernst (1950) reported that railway shipments of dressed steelhead in the past had averaged 230 kg (500 lbs) during the eight week peak of the run. Sport fishery catches in the 1940s and 1950s suggest that abundance has declined considerably and only relatively low numbers of steelhead were present, although glacial sediment in the North Fork and Middle Fork 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 Samish Hatchery prior to this point so it is most probable that the original broodstock was native to the basin. The Wenatchee Daily World reported a sport fisher catching a near-record steelhead in the Samish River in April 1906 ("Lands 30-pound trout" 1906). Production levels during the initial years would have required a few hundred female broodstock (Appendix 5).

Skagit River

Historical accounts indicate that the run of steelhead in the Skagit River extended from November 15th 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 lbs.). 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 8th to May 9th, 81 adults were captured at the base of the lake (Ravenel 1900). 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 to 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 the 15th of June, with over a million eggs collected in 1906 (Riseland commented that the collection would have been higher if the hatchery weir gates didn't 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, undated (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 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. Steelhead were also reported by Smith and Anderson (1921a) to migrate 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 Forest Service Rangers, Smith and Anderson (1921a) also identified a number of tributaries to the Suiattle 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 precontact 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 21 September 1918, indicated that pools in Canyon Creek contained hundred of big (7 to 20 pound) steelhead (Fishing Trips out of Seattle. No. 14. Canyon Creek, 1918). 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) also 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 Washington Department of Fisheries 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" (page 23, WDFG 1925). The Washington Department of Fish and Game surveys in 1929 identified large spawning populations in the main stem North Fork and mainstem South Fork and 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 15th and were fished throughout the winter (Wilcox 1898). Steelhead harvest levels were estimated at 182,000 kg (401,000 lbs) 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 1917). Surveys undertaken by the Washington Department of Fish and Game in 1929 reported large aggregations of steelhead in the Pilchuck River, Sultan River, Skykomish, and Tolt rivers, and medium aggregations in the NF and SF Skykomish, Wallace, Snoqualmie, and Ragging rivers (WDFG 1932). Spawning at the Sultan River USBF hatchery occurred from April 8 to June 4 (Leach 1923). 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 two 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 and coho salmon in addition to steelhead (WDFG 1913). From 1 April 1912 to 31 March 1913, 1308 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 500-2,500, although they did not distinguish between summer- and winter-run steelhead.

The Lake Washington Ship Canal (1916) diverted Lake Washington and Lake Sammamish, their tributaries, and the Cedar River directly to Puget Sound. Washington Department of Fish and Game 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, in 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 undated (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 is 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 the hatchery was destroyed by floods. At its peak, the hatchery produced 1,500,000 fry in 1912. 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 undated(b)).

South Sound Tributaries

The presence of steelhead in the South Sound region was noted by Collins (1888), " 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 Sound tributaries (Appendix 7). 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 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 (Olympic Record 1909). Sport fishery catch data from the 1940 to 1970s (WDG undated(b)) indicate that steelhead catches varied annually from the 10s to 100s 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 (1877) 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, although there is some uncertainty regarding the accessibility of Lake Cushman to anadromous migration. A newspaper article in the Daily Olympian (March 22, 1897) reports that State Senator McReavey was requesting funds to build a fish ladder three 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, November 26, 1921). In 1899, the Washington Department of Fisheries established an egg taking station on the North Fork of Skokomish River below Lake Cushman (WDF 1902). During the first year of operation the station took an estimated 1,500,000 steelhead eggs (representing 533 females @ 2812[4] eggs/female). For unexplained reasons this station was subsequently abandoned two years later, and the 1899 production figures may be viewed with some skepticism. Tribal harvest for winter-run steelhead averaged 351 fish from the 1934/35 to 1944/45 return years, with harvests in the late 1950s averaging over 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 undated(b)).

Hood Canal, East Side Tributaries

There is little detailed information on steelhead abundance in creeks draining from the east side of Hood Canal. There are a number of newspaper accounts from the early 1900s specifically mentioning 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 Washington Department of Fisheries surveyed streams throughout the 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.

[4] Average steelhead fecundity of 2,812 eggs per female based on hatchery averages reported by WDFG (WDFG 1918).

Anderson Creek, Union River, 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 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 Bureau of Fisheries operated egg collection stations or hatcheries on Quilcene, Dosewallips, and Duckabush rivers. Although the primary objective of these operations was the collection of coho and chum salmon eggs there were a number of steelhead eggs collected, especially from the Duckabush River and Quilcene rivers. It was noted that the greater part of the steelhead run ascended by spring high water when the trap could not be operated, many of the fish collected were "too immature to be retained in ponds" (Leach 1927). Ripe fish were spawned from March 24th to May 1st in 1926.

In the 1932 Washington Department of Fisheries survey 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 cutthroats (WDF 1932). 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. It was observed that the steelhead run began 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, Clarence Pautzke with the Washington Department of Fisheries (undated) 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[5]. J.L. Riseland, State Fish commissioner, noted that the steelhead catch (at the hatchery) was the largest of any in the state (output at the time (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" (Riseland 1907).

Elwha River

[5] Assuming 50% survival from green egg to fry and an average fecundity of 2,812. It should also be noted that these fish would all have been natural-origin.

Construction of the Elwha Dam in 1912 blocked access to most of the basin was blocked. 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) identifies 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 unlear if 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 to southern California; however, even within the confines of Puget Sound and the Straits of Georgia there is considerable life history variation. Resident *O. mykiss*, commonly called rainbow trout, complete their life cycle in fresh water. Anadromous *O. mykiss*, steelhead, reside in fresh water for their first one to three years before emigrating to the ocean for one to three years before returning to spawn. Finally, in contrast to Pacific salmon, *O. mykiss* is iteroparous, capable of repeat spawning.

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 fresh water at an early stage of maturation, usually from May to October. These summer-run steelhead migrate to headwater areas and hold for several months prior to spawning in the following spring. Ocean-maturing steelhead, or winter-run steelhead, enter fresh water from November to April at an advanced stage of maturation, spawning from February through June. With the exception of Chinook salmon, steelhead are somewhat unique in exhibiting multiple run times within the same watershed (Withler 1966)[6].

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 steelhead. This survival disadvantage may explain why wintr-run steelhead predominate where no seasonal migrational barriers (Dan Rawding, WDFW, Vancouver, Washington, personal communication).

In 1900, a study by the Smithsonian Institution reported that Puget Sound steelhead begin to returning to fresh water as early as November, but that the principal river fisheries occurred in January, February, and March, when "the fish are in excellent condition" (Rathbun 1900). The average weight of returning steelhead was 3.6 to 6.8 kg (8 to 15 lb.), although fish weighing 11.4 kg (25 lb.) or more were reported. The

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

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-run 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 that the fish were in various stages of maturation: "a few fish were spent, but the majority were well advanced and would have spawned in a short time." Returning steelhead were historically harvested from December through February, using in-river fish traps rather than trolling in salt water (Gunther 1927).

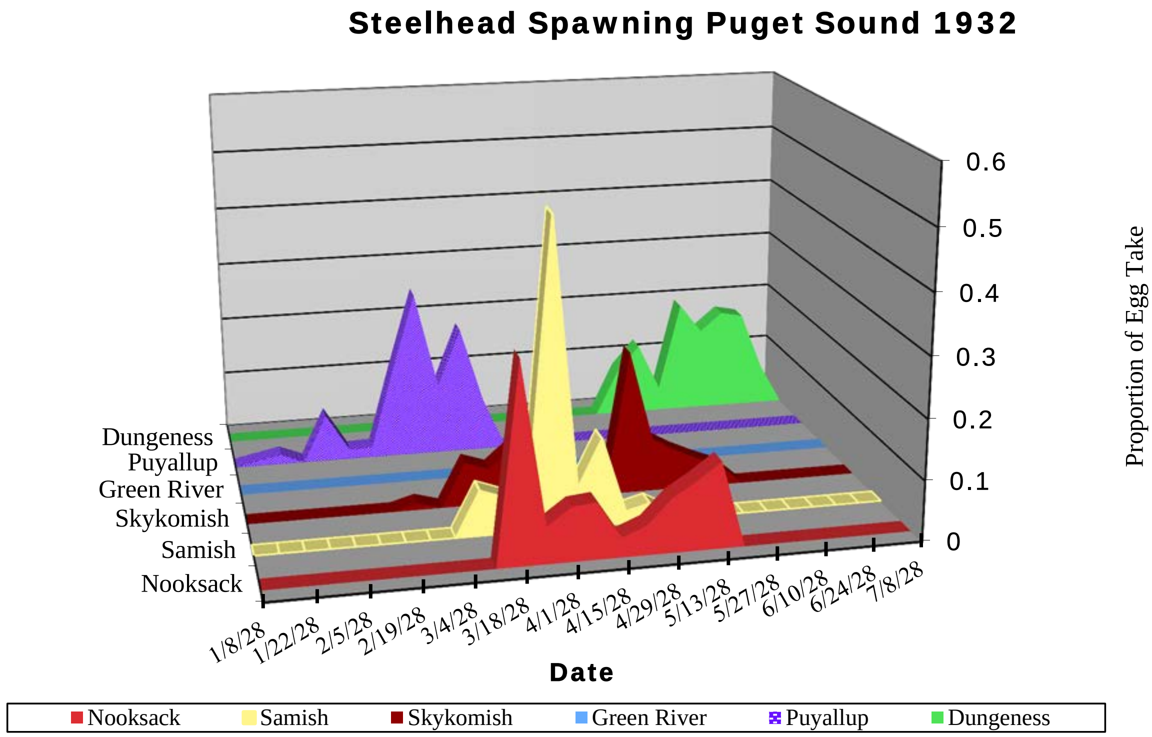
Much of the life-history information taken early in the 1900s comes from the collection and spawning of steelhead intercepted at hatchery weirs. The U.S. Fish Commission Hatchery at Baker Lake initially collected steelhead returning to Baker Lake using gillnets. Fish were collected from 9 March to 8 May, few survived to spawn, and no spawning date was given (USDF 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 it was concluded that much of the run entered the rivers in January (Ravenel 1902). 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 if these fish would have spawned in late June or July, or if they would have held in fresh water until the next spring (e.g. summer-run steelhead). Riseland (1907) reported that the Sauk River Hatchery collected steelhead spawn from the first part of February until the 15th of June. Steelhead were spawned at the Quilcene National Fish Hatchery in Hood Canal from 27 February to 7 June 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 the Hood Canal.

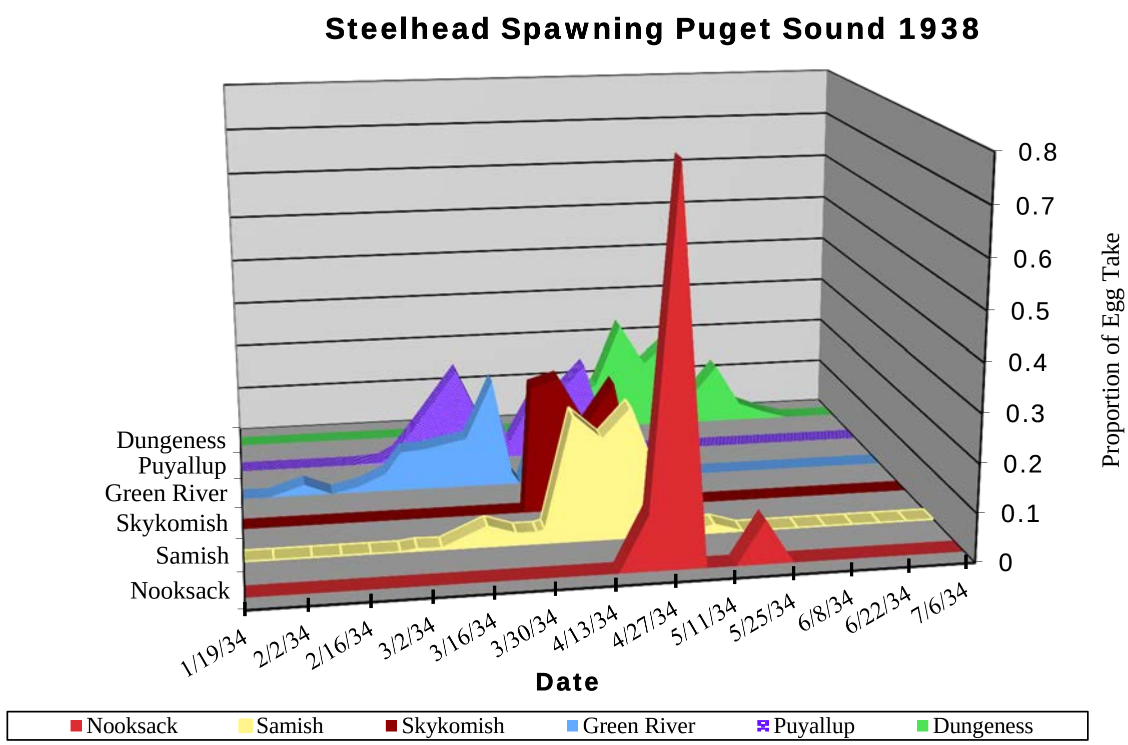
Pautzke and Meigs (1941) indicated that the steelhead run arrived in two phases: "In the early run the fish are small, averaging 8 or 9 pounds. The later run is composed of fish as large as 16 or 18 pounds." It was unclear whether these phases were distinct runs or different segments of the same run. In general summer-run fish run later in the spring than winter-run fish, and the summer-run fish also tend to be physically smaller than winter-run fish. Scale analysis indicates that the majority of first-time spawning summer-run fish have spent only one year in the ocean. Washington Department of Game records from the 1930s indicate a North-South differential in spawn timing (Figures 6a and 6b), 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 newspaper sports column from 1923 also notes that the Dungeness River steelhead run is much later than those found in Hood Canal ("Steelhead to make debut as angler's prey" 1923). Pautzke (undated) states that, "During the summer and fall this river [Dungeness] is the conductor of large runs of Chinook and humpback salmon, also the steelhead trout." This would suggest the presence of a summer run in the Dungeness River. Pautzke further states that the winter-steelhead fishing in the Dungeness River is one of the best in the State. Dick Goin[7], a Port Angeles resident, reported that the Dungeness River produced both winter 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, the steelhead spawning/egg take data for the Puyallup Hatchery indicated that this stock of fish spawned earlier than those at other hatcheries (Figure 7). In some years the majority of the spawning took place prior to March 15th, 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 Hatchery and the widely used Chambers Creek winter-run hatchery stocks may be related to the close geographic proximity of the two basins.

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 the peak timing for natural spawning. Historical hatchery spawning records, despite the obvious caveats, provide important information on within 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) and then remained at sea for two years. Scales from returning adults indicated a minority of the fish had been one-year old or three-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 (see Table 2, pg 38).

[7] Personal communication: Dick Goin, 502 Viewcrest, Port Angeles, WA, 21 November 2011.





Figures 6a and 6b. Temporal distribution (proportion of total egg take) of egg collection for steelhead returning to Washington Department of Game 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 (Washington State Archives, undated).

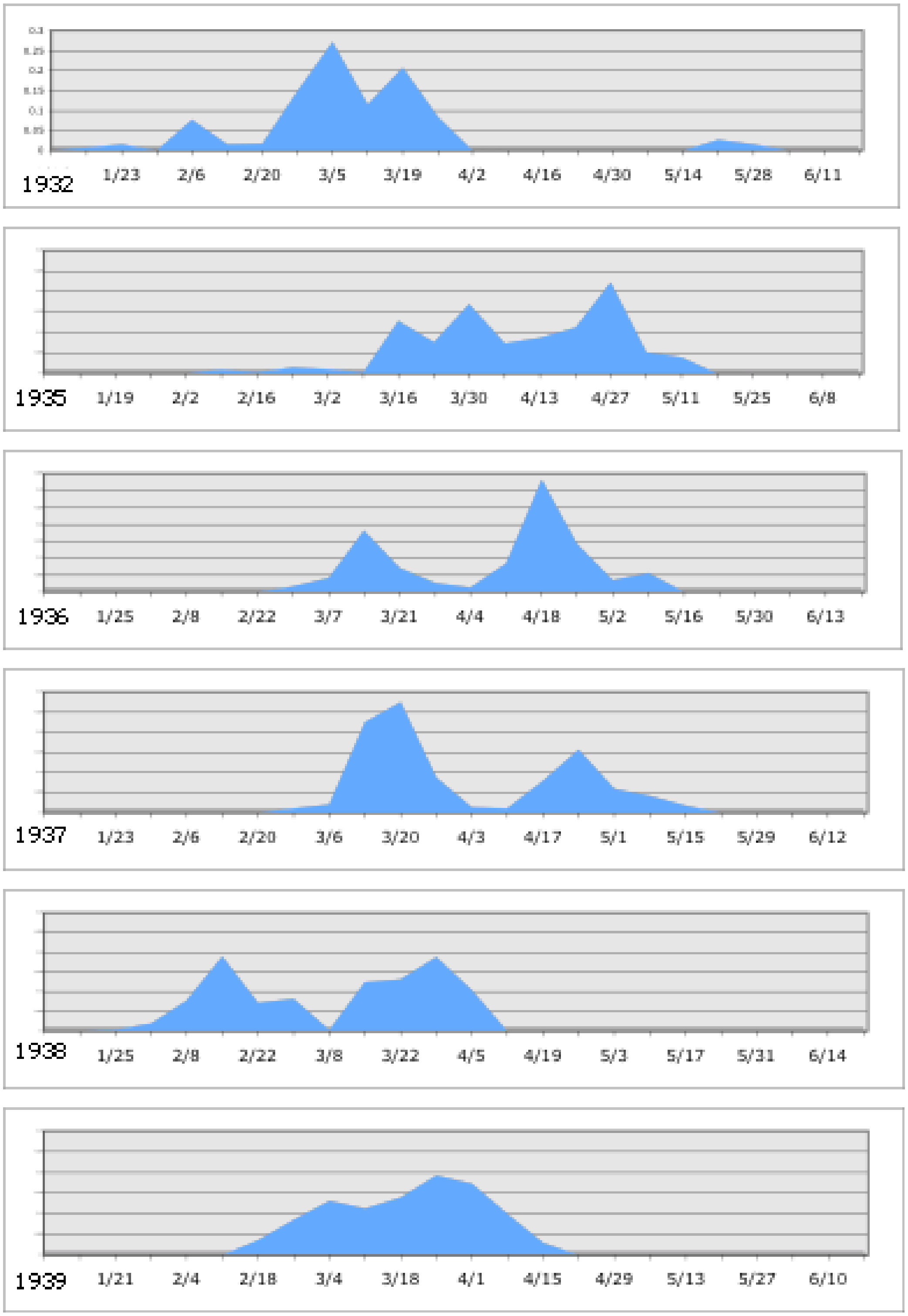


Figure 7. Standardized distribution of steelhead eggs collection at the Puyallup Hatchery from 1932 to 1939 (1934 not included) (WDFW undated).

Within the Puget Sound 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 or summer-run steelhead; for example, in short rain-dominated streams or above partially impassable barriers, respectively. In other areas, winter 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 winter and summer-run fish co-mingle on spawning grounds, it is unclear if 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 to treat these populations as single mixed-run DIPs.

Winter-run Steelhead

In general, winter-run, or ocean maturing, steelhead return as adults to the tributaries of Puget Sound from December to April (WDF et al. 1973). 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 1). 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 (nests), 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 (multi-year) spawning fish, based on scale pattern analyses (McGregor 1986, McMillan et. al 2007, Appendix 8b). If there is lower post-spawning 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, and/or fighting in defense of prime spawning areas or mates (Withler 1966).

In Puget Sound winter steelhead are found in both 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 predominante, in part, because there are relatively few basins with the geomorphological (for example, 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 fresh water 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, which likely results in higher prespawning mortality relative to winter-run steelhead. This potential survival disadvantage may explain why winter-run steelhead predominate where there are no migrational barriers (Dan Rawding, WDFW, Vancouver, Washington, personal communication). In at least two or possibly three Puget Sound river systems lacking obvious migration barriers, the Skagit, Sauk, and Dungeness, there appear to be co-occurring winter 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 Salmonid Stock Inventory (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. In part, this is due 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. 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 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 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.

Table 1. Timing of freshwater entry (shaded months) and spawning (letters) for native populations of steelhead (*O. mykiss*) in Puget Sound and the eastern Strait of Juan de Fuca. SSH denotes summer-run and WSH winter-run steelhead. **P** indicates month of peak spawning, and s indicates months when non-peak spawning occurs. Green shaded periods indicate freshwater migration. Information from WDFW et al. (2002) except Tolt River (G. Pess, personal communication 5/15/2008).

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

Juvenile Life History

The majority of naturally-produced steelhead juveniles reside in fresh water for two years prior to emigrating to marine habitats (Tables 2-4), with limited numbers emigrating as one or three-year old smolts. Additional age class distributions can be found in Appendix 8. Smoltification and seaward migration occurs principally from April to mid-May (WDF et al. 1972). Smolt size varies according to age and location. Wydoski and Whitney (1979) and Burgner et al. (1992) give an average length for two-year-old naturally produced smolts as 140-160 mm in length. 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, range 120-195 mm (Volkhardt et al. 2006). Moore et al. (2010) reported that smolts from Hood Canal streams ranged from 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 (Hart 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.

Table 2. Age structure for Puget Sound steelhead. Freshwater ages at the time of emigration to the ocean. The frequency in bold indicates the most common age. Reproduced from Busby et al. (1996). Populations in italics are representative populations outside of the Puget Sound steelhead DPS.

		Freshwater Age at Migration to Ocean				
Population	Run	1	2	3	4	Reference
Chilliwack River	*WSH*	*0.02*	***0.62***	*0.36*	*<0.01*	*Maher and Larkin 1956*
Skagit River	WSH	<0.01	**0.82**	0.18	<0.01	WDFW 1994b
Skagit River (fishery)	WSH	<0.01	**0.56**	0.27	0.067	Hayman (2005)
Deer Creek	SSH	--	**0.95**	0.05	--	WDF et al. 1993
Snohomish River	WSH	0.01	**0.84**	0.15	<0.01	WDFW 1994b
Green River	WSH	0.16	**0.75**	0.09	--	Pautzke and Meigs 1941
Puyallup River	WSH	0.05	**0.89**	0.06	--	WDFW 1994b
White River	WSH	0.20	**0.72**	0.08	0.00	Smith (2008)
Nisqually River	WSH	0.19	**0.80**	0.01	--	WDFW 1994b
Minter Creek	WSH	0.03	**0.85**	0.12	--	Gudjonsson 1946
Snow Creek	WSH	0.09	**0.85**	0.06	--	Johnson and Cooper 1993
Elwha River	WSH	0.08	**0.77**	.15	0.00	Morrill 1994
Hoh River	*WSH*	*0.03*	***0.91***	*0.06*	--	*Larson and Ward 1952*

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; Hart and Dell 1986; Burgner et al. 1992), although these conclusions are based on a very limited number of recoveries in the ocean.

Table 3. Age structure of Puget Sound steelhead. Frequencies of ocean age at the time of first spawning. The frequency in **bold** indicates the most common age. Reproduced from Busby et al. 1995. Populations in *italics* are representative of adjacent DPSs.

