Historical Population Structure of Willamette and Lower Columbia River Basin Pacific Salmonids

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July 2003

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ABBREVIATIONS AND ACRONYMS

BRT	Biological Review Team
CWT	coded-wire tag
SCTC	Salmon Culture Technology Center
DIPs	demographically independent population
EPA	U.S. Environmental Protection Agency
ESU	evolutionarily significant unit
GDU	genetic diversity unit
NMFS	National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
PNRBC	Pacific Northwest River Basins Commission
PIT	passive integrated transponder
PSTRT	Puget Sound Technical Recovery Team
RKm	river kilometer
SASSI	Salmon and Steelhead Stock Inventory
TRT	Technical Recovery Team
USDOC	U.S. Department of Commerce
USWFS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
VSP	viable salmonid population
WDF	Washington Department of Fisheries
WDG	Washington Department of Game

EXECUTIVE SUMMARY

In 2000, the Population Identification Subcommittee of the Willamette/Lower Columbia Technical Recovery Team (WLC-TRT) convened to review information relevant to the identification of historical, demographically independent populations of chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and steelhead (*O. mykiss*) within their recovery domain. This document presents the preliminary conclusions of the subcommittee. Providing the TRT with an historical perspective is seen as an essential first step in developing delisting criteria as part of an overall recovery strategy.

The historical population boundaries and designations provided are intended to be representative of the range and diversity of populations for each species in the listed evolutionarily significant units (ESUs), not necessarily an exact reconstruction. Furthermore, the population boundaries presented delimit the basin area used by spawning adults from each population. It is understood that many of the populations share areas for juvenile rearing, migration corridors, and ocean feeding. Understanding the historical structure of populations, their abundance, and life-history characteristics provides a framework for understanding the present status of populations, the changes that have affected them, and, potentially, the necessary actions that may be necessary to restore them.

In general, historical documentation on the life-history characteristics, distribution, or abundance of populations prior to 1940 is extremely limited. Although considerable biological information was gathered during the last three decades, it is difficult to relate the biological characteristics of existing populations to those that existed historically in the same basins. This dilemma is primarily due to the widespread transfer of eggs and fry between watersheds by state and federal agencies during the last 100 years. Genetic information is similarly affected by artificial-propagation activities, except in those few basins where there has been little or no activity. Homing fidelity was examined to estimate the extent of adult migrations between spawning aggregations. Within a basin, temporal differences in return migration and spawning timing provided a mechanism for establishing demographically (and reproductively) isolated populations.

The TRT relied heavily on geographic and ecological information to establish proposed population boundaries. Where possible, the geographically determined population boundaries were verified using information from extant populations with minimal hatchery impacts. Geographic information was also useful in identifying barriers (such as cascades or falls) that limit accessibility to upper watershed areas to specific seasons or water-flow events.

For chinook salmon, 30 demographically independent populations (21 fall/late-fall run, 9 spring run) may have historically existed in the Lower Columbia River ESU. In the Upper Willamette River ESU, seven demographically independent populations were thought to have existed historically. In many cases, it is difficult to identify distinct population boundaries; however, subpopulations were provisionally designated to promote further analysis and review. Geographic and ecological factors were important in designating populations. An important tool developed for chinook salmon was the use of the geographic template. Analysis of chinook salmon populations with minimal out-of-basin influence, suggested that discrete basins encompassing more than 250 km^2 appeared capable of maintaining genetically distinct populations, which suggested demographic independence. Additionally, life-history traits (especially run-timing) were useful in identifying some populations.

Twenty-four historical, demographically independent steelhead populations (18 winter run, 6 summer run) are thought to have existed historically in the Lower Columbia River ESU. Additionally, five demographically independent populations were thought to have existed in the Upper Willamette River ESU. In general, both historical and current biological information was less available for steelhead than for chinook salmon. Criteria employed to designate the steelhead population boundaries were similar to those used for chinook salmon. Some TRT members felt that because steelhead utilize more side-channel habitat than chinook, ascend farther upstream in most tributaries, and reside longer in their natal freshwater habitat, the geographic template size for distinct steelhead populations would be smaller than for chinook salmon.

