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). The majority of two-year-old naturally produced smolts are 140-160 mm in length (Wydoski and Whitney 1979, Burgner et al. 1992). The inshore migration pattern of steelhead in Puget Sound was not well known, and it was generally thought that steelhead smolts moved quickly, within a few weeks, offshore (Hart and Dell 1986). Recent acoustic tagging studies (Moore et al. 20xx; Goetz et al. 20xx) have shown that smolts migrate from rivers to the Straits of Juan de Fuca in from X to Y 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 of adjacent DPSs.

		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	**0.84**	0.07	--	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. 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).[1] 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 occured 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.

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*

[1] 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.

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 coding genes) identified two major *O. mykiss* lineages in Washington, inland and coastal forms 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 have a common founding source, this methodology does not offer much potential for identifying finer-scale genetic differences within Puget Sound.

Phelps et al. (1994) and Leider et al. (1995) reported results from an extensive survey of Washington State anadromous and resident *O. mykiss* populations. Populations from Puget Sound and the Strait of Juan de Fuca were grouped into three clusters of genetically similar populations: 1) Northern Puget Sound (including the Stillaguamish River and basins to the north, 2) south Puget Sound, and 3) the Olympic Peninsula (Leider et al. 1995). Additionally, populations in the Nooksack River Basin and the Tahuya River (Hood Canal) were identified as 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 naturally-produced hatchery fish, hatchery x wild hybrids, migrating juvenile steelhead from another population, or potentially distinct resident *O. mykiss* were included in the sample. 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, and Tahuya River and Pilchuck River samples were distinct from other geographically proximate steelhead populations. 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 studies have focused on the analysis of microsatellite DNA variation among populations within specific river basins.

Van Doornik et al. (2007) assessed differences between presumptive steelhead populations in the Puyallup River basin. These results indicated that significant genetic differences exist between winter steelhead in the White River and the Puyallup River. Although the White River is a tributary to the Puyallup, 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. More importantly, the steelhead sampled from the Puyallup and White Rivers were distinct from hatchery-origin fish (derivatives of the Chambers Creek winter steelhead broodstock) that have been released into the Puyallup Basin over the last 50 years (Van Doornik et al. 2007).

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 formally flowed together, but the Cedar River was diverted into Lake Washington to provide adequate flows for the Chittenden Locks in 1916 (Williams et al. 1975). 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.

Preliminary results from the genetic analysis of Hood Canal steelhead (Van Doornik 2007) 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 (Van Doornik 2007). 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 2007).

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 genetics database (Appendix 9). Given that this new information usually represented a limited numbers of samples taken during a single return year, and in some cases were 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 major populations groups (MPGs), 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, the TRTs used MPGs to establish guidelines to ensure 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) language of 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 their Recovery Domain, 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 X) reflect the homing fidelity exhibited by steelhead and the likely degree to which populations will be locally adapted to these conditions. These MPGs are intended to direct recovery planning towards ensuring that recovery efforts are spread adequately across the distribution of distinct life-history and ecological diversity categories.

Table 5. MPGs for 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 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 6) 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 8) provided an initial setting for developing the configuration of steelhead MPGs. In contrast to Chinook salmon that spawn 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 a 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 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, and one 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.

Figure 8. 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).

The EPA Ecoregion designations were useful in identifying ecologically distinct areas in Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Portions of four Level III Ecoregions are found within the Puget Sound DPS (Figure 2): the Coast Range (covering the western side of the Hood Canal), the Puget Lowlands, the Cascades (covering the headwater regions of the Cedar River and south), and the North Cascades (encompassing the Olympic Mountains, and the Cascades south of the Snohomish 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 lowland, rain-driven, streams (Appendix 6). 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 between 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. 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.