		Ocean Age at First Spawning					
Population	Run	0	1	2	3	4	Reference
Chilliwack River	*WSH*	--	*<0.01*	***0.50***	*0.49*	*<0.01*	*Maher and Larkin 1955*
Skagit River	WSH	--	--	**0.57**	0.42	0.01	WDFW 1994b
Deer Creek	SSH		**1.00**	**--**	--	--	WDF et al. 1993
Snohomish River	WSH	--	--	**0.57**	0.42	0.01	WDFW 1994b
Green River	WSH	0.02	0.07	**0.66**	0.25	--	Pautzke and Meigs 1941
White River	WSH	--	0.03	**0.67**	0.30	--	Smith (2008)
Puyallup River	WSH	--	--	**0.70**	0.30	--	WDFW 1994b
Nisqually River	WSH	--	--	**0.63**	0.36	0.01	WDFW 1994b
Elwha River	WSH	--	0.03	**0.51**	0.46	--	Morrill 1994
Hoh River	*WSH*	--	*0.02*	***0.81***	*0.17*	--	*Larson and Ward 1952*

Table 4. Age structure of Puget Sound steelhead. Frequencies of life-history patterns. Age structure indicates freshwater age/ocean age. Reproduced from Busby et al. 1995. Populations in *italics* are representative of adjacent DPSs.

		Life History (frequency)				
Population	Run	Primary		Secondary		Reference
Chilliwack River	*WSH*	*2/2*	*0.31*	*2/3*	*0.31*	*Maher and Larkin 1956*
Skagit River	WSH	2/2	0.48	2/3	0.33	WDFW 1994b
Skagit River (fishery)	WSH	2/2	0.30	2/3	0.18	Hayman 2005
Deer Creek	SSH	2/1	0.95	3/1	0.05	WDF et al. 1993
Snohomish River	WSH	2/2	0.47	2/3	0.36	WDFW 1994b
Green River	WSH	2/2	0.52	2/3	0.17	Pautzke and Meigs 1941
Puyallup River	WSH	2/2	0.61	2/3	0.28	WDFW 1994b
White River	WSH	2/2/	0.50	2/3	0.21	Smith (2008)
Nisqually River	WSH	2/2	0.51	2/3	0.28	WDFW 1994b
Hoh River	*WSH*	*2/2*	*0.74*	*2/3*	*0.14*	*Larson and Ward 1952*

Puget Sound steelhead feed in the ocean for one to three years before returning to their natal stream to spawn. Typically, Puget Sound steelhead spend two years in the ocean obtaining weights of 2.3 to 4.6 kg (Wydoski and Whitney 1979), although, notably, Deer Creek summer-run steelhead only spend a single year in the ocean before spawning (Tables 3 and 4).[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 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 can be found in Appendix 8.

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 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; Reisenbichler et al. 1992). Reisenbichler and Phelps (1989) analyzed genetic variation from 9 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 9 populations rather than the influence of hatchery fish.

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 the Puget Sound and 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

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

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, page 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) Northern Puget Sound (including the Stillaguamish River and basins to the north, 2) South Puget Sound, and 3) the Olympic Peninsula (Leider et al. 1995). Additionally, populations in the Nooksack River Basin and the Tahuya River (Hood Canal) were identified as 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 both 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 was unclear if 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, and North Fork Stillaguamish rivers) that appeared to have undergone minimal hatchery introgression (Phelps et al 1994).

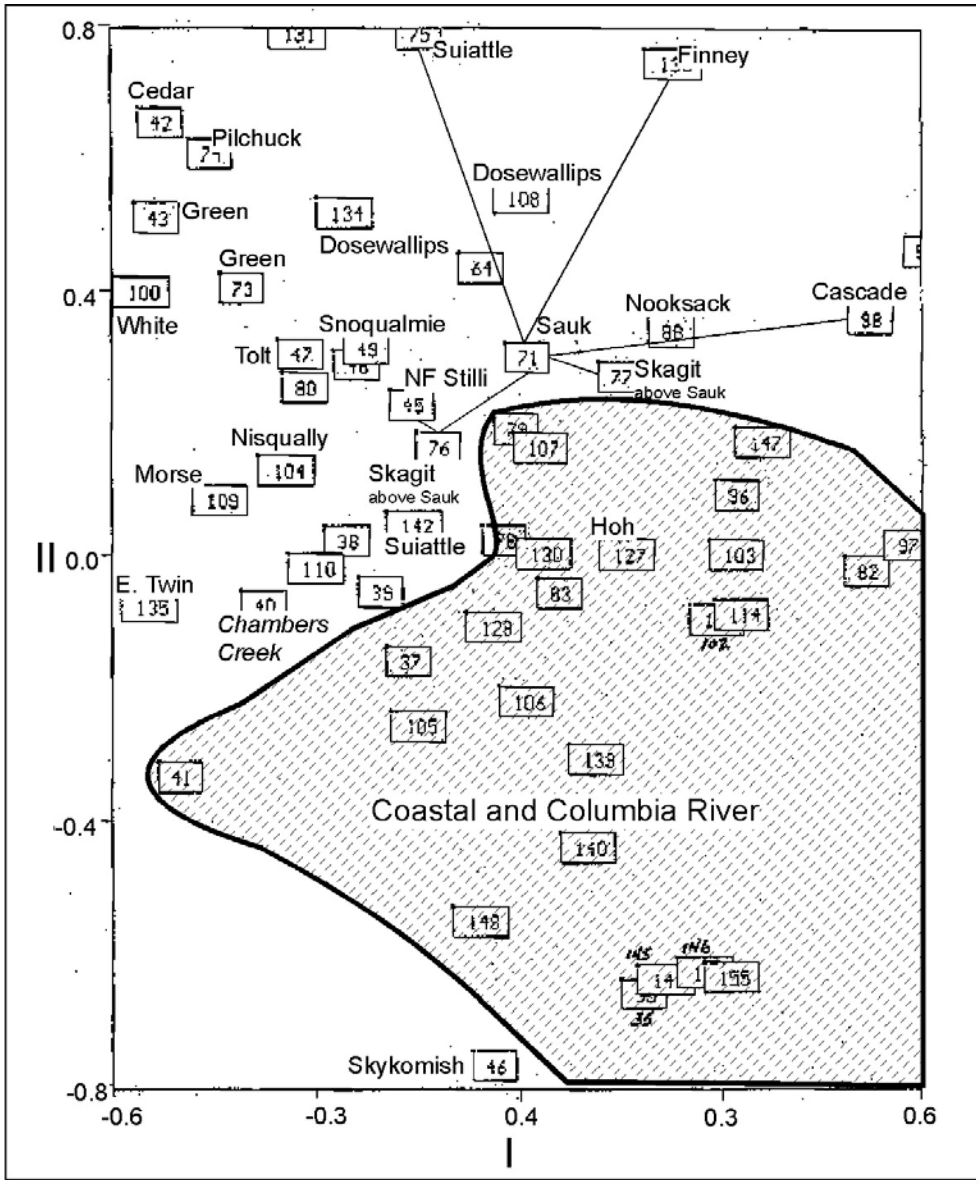
A subsequent study by Phelps et al. (1997) with additional population samples found little evidence for hatchery influence in Puget Sound steelhead populations. Among the North Puget Sound populations sampled in the Phelps et al. (1997) study, four genetic clusters were detected: Nooksack, Skagit (Sauk), 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 8). In general, early allozyme studies on Puget Sound *O. mykiss* did provide substantial evidence for population distinctiveness on a large scale (basin-wide), 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 Coastwide 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.

Van Doornik et al. (2007b) 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, 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. 2007b). 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 (Chrzastowski 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 Chittenden Locks in 1916 (Bogue 1911, Williams et al. 1975, Klingle 2005). Furthermore, Marshall et al. (2006) concluded that the Green and Cedar River steelhead populations were genetically distinct from hatchery-origin winter steelhead (Chambers Creek origin) and summer steelhead (Skamania National Fish Hatchery (NFH) origin), which have been released in the Green River for many years.



Suiattle
Finney
Cedar
Pilchuck
Dosewallips
Green
Dosewallips
Green
White
Cascade
Nooksack
Sauk
Snoqualmie
Tolt
Skagit
above Sauk
NF Stilli
Nisqually
Morse
Skagit
above Sauk
Hoh
Suiattle
E. Twin
Chambers
Creek
Coastal and Columbia River
Skykomish
II
I

Figure 8. Two-dimensional scaling views, based on allozyme analysis, of coastal steelhead populations from Phelps et al. 1997.

Preliminary results from the genetic analysis of Hood Canal steelhead (Van Doornik et al. 2007a) indicated that steelhead from western, Olympic Peninsula, tributaries to Hood Canal are distinct from steelhead in eastern, Kitsap Peninsula, tributaries. Tributaries that enter the eastern side of Hood Canal drain lowland hills and are characterized by low to moderate stream gradients, while west-side 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 2007a). 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. 2007a).

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 NOAA's NWFSC. In many cases the analysis of existing samples was undertaken in response to requests by the TRT for specific information. This new information was incorporated into the existing Puget Sound steelhead genetic database (Appendix 3). 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 major populations group (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 set 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 and winter-run steelhead), major genetic lineages, and/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 10). 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" (SPOIR) consideration in the ESA. 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 (LCR) DPS two major life history types were recognized by the UWLCR 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 LCR, the TRT recognized three ecological zones from the mouth of the Columbia River to the historical location of Celilo Falls. The LCR steelhead DPS included two of these three ecological zones: Cascade and Gorge. These ecological zones were based on the U.S. Environmental Protection Agency's Level III Ecoregions (Omernik 1987) and the Pacific Northwest River Basins Commission physiographic provinces (PNRBC 1969). Ecologically-based MPGs designated by the TRT (Table 5) reflect the homing fidelity exhibited by steelhead and the likely degree to which populations will be locally adapted marine and near shore 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.

Table 5. MPGs for the Lower Columbia River steelhead DPS (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

The Interior Columbia Technical Recovery Team 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 there were six MPGs identified, each associated with a major tributary or mainstem section. Similarly, there were four MPGs 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 (NCCC 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 both geographic and environmental isolation (non-migratory 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 NCCC 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 (Bjorkstadt et al. 2005).

The Puget Sound Chinook salmon TRT established five "Geographic Regions" (Figure 9) 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- 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 9) provided a foundation for developing the configuration of steelhead MPGs. In contrast to Chinook salmon that spawn predominately in the mainstem 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 sub-structuring within the DPS (e.g., MPGs).

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. 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 northern 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

Figure 9. Geographic regions of diversity and correlated risk for Puget Sound Chinook salmon as developed by the Puget Sound Technical Recovery Team (Ruckelshaus et al. 2002).

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 Georgia Straits in addition to another 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 3): 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 Northern Cascades Ecoregion differs from the Cascades Ecoregion in geology and glacial coverage. Currently the Northern 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 9). 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 10). Finally, genetic analysis of steelhead populations suggested a clustering of populations similar to some of the geographic regions developed by the Chinook Salmon TRT (Appendix 3). 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 SF Tolt 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.

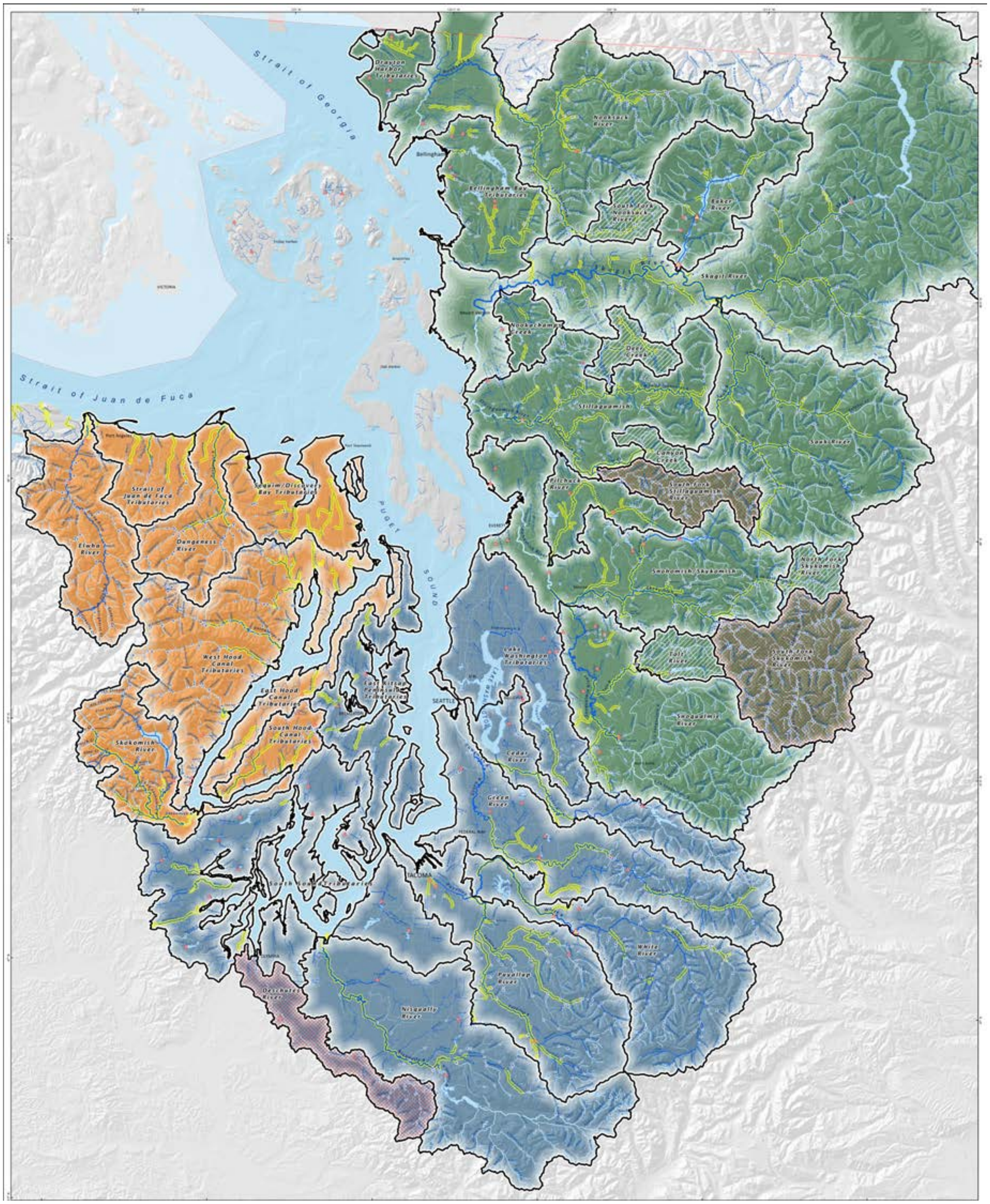


Figure 10. Major population groupings for the Puget Sound steelhead DPS: Northern Cascades, Central and South Puget Sound, and Olympic Peninsula MPGs. Note that the Deschutes, South Fork Stilliguamish, and South Fork Skykomish basins are not included in the DPS and have not been assigned to DIPs. We 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 Puget Sound Steelhead 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, 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", "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 making a decision on the status of the presumptive DIP. In a parallel effort, the TRT employed a number of decision support systems (DSS) to identify DIPs. The decision support system provides a more quantitative and transparent methodology (Appendix 14) than the expert 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 presented in Appendix 3. 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 sections 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 substantial uncertainties among the TRT in the DIP determination.

Northern Cascades (South Salish Sea) Major Population Group

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 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 11).

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 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 (GDU) 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.

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 Puget Sound Steelhead TRT concluded that the Nooksack River basin steelhead populations did not constitute a distinct MPG.

Proposed DIPs within the Northern Cascades MPG

Table 6. Demographically independent populations (DIPs) within the Northern Cascades Major Population Group (MPG) and their respective categorization by state and tribal agencies. WRIA – Water Resource Inventory Area, SASSI/SaSI– Salmon and Steelhead Stock Inventory.

WRIA	1992 SASSI / 2002 SaSI	TRT MPG	TRT DIP
1	Dakota Cr Winter	Northern Cascades	Drayton Harbor Tributaries Winter Run
1	NF Nooksack Winter		
1	MF Nooksack Winter		Nooksack River Winter Run
	SF Nooksack Summer		
1	SF Nooksack Winter		SF Nooksack River Summer Run
3	Samish River Winter		Samish River and Bellingham Bay Winter Run
4	MS Skagit Winter		
4	Finney Cr Summer		Skagit River Summer/Winter Run
4	Cascade R Summer Cascade R Winter		
4			Nookachamps Creek Winter Run
4			Baker River Summer/Winter Run
4	Sauk R Summer Sauk R Winter		Sauk River Summer/Winter Run

[12] Additional genetic analyses have been made of Snohomish Basin populations, but have not been integrated into the DPS-wide data base at the time of this writing.

5	Stillaguamish R Winter	Stillaguamish River Winter Run
5	Deer Cr Summer	Deer Creek Summer Run
5	SF Stillaguamish Summer	Out-of-DPS
5	Canyon Cr Summer	Canyon Creek Summer Run
7	Snohomish/Skykomish R Winter	Snohomish/Skykomish River Winter Run
7	Pilchuck R Winter	Pilchuck River Winter Run
7	SF Skykomish Summer	Out-of-DPS
7	NF Skykomish R Summer	NF Skykomish River Summer Run
7	Snoqualmie R Winter	Snoqualmie River Winter Run
7	Tolt R Summer	Tolt River Summer Run

Northern Cascades DIP Descriptions

1. Drayton Harbor Tributaries Winter-Run Steelhead

This population includes steelhead that spawn in tributaries from the Canadian border to Sandy Point, primarily in Dakota and California Creeks (Smith 2002). This population 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 this population 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, 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 Puget Lowland Level IV Ecoregion, with the maximum elevation in the basin being 89 meters. The basin size for Dakota Creek is 139 km^2, although this does not include some other minor tributaries (i.e. 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 4). Sport fishing punch card records indicate a maximum catch (adjusted)[15] of 67 fish in 1957, with an average catch of 18 fish annually from 1946-1970. Steelhead and presumptive steelhead redds have been observed recently, but in low numbers, although monitoring is intermittent.

2. Nooksack River Winter-Run Steelhead

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 TRT members suggested the presence of multiple winter-run

[13] Brett Barkdull, Washington Department of Fish and Wildlife, La Conner, WA October 2008.
[14] IP estimates of basin capacity are presented as a range using smolt survivals varying from 10 – 20%.
[15] Sport catch estimates were adjusted by 0.60 from numbers published in WDG (undated b) based a personal communication by Peter K. Hahn, Washington Department of Fish and Wildlife, 600 N Capital Way, Olympia, Washington 18 November 2009.

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 (allozyme-based) indicated that North Fork and South Fork Nooksack River 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 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[2]. 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 (redd counts, etc) or life history characteristics (spawn timing, etc.). 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[16] [17].

Historical estimates from in-river harvest suggested 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 and Middle Fork Nooksack rivers in 1930 identified a number of tributaries that supported steelhead. Ernst (1950) reports that the South Fork Nooksack River was the major producer in the basin, and that most of these fish spawned in the mainstem. Adjusted punch card catch estimates (1946-1972) peaked in 1953 at 2,114 winter-run steelhead. Additionally, there are reports of summer-run steelhead being present in the North and Middle Forks of the Nooksack River; however, it was unclear whether these were fish from the South Fork Nooksack summer-run DIP, a distinct North or Middle Fork 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 Steelhead

The TRT identified a DIP in the upper portion of the South Fork Nooksack River based in part on geographic separation between winter- and summer-run steelhead in the Nooksack Basin. According to WDFW (2003) summer-run steelhead spawn in the mainstem South Fork 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

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[16] See footnote 2.
[17] Ned Currence, Natural Resource Department, Nooksack Tribe, Deming, WA, October 2008.

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 estimate range), was estimated to be 1,137 - 2,273 steelhead. WDFW (2003) 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- and summer-run steelhead were significantly different from each other in the South Fork Nooksack River. Preliminary microsatellite DNA analysis of steelhead from the South Fork Nooksack River 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- and summer-run fish in these surveys. Ernst (1950) reports that steelhead migrated as far as 5.6 km above Howard Creek.

4. Samish River Winter-Run Steelhead

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 DIPs, the Samish River exhibits a largely rain-dominated flow pattern. The entire basin is located within the Puget Sound 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 ("Steelhead to make debut as angler's prey" 1923). The present day run is 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, WSFG 1913). Although the basin is relatively small, the basin averaged 617 steelhead over the most recent five-year period (WDFW 2011 unpublished data). Peak catch, based on adjusted punch cards was 1,934 winter-run steelhead in 1951. The IP-based estimate range of capacity for the Samish Basin was 3,193 - 6,386 steelhead (Appendix 4). Furthermore, while the adjacent Nooksack 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 microsatellites DNA indicated samples from the Samish River winter-run were more closely related to Nooksack River fish than to Skagit or Stillaguamish

[18] Brett Barkdull, Washington Department of Fish and Wildlife, La Conner, WA August 2012.

river steelhead. There was a general consensus among the TRT 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 undated (b)) indicate a peak catch of 23 fish in Chuckanut Creek (1958), 8 in Squalicum Creek (1970), and 34 in Whatcom Creek (1953). The intrinsic potential 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 be isolating. 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. Mainstem Skagit River Summer- and Winter-run Steelhead

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 two years of sampling (2010/2011) 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 steelhead (combined winter- and summer-run) DIP includes all steelhead spawning in the mainstem Skagit 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 mainstem 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 3), the Cascade River and Goodell Creek juvenile samples from the anadromous zone were distinct from some of the other Skagit Basin samples, In the case of the Cascade River juvenile fish that did not genetically resemble resident *O. mykiss* 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 mainstem and lower tributaries with summer - run steelhead reported in Day and Finney creeks and the Cascade River (WDG undated (a), Donaldson 1943). 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-runs 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 undated(b)), although accessibility to fishers likely limited the sport catch. Further sampling efforts in these basins were recommended. At a minimum, winter- and summer-run life histories are somewhat reproductively isolated (temporal separation) from each other; however, it was unclear if 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 8). 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 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[19], near confluence of the Cascade and Skagit rivers.

This DIP includes the entire Skagit River except for the Sauk and Baker river sub-basins. 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 4). 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 Steelhead

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,

[19] Todd Kassler, Washington Department of Fish and Wildlife, 26 May 2010.

this lowland sub-basin 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 the 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 DIP and the Nooksack River winter-run DIP. However, it was unclear how geographically separated spawning areas in Nookachamps Creek would be from 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 (WDF undated (a)) suggested that a fair number of fish spawn 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 sub-basin and its proximity to Mt. Vernon, WA, 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 identified as a historical DIP, the TRT agreed that additional information and monitoring was needed to address critical uncertainties.

7. Baker River Summer- and Winter-Run Steelhead

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 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.[20] Many of the TRT members and reviewers considered the Baker River DIP to have

[20] Presentation by Dave Pflug, Seattle City Light, to the Puget Sound steelhead TRT, Seattle, Washington, 25 January 2012.

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* populations 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(s).

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 4). Historically, canyon areas in the lower river below Baker Lake (corresponding with the present locations of Lower 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 draining the slopes of Mt. Baker. Landslides and volcanic activity pose some of the greatest catastrophic risks.