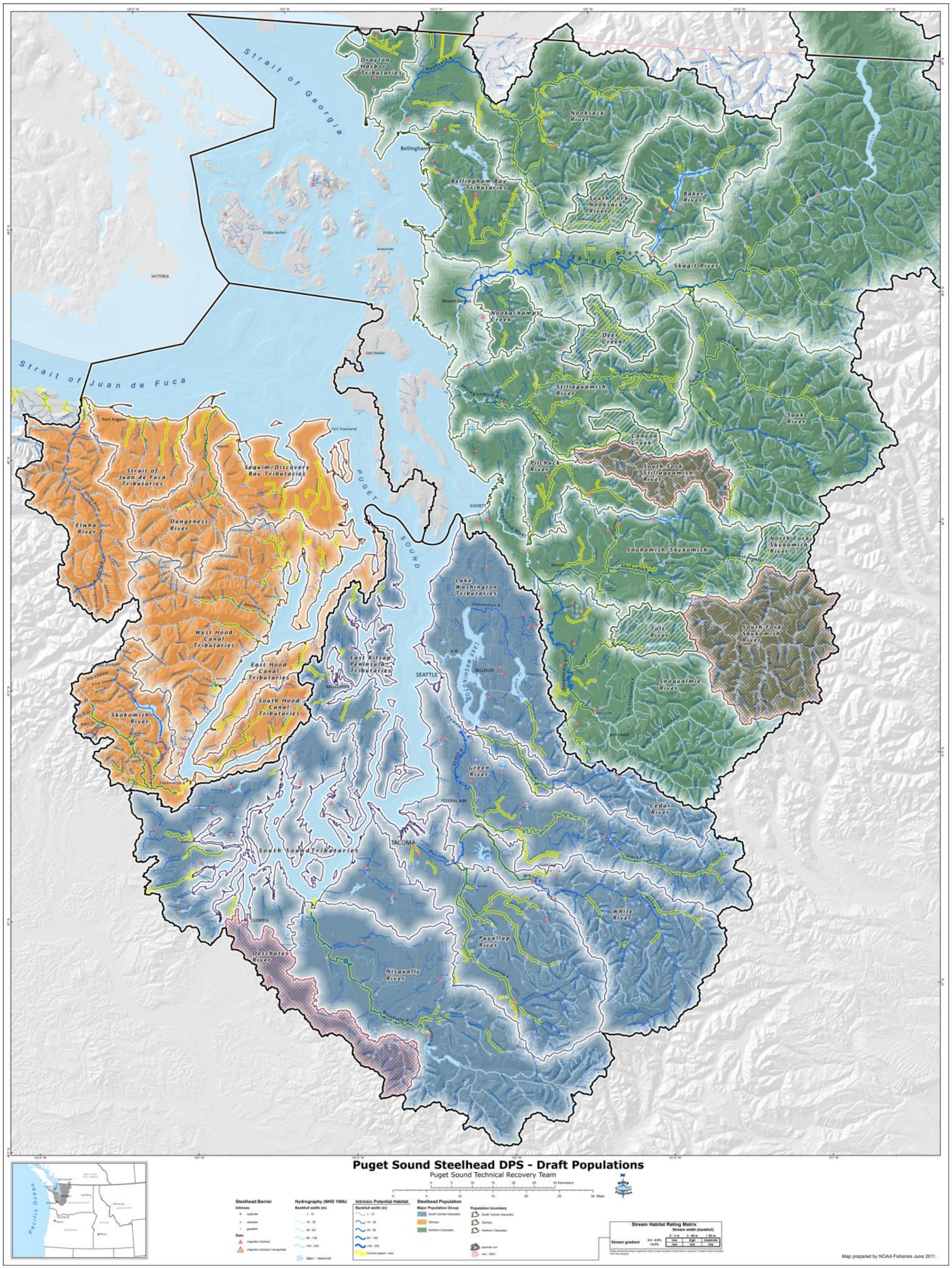

Figure x. Major population groupings for the Puget Sound steelhead DPS: Northern Cascades, Central and South Puget Sound, and Olympic Peninsula MPGs.

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: 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 11), although many of the category weightings 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 from the truth membership functions generated by the TRT. Discussion of this model, and the truth membership functions they relied on, is presented in Appendix 3.

The following sections list the DIPs identified by the TRT and provide some detail on those factors that were especially relevant in that determination. Where appropriate, we have noted if there was substantial uncertainty 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 the Snohomish River Basin. 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 all of the documented 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 not available. 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. Not withstanding 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 an MPG.

Proposed DIPs within the Northern Cascades MPG

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[1].

This population is 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 1,782 fish (Appendix 4). Sport fishing punch card records indicate a maximum catch (adjusted)[2] 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 member suggested the presence of multiple winter-run DIPs within the Basin, including making each of the three forks a DIP. SaSI (WDFW 2005) reported that the Middle Fork Nooksack River may have supported a summer run of steelhead

[1] Brett Barkdull, Washington Department of Fish and Wildlife, La Conner, WA October 2008.
[2] 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.

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 steelhead from the North, Middle, and South Forks of the Nooksack 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 exhibits 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 Nooksack River prevent accurate estimation of escapement or life history characteristics (spawn timing, etc.). Local biologists for the state and tribes suggested that winter-run steelhead spawning is a continuous distribution throughout the basin, with little opportunity for spatial or temporal isolation[3] [4].