8. Sauk River Summer and Winter-Run Steelhead

The identification of a Sauk River 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- 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 winter run of steelhead in the Sauk River basin was significantly earlier than that in the mainstem Skagit, 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 undated (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 Washington Department of Fish and Game hatchery on the Sauk River collected steelhead eggs from early February to 15 June, with over a million eggs collected (WDFG 1907). The wide temporal window for collecting eggs suggests that eggs were collected from both summer and winter runs. For summer- and winter-run steelhead in the Sauk River Basin, there does not appear to be any geographic separation on the spawning grounds. WDFW (2003) reported that summer-run fish spawned 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, 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 undated (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 currently underway in the Skagit River Basin. Preliminary results from recent genetic sampling indicated that *O. mykiss* from Skagit Basin 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 (Appendix 3 Figure 3-6), pooling samples within the Upper and Lower Skagit basins and Sauk Basin reduces the genetic distance between the Skagit and Sauk sample aggragates, but this may be because of variability within sub-basins. 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 4). 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 Steelhead

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. Non-native 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 if 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- 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 steelhead collections (Appendix 3). This genetic relationship is thought to be related to the Sauk River's historical drainage to the North Fork Stillaguamish prior to a series of lahars(volcanic mudflows) diverting the flow of the Upper Sauk River to the Skagit River over 10,000 years bp. WDFW (2003) reports 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 and Canyon Creek DIPs, covers 1,282 km^2. The IP-based capacity ranged from 19,118 to 38,236 steelhead (Appendix 4). 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 Lowland 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 (see above), and as a result the North Fork Stillaguamish River valley is much broader than might be expected based on current river size and flow. River flow in the Stillaguamish River is considered rain and snow transitional. The Stillaguamish River is subject to moderate risks from volcanic, landslide and earthquake events.

10. Deer Creek Summer-Run Steelhead

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 of 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 4). 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 and Skagit rivers (Phelps et al. 1997). Reanalysis of one of the same Deer Creek samples from 1995 using DNA 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 Stilliguamish rivers (Appendix 3). 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 (two years in fresh water and one 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 Steelhead

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 ("Aha! Canyon Creek!" 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-and summer-run steelhead. Above the cascades, there is approximately 26 km of accessible mainstem and tributary habitat (Appendix 4). 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 basin, below the cascades that demark the winter- and summer-run spawning habitat. The upper reaches of Canyon Creek lie in the North Cascades Ecoregion.

12. Snohomish/Skykomish River Winter-Run Steelhead

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 (2003) identified three winter-run populations in the Snohomish Basin based on geographic discreteness. There is no recent genetic information available (i.e. 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 1800 and early 1900s indicated that runs likely exceeded a 100,000 fish (Appendix 4). Basin area is 2,185 km^2 and the intrinsic potential estimates suggest a run size of approximately 21,389 to 42,779 fish (Appendix 4).

The lower reaches of the Snohomish River are in the Puget Lowland 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 predominately a rainfall-driven system, whereas the Snohomish, Snoqualmie, and Skykomish rivers are classified as rain and snow transitional rivers. The Snohomish River is subject to relatively high earthquake catastrophic risks, but low volcanic risks.

13. Pilchuck River Winter-Run Steelhead

In 1876, Glenwild 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 to be sufficient habitat (366 km^2) to support a population as defined by the TRT. The IP-based estimate of capacity was 5,193 to 10,386 steelhead (Appendix 4). 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 weighing 10 kg ("Women catches big steelhead; fishing good in Skykomish" 1918). Although genetic samples from Pilchuck River steelhead were most similar to those from other Snohomish Basin samples, the Pilchuck was an outlier from other Snohomish and central Puget Sound samples (Phelps et al. 1997). More recent genetic sampling indicated that there were significant differences between steelhead from the Pilchuck and other samples; however, the sample size was small (< 25) and no other Snohomish 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 Basin winter-run steelhead, and there appears to a discontinuous spawning distribution between the lower Pilchuck and mainstem Snohomish River (George Pess, personal communication[21]). 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 Steelhead

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 4). Again, the IP estimate appears to underestimate summer-run population's possible abundance. Genetic analysis by Phelps et al. (1997) indicated that a North Fork Skykomish sample, presumably summer-run fish, were 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- 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 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 a more of a snow-dominated pattern than the rest of the Skykomish River.

[21] George Pess, Northwest Fisheries Science Center, NMFS, October 2008

15. Snoqualmie River Winter-Run Steelhead

The Snoqualmie River winter-run steelhead DIP includes fish 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 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. 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 estimate of capacity was 16,740 to 33,479 steelhead ((Appendix 4), and the 20110 escapement estimate of 732 steelhead. Much of the accessible portion of the Snoqualmie River is contained within the Puget Sound Lowland Ecoregion, although stream flows are heavily influenced by flows from inaccessible headwater sub-basins 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 Steelhead

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 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 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- 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 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 3). This association my 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 ranged from 321 to 641 steelhead (Appendix 4), while the most recent (2010) escapement estimate was 116 steelhead. Much of the Tolt River Basin contains glacial sediments, with the exception of harder volcanic formations in the canyons (Haring 2002). The Basin straddles the Puget Lowland and North Cascades Ecoregions. Tolt River flows are generally rain and snow transitional.

Central and South Puget Sound Major Population Group

The Central and South Puget Sound Major Population Group includes populations from the Lake Washington and Cedar River basins, in the Green, Puyallup, and Nisqually rivers, and in South Sound and East Kitsap Peninsula tributaries (Table 7). This MPG includes portions of the Cascades (higher elevation) and Puget Sound 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 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 an MPG established for Chinook salmon by the Puget Sound Chinook salmon TRT.

Areas of the South 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(s). The Deschutes River was historically impassable to anadromous fish at Tumwater Falls.

Proposed DIPs within the Central and South Puget Sound MPG

Table 7. Demographically independent populations (DIPs) within the Central and South Puget Sound Major Population Group (MPG) and their respective categorization by state and tribal agencies. WRIA – Water Resource Inventory Area, SASSI/SaSI– Salmon and Steelhead Stock Inventory.

WRIA	1992 SASSI / 2002 SaSI	TRT MPG	TRT DIP

8	Lake Washington Winter	Central and South Puget Sound	North Lake Washington and Lake Sammamish Winter Run Cedar River Winter Run
9	Green R Summer[22] Green R Winter		Green River Winter Run (Summer)
10	MS Puyallup R Winter		Puyallup/Carbon River Winter Run
10	Carbon R Winter		
10	White R Winter		White River Winter Run
11	Nisqually R Winter		Nisqually River Winter Run
13	Deschutes R Winter[23]		
13,14	Eld Inlet Winter		
14	Totten Inlet Winter		South Sound Tributaries Winter Run
14	Hammersley Inlet Winter		
14,15	Case/Carr Inlet Winter		
15	East Kitsap Winter		East Kitsap Winter Run

DIP Descriptions

17. Cedar River Winter-Run Steelhead

This DIP includes the Cedar River Basin and major tributaries to the southern portion of Lake Washington, primarily Kelsey Creek, May Creek and Coal creeks. 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 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 pre-ship canal environment, therefore 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 glacial recession (~10,000 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 non-anadromous *O. mykiss* downstream and upstream of Landsburg Dam, which until 2003 was impassable to anadromous fish.

[22] The existing Green River summer-run steelhead population is descended from non-native 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.

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

Genetically, Cedar River steelhead were 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 (Ballard) Locks fish ladder (although fish can pass undetected through the locks). The IP estimate of abundance ranged from 5,949 to 11,899 steelhead (Appendix 4). 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 Steelhead

This DIP includes tributaries draining the northern end of Lake Washington (approximately north of Lake Union and Evergreen Point) and the Sammamish River and Lake 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 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 pre-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 (for example: 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 if *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 estimate range for abundance is 5,268 to 10,536 steelhead (Appendix 4). Earthquake and flood events constitute the most likely catastrophic risks.

19. Green River Winter-Run Steelhead

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 of steelhead existed in the Green River, likely passing upstream of the Headworks Diversion Dam (rkm 98.1). The Headworks Diversion Dam blocked migratory access to the upper basin in 1913.

A minority of TRT members indicated that a native run of summer-run steelhead likely occurred in the Green River, in upstream basin areas. An article in the Seattle Daily Times from 29 July 1907 describes how C.W. Willard nearly drowned landing a 4.5 kg steelhead in the Green River above Auburn ("Man nearly drowns in a fight with a big trout", 1907). 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, and Sunday Creeks 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.

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

The Green River Basin covers 1191 km^2, with Soos and Newaukum Creeks constituting the major tributaries. The lower portion of the Green River is in the Puget Lowlands, while the upper basin is in the Cascades Ecoregion. The IP-based estimate range for capacity for this DIP is 19,768 to 39,537 steelhead (Appendix 4); 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 River/Carbon River Winter-Run Steelhead

This population includes winter-run steelhead in the Puyallup River and one of its major tributaries, the Carbon Rivers. The Puyallup Basin's other major tributary, the White River, was designated as a separate DIP. The TRT determined that the mainstem Puyallup below the confluence of the Puyallup and White Rivers was more closely associated with the Carbon River than with the White. Historically, the White River drained to the Green River rather than the Puyallup River, with the Puyallup/Carbon being a separate basin. The Puyallup/Carbon River DIP covers 1,277 km^2 and although recent escapements have averaged 410 steelhead (2007-2011), IP-based capacity estimate is 14,716 to 29,432 steelhead (Appendix 4). 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. (2007b) found that samples from the White and Carbon rivers were genetically significantly different from each other, although genetic divergence (Fst) between samples from the two locations was only 0.015, a relatively low degree of separation.

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 Steelhead

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 Carbon/Puyallup 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 River 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 being 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 4). 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 Steelhead

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 sections the presence of 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, 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 3), 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 relationship among steelhead in the Nisqually 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, 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-based estimate for capacity ranged from 15,330 to 30,660 steelhead (Appendix 4). 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 run-off from Mt. Ranier. This population is most likely at risk from volcanic, earthquake, and flood catastrophic events.

23. South Sound Winter-Run Steelhead

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 into 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 Sound. Sport fishery catch records (Punch Cards) indicate that steelhead were caught in a number independent tributaries to the South Sound area: Coulter Creek, Goldsborough Creek, Kennedy Creek, Mill

Creek, Percival Creek, and Sherwood Creek. The average reported sport harvest was 85 steelhead through the 1950 and 1960s (WDG, undated). 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 stones" interaction process. The tributaries all lie within the Puget Lowlands and are generally shorter rain-dominated systems, with the exception of the Deschutes River, which was not historically accessible to steelhead above Tumwater Falls (rkm 3.2). The only South 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 (Appendix 3). The IP-based estimate range for capacity was 9,854 - 19,709 steelhead (Appendix 4). 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 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 and Carr Inlet DIPs in addition to a combined Eld, Totten and Hammersley Inlet (Southwest 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. This 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 Winter-Run Steelhead

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 undated (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). Intrinsic potential 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 4). 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 Major Population Group

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

Currently winter–run steelhead predominate in this MPG. There is some uncertainty regarding the historical or present day 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 within the MPG: 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 (over 50 km) between major spawning regions. Puget Lowland and Coastal Range Ecoregions dominate the low elevation areas of the MPG, while high elevation areas are located in the EPA's Level III Northern Cascade Ecoregion. This MPG corresponds to the amalgamation of the Puget Sound TRT's Chinook salmon Strait of Juan de Fuca and Hood Canal geographic regions (MPGs).

Proposed DIPs within the Hood Canal and Strait of Juan de Fuca MPG

Table 8. Demographically independent populations (DIPs) within the Hood Canal and Strait of Juan de Fuca Major Population Group (MPG) and their respective categorization by state and tribal agencies. WRIA – Water Resource Inventory Area, SASSI/SaSI– Salmon and Steelhead Stock Inventory.

WRIA	1992 SASSI / 2002 SaSI	TRT MPG	TRT DIP
15	Dewatto R Winter	Hood Canal and Strait of Juan de Fuca	East Hood Canal Winter Run
15	Tahuya R Winter		South Hood Canal Winter Run
15	Union R Winter		
16	Skokomish R Summer Skokomish R Winter		Skokomish River Winter Run (Summer)
16	Hamma Hamma R Winter		West Hood Canal Winter Run
16	Duckabush R Summer Duckabush R Winter		
16	Dosewallips R Summer Dosewallips R Winter		
17	Quilcene/Dabob Bays Winter		
17	Discovery Bay Winter		Sequim/Discovery Bay Independent Tributaries Winter Run
17	Sequim Bay Winter		
18	Dungeness R Summer Dungeness R Winter		Dungeness River Winter/Summer Run
18	Morse Cr Winter		Strait of Juan de Fuca Independent TributariesWinter Run
18	Elwha R Summer Elwha R Winter		Elwha River Winter Run (Summer[24])

DIP Descriptions

25. East Hood Canal

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 Dewatto River. Stream surveys conducted in 1932 give 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 (WDG, 1932). Maximum harvest (adjusted) in the Dewatto was 232 steelhead in 1952 and 242 in 1963 in Big Beef Creek (WDG undated(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 of potential abundance ranged from 1,270 to 2,540 steelhead (Appendix 4).

[24] 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.

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 use patterns over the last century.

There was considerable disagreement 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, grouping four main components (Northwest Kitsap, 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 was thought to allow a higher rate of exchange than is allowable for a demographically independent population; however, genetic data indicated that despite their relative proximity steelhead populations in the Dewatto, Tahuya, and Union rivers steelhead were genetically distinct, although these differences were smaller than those observed in comparisons between the East and West Hood Canal steelhead DIPs (Appendix 3). Ongoing research on steelhead populations in Hood Canal should provide additonal information on the rate of straying and further boundary adjustments may be necessary.

26. South Hood Canal

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 primary streams in this DIP include the Tahuya and Union rivers (the primary streams) and 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 (WDG, 1932). Maximum harvest (adjusted) was 640 steelhead in 1952 (WDG undated(b)).. Overall, the IP estimate of capacity ranged from 2,985 to 5,970 fish (Appendix 4), 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 the Hood Canal. In general, samples from within this DIP clustered together relative to samples from the Skokomish and west side of Hood Canal.

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 (<20km) was thought to allow a higher rate of exchange than is allowable for a demographically independent population. 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 Steelhead

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 River 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 et al. 2007a).

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 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 Skokomish River winter-run section (23) may include summer-run steelhead. Fish classified as summer run based on post-30 May harvest were caught in the sport fishery from 2000-2004, with 50 fish recorded in 2003 (WDFW et al. 2004). Based on information available the TRT was unable to establish whether a self-sustaining run was present currently or historically. Furthermore, additional monitoring would be needed to assess any differences among winter-run steelhead in the North Fork and South Fork.

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 the Hood Canal. The entire basin covers approximately 628 km^2, with the North Fork and South Fork basin being or roughly equal size. The habitat-based IP estimate of capacity for this basin was 10,030 to 20,060 steelhead (Appendix 4). The Skokomish Basin lies in the Coast Range and Puget Lowland Ecoregions. Earthquake, landslide, and flood events pose a relatively high catastrophic risk to the Skokomish Basin.

28. West Hood Canal Winter-Run Steelhead

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 the Hood Canal (Van Doornik et al. 2007b). 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 escapment (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 Northern Cascade 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 30 May) from 2000-2004 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 for capacity in this DIP ranges from 3,608 to 7,217 fish (Appendix 4). Stream surveys conducted in 1932 identified a "large" run of steelhead on the Dosewallips River, with steelhead runs reported in almost every stream (WDF 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 being 227 adults (WDFW 2011).

There was considerable discussion among the TRT members regarding this DIP; based on basin size and IP estimates of potential population size, some members argued that this DIP should be split into 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 west Hood Canal streams, resulted in a majority of the TRT concluding that there was a single western Hood Canal population.

29. Sequim/Discovery Bay Independent Tributaries Winter-Run Steelhead

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 and stream flows are rain-dominated with many streams lacking surface flow during summer. Although the basin size for this DIP, 802 km^2, 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, and provided most of the data available for this DIP, and provided the TRT with an understanding of the potential productivity of small independent steams. Steelhead in this DIP spawn from early-February to mid-May, with the majority of smolts emigrating as two-year olds. Combined recorded sport catch for these tributaries averaged over 60 steelhead annually during the 1950s and 1960s, with an adjusted peak catch of 200 steelhead in 1962 (WDG undated(b)). The IP-based estimate of capacity is 512 to 1,024 steelhead (Appendix 4). 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/Winter-Run Steelhead

This population includes steelhead spawning in the mainstem Dungeness and Greywolf rivers. Winter-run steelhead in the Dungeness spawn from mid-March to early June (WDFW 2002). Haring (1999) and Goin[25] indicate that summer-run steelhead were present in the early 1940s, prior to the introduction of Skamania Hatchery steelhead. It is unclear if 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 is approximately 560 km^2 in area, with its 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 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 (Strait of Juan de Fuca Lowland Tributaries DIP) and the Elwha River, but is also part of a large clusters of populations belonging to rivers draining the Olympic Peninsula (Appendix 3). Each year a few hundred steelhead spawn in the Dungeness River, although high flows, particularly during the spring snow melt, limits the accuracy of redd surveys. The last escapement estimate for the year 2000/2001 was 183 steelhead and this was 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-based estimate for capacity was 2,465 to 4,930 steelhead (Appendix 4).

A majority of the TRT agreed that a winter-run population of steelhead 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 River and Greywolf rivers. The relatively late-timing of winter-steelhead in the Dungeness River may have resulted in some winter-run steelhead being identified as summer-run fish, as likely occurred in the Dosewallips and Duckabush rivers. Steelhead were historically harvested by Native Americans from December through February, using fish traps or lines (Gunther 1927), 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.

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[25] Personnal communication: Dick Goin, 502 Viewcrest, Port Angeles, WA, 21 November 2011.

31. Strait of Juan de Fuca Independent Tributaries Winter-Run Steelhead

This population consists of steelhead spawning in small independent tributaries to the Strait of Juan de Fuca between the Dungeness and Elwha rivers, including: Ennis, White, Morse, Siebert, and McDonald creeks. While each of the tributaries is relatively small, collectively the creeks contain a 410 km^2 watershed. Sports catch (punch card) data for Morse, Siebert, and McDonald creeks indicate that well over a 100 wild fish were caught annually through the 1950s and 1960s, with a peak catch of 258 in 1958 (WDG undated(b)). The IP-based estimate for capacity is 728 to 1,456 fish (Appendix 4), 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[26], although it is unclear whether these fish are 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 the Dungeness 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 Steelhead

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 mainstem and tributaries below the (now former) 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* from 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 if existing resident *O. mykiss* populations contain an anadromous legacy. If so it may take several years following the removal of the Elwha River 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 if summer-run

[26] Personnal communication: Dick Goin, 502 Viewcrest, Port Angeles, WA, 21 November 2011.

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. 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 was 7,116 - 14,231 (Appendix 4), 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 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 the run was residualized when the two Elwha River dams were constructed in the early 1900s at Rkm 7.9 and Rkm 21.6. Summer-run steelhead have been observed in the pools below the lower Elwha Dam in recent years, although it is most probable that these fish are the product of non-native Skamania Hatchery summer-run steelhead releases into the Elwha River (see Appendix 6 for summer-run releases). Oversummering temperatures in the lower Elwha River, in addition to frequent out breaks of *Dermocystidium*, greatly reduce survival of returning adult salmonids, thus it is likely that the native anadromous summer-run steelhead run(s) was extirpated follow the construction of the Elwha River dams. Alternatively, steelhead runs, summer or winter run, 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 a isolating mechanism for migrating winter- 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 the summer run, above or below the dam.

Puget Sound Steelhead DPS Population Considerations

The TRT conclusions presented are based on available information. 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 re-delineation 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 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 gate-keeper model to identify the historical DIPs and MPGs with 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 both 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.

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Appendix 1. Comparison of populations and management units.

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 co-managers 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[27]
Dakota Cr.		Dakota Cr Winter	1
Nooksack R.			1
North Fork	North Puget Sound GDU 8	NF Nooksack Winter	1
Middle Fork	North Puget Sound GDU 8	MF Nooksack Winter	1
South Fork		SF Nooksack Summer	
		SF Nooksack Winter	1
		Samish River Winter	3
Skagit R.	North Puget Sound GDU 8	MS Skagit Winter	4
Finney Cr.	North Puget Sound GDU 8	Finney Cr Summer	4
Grandy Cr.			4
Bacon Cr.			4
Baker R.			4
Cascade R.	North Puget Sound GDU 8	Cascade R Summer	
		Cascade R Winter	4
Sauk R.	North Puget Sound GDU 8	Sauk R Summer	
		Sauk R Winter	4
Dan Cr.			4
Stillaguamish R.		Stillaguamish R Winter	5
NF Stillaguamish	North Puget Sound GDU 8		5
Pilchuck R.	North Puget Sound GDU 8		5
Deer Cr.	North Puget Sound GDU 8	Deer Cr Summer	5
Boulder Cr.			5
French Cr.			5
Squire Cr			5
SF Stillaguamish		SF Stillaguamish Summer[28]	5
Jim Creek			5
Canyon Cr		Canyon Cr Summer	5
Snohomish R		Snohomish R Winter	7
Pilchuck R	South Puget Sound GDU 2	Pilchuck R Winter	7
Skykomish R	South Puget Sound GDU 2		7
Woods Cr			7
Elwell Cr			7
Wallace R			7
SF Skykomish R		SF Skykomish Summer[29]	7
NF Skykomish R	South Puget Sound GDU 2	NF Skykomish R Summer	7

[27] Water Resource Inventory Area - WRIA
[28] SF Stillaguamish River was considered non-native
[29] SF Skykomish River was considered non-native

1930 Survey	Genetic Analysis 1997	1992 SASSI / 2002 SaSI	WRIA
Snoqualmie R		Snoqualmie R Winter	7
Tolt R	South Puget Sound GDU 2	Tolt R Summer	7
Raging R	South Puget Sound GDU 2		7
Cedar River[30]	South Puget Sound GDU 2	Lake Washington Winter	8
Duwamish R			9
Green R	South Puget Sound GDU 2	Green R Summer[31]	
		Green R Winter	9
Soos Cr			9
Puyallup R	South Puget Sound GDU 2	MS Puyallup R Winter	10
Carbon R		Carbon R Winter	10
Voight Cr			10
S. Prairie Cr			10
White R	South Puget Sound GDU 2	White R Winter	10
Nisqually R	South Puget Sound GDU 2	Nisqually R Winter	11
Mashel R			11
Not Surveyed		Deschutes R 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 R Winter	15
Not Surveyed	South Puget Sound GDU 2	Tahuya R Winter	15
Not Surveyed		Union R Winter	15
Not Surveyed	South Puget Sound GDU 2	Skokomish R Summer	
		Skokomish R Winter	16
Not Surveyed	South Puget Sound GDU 2	Hamma Hamma R Winter	16
Not Surveyed		Duckabush R Summer	
		Duckabush R Winter	16
Not Surveyed	South Puget Sound GDU 2	Dosewallips R Summer	
		Dosewallips R 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 R Summer	
		Dungeness R Winter	18
Not Surveyed	South Puget Sound GDU 2	Morse Cr Winter	18
Not Surveyed	North Coast GDU 9	Elwha R Summer	
		Elwha R Winter	18

[30] Cedar River steelhead were considered "scarce"
[31] Green River Summer was considered non-native (the historical population was extirpated)

Appendix 2. Puget Sound Steelhead TRT checklist for identifying 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.

Demographically Independent Population Checklist

The TRT developed a layered checklist to assist in the identification of historical demographically independent populations (DIPs). 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 demographically influenced by other populations (via migration), it qualifies as DIP. There was some discussion regarding how large is large enough. Work by Allendorf et al. (1997) suggests that an "effective population size, Ne" of 500 or more would be sufficient to ensure a less than 5% risk of extinction in the near future (100 years). Converting Ne to a census population size (N) is somewhat challenging. Waples suggests that Ne/N is 0.2 – 0.25 for Chinook salmon, this number should be somewhat larger for iteroparous steelhead (approximately 0.50), giving a target N of possibly 1,000 spawners per generation (this adjusted Ne/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). Demographic independence was most clearly demonstrated when the abundance trajectory of a presumptive population is clearly distinct from its neighboring populations. The 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 model, with the amount of habitat in each presumptive DIP compared to that in Snow Creek.

Tier 1 Checklist:

- ☐ a. Historically Present
- ☐ b. Abundance (actual or IP-estimated)
- ☐ c. 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 boxes 1a and/or 1c 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 intrinsic potential model was used as the abundance proxy for historical abundance.

Demographic independence – there are a number of possible proxies for this measure, all of which provide some indicator of the degree of isolation. Geographic isolation – the distance between presumptive population spawning locations. Isolation barriers – normally falls, cascades, velocity barriers that may provide temporal windows to upstream access. Genetic distinctiveness – measure of genetic differences indicate the degree to which populations interbreed (gene flow rates and time of isolation). Ecological differences – differences between natal streams may result in local adaptation by presumptive populations. Strong freshwater adaptation would reinforce homing fidelity. Temporal isolation – 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 – Intrinsic potential 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 and/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 checkboxes, 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, the Tier 3 checklist 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.

Gatekeeper Model

In an effort to develop a simplified methodology for identifying historical demographically independent populations (DIPs), the TRT established a number of DIP threshold values related to the biological and geographic characteristics of the provisional population. These threshold values were set such that if any pair-wise comparison of DIPs exceeded the value there was 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 indentifying those hydrological units or combinations of hydrological units with intrinsic potential 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 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 Edward's (CSE) 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 CSE chord distance of 0.200, 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 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. 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.

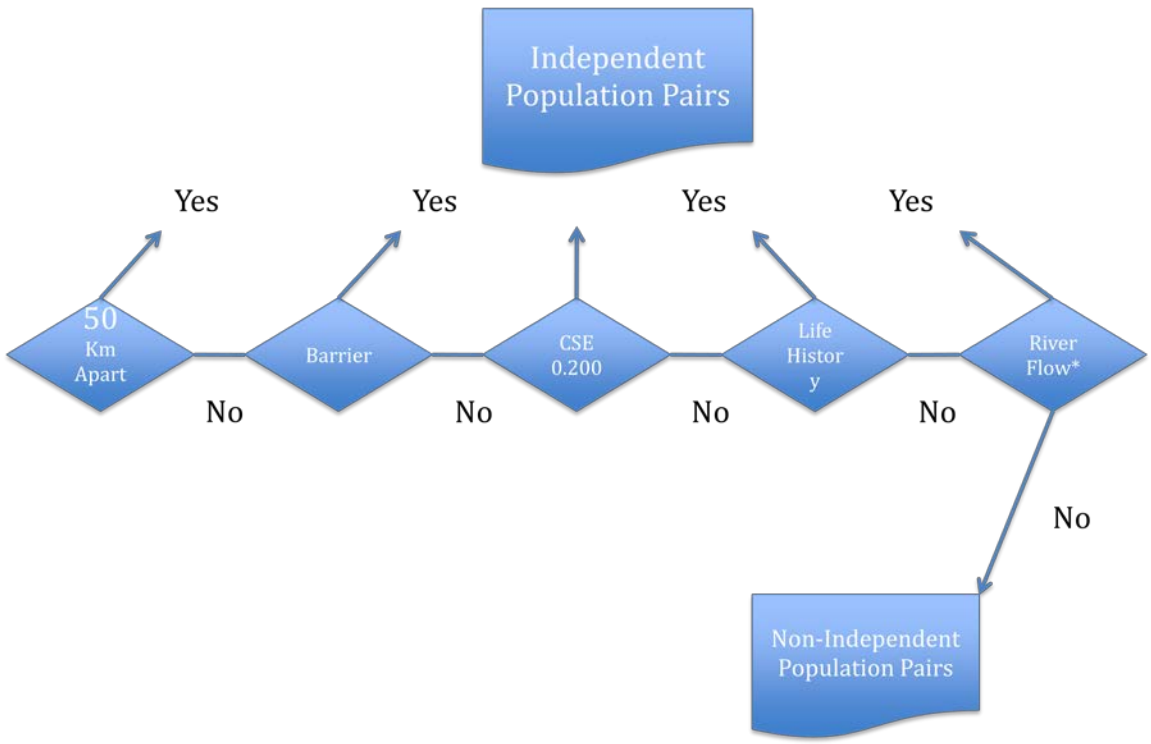

Figure 2-1. Schematic of the gatekeeper model used to identify historical demographically independent populations. If differences between presumptive populations exceed the threshold for any of the gatekeeper criteria, those populations were considered independent of each other.

Table 2A. 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 that information was definitive in identifying the DIP.

	DIP Criteria									VSP Data			
	Tier 1			Tier 2 and 3									
Population Name	Historical Presence	Sustainability (Abundance)	Demographic Independence	Basin Size (IP)	Temporal Isolation	Geographic Isolation	Life History (xpt run type)	Genetics	Habitat Type	Abundance Data[1]	Genetics Data	Age Data	Punch Card Data
Baker River	√	√		√	?						√		
Canyon Creek	√				★								√
Cedar River	√			√		★			★	√	√		√
Deer Creek	√	√		√	★			√			√	√	√
Drayton Harbor	√			√		★	√		★				√
Dungeness River	√			√				★	★		√		√
East Hood Canal Tributaries	√		√	√				★	★	√	√		√
East Kitsap Peninsula Tributaries	√			√					√				√
Elwha River	√			√				√		√	√		√
Green River	√	√		√		★		√		√	√	√	√
Nisqually River	√			√				★	★	√	√	√	√
Nookachamps Creek	√			√					★				
Nooksack River	√	√		√				★	★		√	√	√
North Fork Skykomish River	√			√	★			★			√		√
North Lake Washington Tributaries	√			√		★			★				
Pilchuck River	√	√		√			★		√	√		√	√
Puyallup River	√			√				★		√	√	√	√
Samish River/Bellingham Bay Tributaries	√	√	★	√				★	★	√	√		√
Sauk River	√	√		√			★	√			√	√	√
Sequim/Discovery Bay Tributaries				√				√	★	√	√	√	√
Skagit River	√	√		√				√	√	√	√	√	√
Skokomish River	√	√		√				√	★	√	√		√
Snohomish/Skykomish River	√	√		√						√		√	√
Snoqualmie River	√	√		√	★	★				√		√	√
South Fork Nooksack River	√			√	★								√
South Hood Canal	√	√	√	√				★	√	√	√		√
South Sound Tributaries	√			√		★		√	★				√
Stillaguamish River	√	√		√	★					√	√	√	√
Strait of Juan de Fuca Independents	√			√				√	★	√	√		√
Tolt River	√				★			√		√	√		√
West Hood Canal Tributaries	√			√				★	√	√	√		√
White River	√	√		√				★		√	√		√

[1]- Abundance information available for 5 of last 10 years.

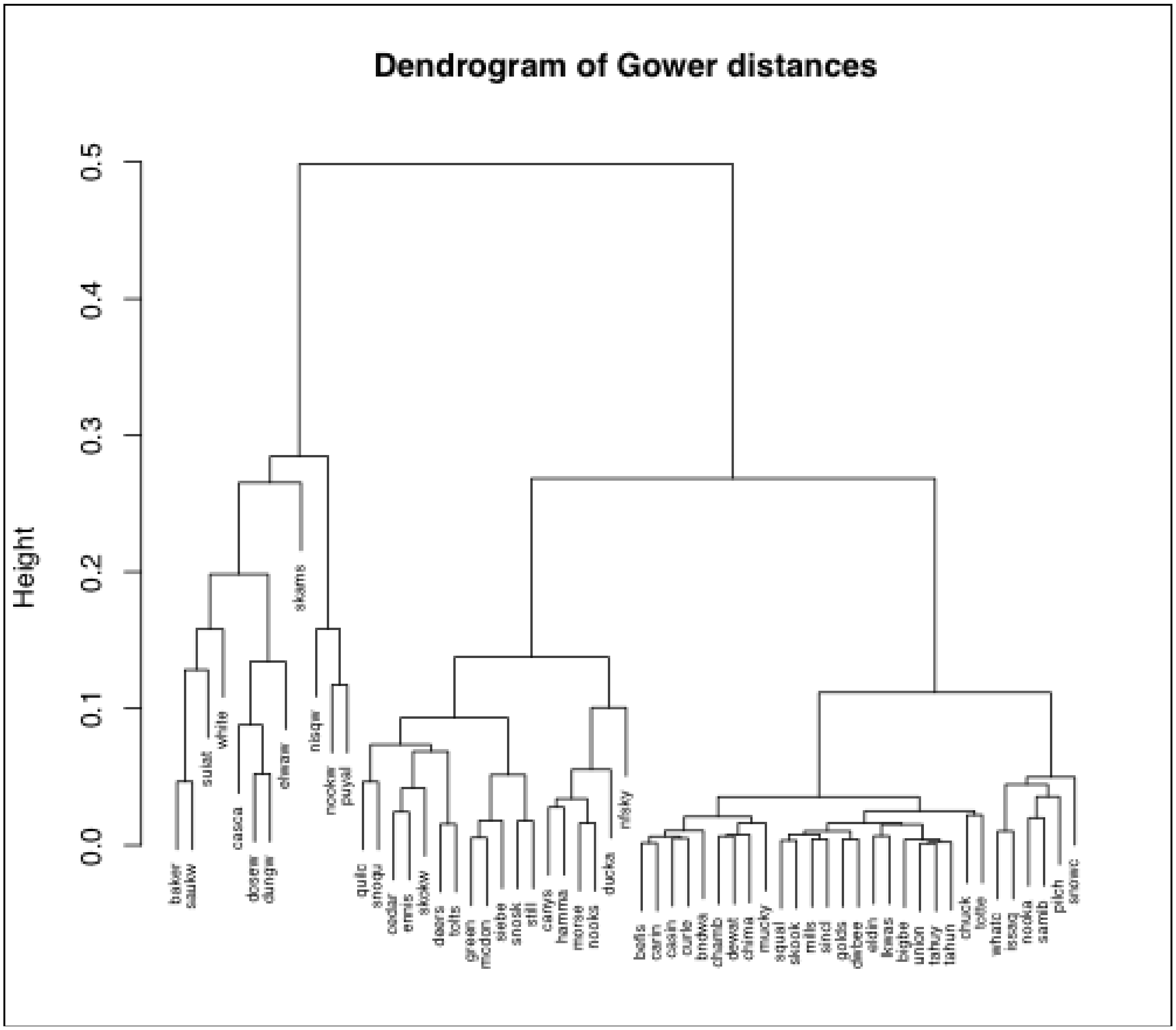

Figure 3-2. Gower chart of candidate demographically independent population (DIP) ecological parameters used to distinguish habitat characteristics in each basin. The Gower index includes information on permanent snow cover, elevation, and basin size. Groups that clustered below the 0.2 Height thresholds were considered to have similar habitat types.

Appendix 3. Genetic analysis of steelhead from Puget Sound.

A number of studies have analyzed genetic variation among steelhead 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 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 3-1).

Samples representing all three major population groups (MPGs) and the majority of DIPs within those MPGs were obtained on an as available basis (Table 3-1). Data were analyzed for 13 microsatellite DNA loci for 4,563 fish from 39 collections available from four published and unpublished sources (Table 3-2). 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, Goudet 2001). 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 Cavalli-Sforza and Edwards chord metric (Cavalli-Sforza and Edwards 1967) calculated with POPULATIONS (Langella 2001). Precision of branching patterns was evaluated by bootstrapping over loci 1000 times. The tree was printed with TreeView (). An additional independent assessment of among-collection variability was done using a factorial correspondence analysis, FCA, using GENETIX 4.05.2. It was believed that some collections (for example: 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 (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.

Table 3-1. Geographic distribution of steelhead genetic samples from the Puget Sound 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 #	39 Sample #
North Cascades	Drayton Harbor Tributaries	-	-
	Nooksack River Winter Run	1,2 (3,4?)	1,2,5 (3,4?)
	SF Nooksack River Summer Run	(3,4?)	(3,4?)
	Samish River and Bellingham Bay Winter Run	5	6,7
	Skagit River Summer/Winter Run	6	8,9,10,13, 15,16
	Nookachamps Creek Winter Run	-	-
	Baker River Summer/Winter Run	-	-
	Sauk River Summer/Winter Run	7	11,12
	Stillaguamish River Winter Run	8	18
	Deer Creek Summer Run	9	17
	Canyon Creek Summer Run	-	-
	Snohomish/Skykomish River Winter Run	-	-
	Pilchuck River Winter Run	-	-
	NF Skykomish River Summer Run	-	-
	Snoqualmie River Winter Run	-	-
	Tolt River Summer Run	10	21
Central and South Puget Sound	North Lake Washington and Lake Sammamish Winter Run	-	-
	Cedar River Winter Run	11	22
	Green River Winter Run	12	24
	Puyallup/Carbon River Winter Run	14	26
	White River Winter Run	12	25
	Nisqually River Winter Run	15	27
	South Sound Tributaries Winter Run	16	28
	East Kitsap Winter Run	-	-
Olympic Peninsula	East Hood Canal Winter Run	17	29,30
	South Hood Canal Winter Run	18	31
	Skokomish River Winter Run	19	32
	West Hood Canal Winter Run	20	33,34,35
	Sequim/Discovery Bay Independent Tributaries	21	36
	Dungeness River Winter/Summer Run	22	37
	Strait of Juan de Fuca Winter Run	-	-
	Elwha River Winter Run (Summer?)	23	39

Table 3-2:. Information for collections of steelhead used in the genetic analyses. Fis values testing for significant departure from Hardy-Weinberg where a significant positive Fis P-value for Fis within samples. The adjusted nominal level of *P* (5%) for Fis is 0.00011.

Pop	Sample	Source	Fish Sampled	N	Fis	*P* values
1	Nooksack R. 1	NMFS\Nooksack Tribe	mix, 2008-2009	25	0.086	0.002
2	Nooksack R. 2	NMFS	n/a	37	0.045	0.021
3	SF Nooksack A	WDFW unpublished	adults, 2007-10	38	0.04	0.031
4	SF Nooksack J	WDFW unpublished	juveniles, 2009	26	0.018	0.234
5	Main Nooksack	WDFW unpublished	juveniles, 2009	47	0.02	0.151
6	Samish R. 2009	WDFW unpublished	adults, 2009	37	0.025	0.141
7	Samish R. 2008	WDFW unpublished	adults, 2008	41	0	0.480
8	Skagit/Manser	unpublished WDFW	parr, 2007	235	0.019	0.009
9	Upper Skagit R.	WDFW unpublished	adults, 2008-11	81	0.014	0.159
10	Cascade R.	WDFW unpublished	juv., 2009-10	98	0.006	0.327
11	Suiattle R.	WDFW unpublished	adults, 2010-11	51	0.01	0.279
12	Sauk R.	WDFW unpublished	adults, 2008-11	81	0.021	0.072
13	Finney Ck.	WDFW unpublished	juv., 2009-10	105	0	0.511
14	Marblemount H	WDFW unpublished	adults, 2008-10	151	0.02	0.024
15	Mid Skagit R/	WDFW unpublished	adults-2009-10	42	0.035	0.034
16	Goodell Ck.	WDFW unpublished	juv., 2010-11	88	0.008	0.280
17	Deer Ck.	WDFW unpublished	juveniles, 1995	31	0.02	0.205
18	Stillaguamish R.	unpublished WDFW??	smolts, 2006	109	0.036	0.001
19	Tokul Creek H		adults, 2001	95	-0.008	0.7391
20	Skamania H.	unpublished WDFW??	n/a, 2008	95	-0.033	0.990
21	SF Tolt (above)	WDFW unpublished	juveniles, 2010	75	0.005	0.382
22	Cedar R.	Marshall et al 2004	mixed, 2007	144	0.033	0.001
23	Soos Ck. H.	Winans et al 2010	adults, 2008	48	0.038	0.0211
24	Green R.	Winans et al 2010	adults, 2006	43	0.076	0.000
25	White R.	VanDoornik et al 2007	mixed, 2002, 2004-6	438	0.015	0.006
26	Pulyallup R.	VanDoornik et al 2007	mixed, 2002, 2004-6	70	0.008	0.287
27	Nisqually R.	NMFS-Montlake	juv., 2006 to 2008	151	0.018	0.048
28	Minter Ck.	unpublished WDFW??	mixed, 2006-7	13	0.039	0.160
29	Big Beef Ck.	NMFS-Manchester	mix, 2006-7	264	0.023	0.002
30	Dewatto R.	NMFS-Manchester	parr, smolts, 2006-7	295	0	0.510
31	Tahuya R.	NMFS-Manchester	smolts, 2006-7	179	0.014	0.072
32	Skokomish R.	NMFS-Manchester	parr, smolts, 2006-7	299	0.041	0.000
33	Hamma Hamma	NMFS-Manchester	smolts, 2006,2007	64	0.049	0.001
34	Duckabush R.	NMFS-Manchester	parr, smolts, 2006-7	228	0.04	0.000
35	Dosewallips R.	NMFS-Manchester	parr, smolts, 2006-7	169	0.033	0.000
36	Snow Ck.	NMFS-Manchester/WDFW	smolts, 2006-7	129	0.011	0.171
37	Dungeness R.	unpublished WDFW	parr, smolts, 2006-7	251	0.017	0.013
38	LEK H	Winans et al 2008	juv., 2005, 2006	142	0.029	0.007
39	Elwha R.	Winans et al 2008	juv., 2005	48	0.032	0.969
			Total	4563		

Results

Of the 4,363 samples analyzed, five fish from Snow Creek and the Samish River were identified with substantial Chambers Creek ancestry, five from Snow and Samish respectively. 4353 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 3-2). 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 3-1), 7 groups are apparent:

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

In a Cavalli-Sforza and Edwards chord tree with unweighted pair group method with arithmetic mean (UPGMA) clustering (Figure 3-2), 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 Sound, Stillaguamish, and Skagit collections. The Puyallup is distinctive.

The first three factorial correlation analysis (FCA) components explained 30.6% of the total variance in the 39 collection data set. Along the first axis, the East and West Hood Canal, Chambers Creek stocks, 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; Figure 3-3). Along FCA1 and FCA2, collections grouped by DIP. Noticeably similar are Skagit and Nooksack/Samish; and particularly distinguished are Tahuya and Skokomish. Along FCA3 the Skagit collections are more different from Nooksack/Samish collections as are the summer-run fish compared to their variability along FCA1 and FCA2. Nisqually is distinctive from the other south/central Sound collections along FCA3 (Figure 3-4). Collections from Big Beef and Dewatto 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 (Figures 3-3 and 3-4). 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; and it is safe to say that populations in the Puget Sound that are genetically similar have probably experienced introgression with the non-native 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.

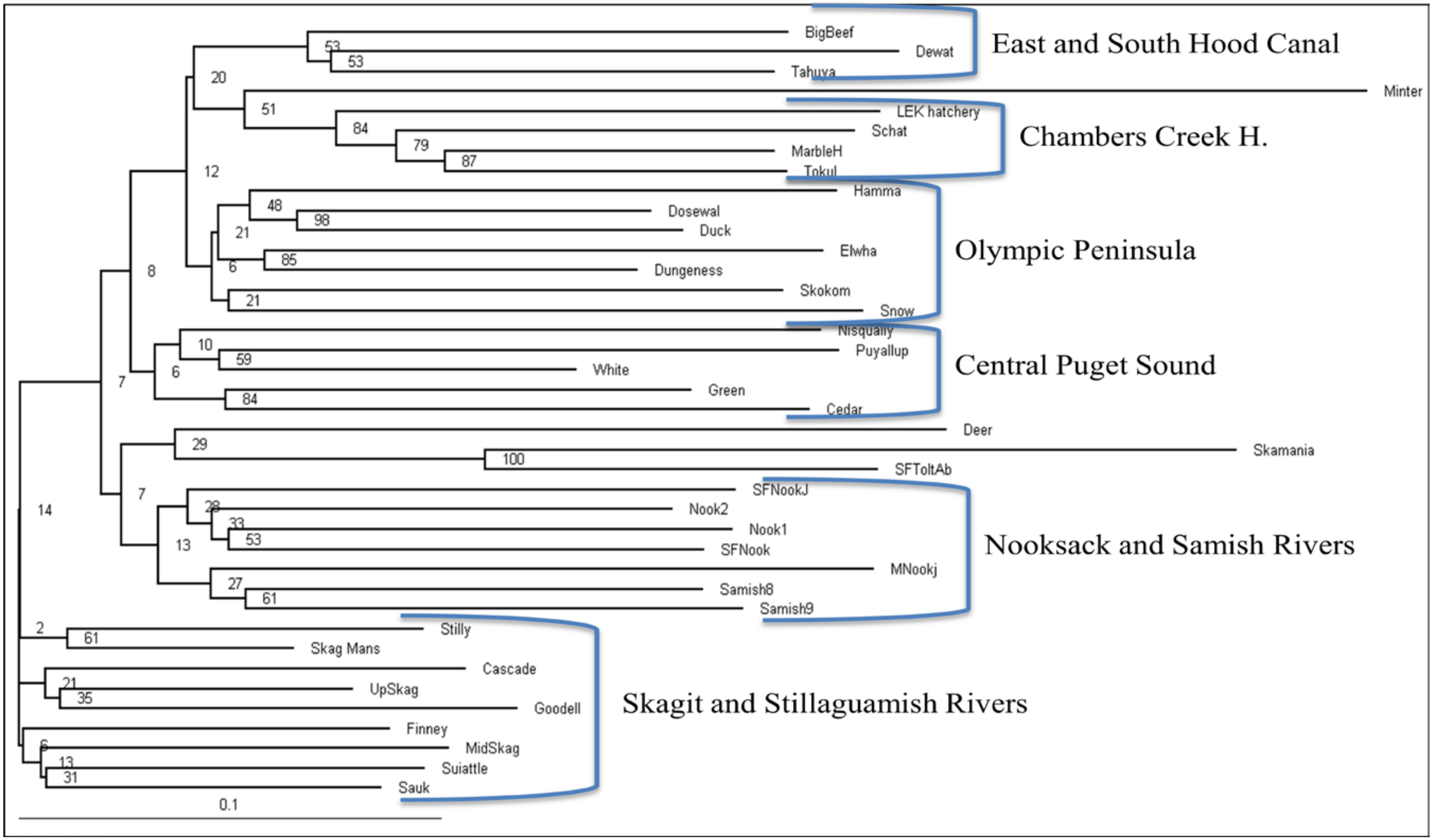

Figure 3-1. Dendrogram of 39 Puget Sound steel collections analyzed for 13 microsatellite DNA loci and displayed using Cavalli-Sforza and Edwards chord metric and neighbor joining clustering. Numbers at the branches of the tree are representative of bootstrap values (percent).