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 5,422 steelhead. Given the magnitude of historical abundance estimates, the IP estimate seems especially low. Spawner surveys of the North and Middle Fork Nooksack rivers in 1930 identified a number of tributaries that supported steelhead. Adjusted punch card catch estimates 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; however, it was unclear whether these were South Fork fish, a distinct 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 fall at Rkm 40 and in upper watershed tributaries, Hutchinson and Wanlick creeks (Rkm 16.3 and 54.9, respectively). Smith (2002) suggested that the summer run of steelhead in the South Fork Nooksack has always been relatively small compared to the winter run, although the run size, based on habitat, was estimated to be 4,253 steelhead, although this includes the entire South Fork. WDFW (2003) suggested that summer-run spawning extends from February to April, while winter-run steelhead exhibit a more protracted spawning

[3] See footnote 1.
[4] Ned Currence, Natural Resource Department, Nooksack Tribe, Deming, WA, October 2008.

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 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 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. Hydrologically the South Fork Nooksack River is categorized 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 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, Skookum Creeks (WDFG 1932), although no distinction was made between winter- and summer-run fish in these surveys.

4. Samish River Winter Run Steelhead

This DIP exists in 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 2005). 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, recent escapements have averaged several hundred steelhead (WDFW 2010). Peak catch, based on adjusted punch cards was 1,934 winter steelhead in 1951. The IP-based estimate of capacity for the Samish Basin was 2,005 steelhead. 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 DNA microsatellites indicated samples from the Samish River winter-run were more closely related to Nooksack River fish than to Skagit or Stillaguamish 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, and Chuckanut 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 Winter-run and Summer-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 year of sampling (2010) did not provide evidence for much divergence within the basin, except between steelhead and resident *O. mykiss* above barriers. Sample sizes for steelhead in tributaries were relatively small and results should be considered preliminary. The majority of the TRT members felt it necessary to move forward using available data, while other members recommended deferring any decisions until the study was complete. Additionally, given the recent decline in steelhead abundance in the Skagit River, especially in the tributaries, it is not clear 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 escapement, Skagit River steelhead represent one of the predominant steelhead populations in Puget Sound, accounting annually for several thousand spawning steelhead. WDFW (2005) notes that although they consider winter 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, the Cascade River sample of juvenile *O. mykiss* from the anadromous zone was distinct from other Skagit Basin samples. It is currently unclear whether these juveniles were offspring of steelhead, resident rainbow trout, or rainbow trout upstream of migrational barriers. Winter 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. Of these summer-runs, the Cascade River came the closest to meeting DIP criteria, although much of the biological data were limited. For example, peak adjusted punch card catch was 58 summer run fish in 1970 (WDG undated(b)). Further sampling efforts in this basin were recommended. At a minimum, winter- and summer-run life histories are somewhat reproductively isolated 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.

Genetically, samples from the Skagit, Sauk, and N.F. Stillaguamish formed a cluster within the greater Puget Sound grouping (Phelps et al. 1997). Steelhead samples (possibly containing summer-run fish) from Finney Creek and the Cascade River were similar to samples from Deer Creek and the Nooksack River Basin (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 are adjacent to each other. While there is considerable information that summer-runs 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. Given the large size of this DIP relative to other populations, there is considerable within-population ecological, spatial, and genetic (life history) diversity that needs to be characterized. Preliminary results from the recent sampling indicated that Skagit River steelhead are distinct from steelhead broodstock (Chambers Creek-origin) used at Marblemount Hatchery[5].

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 abundance, based on IP estimates, is 54,802 steelhead. 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 steelhead. This basin met the criteria for basin size and IP production. In contrast to much of the Skagit Basin, 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 only supported winter-run 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 the Nookachamps would be from other Skagit tributaries.

WDF (1932) identified steelhead as being "very scarce", while notations on the 1940 steelhead map of the Skagit 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 (similar to the mainstem Nookachamps) was noted in East Fork Nookachamps Creek. Given the lowland nature of this sub-basin and its proximity to Mt. Vernon, Washington, it is thought that significant habitat alterations had likely occurred by the time of the 1932 and 1940 surveys.

There was little information available on the characteristics of historical or contemporary steelhead in the Nookachamps Basin. Potential abundance was estimated at 911 using the IP method. Although identified as a historical DIP, the TRT agreed that additional information and monitoring was needed to address critical uncertainties.

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

7. Baker River Winter/Summer-Run Steelhead

Historically, the Baker River was likely a major contributor to Skagit River 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 (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 (1958) inundated the lower reaches of numerous tributaries. It is unclear whether steelhead currently spawning in the Baker River retain any genetic association with the historical population. It would be useful to genetically analyze the existing population to see if it is distinct from steelhead spawning in the Skagit River. Many of the TRT members and reviewers considered the Baker River DIP to have been extirpated, although resident *O. mykiss* in the Baker River Basin may retain some of the historical genetic legacy of this population. 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 spawns within the North Cascades Ecoregion and the river exhibits a glacial snowmelt-dominated hydrograph. Habitat-based abundance estimates (IP) suggest a capacity for 4,353 steelhead. 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

While summer- and winter-run steelhead are present in the Sauk River, they were not assigned into separate DIPs. Current abundance of summer-run fish is relatively low and is thought to have historically been a minor contributor to total abundance (WDFW 2005). In contrast to other basins in Puget Sound that contain summer-run steelhead, no migrational barriers (falls or cascades) have been identified that would provide a reproductive isolating mechanism. Historical surveys report the presence of an early winter run of steelhead in the Sauk River basin, specifically in the Suiattle River (WDG undated (a)). It was deduced that the early run timing allowed fish to access spawning grounds while stream conditions were good and prior to the spring glacial runoff. For summer- and winter-runs, there does not appear to be any temporal or geographic separation on the spawning grounds. WDFW (2003) reports that summer-run fish spawn from mid-April to early June and winter-run fish spawn from mid-March to mid-July. Genetically, summer- and winter-run fish from the Sauk clustered closely together with winter-run fish from the mainstem Skagit River (Phelps et al. 1997). Sauk River flows are strongly influenced by snow melt and, as mentioned earlier, are subject to considerable glacial turbidity for all or part of the year, depending on the tributary. The Suiattle and Whitechuck rivers were specifically noted as containing high levels of glacial debris (WDG undated (a)). Biologists infer that there is little mainstem spawning in these glacial systems, but young steelhead have been observed in several of their smaller, clearer, side tributaries. 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 and it may be necessary to revisit the TRT's DIP conclusions based on any new information. Preliminary sampling efforts were unable to obtain sufficient numbers of steelhead from the Sauk River to adequately test for population distinctiveness.

The entire Sauk 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. Recent escapement (2006) to the Sauk River was estimated to be 3,068. The IP estimate of basin capacity is 18,913 steelhead. At a minimum there is likely to be some population substructure that should be considered in maintaining within population diversity. Good et al. (2008) identified the Sauk River Basin as being at a high risk from volcanic and landslide hazards.

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 considered 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) spawning above Granite Falls (S.F. Stillaguamish River) were not considered. Genetic analysis indicated that there was some reproductive isolation between the native winter-run (N.F. Stillaguamish River) and summer-run (Deer Creek) spawners (Phelps et al 1997). Stillaguamish winter-run steelhead clustered with winter and summer Sauk River steelhead and other Skagit River steelhead (Phelps et al 1997). 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 estimate of capacity is 14,657 steelhead. 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 N.F. and S.F. Stillaguamish are located in the North Cascades Ecoregion. Historically, the Sauk River flowed into the North Fork Stilliguamish River, and as a result the North Fork river valley is much broader than might be expected based on current river size and flow. River flow in the Stillaguamish 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 steelhead up to approximately Rkm 32. 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 for Deer Creek is 1,462 adults. There are no recent estimates of escapement, and given the inaccessibility of the basin there is considerable uncertainty regarding those escapements that are available. The supporting basin is relatively small, 172 km^2. Deer Creek steelhead were genetically distinct from winter-run fish in the Stillaguamish and Skagit Rivers (Phelps et al. 1997). 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 existing 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. There is no genetic information available on this run. A series of cascades and falls at Rkm 2 is thought to be a partial 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 1,052. 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, Skykomish, and Wallace Rivers. WDFW (2003) identifies three winter-run populations in the Snohomish Basin based on geographic discreteness. There is no recent genetic information available (i.e. DNA microsatellite analysis). Based on the work of Phelps et al. (1997) winter-run steelhead in the Tolt, Skykomish, and Snoqualmie 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, the 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 were indicative of runs over 100,000 fish (Appendix 4). Basin area is 2,185 km^2 and the intrinsic potential estimates suggest a run size of approximately 15,000 fish.

The low 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 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 exhibits a rainfall dominated flow pattern. There appears to be sufficient habitat (366 km^2) to support a sustainable population. The IP-based estimate of capacity was 4,219 steelhead. The last escapement estimate (2006) was 580 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. 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[6]). 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 above Bear Creek Falls (Rkm 21; WDFW 2005). 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 2,452 fish, based on the IP estimate. Genetic analysis by Phelps et al. (1997) indicated that summer-run fish in the North Fork 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 by introduced Skamania Hatchery 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 N.F. Skykomish summer-run are significantly different from Skamania Hatchery summer-run steelhead and that the level of introgression may be less than previously thought. The Kassler et al. (2008) study did

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

not include samples from other Puget Sound basins so no comparisons could be made among N.F. Skykomish 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.