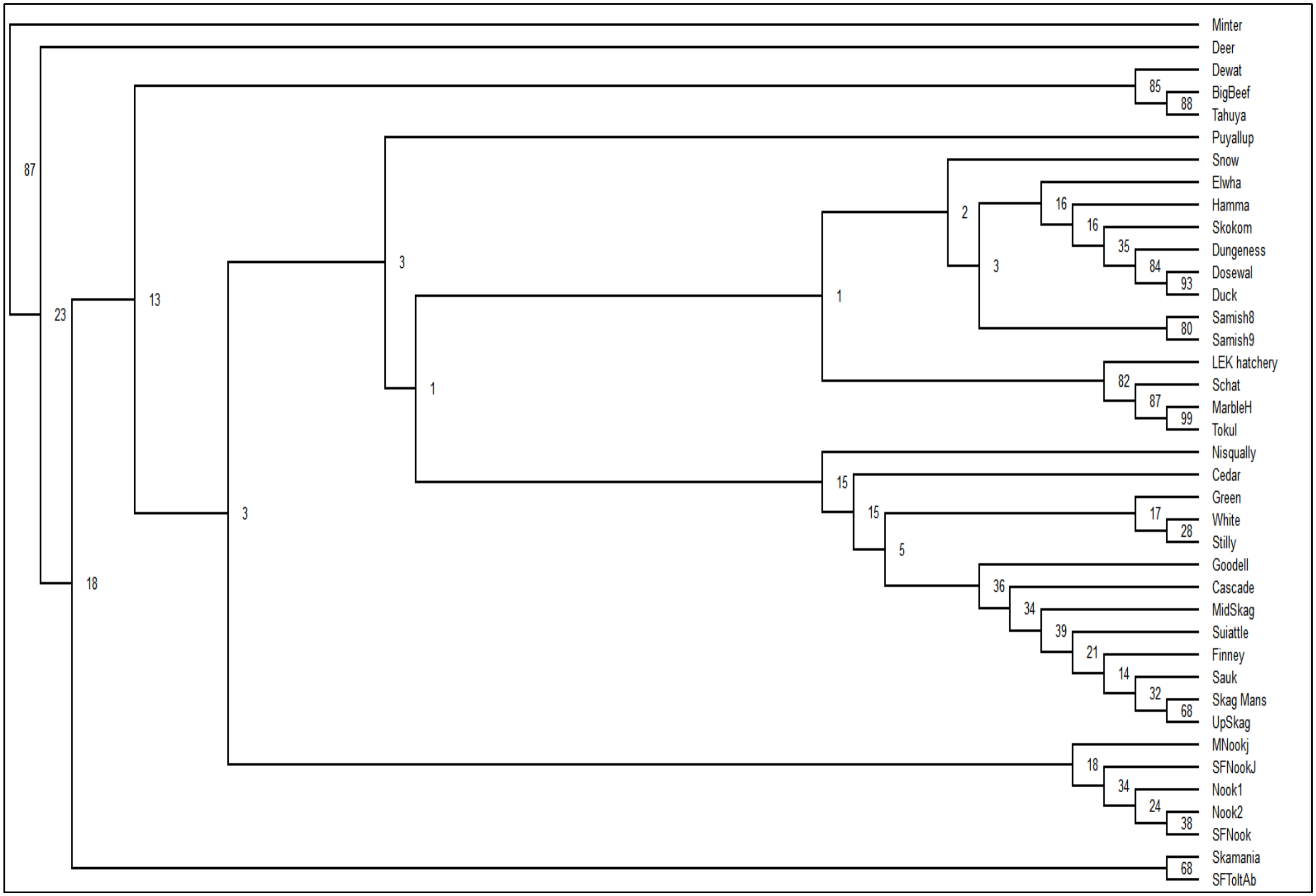

Figure 3-2. Dendrogram of 39 Puget Sound steelhead collections analyzed for 13 microsatellite DNA loci and displayed using Cavalli-Sforza and Edwards chord tree with unweighted pair group method with arithmetic averages (UPGMA) clustering. Numbers at the branches of the tree are representative of bootstrap values (percent).

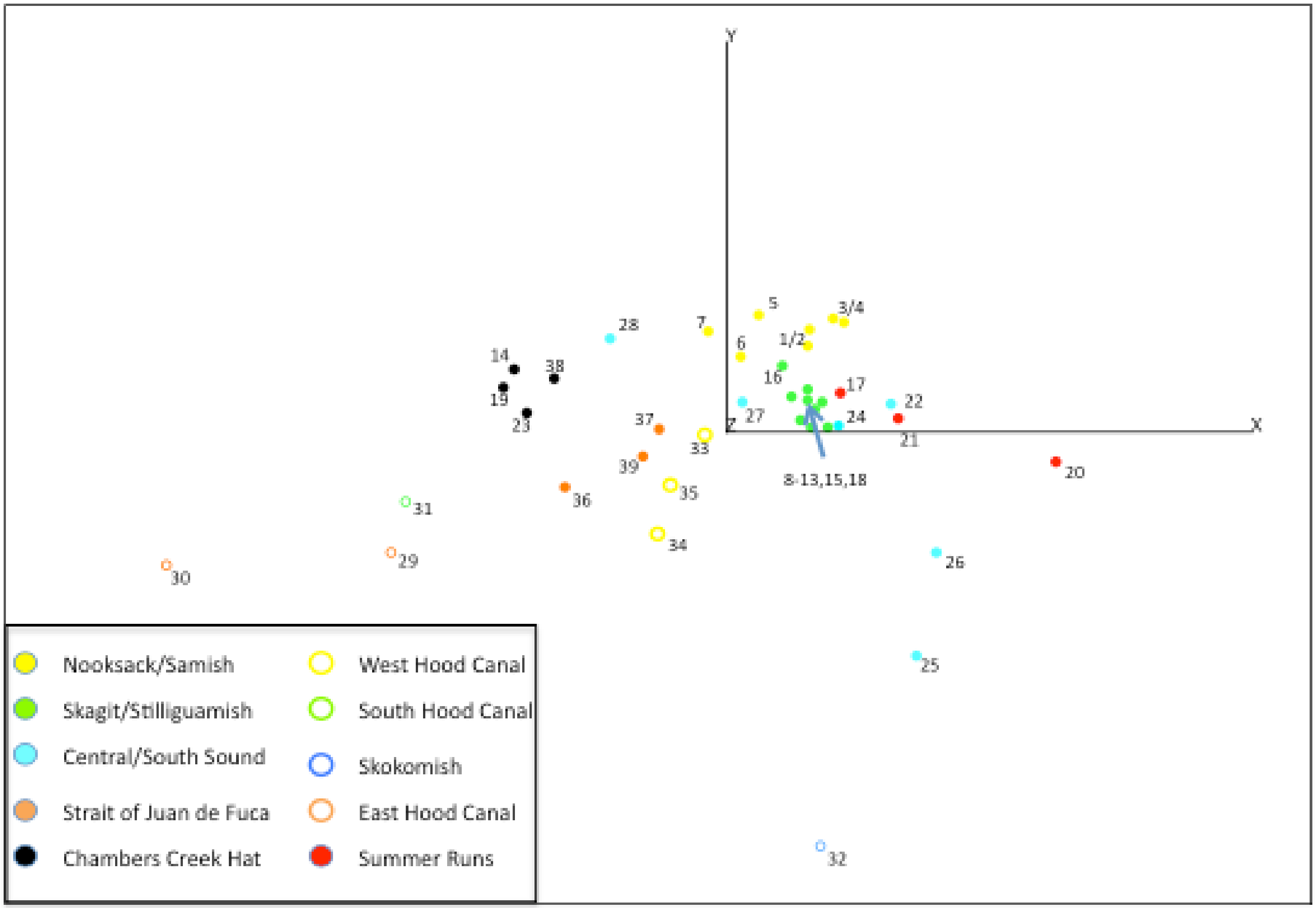

Figure 3-3. Relationships between 39 steelhead population samples from Puget Sound based on 13 microsatellite DNA loci. X axis corresponds to the primary principal component variable (FCA1), Y axis corresponds to the secondary principal component variable (FCA2). Numbers correspond to samples listed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

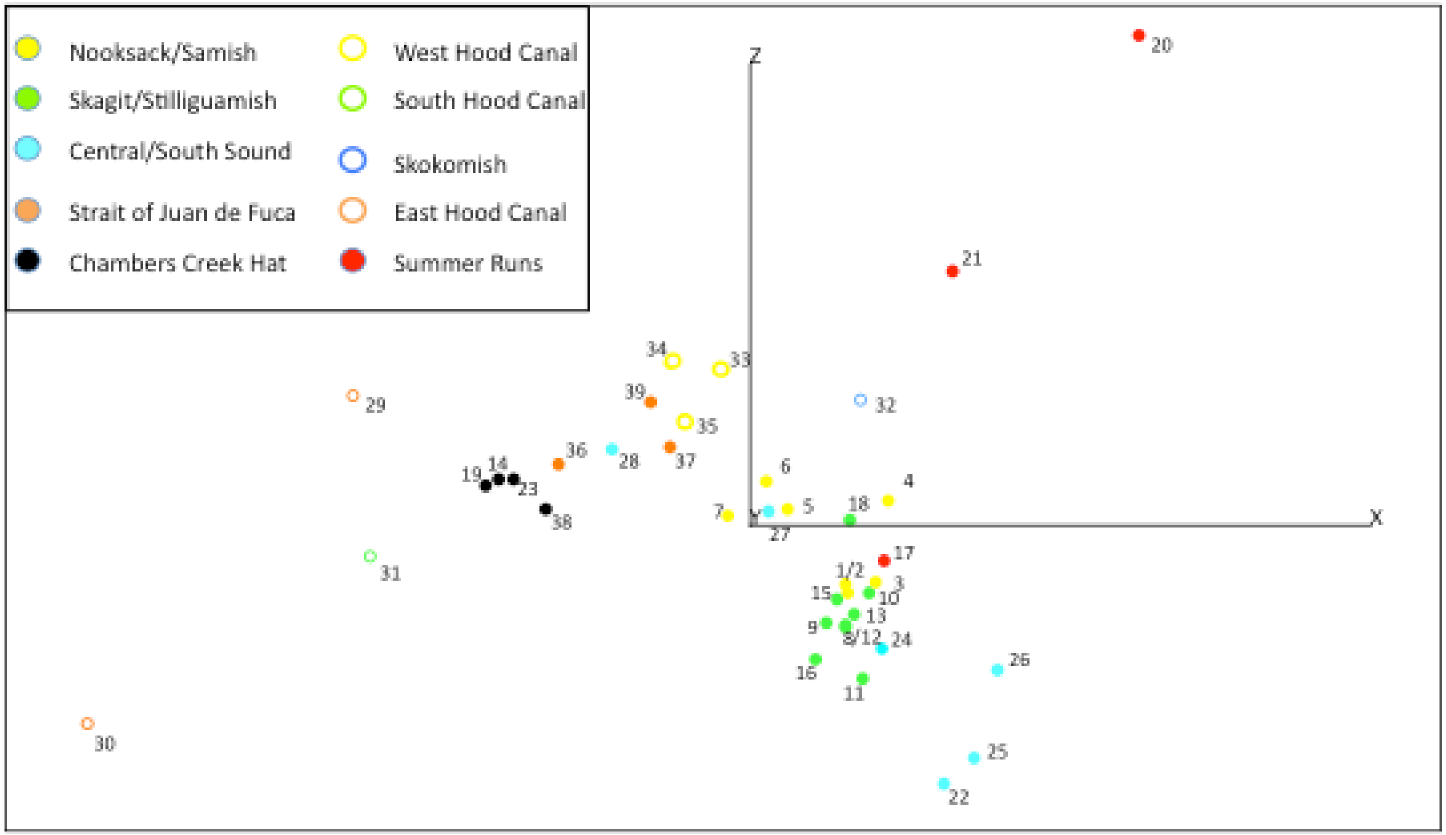

Figure 3-4. Relationships between 39 steelhead population samples from Puget Sound based on 13 microsatellite DNA loci. X axis corresponds to the primary principal component variable (FCA1), Z axis corresponds to the tertiary principal component variable (FCA3). Numbers correspond to samples listed in Table 3-2. Colors indicate the general geographic location of the samples.

Table 3-3:. Information for collections of steelhead used in the genetic analyses. Presumptive populations were created by pooling samples from Table 3-2 by basin, with the exception of the Nooksack River Basin samples.

Pop	Sample	Fish Sampled	N	Sample Number from Table 3-2
1	Main Nooksack	juveniles, 2009	47	5
2	Nooksack1/2	mix 2008/9	62	1 and 2
3	SF Nooksack A	adults, 2007-10	38	3
4	SF Nooksack J	juveniles, 2009	26	4
5	Samish R.	adults, 2008/9	78	6 and 7
6	Skagit R.	mix 2008-11	551	8,9,10,13,15, and 16
7	Sauk R.	adults, 2008-11	132	11 and 12
8	Stillaguamish R	smolts, 2006	109	18
9	Deer CK.	juveniles, 1995	31	17
10	SF Tolt (above)	juveniles, 2010	75	21
11	Cedar R.	mixed, 2007	144	22
12	Green R.	adults, 2006	43	24
13	White R.	mixed, 2002, 2004-6	438	25
14	Puyallup R.	mixed, 2002, 2004-6	70	26
15	Nisqually R.	juv., 2006 to 2008	151	27
16	Minter Cr	mixed, 2006-7	13	28
17	East Hood Canal	mix, 2006-7	558	29 and 30
18	Tahuya/South Hood Canal	smolts, 2006-7	179	31
19	Skokomish R	parr, smolts, 2006-7	299	32
20	West Hood Canal	smolts, 2006,2007	461	33,34, and 35
21	Snow Ck.	smolts, 2006-7	129	36
22	Dungeness R.	parr, smolts, 2006-7	251	37
23	Elwha R.	juv., 2005	48	39
24	Chambers Creek Hatcheries	juv., 2005, 2006	436	14,19,23,and 38
25	Skamania H.	n/a, 2008	95	20
		Total	4563	

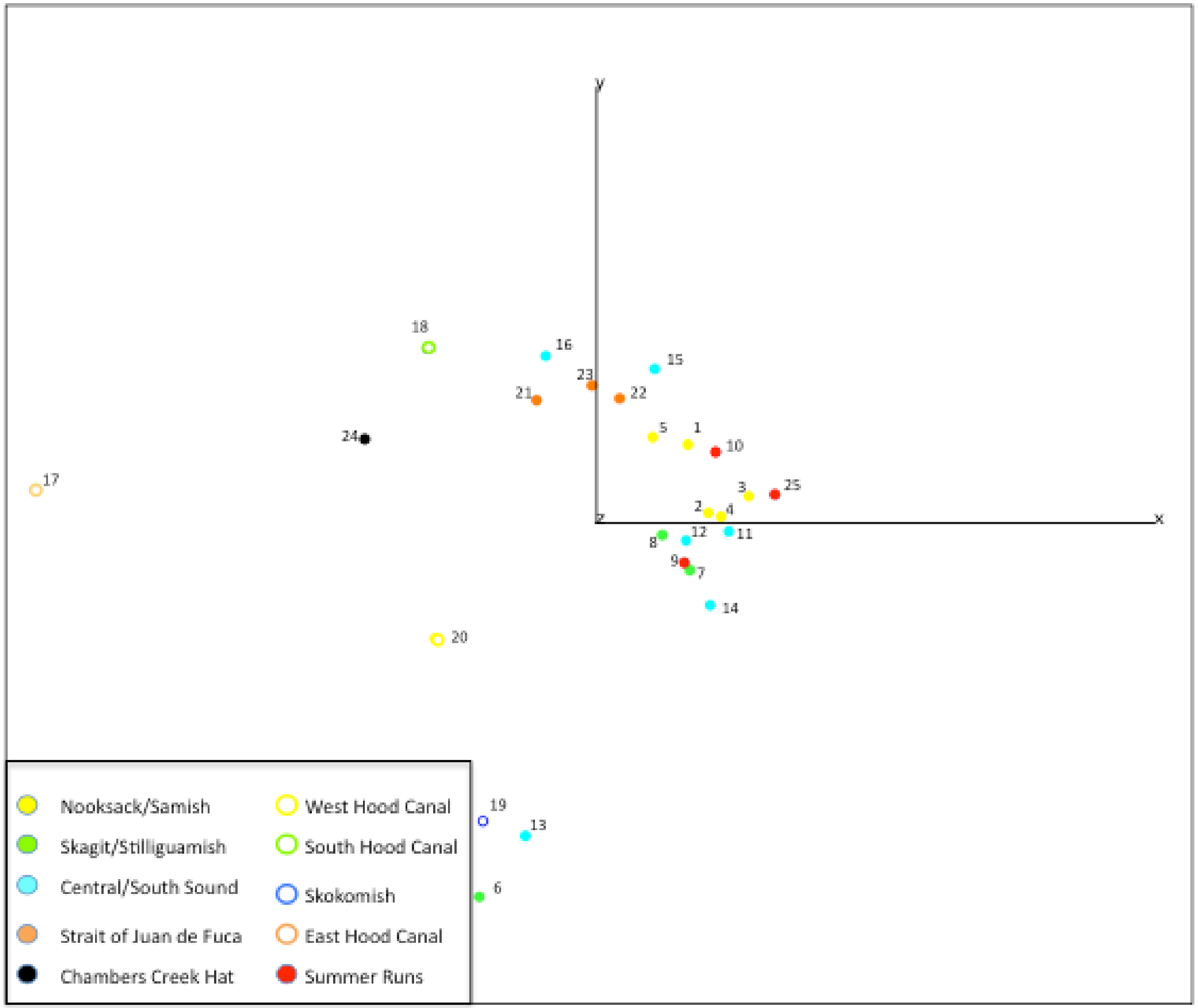

Figure 3-5. Relationships between 25 steelhead population samples from Puget Sound based on 13 microsatellite DNA loci. X axis corresponds to the primary principal component variable (FCA1), Y axis corresponds to the secondary principal component variable (FCA2). Numbers correspond to samples listed in Table 3-3. Colors indicate the general geographic location of the samples.

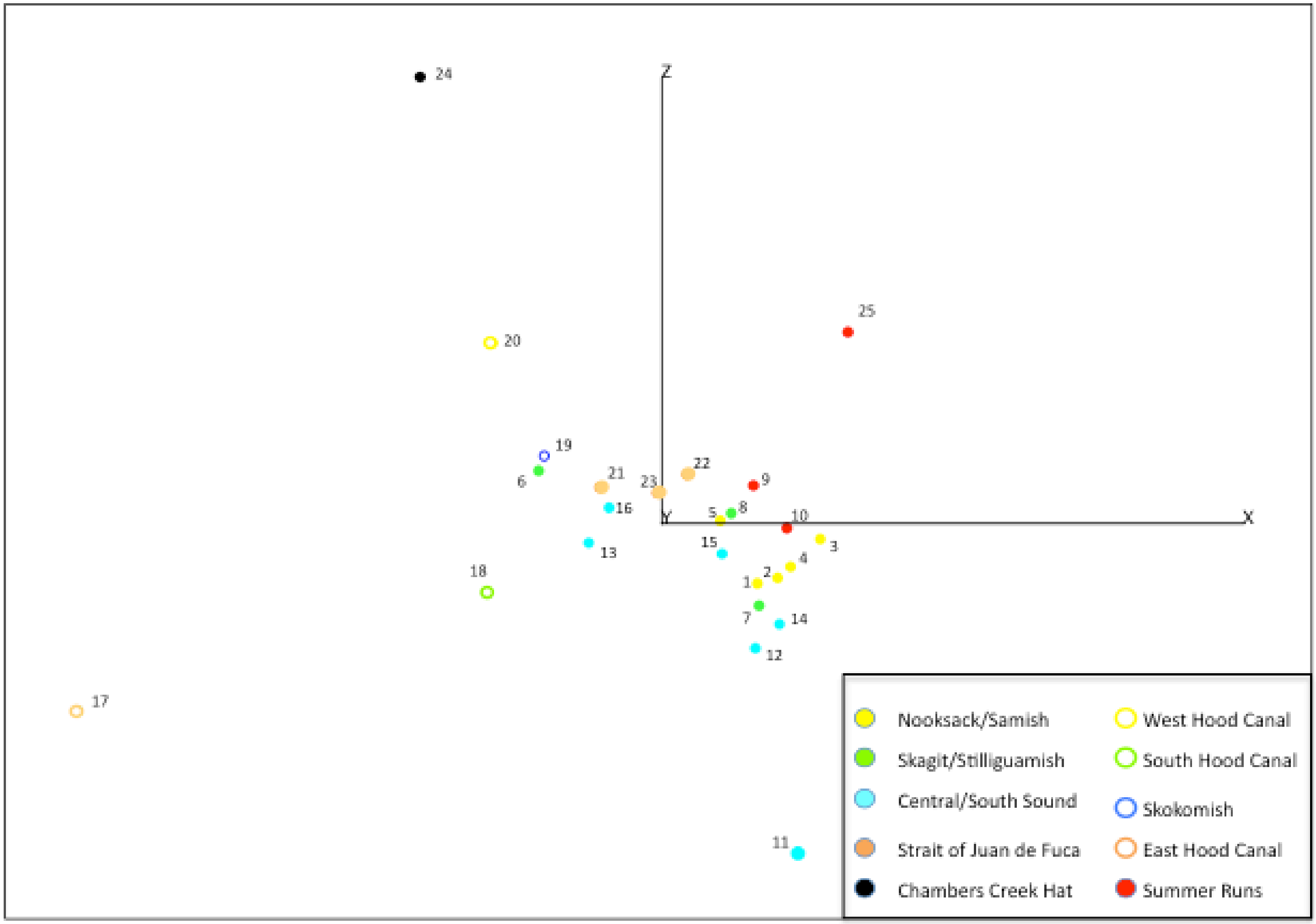

Figure 3-6. Relationships between 25 steelhead population samples from Puget Sound based on 13 microsatellites DNA loci. X axis corresponds to the primary principal component variable (FCA1), Z axis corresponds to the tertiary principal component variable (FCA3). Numbers correspond to samples listed in Table 3-3. Colors indicate the general geographic location of the samples.