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, below 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 a temporal migrational barrier on the North and South Fork Tolt River. Genetic analysis by Phelps et al (1997) indicated that Snoqualmie River winter-run fish generally clustered with other central Puget Sound samples, but were most closely associated with Green River winter-run rather than Tolt or Skykomish steelhead samples. The presence of offspring from hatchery-origin fish may have confounded the analysis. The Snohomish River Basin is one of the large basins in Puget Sound that have yet to be comprehensively assessed using DNA microsatellite analysis.

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 of capacity was 12,556 steelhead, with the 2006 estimate of escapement being 1,856 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 inaccessible headwater sub-basins 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 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 samples were comprised of juveniles and progeny of native or hatchery winter- or summer-run steelhead were not distinguishable. Thus genetic relationships among Tolt summer-run steelhead and other populations are not clear. Spawn timing for Tolt River summer run fish is from January to May, somewhat earlier than other summer-runs 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 potential temporal migratory barriers. The IP-based estimate of capacity was 1,575 steelhead, while the most recent (2006) escapement estimate was 120 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. 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 cluster 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 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 that historically contained steelhead. The Deschutes River was historically impassable to anadromous fish at Tumwater Falls.

Proposed DIPs within the Central and South Puget Sound MPG

17. Cedar River Winter-Run Steelhead

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 and 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 existing 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 post-glacial recession. 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.

Genetically, Cedar River steelhead are very similar to native Green River winter run (Phelps et al. 1997, Marshall et al. 2004). Based on fish ladder counts, the abundance of steelhead has been at critically lows (10s of fish) for at least a decade. 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 exhibits a rain and snow transitional flow pattern, which is very distinct from most of the tributaries to Lake Washington. Earthquake and flood events constitute the most likely catastrophic risks.

18. Lake Washington Winter-Run Steelhead

Dramatic changes in the Lake Washington/Green River Basin in the early 1900s resulted in the lowering of Lake Washington and the drying up 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 utilized tributaries 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. Currently, WDFW (2005) lists a number of tributaries (for example: Swamp Creek, Bear Creek, Issaquah Creek) to Lake Washington and Lake Sammamish as supporting steelhead, although given the 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.

Based on fish ladder counts, the abundance of steelhead has been at critically lows (10s of fish) for at least a decade, with the majority of those steelhead destined for the Cedar River. 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. 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 each other. WDFW (2005) reports that winter 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.

A minority of TRT members indicated that a native run of summer steelhead may have once occurred in the Green River, most likely above the present location of the Headworks Diversion Dam that blocked migratory access to the upper basin in 1913. The upper basin of the Green River is characteristic of summer 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. The historical summer-run in the Green River should not be confused with the existing, Skamania Hatchery origin, summer run. 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 Tacoma Headworks Diversion Dam (Rkm 98.1), 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 of capacity for this DIP is 15,809 steelhead. 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 two SaSI (WDFW 2005) stocks, the Puyallup and Carbon Rivers. 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. The Puyallup/Carbon River DIP covers 1,277 km^2 and although recent escapements have averaged 867 steelhead (1998-2008), IP-based run capacity is 11,897. There is little life history information available on these stocks other than spawn timing extends from early March to mid-June (WDFW 2005). Phelps et al. (1997) reported that steelhead genetic samples from the Green, White, and Puyallup rivers clustered together, with Puyallup River steelhead being slightly more distinct. Van Doornik et al. (2007) found that samples from the White and Carbon rivers were genetically significantly different from each other, although genetic divergence (Fst) between samples from the two locations was only 0.015, a relatively low degree of separation.

Historically, the White River drained to the Green River rather than the Puyallup River. 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

This population includes one SaSI (WDFW 2005) stock, the White River. The TRT determined this population begins at the confluence of the White and Puyallup rRivers. 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. Although 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.

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 14,420 fish. 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 2005), although as mentioned in earlier sections the presence of early-returning hatchery-origin fish may have truncated the early portion of the 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. We speculate that this anomalous result could be due to out-planting of Chambers Creek Hatchery stock steelhead being widely planted in Strait of Juan de Fuca streams. Chambers Creek is close to Nisqually River and native populations in both basins may have been genetically relatively similar. More recently DNA microsatellite analysis suggests that the Nisqually River steelhead are somewhat of a genetic outlier from other Puget Sound populations, although they are still more closely associated with Puget Sound steelhead than steelhead from other geographic regions. 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 of capacity is 12,357 steelhead. In the late 1980s, run size estimates for “wild” Nisqually River steelhead were in excess of 6,000 fish, although recent estimates are well below 1,000 steelhead. Currently, the Nisqually River exhibits a rain-dominated flow pattern, which is most likely heavily influenced by the two dams present. This population is most likely at risk from volcanic, earthquake, and flood catastrophic events.

23. South Sound Winter-Run Steelhead

This population includes four SaSI winter steelhead stocks (WDFW 2005): Eld Inlet, Totten Inlet, Hammersley Inlet and Case/Carr Inlet – effectively all of the lowland tributaries entering into South Puget Sound. 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. A majority of the TRT concluded that the Chambers Creek Basin historically supported a population of 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 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 IP-based estimate of capacity was 8,312 steelhead. 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, although there are no specific estimates of production. Intrinsic potential estimates for this DIP are relatively low, 816, especially given the relatively large basin size, 678 km^2. 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 stones" interaction process. 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 overall 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 independence.

Olympic Peninsula Major Population Group

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

Currently winter runs of steelhead predominate in this MPG, but there is some uncertainty regarding the historical or present day presence of summer-run steelhead in some streams. 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 also influenced in its decision by the geographic discreteness of this MPG. 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 Ecoregions dominate low elevation areas, while high elevation areas are located in the 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 MPGs.

Proposed DIPs within the Central and South Puget Sound MPG

25. East Hood Canal

This DIP includes winter steelhead spawning in small independent tributaries on the west side of the Kitsap Peninsula (eastern shore of Hood Canal) from Point No Point to the southern end of Hood Canal (Alderbrook and Twanoh creeks). The primary streams in this DIP include: Big Beef Creek, Anderson Creek, and the 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)). The rivers in this DIP demonstrate the potentially large abundance contribution by these smaller lowland steams to overall DPS abundance,

The streams in this DIP shared 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 Tayhuya/Union DIPs as one unit. There were numerous other variations, grouping the four main components (NW 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 the relative proximity of the populations the Dewatto, Tahuya, and Union river steelhead were genetically distinct, although these differences were not as large as was observed in comparing East and West Hood Canal samples. Ongoing research on steelhead populations in Hood Canal should provide further information the rate of straying and further adjustments may be necessary.

26. South Hood Canal

This DIP includes winter steelhead spawning in independent tributaries on the southwest side of the Kitsap Peninsula (eastern shore of Hood Canal) including the Tahuya and Union rivers to the southern end of Hood Canal (Alderbrook and Twanoh creeks). The primary streams in this DIP include: the Tahuya, and Union rivers. 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 was 4,175 fish, which is somewhat high, relative to adjacent DIPs, for the basin size, 641 km^2. The rivers in this DIP demonstrate the potentially large abundance contribution by these smaller lowland steams to overall DPS abundance,

The streams in this DIP shared 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 maintained through a “stepping stones” 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 the four main components (NW 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 (<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 the rate of straying and further adjustments may be necessary.

27. Skokomish River Winter-Run Steelhead

This population contains native winter-run steelhead in the North and South Forks 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 North Fork Skokomish River from mid-February to mid-June (WDFW 2005). Genetically, Skokomish River steelhead are distinct from other populations in the region, but most similar to West Hood Canal steelhead populations: Duckabush, Dosewallips, etc (Phelps et al. 1997, Van Doornik et al. 2007).

A summer-run of steelhead was identified in SaSI (WDFW 2005), but there is no information on this presumptive population. WDFW (2005) 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), the upper 10 km is characterized by very high gradient reaches that would be suitable for summer 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 fish. Based on information available the TRT was unable to establish whether such a run was present currently or historically. Furthermore, additional monitoring would be needed to assess any differences among winter run steelhead in the North and South Forks.

The Skokomish River exhibits a rain dominated flow regime, although this may be due the majority of the flow from the more mountainous North Fork being diverted for hydropower. The entire basin covers approximately 628 km^2, with the North and South Fork basin being or rough equal size. The habitat-based IP estimate of capacity for this basin is 8,275. The Skokomish Basin lies in the Coastal and Puget Lowland Ecoregions. Earthquake, landslide, and flood events pose a relatively high catastrophic risk to the Skokomish Basin.

28. Olympic West Hood Canal Winter-Run Steelhead

This population combines winter-run steelhead from four SaSI stocks (WDFW 2005: Hamma Hamma, Duckabush, Dosewallips, and Quilcene/Dabob Bay. WDFW (2005) identified these as distinct stocks based on their geographic separation. However, resident, parr, and smolt *O. mykiss* from the Duckabush and Dosewallips clustered together genetically relative to steelhead populations on the east side of the Hood Canal (Van Doornik 2007). Samples from the Hamma Hamma River, were genetic outliers from samples from other rivers in this DIP, although that appears to be related to the small populations size (less than 20 fish) and potentially biased sampling. Spawn timing for winter-run steelhead in these rivers is similar, occurring from mid-February to mid-June. This population lies mostly in the Coastal 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.

Total watershed area is 1,423 km^2, although the topography of the area has resulted in inaccessible barrier falls on a number of the streams. The IP estimate for capacity in this DIP is 4,148 fish. 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, escapement to this DIP is likely a few hundred fish, with the most recent (2007/2008) estimate being 299 adults (WDFW 2010).