POP		POP_1	POP_2	POP_3	POP_4	POP_5	POP_6	POP_7	POP_8	POP_9	POP_10	POP_11	POP_12	POP_13	POP_14	POP_15	POP_16	POP_17	POP_18	POP_19	POP_20	POP_21	POP_22	POP_23	POP_24	POP_25	POP_26	POP_27	POP_28	POP_29	POP_30	POP_31	POP_32	POP_33	POP_34	POP_35	POP_36	POP_37	POP_38	POP_39
BBC	POP_1	0	0.262116	0.241455	0.262637	0.279043	0.290157	0.214851	0.332614	0.265447	0.287926	0.297039	0.29912	0.409008	0.260616	0.421685	0.333143	0.262464	0.257255	0.336913	0.31123	0.270676	0.276755	0.28862	0.286295	0.270891	0.270903	0.293439	0.268846	0.370476	0.324545	0.314759	0.337109	0.336429	0.292386	0.297191	0.307446	0.279919	0.299071	0.296569
Dewatt	POP_2	0.262116	0	0.286243	0.293168	0.315803	0.318019	0.239286	0.359593	0.307553	0.32527	0.316219	0.32593	0.445069	0.289429	0.441543	0.352983	0.29145	0.284414	0.341797	0.324536	0.294632	0.314458	0.312604	0.301935	0.307891	0.299876	0.301672	0.293805	0.366557	0.364875	0.34422	0.351399	0.369378	0.314068	0.332507	0.31565	0.296422	0.342052	0.313922
Dose	POP_3	0.241455	0.286243	0	0.175085	0.228511	0.268656	0.243821	0.293635	0.227053	0.265088	0.236469	0.258079	0.38019	0.191793	0.406143	0.293839	0.214412	0.209617	0.308496	0.290164	0.22491	0.247853	0.259065	0.255646	0.243761	0.23684	0.279179	0.242732	0.345459	0.291886	0.300838	0.293936	0.322172	0.248982	0.286921	0.277532	0.247468	0.233147	0.276336
Duck	POP_4	0.262637	0.293168	0.175085	0	0.237968	0.266607	0.258463	0.301843	0.23612	0.274664	0.266258	0.261443	0.37898	0.195368	0.400416	0.28946	0.222831	0.215832	0.31886	0.293473	0.22814	0.257809	0.263651	0.267996	0.254745	0.236662	0.291768	0.259085	0.364302	0.289282	0.309086	0.311733	0.32502	0.261353	0.284363	0.283882	0.260761	0.241947	0.288313
Skokomish	POP_5	0.279043	0.315803	0.228511	0.237968	0	0.281614	0.282103	0.303785	0.258416	0.313629	0.285213	0.294091	0.394588	0.249072	0.43643	0.316655	0.259532	0.261767	0.343484	0.319683	0.263425	0.2803	0.27006	0.283659	0.267928	0.261582	0.302318	0.305934	0.370736	0.319169	0.324501	0.33416	0.338686	0.298857	0.30349	0.304858	0.307233	0.278394	0.317479
Snow	POP_6	0.290157	0.318019	0.268656	0.266607	0.281614	0	0.282242	0.345242	0.283369	0.321052	0.291876	0.319159	0.446388	0.251927	0.438207	0.334837	0.28187	0.272643	0.354178	0.334226	0.289793	0.28848	0.302447	0.301296	0.284099	0.293311	0.321544	0.293909	0.39658	0.346591	0.34664	0.353473	0.358526	0.310697	0.315319	0.296743	0.282423	0.300938	0.302252
Tahuya	POP_7	0.214851	0.239286	0.243821	0.258463	0.282103	0.282242	0	0.341022	0.270277	0.286171	0.291943	0.299414	0.437625	0.239008	0.431098	0.318299	0.270271	0.255704	0.325958	0.301917	0.255529	0.276764	0.287364	0.283013	0.266308	0.265983	0.279469	0.259775	0.364632	0.343278	0.322223	0.331402	0.33626	0.281388	0.298967	0.282911	0.267917	0.295151	0.291281
Puallup	POP_8	0.332614	0.359593	0.293635	0.301843	0.303785	0.345242	0.341022	0	0.230843	0.294474	0.319542	0.289932	0.40821	0.285152	0.455574	0.295857	0.276437	0.274446	0.343759	0.342053	0.289025	0.307629	0.302185	0.29108	0.294726	0.296803	0.3296	0.333254	0.363295	0.331715	0.336414	0.341541	0.360462	0.337938	0.350057	0.358379	0.331927	0.335092	0.33756
White	POP_9	0.265447	0.307553	0.227053	0.23612	0.258416	0.283369	0.270277	0.230843	0	0.258035	0.286888	0.216689	0.382943	0.228604	0.424696	0.243325	0.197018	0.180758	0.269087	0.271969	0.202947	0.210108	0.238197	0.195495	0.209449	0.205955	0.251493	0.270701	0.348754	0.282519	0.285603	0.299376	0.313057	0.269045	0.296533	0.304343	0.269091	0.284766	0.26705
Nisqually	POP_10	0.287926	0.32527	0.265088	0.274664	0.313629	0.321052	0.286171	0.294474	0.258035	0	0.306498	0.297183	0.399713	0.274427	0.443317	0.320326	0.272815	0.267719	0.329307	0.316956	0.278837	0.296812	0.308837	0.28479	0.288656	0.277488	0.310393	0.285184	0.381735	0.321114	0.331376	0.322761	0.347254	0.288837	0.324683	0.323565	0.278677	0.29701	0.281003
Elwha	POP_11	0.297039	0.316219	0.236469	0.266258	0.285213	0.291876	0.291943	0.319542	0.286888	0.306498	0	0.308999	0.418636	0.220238	0.428818	0.334763	0.258143	0.26486	0.342332	0.319534	0.276714	0.300449	0.308239	0.294026	0.284461	0.284488	0.311858	0.284894	0.358883	0.324569	0.322516	0.331165	0.32962	0.283959	0.306425	0.323403	0.301051	0.30129	0.321389
Green	POP_12	0.29912	0.32593	0.258079	0.261443	0.294091	0.319159	0.299414	0.289932	0.216689	0.297183	0.308999	0	0.416368	0.264104	0.448291	0.248451	0.242932	0.221565	0.306815	0.297634	0.236125	0.245891	0.263302	0.234859	0.240422	0.241039	0.274439	0.291091	0.330676	0.303572	0.313397	0.327285	0.32146	0.305436	0.3159	0.317216	0.288881	0.303257	0.296117
Skamania	POP_13	0.409008	0.445069	0.38019	0.37898	0.394588	0.446388	0.437625	0.40821	0.382943	0.399713	0.418636	0.416368	0	0.389832	0.50145	0.439181	0.346478	0.381906	0.404724	0.398205	0.404531	0.398347	0.381994	0.401148	0.408236	0.390311	0.414342	0.4186	0.420397	0.270701	0.39593	0.391858	0.434785	0.402356	0.402566	0.446427	0.428447	0.399595	0.41893
Dungeness	POP_14	0.260616	0.289429	0.191793	0.195368	0.249072	0.251927	0.239008	0.285152	0.228604	0.274427	0.220238	0.264104	0.389832	0	0.397546	0.286452	0.207397	0.195191	0.304009	0.270711	0.217505	0.242066	0.260985	0.248012	0.229248	0.232278	0.275331	0.225636	0.35451	0.302472	0.280491	0.291844	0.311412	0.24081	0.252417	0.26555	0.238966	0.244495	0.260958
Minter	POP_15	0.421685	0.441543	0.406143	0.400416	0.43643	0.438207	0.431098	0.455574	0.424696	0.443317	0.428818	0.448291	0.50145	0.397546	0	0.445248	0.410468	0.405612	0.4418	0.423518	0.409157	0.412304	0.423223	0.432298	0.420127	0.420708	0.421917	0.400976	0.506952	0.466584	0.425616	0.431605	0.442822	0.421185	0.403525	0.413726	0.405815	0.421153	0.402961
Cedar	POP_16	0.333143	0.352983	0.293839	0.28946	0.316655	0.334837	0.318299	0.295857	0.243325	0.320326	0.334763	0.248451	0.439181	0.286452	0.445248	0	0.284919	0.26221	0.328132	0.317118	0.284095	0.291643	0.294278	0.270615	0.28286	0.283001	0.30048	0.31243	0.374539	0.333043	0.334013	0.341644	0.342884	0.315321	0.34073	0.333218	0.313088	0.335307	0.326066
Stillaguamish	POP_17	0.262464	0.29145	0.214412	0.222831	0.259532	0.28187	0.270271	0.276437	0.197018	0.272815	0.258143	0.242932	0.346478	0.207397	0.410468	0.284919	0	0.137383	0.264259	0.252405	0.170106	0.204741	0.203564	0.191996	0.187856	0.180195	0.216016	0.259171	0.306421	0.255692	0.262809	0.270677	0.298489	0.245746	0.252544	0.292708	0.271132	0.271388	0.274657
Skagit Manser	POP_18	0.257255	0.284414	0.209617	0.215832	0.261767	0.272643	0.255704	0.274446	0.180758	0.267719	0.26486	0.221565	0.381906	0.195191	0.405612	0.26221	0.137383	0	0.252524	0.227307	0.131883	0.165032	0.174665	0.153392	0.150035	0.152284	0.188604	0.251124	0.30329	0.284347	0.242951	0.241158	0.28411	0.23654	0.253471	0.278425	0.256791	0.268114	0.279389
Nook1	POP_19	0.336913	0.341797	0.308496	0.31886	0.343484	0.354178	0.325958	0.343759	0.269087	0.329307	0.342332	0.306815	0.404724	0.304009	0.4418	0.328132	0.264259	0.252524	0	0.23223	0.246735	0.252575	0.283602	0.252331	0.257765	0.252271	0.273522	0.313982	0.335933	0.334152	0.231305	0.258098	0.282598	0.27647	0.274514	0.349498	0.324349	0.323223	0.333105
Nook2	POP_20	0.31123	0.324536	0.290164	0.293473	0.319683	0.334226	0.301917	0.342053	0.271969	0.316956	0.319534	0.297634	0.398205	0.270711	0.423518	0.317118	0.252405	0.227307	0.23223	0	0.240708	0.254176	0.250281	0.249163	0.257406	0.252109	0.241893	0.313714	0.310287	0.333401	0.225257	0.244985	0.27399	0.25745	0.258904	0.327139	0.317552	0.311459	0.326814
upSkag	POP_21	0.270676	0.294632	0.22491	0.22814	0.263425	0.289793	0.255529	0.289025	0.202947	0.278837	0.276714	0.236125	0.404531	0.217505	0.409157	0.284095	0.170106	0.131883	0.246735	0.240708	0	0.184463	0.176769	0.172175	0.154893	0.16396	0.177206	0.260332	0.314434	0.300263	0.247637	0.254225	0.299856	0.243389	0.250606	0.291563	0.268008	0.283746	0.291879
midSkag	POP_22	0.276755	0.314458	0.247853	0.257809	0.2803	0.28848	0.276764	0.307629	0.210108	0.296812	0.300449	0.245891	0.398347	0.242066	0.412304	0.291643	0.204741	0.165032	0.252575	0.254176	0.184463	0	0.209389	0.189032	0.174744	0.186015	0.219964	0.27691	0.317836	0.302139	0.256454	0.264854	0.29522	0.26398	0.263898	0.302241	0.281089	0.305176	0.295808
Cascade	POP_23	0.28862	0.312604	0.259065	0.263651	0.27006	0.302447	0.287364	0.302185	0.238197	0.308837	0.308239	0.263302	0.381994	0.260985	0.423223	0.294278	0.203564	0.174665	0.283602	0.250281	0.176769	0.209389	0	0.206946	0.178446	0.193578	0.20582	0.298777	0.304327	0.295647	0.262545	0.260629	0.33038	0.275314	0.29025	0.313606	0.292854	0.301793	0.304853
Suiattle	POP_24	0.286295	0.301935	0.255646	0.267996	0.283659	0.301296	0.283013	0.29108	0.195495	0.28479	0.294026	0.234859	0.401148	0.248012	0.432298	0.270615	0.191996	0.153392	0.252331	0.249163	0.172175	0.189032	0.206946	0	0.168374	0.183244	0.208057	0.281571	0.310301	0.303513	0.256778	0.255716	0.300496	0.2634	0.275237	0.318323	0.28204	0.301037	0.297502
Sauk	POP_25	0.270891	0.307891	0.243761	0.254745	0.267928	0.284099	0.266308	0.294726	0.209449	0.288656	0.284461	0.240422	0.408236	0.229248	0.420127	0.28286	0.187856	0.150035	0.257765	0.257406	0.154893	0.174744	0.178446	0.168374	0	0.171487	0.206453	0.275394	0.307677	0.303311	0.249819	0.249106	0.29309	0.249145	0.261353	0.301161	0.276532	0.292387	0.297475
Finney	POP_26	0.270903	0.299876	0.23684	0.236662	0.261582	0.293311	0.265983	0.296803	0.205955	0.277488	0.284488	0.241039	0.390311	0.232278	0.420708	0.283001	0.180195	0.152284	0.252271	0.252109	0.16396	0.186015	0.193578	0.183244	0.171487	0	0.212237	0.267714	0.30805	0.283384	0.248863	0.252053	0.287072	0.255524	0.254635	0.285637	0.262379	0.285257	0.299291
Goodell	POP_27	0.293439	0.301672	0.279179	0.291768	0.302318	0.321544	0.279469	0.3296	0.251493	0.310393	0.311858	0.274439	0.414342	0.275331	0.421917	0.30048	0.216016	0.188604	0.273522	0.241893	0.177206	0.219964	0.20582	0.208057	0.206453	0.212237	0	0.302677	0.313351	0.328118	0.262411	0.267763	0.29511	0.283847	0.277195	0.317065	0.313843	0.319196	0.327031
MableH	POP_28	0.268846	0.293805	0.242732	0.259085	0.305934	0.293909	0.259775	0.333254	0.270701	0.285184	0.284894	0.291091	0.4186	0.225636	0.400976	0.31243	0.259171	0.251124	0.313982	0.313714	0.260332	0.27691	0.298777	0.281571	0.275394	0.267714	0.302677	0	0.371994	0.336912	0.318152	0.331069	0.315008	0.262116	0.295466	0.231527	0.159131	0.2842	0.209113
Deer	POP_29	0.370476	0.366557	0.345459	0.364302	0.370736	0.39658	0.364632	0.363295	0.348754	0.381735	0.358883	0.330676	0.420397	0.35451	0.506952	0.374539	0.306421	0.30329	0.335933	0.310287	0.314434	0.317836	0.304327	0.310301	0.307677	0.30805	0.313351	0.371994	0	0.362203	0.317951	0.323598	0.37625	0.359234	0.35583	0.387189	0.37425	0.388456	0.395013
SF Tolt	POP_30	0.324545	0.364875	0.291886	0.289282	0.319169	0.346591	0.343278	0.331715	0.282519	0.321114	0.324569	0.303572	0.270701	0.302472	0.466584	0.333043	0.255692	0.284347	0.334152	0.333401	0.300263	0.302139	0.295647	0.303513	0.303311	0.283384	0.328118	0.336912	0.362203	0	0.330266	0.330302	0.365296	0.325833	0.332953	0.359809	0.33707	0.314794	0.334958
SFNook	POP_31	0.314759	0.34422	0.300838	0.309086	0.324501	0.34664	0.322223	0.336414	0.285603	0.331376	0.322516	0.313397	0.39593	0.280491	0.425616	0.334013	0.262809	0.242951	0.231305	0.225257	0.247637	0.256454	0.262545	0.256778	0.249819	0.248863	0.262411	0.318152	0.317951	0.330266	0	0.251182	0.27384	0.261897	0.264236	0.340588	0.320555	0.320264	0.334033
SFNook j	POP_32	0.337109	0.351399	0.293936	0.311733	0.33416	0.353473	0.331402	0.341541	0.299376	0.322761	0.331165	0.327285	0.391858	0.291844	0.431605	0.341644	0.270677	0.241158	0.258098	0.244985	0.254225	0.264854	0.260629	0.255716	0.249106	0.252053	0.267763	0.331069	0.323598	0.330302	0.251182	0	0.313267	0.274127	0.286343	0.351923	0.335666	0.334894	0.341975
Main Nook	POP_33	0.336429	0.369378	0.322172	0.32502	0.338686	0.358526	0.33626	0.360462	0.313057	0.347254	0.32962	0.32146	0.434785	0.311412	0.442822	0.342884	0.298489	0.28411	0.282598	0.27399	0.299856	0.29522	0.33038	0.300496	0.29309	0.287072	0.29511	0.315008	0.37625	0.365296	0.27384	0.313267	0	0.286991	0.268826	0.344762	0.330004	0.336249	0.361875
Samish 08	POP_34	0.292386	0.314068	0.248982	0.261353	0.298857	0.310697	0.281388	0.337938	0.269045	0.288837	0.283959	0.305436	0.402356	0.24081	0.421185	0.315321	0.245746	0.23654	0.27647	0.25745	0.243389	0.26398	0.275314	0.2634	0.249145	0.255524	0.283847	0.262116	0.359234	0.325833	0.261897	0.274127	0.286991	0	0.225735	0.303091	0.275504	0.304365	0.291041
Samish 09	POP_35	0.297191	0.332507	0.286921	0.284363	0.30349	0.315319	0.298967	0.350057	0.296533	0.324683	0.306425	0.3159	0.402566	0.252417	0.403525	0.34073	0.252544	0.253471	0.274514	0.258904	0.250606	0.263898	0.29025	0.275237	0.261353	0.254635	0.277195	0.295466	0.35583	0.332953	0.264236	0.286343	0.268826	0.225735	0	0.307622	0.304091	0.312427	0.3203
L Elwah H	POP_36	0.307446	0.31565	0.277532	0.283882	0.304858	0.296743	0.282911	0.358379	0.304343	0.323565	0.323403	0.317216	0.446427	0.26555	0.413726	0.333218	0.292708	0.278425	0.349498	0.327139	0.291563	0.302241	0.313606	0.318323	0.301161	0.285637	0.317065	0.231527	0.387189	0.359809	0.340588	0.351923	0.344762	0.303091	0.307622	0	0.215918	0.318801	0.261522
Tokul	POP_37	0.279919	0.296422	0.247468	0.260761	0.307233	0.282423	0.267917	0.331927	0.269091	0.278677	0.301051	0.288881	0.428447	0.238966	0.405815	0.313088	0.271132	0.256791	0.324349	0.317552	0.268008	0.281089	0.292854	0.28204	0.276532	0.262379	0.313843	0.159131	0.37425	0.33707	0.320555	0.335666	0.330004	0.275504	0.304091	0.215918	0	0.293326	0.189651
Hamma	POP_38	0.299071	0.342052	0.233147	0.241947	0.278394	0.300938	0.295151	0.335092	0.284766	0.29701	0.30129	0.303257	0.399595	0.244495	0.421153	0.335307	0.271388	0.268114	0.323223	0.311459	0.283746	0.305176	0.301793	0.301037	0.292387	0.285257	0.319196	0.2842	0.388456	0.314794	0.320264	0.334894	0.336249	0.304365	0.312427	0.318801	0.293326	0	0.301092
Soos Ck H	POP_39	0.296569	0.313922	0.276336	0.288313	0.317479	0.302252	0.291281	0.33756	0.26705	0.281003	0.321389	0.296117	0.41893	0.260958	0.402961	0.326066	0.274657	0.279389	0.333105	0.326814	0.291879	0.295808	0.304853	0.297502	0.297475	0.299291	0.327031	0.209113	0.395013	0.334958	0.334033	0.341975	0.361875	0.291041	0.3203	0.261522	0.189651	0.301092	0

Figure 3-7. CSE Chord distances for 39 steelhead collections from Puget Sound. The Gatekeeper model (Appendix 2) used a CSE Chord distance of 0.200 as a threshold for population independence. Numbers highlighted in green have distances less than 0.200. Numbers framed within lined boxes represent intra-Skagit Basin collections.

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Appendix 4 Basin geographic, hydrologic, and ecological characteristics with intrinsic potential estimates of spawners using two smolt to adult survival (SAS) rates.

POPULATION BASIN				BASIN CLIMATE											
				Mean Max. Temp.		**Mean Min. Temp.**		**Mean Precipitation (mm)**			**Hydrograph Type (%)**				
Population Name	Area KM2	Mean Elev. (m)	Total Stream Len. (m)	January	July	January	July	January	July	Annual	Highland	Lowland	Rain Dominated	R/S Dominated	Snow Dominated
Baker River	770.68	999	421859	186	2041	-457	817	408	80	3017	0.46	0.00	0.19	0.12	0.22
Canyon Creek	99.84	864	47716	311	2054	-271	937	527	106	3610	0.10	0.00	0.10	0.36	0.44
Cedar River	649.93	461	402349	472	2252	-112	1001	263	49	1867	0.06	0.48	0.15	0.13	0.17
Deer Creek	180.44	761	105313	367	2129	-246	939	472	91	3322	0.06	0.00	0.21	0.28	0.44
Deschutes River	439.69	272	249909	654	2424	-40	1004	179	28	1306	0.00	0.58	0.25	0.14	0.03
Drayton Harbor	223.07	37	206057	569	2238	-35	1102	150	41	1168	0.00	1.00	0.00	0.00	0.00
Dungeness River	564.16	978	306740	311	1912	-309	855	218	34	1493	0.16	0.20	0.12	0.33	0.20
Eastside Hood Canal Tributaries	341.99	99	174736	694	2412	85	1132	207	25	1446	0.00	1.00	0.00	0.00	0.00
Eastside Kitsap Peninsula Tributaries	703.00	75	259413	723	2384	132	1175	169	23	1194	0.00	0.99	0.01	0.00	0.00
Elwha River	832.87	1021	472871	309	1899	-301	850	380	41	2574	0.11	0.05	0.09	0.36	0.39
Green River	1443.92	463	834472	470	2280	-135	989	227	41	1621	0.06	0.51	0.10	0.17	0.17
Nisqually River	1991.50	524	1030771	528	2306	-147	952	228	38	1610	0.08	0.47	0.13	0.16	0.15
Nookachamps Creek	182.95	252	159503	556	2264	-52	1048	185	57	1553	0.00	0.45	0.40	0.09	0.06
Nooksack River	1982.16	619	1257480	362	2164	-266	956	278	64	2133	0.22	0.31	0.15	0.15	0.17
North Fork Skykomish River	156.19	1195	117602	-17	2124	-636	768	432	63	2825	0.61	0.00	0.01	0.12	0.27
North Lake Washington Tributaries	977.61	119	441887	677	2360	79	1142	152	31	1151	0.00	0.90	0.07	0.02	0.00
Pilchuck River	355.62	253	242383	567	2314	-21	1068	246	51	1863	0.00	0.56	0.35	0.06	0.03
Puyallup River	1394.77	672	803817	459	2194	-216	904	218	49	1635	0.20	0.35	0.16	0.16	0.12
Samish River/Bellingham Bay Tributaries	661.49	203	453694	561	2290	-58	1083	191	52	1500	0.00	0.50	0.41	0.08	0.02
Sauk River	1896.68	1132	1079263	42	2083	-611	822	406	63	2758	0.54	0.00	0.13	0.12	0.21
Sequim/Discovery Bay Tributaries	557.46	197	234042	628	2237	48	1102	98	28	771	0.00	0.74	0.17	0.08	0.00
Skagit River	5542.66	1098	2815113	98	2052	-567	810	311	57	2148	0.47	0.12	0.10	0.13	0.18
Skokomish River	634.47	570	411699	485	2192	-120	1000	428	46	2969	0.02	0.21	0.25	0.40	0.12
Snohomish/Skykomish River	1595.49	420	1021690	481	2249	-112	1026	308	60	2222	0.09	0.45	0.21	0.13	0.12
Snoqualmie River	1615.45	620	1134038	358	2195	-210	924	334	65	2408	0.18	0.24	0.28	0.14	0.16
South Fork Nooksack River	172.44	926	99347	324	2059	-339	903	499	86	3516	0.30	0.00	0.06	0.23	0.41
South Fork Skykomish River	925.42	1082	663837	82	2033	-488	764	410	57	2682	0.48	0.00	0.08	0.19	0.24
South Fork Stillaguamish River	306.23	773	191395	252	2137	-326	957	486	89	3443	0.19	0.00	0.30	0.23	0.28
South Hood Canal	294.73	126	216935	683	2473	56	1117	238	27	1649	0.00	0.92	0.08	0.00	0.00
South Sound Tributaries	1859.99	84	582451	702	2454	66	1107	205	24	1432	0.00	0.98	0.02	0.00	0.00
Stillaguamish River	1230.17	398	927234	508	2248	-96	1038	303	62	2201	0.05	0.33	0.35	0.14	0.13
Strait of Juan de Fuca Independents	403.06	611	246441	431	2081	-130	1007	196	24	1300	0.04	0.37	0.24	0.23	0.12
Tolt River	181.79	784	117732	264	2094	-268	882	419	91	3055	0.12	0.00	0.26	0.31	0.31
Westside Hood Canal Tributaries	1433.45	715	842382	417	2075	-193	962	276	37	1986	0.09	0.31	0.13	0.31	0.16
White River	1284.83	1061	863251	173	2035	-447	751	262	43	1767	0.41	0.15	0.07	0.15	0.23

Appendix 4 Basin geographic, hydrologic, and ecological characteristics with intrinsic potential based estimate of spawners using two smolt to adult survival (SAS) rates.

	LOW IP		MODERATE IP		HIGH IP		Total IP Area	Total IP Length	10% SAS	20% SAS
Population Name	Area	Length	Area	Length	Area	Length			Capacity	Capacity
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	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	316,861	48,602	13,725	21,355	538,539	61,704	869,125	131,661	1,270	2,540
Eastside 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
North Lake Washington Tributaries	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 River/Bellingham Bay Tributaries	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 Bay Tributaries	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 River	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	277,401	34,043	0	0	1,297,905	117,841	1,575,306	151,884	2,985	5,970
South 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 Independents	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
Westside 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
									306,831	613,662

Appendix 5. Puget Sound steelhead hatchery production from 1900 to 1945. Release numbers represent fry or fingerlings (subyearlings), E – egg production (in addition to fish listed), out – transfers of eggs or fish from the hatchery. Data for 1900-1911 is incomplete.

Basin	Hatchery/Station	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916
Nooksack	Kendall							55,000 E						50,000 E	203,400	98,705	74,176	
	Kendall (out)																	
Samish	Samish													2,310,000 E	994,000	1,406,252	1,311,149	
	Samish (out)																	
Skagit	Baker	26,000		110,000	80,000 E 663,815	255000 E 70,000		103000 E 540,000				1,368,000			12,400			
	Birdsview						400,000 E							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
	Birdsview (out)													125,000 E	350,000 E	150,000 E	125,000 E	
	Darrington														114,000			
	Day Creek											769,000 E					47,500 E	
	Illabott Creek													255,665	347,500 E	187,755 E	60,000 E	277,000 E
	Sauk River							1,027,000 E										
	Skagit River													95,000 E	38,920	27,849		
Stilliguamish	Stilliguamish													205,400	20,600 E	29,575	577,570	
Snohomish	Snohomish				369,000 E		435,000	577,820 E								66,740	119,225	
	Pilchuck																	
	Pichuck (out)																	
	Skykomish (Startup)													524,000 E	578,685	232,046	182,712	
	Skykomish (out)																	
	Sultan														486,700	112,000	292,425	34,000
Green	Green/White				96,800 E		84,426	417,000						315,200 E	516,500	505,150	558,750	
	G/W (out)																	
Puyallup	Puyallup																	
	Puyallup (out)																	
South Sound	Chambers Creek																	
	Chambers Creek (out)																	
	Nisqually				265,000 E		962,000	218,000 E						1,500,000	740,365	305,932	981,402	
Hood Canal	Skokomish	1,500,000 E																
	Tahuya Station																	
	Dungeness (Brinnon)																35,000 E	100,000
	Duckabush														200,00 E 258,000	603,000		91,000
	Quilcene													47,000 E 27,000	34,000	37,700	101,400	
Dungeness	Dungeness			1,500,000 E	3,100,000 E		1,384,000	1,168,000						912,456			589,850	
Elwha	Elwha																	
	Elwha (out)																	
WDF Total Egg Take/Production						2,395,150	2,886,926	3,463,970	4,429,575	3,681,450	4,855,000	5,234,240	5,912,656	11,059,000	3,462,639	4,975,460	5,545,652	5,545,653
WDG Total Release																		
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	6,292,338	4,841,330	3,732,805	9,731,400	4,444,271	4,922,555	5,102,566
Total	Fingrling				218,200			15,000						1,000				891,000

Note 1902 - Baker Lake Phinney and Gandy Creeks -- 483,000 eggs were collected.

Appendix 5. (cont)

Basin	Hatchery/Station	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Nooksack	Kendall	52,826		61,000	80,200	19,425				122,500	105,600	-	141,775	122,250	65,175	
	Kendall (out)		40,000 E									122,975			250,000	
Samish	Samish	1,639,777	980,600	129,700	9,575	661,783	273,955	271,316	1,789,790	141,655	842,100	963,550	499,905	923,840	1,040,170	
	Samish (out)					279,500 E	667,000 E 167,000	751,000	250,000		800,000	400,000	475,000	400,000	50,000	
Skagit	Baker															
	Birdsview	240,000 E	270,000 E 1,589,500	25,000 E 198865	255,000 E	128,250	78,000	353,305	70,000 E 555,000	418,000	346,500	200,000 E 715,600	290,000 E 1,033,300	750,000	535,000 E 1,706,000	90,000 E 281,680
	Birdsview (out)					85,000 E	55,000 E			10,0000 E			25,000 E			
	Darrington															
	Day Creek		43,000 E													
	Illabott Creek	451,000														
	Sauk River															
	Skagit River															
Stilliguamish	Stilliguamish	139,765														
Snohomish	Snohomish															
	Pilchuck	644,100	480,000	838,000	229,900	335,200								2,071,000	984,700	
	Pichuck (out)			100,000 E	100,000 E	200,00								600,000 E		
	Skykomish (Startup)	395,540	227,490	359,200	151,200	264,855	287,509	486,408	609,730	348,915	334,390	482,950	684,760	664,894	848,500	
	Skykomish (out)					100,000	25,000 E	250,000 E	5,000 E		250,000	200,000	100,000	200,000		
	Sultan		50,000 E 109,000	92,500	92,000 E	76,800	104,400 E	207,800	216,000	83,000	64,000		533,500	247,500	431,000	73,800
Green	Green/White	198,600	42,600	277,500	70,100	41,300	32,000		450,500	204,500	65,000	50,000	221,000	335,000	87,000	
	G/W (out)				490,000 E	44,000 E 226,000				20,000		283,000				
Puyallup	Puyallup		390,200	153,200	273,237									138,250	430,000	
	Puyallup (out)														33,827 E	
South Sound	Chambers Creek	119,300	395,000	160,000	273,000	385,000										
	Chambers Creek (out)			10,000 E	105,000 E	109,600										
	Nisqually	123,220	112,200	Floods												
Hood Canal	Skokomish		114,825	56,560												
	Tahuya Station				2,000											
	Dungeness (Brinnon)		129,000			100,000 E										
	Duckabush	689,700 E	446,840 E		405,000 E	1,095,000 E	90,300	139,445	209,110	90,400	34,200	60,100			206,000	
	Quilcene	626,500 E	284,000	50,000 E, 170,000 F	460,000	85,000 E 303,500	83,400	545,555	658,400	167,875	349,300	44,000	190,500	540,000	578,000	50,000 E 204,000
Dungeness	Dungeness	633,000	189,537	784,800	1,068,100	144,350	253,000	939,000	839,000	223,000	470,000	331,000	*	304,000	771,000	683,000 E
Elwha	Elwha	395,200	38,000	24,600	150,500	121,000	-									
	Elwha (out)						22,000 E									
WDF Total Egg Take/Production		567,625	3,551,830	3,764,450	3,784,050											
WDG Total Release																
USBF Est	Fry	1,979,010	4,851,092	3,152,452												
Total	Fingrling	1,420,500	352,420													

Note 1902 - Baker Lake Phinney and Gandy Creeks -- 483,000 eggs were collected.

Appendix 5. (cont)

Basin	Hatchery/Station	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Nooksack	Kendall					268,500 E	128,000 E	88,000 E	36,579 E						
	Kendall (out)														
Samish	Samish				1,116,900 E	2,725,700 E	1,392,800 E	2,196,100 E	799,511 E	456,248 E	555,485 E	486,267 E	219,152 E	118,315 E	502,947 E
	Samish (out)														
Skagit	Baker														
	Birdsview	616,000	113,000 E 672,000	1,145,000	603,000	289,000	184,000	666,500	813,700	810,000					
	Birdsview (out)	143,000 E		110,000 E			375,000 E		35,000 E	38,500 E					
	Darrington														
	Day Creek														
	Illabott Creek														
	Sauk River														
	Skagit River														
Stilliguamish	Stilliguamish														
Snohomish	Snohomish														
	Pilchuck														
	Pichuck (out)														
	Skykomish (Startup)				50,000 E	71,500	93,000	60,000	51,110	10,814					
	Skykomish (out)														
	Sultan	270,660													
Green	Green/White				5,000 E	40,000 E	48,000 E	107,000 E	95,197 E	25,488 E					
	G/W (out)														
Puyallup	Puyallup				674,000 E	585,000 E	628,000 E	597,000 E	86,670 E	167,223 E					
	Puyallup (out)														
South Sound	Chambers Creek														
	Chambers Creek (out)														
	Nisqually														
Hood Canal	Skokomish														
	Tahuya Station														
	Dungeness (Brinnon)														
	Duckabush	19,000	108,000	53,500											
	Quilcene	50,000 E 380,000	283,319	290,500	185,500	153,000	259,115	322,305	39,020	509,285					
Dungeness	Dungeness	394,000 E	968,500 E	806,500 E	1,265,000 E	1,080,000 E	978,000 E	712,000 E	995,414 E	405,701 E	189,050 E	1,014,568 E		221,763 E	121,659 E
Elwha	Elwha														
	Elwha (out)														
WDF Total Egg Take/Production															
WDG Total Release							3,198,943	4,657,106	4,342,230	2,603,785	2,172,564	1,413,151	979,526	485,437	763,093
USBF Est	Fry														
Total	Fingrling														

Note 1902 - Baker Lake Phinney and Gandy Creeks -- 483,000 eggs were collected.

Appendix 6. Releases of winter-run steelhead smolts into tributaries to Puget Sound from 1978 to 2008.

Name of Stream	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Dakota Creek								10,000								
Nooksack River								35,261	62,600	34,219	10,000	20,019	87,680	69,572	57,759	55,795
Whatcom Creek/Squalicum										8,650		10,075	9,702	10,032	9,900	8,000
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	80,200	80,007	90,600
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*	*275,847*	*372,227*	*283,417*
Skagit River Mainstem	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	244,467	273,385	166,678
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	31,380	98,842	78,758
Cascade River		1,950	11,863	32,094	30,490	33,006			10,604	10,594	20,400	15,743				37,981
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*	*103,726*	*56,881*	*83,897*
Stillaguamish R. Mainstem					36,000							89,202				
Canyon Creek						18,058	5,468					10,123	12,104	9,983		
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		13,159	31,842
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	77,659	20,494	26,851
South Fork		28,896		51,050	22,478	19,935	21,635	30,149	30,045	19,265	25,274	20,287	21,309	16,084	23,228	25,204
Snohomish River System	*303,073*	*252,032*	*212,535*	*266,588*	*469,136*	*332,843*	*332,428*	*364,406*	*389,579*	*417,714*	*345,894*	*583,717*	*664,396*	*593,274*	*481,599*	*501,886*
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	141,801	108,873	118,522
Pilchuck River (Snoh.)	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	39,915		
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	94,265	99,539	91,299
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	37,915	6,666	40,714
Raging River																
Sultan River							15,062	10,001	10,160	25,010	13,206		21,063	18,239	17,727	16,927
Wallace River	10,000	8,260	16,920	20,005	15,578		15,132	9,976		25,024		20,138	15,010	7,840	20,894	20,224
Skykomish River, N. Fork	26,200		9,867	9,992	20,076	60,224		25,652	14,956	15,000	15,272	30,437		25,199		
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	33,600	39,200	52,600
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	194,500	188,700	161,600
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*	*174,449*	*67,265*	*92,516*
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	101,449	54,265	92,516
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	73,000	13,000	
Carbon River (Voight Cr.)	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	w/Puyallu	14,000	
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	10,000	10,000	30,200
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	40,800	32,600	40,300
Kennedy Creek										10,001	10,200	10,000	15,005	15,000	15,000	10,100
Burley Creek													10,025	10,080		
Goldsborough Creek	5,082	4,290		4,410		11,872			5,025	14,649	5,100	10,165	15,000	17,400	15,000	15,200
Curley Creek/Kitsap													5,025	10,080		
Dewatto River					10,020	3,600		10,060	8,640	10,014	10,013	10,000		10,000	10,010	10,254
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	9,900	10,100	10,500
Union River		5,012		5,084	10,330	9,998	10,112	10,126	10,068	10,000	9,993	17,850	10,066	10,000	10,100	10,300
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	18,700	10,500	17,000
Hamma Hamma																
Duckabush River						19,987	19,017	20,010	19,825	20,119	15,000	35,477	20,005	26,400	15,100	15,000
Dosewallips River						20,160	20,025	20,015	19,800	20,007	44,180	25,033	40,046	30,000	25,200	23,200
Quilcene River						10,260	10,350	10,356	10,046	20,849	10,547	15,000	15,080	15,000	15,300	9,585
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	30,300	24,800	20,000
Morse Creek	3,544											4,174	10,032	15,000	12,900	12,300
Elwha River	24,000	15,000	14,694	12,306	38,998	15,022	15,347	17,180	20,076	20,100	20,075	20,020	30,374	45,200	60,400	51,000
P. Snd. 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	1.83	1.62	1.61

Appendix 6. Releases of winter run steelhead smolts into tributaries to Puget Sound.

Name of Stream	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Dakota Creek																
Nooksack River	70,470	65,900	81,485	130,900	110,100	123,800	131,000	111,000	109,400	100,100	55,000	47,400	81,800	70,500	75,900	89,300
Whatcom Creek/Squalicum	103,000	7,000	10,000	10,000	14,300	7,600	6,400	6,600	11,200	13,500	10,000	7,200	5,500	6,500	5,100	9,700
Samish River	41,100	40,100	46,951	45,138	30,100	27,800	29,900	40,900	39,000	50,100	13,900	27,000	19,600	6,600	32,100	31,200
Skagit River System	*194,744*	*247,117*	237,300	258,200	336,400	298,400	136,000	228,300	286,800	172,200	205,800	166,300	364,200	446,400	354,100	289,000
Skagit River Mainstem	146,599	191,368	167,100	197,000	276,000	269,200	112,400	203,300	251,800	163,000	183,100	145,900	332,600	415,800	239,200	202,900
Nookachamps/Big Lake																
Baker River			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sauk River	20,953	30,278	20,700	61,200	60,400	29,200	16,100	25,000	35,000	9,200	22,700	20,400	31,600	30,600	30,200	25,900
Cascade River	27,192	25,471	49,500	-	-	-	7,500	-	-	-	-	-	-	-	84,700	60,200
Stillaguamish River System	111,554	91,241	127,542	110,000	114,600	117,500	128,900	116,100	145,300	122,000	137,900	106,800	133,200	140,600	122,900	130,900
Stillaguamish R. Mainstem		29,498	33,944		-	-	-	-	-	-	-	19,100	-	-	-	-
Canyon Creek	7,498	6,300	11,998	12,300	12,700	10,100	9,300	11,900	10,600	9,800	10,100	10,000	10,200	10,300	5,000	15,000
Pilchuck Creek (Still.)	29,068	25,172	10,000	15,500	10,000	10,300	5,000	15,000	15,000	10,100	15,800	4,700	10,000	4,000	4,900	10,700
North Fork	52,466	20,248	49,600	64,900	71,800	77,100	90,800	63,800	101,200	102,100	96,000	73,000	113,000	119,200	113,000	105,200
South Fork	22,522	10,023	22,000	17,300	20,100	20,000	23,800	25,400	18,500	-	16,000	-	-	7,100	-	-
Snohomish River System	521,995	437,934	335,200	227,300	359,900	353,100	230,000	436,800	424,900	350,200	345,000	343,200	436,200	326,600	288,600	414,900
Skykomish River	84,796	80,496	170,500	29,600	125,800	151,100	90,200	155,200	159,600	139,100	128,300	129,100	161,000	110,200	111,300	173,000
Pilchuck River (Snoh.)			21,000	19,600	28,800	24,300	19,100	26,700	30,400	5,700	21,400	14,900	28,400	7,500	25,000	21,900
Snoqualmie River	105,002	100,650	65,200	89,800	119,400	93,600	62,000	129,700	122,500	117,400	114,000	153,500	150,000	113,800	100,300	117,200
Tolt River	28,400	16,664	16,700	20,000	20,100	14,800	10,900	47,600	35,000	40,900	23,400	10,700	39,300	35,700	17,400	35,300
Raging River			12,000	14,600	15,000	16,000	9,800	13,900	10,200	10,300	4,000	4,100	10,900	8,600	10,100	14,900
Sultan River	38,451	20,000	15,300	20,300	10,500	10,500	10,800	23,000	19,800	15,400	16,200	5,800	8,500	20,300	12,400	17,200
Wallace River	20,246	15,024	20,000	20,400	20,100	20,700	12,100	7,800	25,000	-	19,100	15,000	18,800	20,200	12,100	20,200
Skykomish River, N. Fork			14,500	13,000	20,200	22,100	15,100	32,900	22,400	21,400	18,600	10,100	19,300	10,300	-	15,200
Lake Wash. System	56,800	38,500	45,000	64,900	66,400	50,300	75,200	76,800	48,900	50,160	38,000	-	-	-	-	-
Green River (King Co.)	188,300	166,600	164,600	221,100	223,500	151,100	140,000	186,100	231,300	225,800	212,400	137,000	197,400	231,200	237,700	210,900
Puyallup River System	*88,605*	*86,213*	106,844	149,800	167,100	186,078	132,517	165,800	138,700	169,400	182,800	123,600	336,500	317,000	221,500	252,900
Puyallup River	73,539	81,171	85,900	139,800	157,100	176,100	132,500	140,700	123,500	149,400	162,900	98,500	287,700	238,600	152,300	179,300
White (Stuck) River	15,066	5,042	10,444									41,300	24,900	19,700	24,900	24,000
Carbon River (Voight Cr.)	6,270	17,228	10,500	10,000	10,000	10,000		25,100	15,200	20,000	19,900	25,100	23,900	58,700	44,300	49,600
Nisqually River	10,000	35,400														
Deschutes River	30,000	19,100	32,100	32,000	24,500	25,100	9,500	35,000	49,300	22,300	10,100	15,000	20,000	15,600		95,900
Kennedy Creek	15,200	6,400	18,000	18,100	11,300	15,000	4,900	15,500	15,000	10,000	5,000	10,200	7,900	7,000		10,000
Burley Creek																
Goldsborough Creek	15,000	3,100	13,000	13,000	4,900	10,100	5,200	10,100	15,000	10,100	5,000	9,300	9,100	14,200		
Curley Creek/Kitsap																
Dewatto River	12,400	9,996	12,000	12,000	11,000	9,900	3,000	10,100	14,800	10,000						
Tahuyha River	10,700	8,400	15,100	10,300	10,000	10,000	10,000	10,000	15,000				9,800	14,976		
Union River	9,900	10,010	10,000	10,000	9,400	10,000	10,000	15,000	14,850	10,035	5,000	10,000	11,500	15,028		
Skokomish River	27,200	14,800	27,082	29,600	23,100	20,900	20,000	44,800	39,975	39,000	19,900	28,500	20,000	39,130	39,296	53,684
Hamma Hamma																
Duckabush River	17,800	18,100	20,000	20,000	20,100	22,300	5,000	20,000	20,000	15,000		15,100	17,000	15,142	5,000	10,080
Dosewallips River	23,700	18,200	20,000	25,100	20,800	19,600	15,000	25,400	25,000	15,100	5,600	15,000	20,100	14,742	5,000	12,648
Quilcene River	15,043	13,060	11,900	10,300	10,200	10,200	5,300	5,100	10,160	10,100						
Dungeness River	20,100	17,000	18,600	14,800	15,900	15,400	15,545	20,100	20,123	20,300	15,000	15,100	15,300	18,800	9,900	10,000
Morse Creek	18,000	15,400	16,400	15,500	15,900	18,800	15,200	15,000	15,514	10,100	14,700	15,200	15,400	15,338	15,029	5,100
Elwha River	66,400	63,600	86,300	95,600	90,000	118,800	73,600	88,200	118,600	46,100	91,000	83,500	229,100	92,400	94,000	170,100
P. Snd. Total for year	1.67	1.43	1.46	1.52	1.69	1.62	1.20	1.68	1.81	1.47	1.37	1.18	1.95	1.81	1.51	1.80

Appendix 6. Releases of winter run steelhead smolts into tributaries to Puget Sound.

Name of Stream	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	21-year ave.	10-year ave.
Dakota Creek														
Nooksack River	43,300	63,900	33,900	35,000	56,500	34,800	160,000						83,099	66,310
Whatcom Creek/Squalicum	5,400	20,000	20,100	-	5,000	-	5,370						8,546	7,717
Samish River	22,900	47,900	12,100	25,000	31,000	-	-						27,580	20,880
Skagit River System	328,400	562,700	414,400	417,600	463,500	241,200	513,330	529,821	466,100	517,000	511,560	235,010	329,561	403,063
Skagit River Mainstem	194,300	400,600	238,300	214,300	242,000	20,000	225,000	243,500	200,000	210,000	185,000	20,000	223,514	239,240
Nookachamps/Big Lake														
Baker River	-	-	49,000	60,000	93,000	-	68,000	70,000	30,000	30,000	30,000	30,000	12,857	27,000
Sauk River	21,600	30,800	26,800	20,900	21,800	21,200	20,000	20,000	20,000	30,000	30,000	10	27,681	24,980
Cascade River	112,500	131,300	100,300	122,400	106,700	200,000	200,330	196,321	216,100	247,000	266,560	185,000	55,973	111,843
Stillaguamish River System	100,175	162,700	106,500	98,600	129,800	138,600	161,662	150,027	152,427	148,760	153,937	145,734	127,378	129,244
Stillaguamish R. Mainstem	-	8,000	-	-		15,700	-						4,039	2,633
Canyon Creek	9,975	10,200	9,100	10,000	-	4,700	15,225						9,928	8,950
Pilchuck Creek (Still.)	-	10,000	-	-	-	-	-	5,226	10,000	10,004	10,018	1,080	7,190	2,960
North Fork	90,200	132,500	97,400	88,600	121,400	118,200	146,437	144,801	142,427	138,756	143,919	144,654	96,926	113,214
South Fork	-	2,000	-	-	8,400	-	-						8,600	1,750
Snohomish River System	196,200	474,000	442,700	402,300	418,000	418,650	433,552	442,790	444,677	442,308	436,224	439,326	368,186	381,550
Skykomish River	44,200	132,600	161,200	119,700	112,600	133,400	143,584	173,500	160,025	184,324	181,536	150,740	127,680	124,178
Pilchuck River (Snoh.)	14,800	20,700	31,200	34,200	29,000	25,500	35,295	33,314	25,108	28,014	35,025	25,314	23,114	24,510
Snoqualmie River	93,400	184,400	151,900	145,400	180,900	165,500	161,661	156,333	188,573	160,437	177,712	166,585	125,312	141,446
Tolt River	9,100	30,900	24,800	20,900	21,200	20,000	20,017	22,160				24,970	24,510	23,532
Raging River	9,000	14,100	10,000	10,400	11,700	10,000	11,795	4,650	15,117	20,273		24,998	11,019	11,060
Sultan River	7,700	43,600	45,000	35,900	17,700	29,100	24,575	19,906	20,270	15,660	15,073	25,014	19,504	25,348
Wallace River	13,000	5,200	14,800	15,800	20,000	20,000	19,700	18,500	22,000	22,000	26,878	21,705	16,190	16,100
Skykomish River, N. Fork	5,000	42,500	3,800	20,000	24,900	15,150	16,925	14,427	13,584	11,600			17,304	15,378
Lake Wash. System	-	-	12,400	14,300	-	-	-						25,827	2,670
Green River (King Co.)	262,300	220,100	285,800	274,600	280,000	102,200	155,432	76,895	253,318	243,246	254,669	281,430	207,168	226,023
Puyallup River System	235,550	223,500	240,300	305,600	207,300	211,300	200,000	231,859	207,400	211,900	128,000	218,353	203,528	241,495
Puyallup River	157,700	14,800	42,100	107,000	10,000								134,521	112,725
White (Stuck) River	18,600	19,600	18,200	20,000	21,000	20,000						56,378	21,887	20,667
Carbon River (Voight Cr.)	59,250	189,100	180,000	178,600	176,300	191,300	200,000	231,859	207,400	211,900	128,000	161,975	74,843	132,715
Nisqually River													-	-
Deschutes River	18,000	29,400	26,900		24,400	25,000	27,000	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	14,688	53,495	46,700	62,300	63,000	68,400	55,803	49,946				4,091	38,541	49,650
Hamma Hamma			1,524	1,336	489	1,454	877		965			131	1,136	1,136
Duckabush River		10,032	10,638	10,200	10,000	10,000	10,032						13,980	10,125
Dosewallips River		12,500	12,300	12,500	12,600	12,500	12,533						15,701	11,925
Quilcene River													9,158	-
Dungeness River	9,800	9,000	11,000	10,500	12,200	10,250	13,715	10,500		10,900	10,700	10,200	14,349	11,517
Morse Creek	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000					11,342	7,047
Elwha River	59,600	61,300	182,200	225,200	120,000	151,700	99,600	59,500		38,850	29,150	267,899	113,186	125,610
P. Snd. Total for year	1.30	1.96	1.86	1.90	1.84	1.43	1.85	1.59	1.55	1.61	1.52	1.60	1.63	1.73

Appendix 6. Releases of summer run steelhead smolts into tributaries to Puget Sound from 1987 to 2008.