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 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 DIP, so they, in turn 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. Strait of Juan de Fuca Lowland Tributaries

This population combines two SaSI stocks, Sequim Bay and Discovery Bay, and includes winter-run steelhead that occupy streams in the Quimper Peninsula (Pt. Townsend) that were not included in the WDFW (2005) stock list. The entire population is located within the Puget Lowland 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 for understanding the dynamics of small populations throughout the DPS. Steelhead in this DIP spawn from early-February to mid-May, with the majority of smolts emigrating at age two. 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, 458, was near the abundance threshold. 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 provide an isolating mechanism to minimize interpopulation migration.

30. Dungeness River Winter-Run Steelhead

This population includes steelhead spawning in the mainstem Dungeness and Grey Wolf rivers. Winter steelhead in the Dungeness spawn from mid-September to early June (WDFW 2005). The Dungeness River is accessible to Rkm 30, where a waterfall above Gold Creek prevents passage. Grey Wolf Creek, the major tributary to the Dungeness River, is accessible to Rkm 15.5, above where the three forks of the Grey Wolf Creek 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 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 is snowmelt dominated. Geologically, the basin consists of volcanic bedrock and unstable glacial deposits that produce a high sediment load (Haring 1999). A few hundred steelhead spawn in the Dungeness yearly, although sediment in the river limits redd surveys. The last escapement estimate for the year 2000/2001 was 183 steelhead and this was based on index areas. 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 2,039 steelhead.

A majority of the TRT agreed that a winter-run population of steelhead existed as a DIP in the Dungeness Basin. A minority of the TRT concluded that summer-run steelhead likely existed in the upper accessible reaches of the mainstem Dungeness River and Grey Wolf Creek. The relatively late-timing of winter-steelhead in the Dungeness River may have resulted in some winter-run fish being identified as summer-run fish, as occurred in the Dosewallips and Duckabush rivers. Steelhead were historically harvested 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 fish were present although conditions in the river limited direct observation. Although, the proposed Dungeness River steelhead DIP includes only winter-run steelhead, the TRT strongly encourages further monitoring to establish whether native summer-run fish are present and if they are part of a combined summer/winter DIP or represent an independent population.

31. Strait of Juan de Fuca Independent Tributary 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 cover 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 from the 1950s and 1960s, with a peak catch of 258 in 1958 (WDG undated(b)). The IP-based estimate for capacity is 508 fish, with the most recent (2006/2007) abundance estimate, 181 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).

The TRT concluded that it was unlikely that any one of the streams within this DIP was large enough persist as a DIP, and 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 these distances were somewhat less than desired for a DIP, ecological differences between the smaller creeks and larger river systems would provide an additional isolating mechanism.

32. Elwha River Winter-Run Steelhead

Winter-run steelhead were historically present in the Elwha River Basin, although little is known of their distribution of 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 in Elwha River, one presumptive native late-winter run and one early-spawning hatchery-origin run (Chambers Creek origin). Natural spawning occurs throughout the mainstem and tributaries below the 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 indicates 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 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 dam.

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 (above Mills Dam) exhibits a rain and snow transitional flow pattern. Earthquake and landslide catastrophes were the most likely in the Elwha Basin. 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 5,873, 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 likely that the run was extirpated or the run 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 pool below the 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. Oversummering temperatures in the lower Elwha River, in addition to frequent out breaks of *Dermocystidium*, greatly reduce summer survival, thus it is likely that the native anadromous steelhead run(s) was extirpated follow the construction of the Elwha River dams. Alternatively, steelhead runs, summer or winter, may have been residualized in tributaries to the Elwha River above the dams. The historical distribution of summer-run steelhead in the Elwha River is not know, but it is possible that rapids and cascades in canyon areas may have provided a isolating mechanism for migrating winter and summer 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 clear consensus regarding the historical existence of summer-run steelhead in the Elwha River. The majority conclusion was that summer-run steelhead were not present. Further monitoring is needed to detect if residualized *O. mykiss* attempt to reestablish a summer-run life history.

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 DSS 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 2005) steelhead inventories.

1930 Survey	Genetic Analysis 1997	1992 SASSI / 2002 SaSI	WRIA[7]
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[8]	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[9]	7
NF Skykomish R	South Puget Sound GDU 2	NF Skykomish R Summer	7

[7] Water Resource Inventory Area - WRIA
[8] SF Stillaguamish River was considered non-native
[9] 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[10]	South Puget Sound GDU 2	Lake Washington Winter	8
Duwamish R			9
Green R	South Puget Sound GDU 2	Green R Summer[11]	
		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
Not Surveyed		Salt Creek/Independents Winter	19

[10] Cedar River steelhead were considered "scarce"
[11] 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 provided a conceptual framework for a "first cut" list of provisional DIPs.

Demographically Independent Population Checklist

The TRT developed (or is developing) a layered checklist to identify 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 influenced by other populations (via migration). 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 ration roughly accounts for an unknown number of resident fish contributing to the anadromous DPS and the presence of a small proportion of repeat spawners). Lastly, if the abundance trajectory of a presumptive population is clearly distinct from its neighboring populations then by definition it is demographically independent.

Tier 1 Checklist:

- [ ] a. Historically Present
- [ ] b. Abundance (actual or modeled)
- [ ] c. Demographic Independence

If all boxes get "checked" the presumptive population is considered a DIP, for that population the only further discussion necessary is to discern whether there are DIPs within the population in question.

For Puget Sound steelhead it is more likely that insufficient information will be present to fill out boxes 1a and/or 1c. In theses cases it will become necessary to use proxies, more indirect measures of abundance and demographic independence.

Abundance proxies – the most likely proxies for abundance include: modeling intrinsic potential from habitat information.

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 25 km independent, bays and shoreline morphology
- ☐ Genetic Distance (Fst)
- ☐ Barriers – physical (seasonal, flow (high or low), substrate)
- ☐ Ecological separation (geology, flow regime, ecoregion)
- ☐ Temporal isolation

While there is no minimum number of Tier 2 boxes that need to be checked; however, it is assumed that meeting just one of the above conditions would not 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 assessed using a surrogate species (i.e. Chinook or coho).

Tier 3 Checklist

- ☐ Genetic distance – species surrogate
- ☐ Geographic Isolation – species surrogate (here the TRT considers that 95% of all CWT recoveries occur within 25 km of release point for Chinook and coho).

Appendix 3: 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 pairwise 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 (see page xx) 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 pairwise 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 DNA microsatellite analysis of 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.

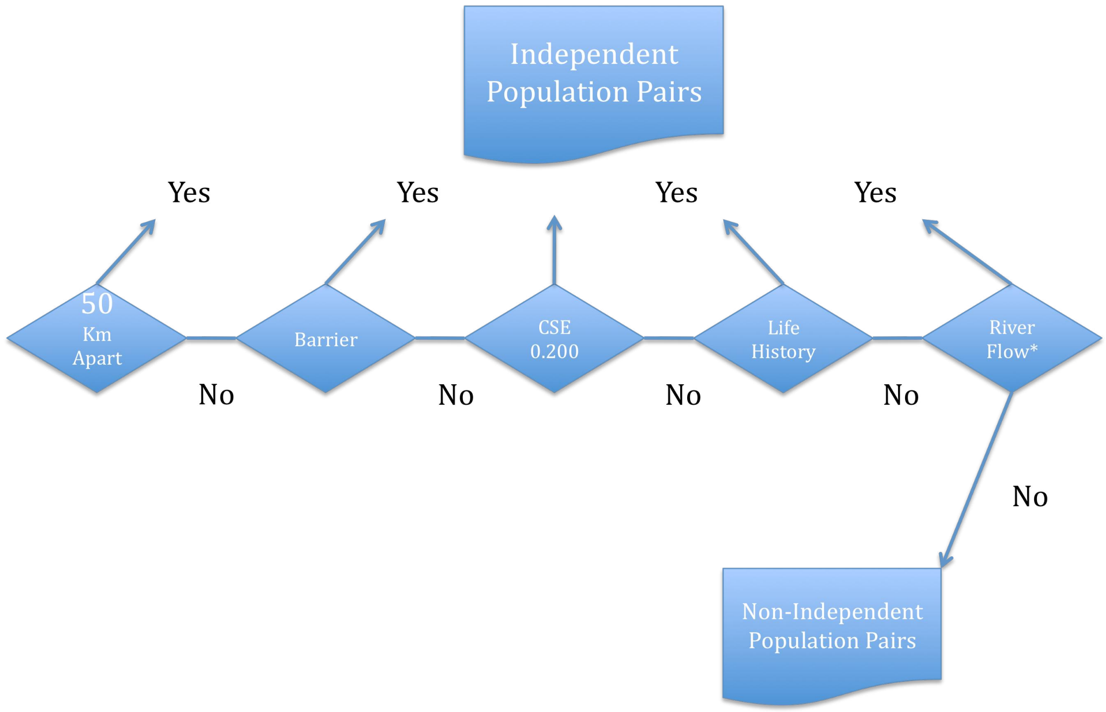

Figure x-1. Schematic of the gatekeeper model used to identify historical demographically independent populations. If differences between presumptive populations exceed the threshold for any of the gatekeeper criteria, those populations were considered independent of each other.