Name of Stream	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Nooksack River											20,028			63,000		3,078
Whatcom Creek																
Skagit River System																
Skagit River Mainstem							132,726	141,503	92,187	69,432	50,413	36,470	63,962	59,731	23,306	53,559
Sauk River																
Cascade River							48,815		11,380	30,656	26,775	15,369	15,930	22,345	60,966	16,279
Stillaguamish River System																
Stillaguamish R. Mainstem																
Canyon Creek									26,678	11,358	9,900	12,815	13,616	12,698		5,121
South Fork	12,462		43,000	28,170	26,164	21,627	17,139	20,934	24,610	52,732	21,466	17,034	24,097	24,236	25,018	
North Fork	26,902	33,050	32,020	33,240	36,264	81,944	46,288	44,981	48,888	55,893	43,902	28,169	47,260	53,413	53,184	121,543
Snohomish River System																
Skykomish River	24,350	11,520	35,110					9,240			76,374	74,975	62,629	64,307	61,478	59,409
Pilchuck River (Snoh.)																
Snonomish River River																
Snoqualmie River			20,005	31,967			23,088	25,622	19,764	30,854	41,300	20,988	35,956	16,951	16,951	17,955
Tolt River	22,200	14,130				43,505	25,787	15,886	35,993	47,901	34,799	17,297	37,055	30,337	11,598	32,498
Raging River																
Sultan River													7,623			
Wallace River																
Skykomish River, N. Fork	9,900	39,635	32,860	40,005	39,322	5,783	37,183	18,518	57,045	66,720	20,662	10,923	42,460	35,530	32,590	41,290
Skykomish River, S. Fork											11,121	10,278	10,236	4,930	52,833	18,469
Green River (King Co.)						49,713	64,440	58,532	68,921	58,328	94,477	63,840	93,872	90,016	140,044	118,666
Puyallup River System																
White (Stuck) River																
Carbon River (Voight Cr.)																
Nisqually River	25,000	40,000	30,000	25,084		38,025	11,050	6,909	26,980	29,428	29,210		29,120	19,500	47,640	19,355
Deschutes River													689			
East Hood Canal						17,450										
Skokomish River								20,130	20,430	21,588	20,085				20,215	17,010
West Hood Canal																
Dungeness River										20,025	20,136	19,430	19,530	18,300	20,025	10,010
Morse Creek																
Elwha River				20,127	22,747	21,180	20,940	20,010	20,195	20,080	30,600	19,826	20,776	27,100	20,007	20,029
P. Snd. 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	524,811	542,395	585,765	554,262

Appendix 6. Releases of summer run steelhead smolts into tributaries to Puget Sound.

Name of Stream	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Nooksack River	10,818															
Whatcom Creek																
Skagit River System							0	30,900	0	24,100	18,700	19,800	32,300	27,000	25,200	25,000
Skagit River Mainstem	73,322		30,958		10,022	10,089				24,100	18,700	19,800	27,300	27,000	25,200	25,000
Sauk River	7,463												5,000			
Cascade River	29,081			34,897	10,104	25,030		30,900								
Stillaguamish River System							73,111	82,800	59,500	100,000	80,600	85,100	81,300	87,100	74,000	85,100
Stillaguamish R. Mainstem							3,500									
Canyon Creek	5,217			2,475	10,877	10,243	9,711	9,700		7,500	9,200	9,600	7,900	9,700	5,300	13,500
South Fork	33,071			34,143	15,806	26,342		18,500		23,300	8,100	15,500	15,300	18,500	20,100	21,000
North Fork	39,160	27,704	24,530	42,167	33,014	63,172	59,900	54,600	59,500	69,200	63,300	60,000	58,100	58,900	48,600	50,600
Snohomish River System							63,100	233,000	137,700	184,300	179,900	235,100	127,100	230,500	180,900	226,400
Skykomish River	24,960	54,598	65,760	112,063	36,744	95,235	63,100	76,400	101,600	91,800	104,500	111,500	72,800	146,200	120,000	127,400
Pilchuck River (Snoh.)																
Snonomish River River												26,900	0	0	0	0
Snoqualmie River	7,655	16,650		16,650	27,376	68,381		72,700	30,800	38,300	44,900	46,200	30,500	56,500	48,700	73,500
Tolt River	23,651	15,952	11,763	7,854	11,013	14,175		15,800	5,300	8,700	0	0	8,000	0	0	0
Raging River				5,050	5,785	5,600		4,100								
Sultan River				18,677	20,378	9,800		19,400		15,000	0	10,100	8,200	8,200	5,500	9,700
Wallace River																
Skykomish River, N. Fork		13,342	19,147	26,935	16,322	18,092		24,700		14,600	15,300	20,400	7,600	19,600	6,700	15,800
Skykomish River, S. Fork	25,465	15,000	8,165	32,132	11,665	20,287		19,900		15,900	15,200	20,000	0	0	0	0
Green River (King Co.)	54,096	76,633	76,398	72,208	69,304	114,085		74,800	5,200	71,300	23,700	79,600	83,700	81,300	83,600	100,100
Puyallup River System							0	0	0	0	0	0	0	0	0	0
White (Stuck) River																
Carbon River (Voight Cr.)																
Nisqually River	11,250	20,243	34,390	42,646	19,952	26,028		22,200		13,400	0	24,800	23,700	12,800		
Deschutes River							115,011				3,300	3,000				
East Hood Canal																
Skokomish River	10,107															
West Hood Canal	15,043															
Dungeness River	5,141	4,530	4,150	5,000	10,371	5,150	10,200	10,100	10,100	6,100	0	15,100	16,100	10,500		
Morse Creek																
Elwha River	26,115	17,829	15,175	20,285	20,747	18,949	19,800	25,400	19,800	15,000	0	23,600	25,100	0	25,100	20,200
P. Snd. Total for Year	401,635	262,472	290,436	473,182	329,480	530,658	281,222	479,200	232,300	414,200	306,200	466,100	389,300	449,200	388,800	456,800

Appendix 6. Releases of summer run steelhead smolts into tributaries to Puget Sound.

Name of Stream	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	10 Year Average
Nooksack River													
Whatcom Creek													
Skagit River System	0	21,000	0	0	0	0	0	0	0	0	0	0	0
Skagit River Mainstem		21,000											
Sauk River													
Cascade River													
Stillaguamish River System	38,600	74,700	17,600	70,000	106,900	90,600	45,633	77,776	73,633	105,575	97,000	96,858	78,158
Stillaguamish R. Mainstem		31,300	17,600	21,800		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	38,600	43,400		48,200	60,000		45,633	77,776	73,633	76,254	76,928	76,428	66,857
Snohomish River System	168,631	265,300	266,300	167,200	223,400	221,200	177,849	248,268	261,770	234,006	245,057	271,686	231,674
Skykomish River	93,700	175,000	185,700	117,400	136,500	0	107,217	165,000	168,800	149,440	160,135	178,361	136,855
Pilchuck River (Snoh.)													
Snonomish River River	0	0	0	0	0	0	0						
Snoqualmie River	45,221	41,600	27,800	22,000	28,300	0	44,901	18,865	52,470	50,838	28,840	62,763	33,680
Tolt River	0	0	0	0	0	0	0						
Raging River			21,700	9,200	21,700	51,500	0	23,786			27,720		22,229
Sultan River	15,100	15,400	13,300	14,000	20,600	14,900	10,449	20,447	20,340	20,330	28,362	30,562	19,329
Wallace River													
Skykomish River, N. Fork	14,610	33,300	17,800	4,600	16,300	154,800	15,282	20,150	20,160	13,398			32,811
Skykomish River, S. Fork	0	0	0	0	0	0	0						0
Green River (King Co.)	36,000	86,300	67,300	65,300	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	0	0	0	0
White (Stuck) River													
Carbon River (Voight Cr.)													
Nisqually River													
Deschutes River													
East Hood Canal													
Skokomish River													
West Hood Canal													
Dungeness River													
Morse Creek													
Elwha River	10,000	10,000	10,100	10,000									10,050
P. Snd. Total for Year	253,231	457,300	361,300	312,500	369,900	412,900	283,315	400,649	499,866	436,422	438,621	422,944	393,842

Appendix 7. Steelhead fisheries reported harvest for Puget Sound, by county.

Steelhead fisheries reported harvest for Puget Sound counties for 1895 (Wilcox, 1898)

	Gear (Catch kg)		Total (kg)	Count (@ 4.5 kg)	Run (40% harvest)
County	Gill Net	Seine Nets			
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**

Steelhead fisheries reported harvest for Puget Sound, by county, for 1904 (Wilcox 1905).

		Total (kg)	Count (@ 4.5 kg)	Run (40% harvest)
County	Rivers			
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**

Steelhead fisheries reported harvest for Puget Sound, by county, for 1909 (Cobb 1911).

		Total (kg)	Count (@ 4.5 kg)	Run (40% harvest)
County	Rivers			
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 8a. Steelhead age structure, by broodyear (BY), for selected Puget Sound rivers. Age structure was based on scales collected from steelhead captured in in-river tribal net fisheries and sport fisheries. Data from WDFW. Numbers in bold indicate the most common age class.

River	Broodyear(s)	W 1.1+	W 1.2+	2.1+	W 1.3+	2.2+	3.1+	2.3+	3.2+	4.1+
Nooksack	BY 78/80	0.00%	0.00%	**78.72%**	0.00%	13.18%	7.09%	0.00%	1.01%	0.00%
Skagit	BY 79/86	0.29%	0.06%	45.85%	0.00%	30.42%	13.60%	1.06%	8.57%	0.15%
Sauk	BY 83	0.00%	0.00%	29.47%	0.00%	43.16%	5.26%	0.00%	22.11%	0.00%
Snohomish (All)	BY 78/86	1.07%	0.27%	47.40%	0.00%	37.27%	5.69%	0.84%	7.46%	0.00%
Snohomish (Sp)	BY 80/86	0.86%	0.32%	48.82%	0.00%	31.69%	8.40%	0.92%	9.00%	0.00%
Pilchuck	BY 83/85	1.90%	0.68%	46.70%	0.00%	36.60%	8.19%	3.49%	2.44%	0.00%
Skykomish (1)	BY 85/86	0.36%	1.49%	**62.22%**	0.00%	34.19%	0.00%	0.00%	1.74%	0.00%
Skykomish (Sp) (1+2)	BY 79/81	0.58%	0.00%	**61.39%**	0.00%	27.96%	2.16%	1.24%	6.67%	0.00%
Tolt	BY 1984	0.00%	48.98%	0.00%	0.00%	**51.02%**	0.00%	0.00%	0.00%	0.00%
Snoqualmie	BY 79/85	0.61%	0.90%	**58.33%**	0.00%	36.04%	1.60%	0.00%	2.51%	0.00%
Green	BY 81/86	6.14%	2.37%	42.82%	0.00%	40.72%	3.52%	1.90%	2.53%	0.00%
Puyallup	BY 76/77	7.57%	0.58%	**62.98%**	0.00%	20.57%	8.31%	0.00%	0.00%	0.00%
Nisqually	BY 78/80	10.49%	3.86%	**66.61%**	0.00%	17.41%	1.49%	0.05%	0.08%	0.00%

Appendix 8b. Distribution of adult age classes (including multiple spawner information) by sex for winter-run steelhead captured in sport and tribal fisheries for selected Puget Sound Rivers. Data from WDFW.

River Basin		W1.1+		W1.2+		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		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 River	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

Appendix 9. Normalized average monthly flows for Puget Sound Streams. Peak monthly flows for each river are set to 100 (in bold).

River	Dates	Jan	Feb	Mar	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 R 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 Ck (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
MF 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
NF Snoqualmie nr 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 MS	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
Nooksack River NF	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
Nooksack river SF	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 River Carbon River	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 River 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 MS	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

Appendix 9 (cont). Standardized average monthly flows for Puget Sound Streams. Peak monthly flows for each river are set to 100 (in bold).

River	Dates	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
S. 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
SF 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 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 River 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

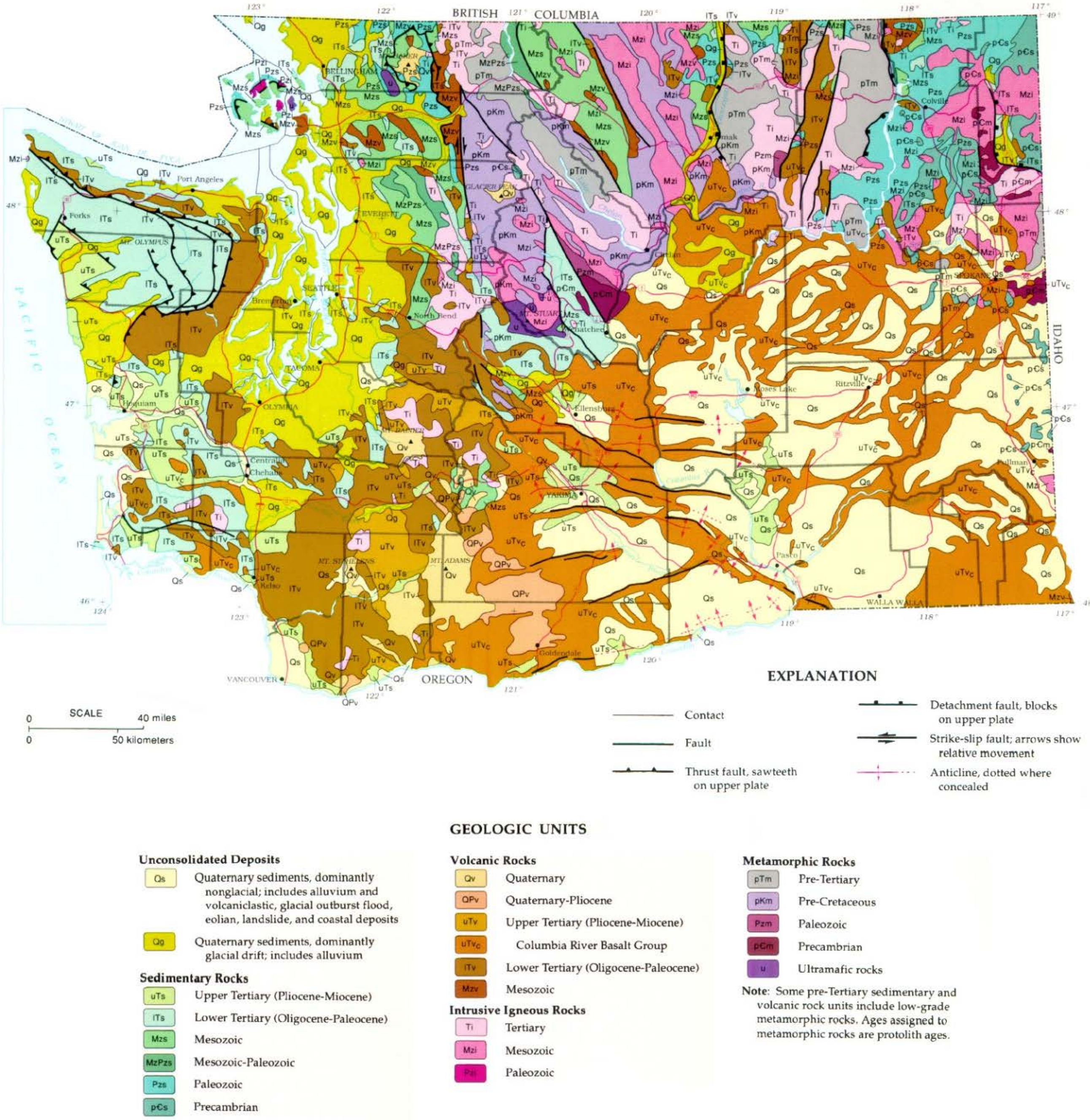
Appendix 10. Catastrophic-risk categories for Puget Sound Chinook salmon (Good et al. 2008)

		Risk Source							
Georegion	Basin/Population	Volcano[1]	Earthquake[2]	Landslide[3]	Flood[4]	Toxic Leak[5]	Toxic Spill[6]	Hatchery[7]	Dam Breach[8]
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	0.0	0.0	0.0
CE	Suiattle	99.2	25.7	31.0	23	0.01	0.03	0.0	0.0
CE	N.F. Stilliguamish	79.7	34.0	21.3	25	0.02	0.26	9.0	0.0
CE	S.F. Stilliguamish	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

[1] Chinook salmon distribution overlapping with volcanic hazard zones (%).
[2] Chinook salmon distribution falling under earthquake risk; weighted mean of the amount of the distribution under each contour value (%).
[3] Chinook salmon distribution under high landslide risk (%).
[4] Mean chance of annual flood occurrence (%).
[5] Potential point source pollution facilities per km of Chinook salmon reaches (no./km).
[6] Major transportation routes per km of chino salmon reaches (km/km).
[7] Releases of hatchery Chinook salmon per meter of Chinook salmon reaches (no. releases/km).
[8] Chinook salmon distribution impacted by unplanned dam breaches (%).

Appendix 11. Geologic Regions of Washington State.

Schuster, J.E. 2005. Geologic map of Washington State. Washington Division of



Geology and Earth Resources. Geologic Map GM-53. 48 p. Map available from: http://www.dnr.wa.gov/ResearchScience/Pages/PubMaps.aspx

Appendix 12. TRT score sheet for identifying factors contributing to

Summary of Distances to Nearest Neighbor Spawning Grounds				
Spawning Area	**Nearest Neighbor(s)**	**Distance (km)**	**Next Nearest**	**Distance (km)**
Boundary tribs	**Nooksack - mainstem**	25.5	Samish	39.8
Nooksack - mainstem	**NF, MF, & SF Nooksack**	0	Boundary Tribs	25.5
Nooksack - NF	**Mainstem & MF Nooksack**	0	Nooksack - SF	5.6
Nooksack - MF	**Mainstem & NF Nooksack**	0	Nooksack - SF	5.6
Nooksack - SF	**Nooksack - mainstem**	0	NF & MF Nooksack	5.6
Samish	**Boundary tribs**	39.8	Nooksack - mainstem	61.3
Skagit - Lower	**Middle Skagit & Finney & Sauk**	0	Baker	26.1
Skagit - Middle	**Lower Skagit & Cascade & Sauk**	0	Finney	14.5
Sauk	**Middle Skagit**	0	Lower Skagit	19.1
Skagit - Finney	**Lower Skagit**	0	Middle Skagit	14.5
Skagit - Baker River	**Lower Skagit**	26.1	Finney	40.5
Skagit - Cascade	**Middle Skagit**	0	Sauk	19.5
Stillaguamish	**NF & SF Stillaguamish**	0	Deer Creek	37.6
Stillaguamish - NF	**Stillaguamish & SF Stillaguamish**	0	Deer Creek	14.7
Stillaguamish - SF	**Stillaguamish & NF Stillaguamish**	0	Deer Creek	37.7
Stillaguamish - Deer Creek	**NF Stillaguamish**	14.7	Stillaguamish	37.6
Snohomish	**Skykomish**	1.2	Snoqualmie	4.2
Snohomish - Pilchuck River	**Snohomish**	8.3	Skykomish	11.4
Skykomish - NF	**Skykomish**	0	Snohomish	47.6
Skykomish NF and SF	**NF Skykomish**	0	Snohomish	1.2
Snoqualmie	**Skykomish**	3.6	Tolt	3.9
Snoqualmie - Tolt River	**Snoqualmie**	3.9	Skykomish	39.5
Sammamish	**Cedar**	68.3	East Kitsap	81.2
Cedar River	**East Kitsap**	51	Sammamish	68.3
Green River	**East Kitsap**	66.3	Cedar	89
Puyallup - entire basin	**Carbon**	0	White	7.5
Puyallup - White	**Puyallup**	7.5	Carbon	19.6
Puyallup - Carbon	**Puyallup**	0	White	19.6
Nisqually	**South Sound Inlets**	35.7	Puyallup	61
South Sound Inlets	**Nisqually**	35.7	East Kitsap	79.5
Kitsap - East/Curley	**Cedar**	51	Puyallup	56.2
Hood Canal East	**Dosewallips**	13.2	Hamma Hamma	15.8
Tahuya	**Skokomish**	10.1	East Hood Canal	18.9
Skokomish - entire basin	**NF & SF Skokomish**	0	Tahuya	10.1
Skokomish - NF	**Skokomish & SF Skokomish**	0	Tahuya	24.1
Skokomish - SF	**Skokomish & NF Skokomish**	0	Tahuya	24.1
Hamma Hamma	**East Hood Canal**	15.8	Duckabush	18.8
Duckabush	**Dosewallips**	12	Hamma Hamma	18.8
Dosewallips	**Duckabush**	12	Hamma Hamma	24.7
Big Quilcene	**Dabob Bay**	20.9	Dosewallips	27.5
Sequim/Discovery/Dabob Bays	**Big Quilcene**	20.9	Dungeness	21.8
Dungeness	**Strait/PA Independents**	21.6	Sequim/Discovery/Dabob	21.8
Strait Independents/PA Independents	**Elwha**	18.5	Dungeness	21.6
Elwha	**Strait/PA Independents**	18.5	Dungeness	44.7
		(green)	= < 10 km separation	
		(yellow)	= 10 to 25 km separation	
		(orange)	= 25 to 35 km separation	
		(red)	= > 35 km separation	

population independence.

Appendix 13. Decision Support Systems.

Previous TRTs have employed a number of different decision systems to identify demographically independent populations in their respective DPSs and ESUs. Most have relied on an expert opinion system, either to directly identify populations or to establish criteria for decision systems, which, in turn, identify demographically independent populations. Myers et al. (2006) utilized a simple set of basin size and distance parameters (geographic template model) to identify presumptive populations in the Lower Columbia and Upper Willamette River Recovery Domain. The Southern Oregon/Northern California Coast (SONCC) Coho Salmon Workgroup of the TRT developed a method for using principal component and clustering analyses of climate, physiographic, and biogeographic data to identify areas of similar environmental conditions (Williams et al. 2006). Lawson et al. (2007) proposed a different approach to identifying historical populations of coho salmon in the Oregon Coast ESU. Independent drainages along the Oregon Coast were evaluated according to their persistence and independence. Functionally independent populations, the equivalent of DIPs (McElhany et al. 2000), had to be both large enough to persist into the foreseeable future and remote enough to experience minimal demographic influence from adjacent populations. Potentially independent populations met the persistence criteria, but were not sufficiently isolated to meet the independence criteria, while dependent populations were both too small to persist independently and subject to demographic influences from adjacent populations.