Of the three species examined, information on historical and existing chum salmon populations is the most limited. Much of the structure of historical chum salmon populations in the Columbia River ESU was inferred using population boundaries derived for fall-run chinook salmon. Consideration was given to the limited ability of chum salmon to ascend in-stream obstacles and the relative preference of chum salmon for mainstem reaches or the lower reaches of tributaries. It is estimated that 17 demographically independent populations of chum salmon existed historically in the Columbia River.

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

—Willis H. Rich, 1939

1. INTRODUCTION

The Willamette/Lower Columbia Technical Recovery Team's (WLC-TRT) goal is to identify historical and extant independent populations of salmonids in listed evolutionarily significant units (ESUs). Understanding the size and spatial extent of populations is critical for the viability analyses, which are a necessary step in recovery planning and conservation assessments for any species. The Washington Department of Fisheries (WDF) et al. (1993) identified Salmon and Steelhead Stock Inventory (SASSI) stocks of salmonids in Washington State and the Oregon Department of Fish and Wildlife (ODFW) (Kostow 1995) identified populations in Oregon. It is likely that, in many cases, the populations we identify will be the same as those identified by state agencies and tribal governments. Alternatively, different population identifications may result from several inherent differences in the population definitions employed and underlying management purpose with each classification scheme. It is also possible that, in the end, we will not be left with a single classification scheme for populations, but a few equally likely scenarios that can then be analyzed as part of recovery planning.

The populations ultimately identified are the demographically independent units for which viability will be estimated. These populations are the independent groups of fish whose historical and present condition will be characterized in future papers. For each population, we will describe numbers and productivity of salmon, life-history and phenotypic diversity, and spatial distribution of spawning and rearing groups. In addition, we will estimate the habitat capacity for each population under historical and present conditions. In the ultimate recovery goals expressed, the populations identified in this document will be those considered when answering the question: "How many and which populations are necessary for the persistence of the ESU?"

1.1 Definition of a Population

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

Structure Below and Above Population Level

Just as there may be substructuring within a population, there may be structure above the level of a population. This is explicitly recognized in the designation of an ESU. An ESU may contain multiple populations that are connected by some small degree of migration; however, a population cannot be larger than an ESU. Thus, organisms can be grouped in a hierarchical system in which we define the levels of individual, subpopulation, population, ESU, and finally species. Other hierarchical systems with more or fewer levels could be constructed. Though reproductive isolation forms a continuum, it is probably not a smooth continuum, and there exists a biological basis for designating a hierarchy of subpopulations, populations, and ESUs.

A population is described as a group of fish that is reproductively isolated “to a substantial degree” (McElhany et al. 2000). As a criterion for defining fish groups, the degree of reproductive isolation is a relative measure, however, and can vary continuously from the level of fish pairs to the degree of reproductive isolation separating species. The population defined here is not, therefore, the only biologically logical grouping that can be constructed. Below the level of the population, for example, there will often be groups of fish that are to some degree reproductively isolated from other fish groups within the population, but are not sufficiently isolated to be considered independent by the criteria adopted here. These fish groups are referred to as subpopulations. Few populations have been studied sufficiently in depth to characterize their component subpopulations. The existence and interaction of subpopulations can have important consequences for characterizing a VSP, and population spatial structure is proposed as one of four key parameters for eventually evaluating the status of a population. Furthermore, subpopulations play an important role in the sustainability and evolution of populations.

Independent populations will generally (but not always) be smaller than a whole ESU and will generally inhabit geographic ranges on the scale of whole river basins or major subbasins that are relatively isolated from outside migration.

1.2 Conceptual Approach to Identifying Populations

Indicators of Population Structure

The definitive information needed to identify populations is intergroup migration rates and the demographic consequences of those migration rates. In practice, information on straying of salmon between streams is rarely available. Our approach in identifying population structure is to use diverse sources of information that are proxies for understanding the degree of reproductive isolation between groups of fish. Each type of information contributes to our understanding of population boundaries, but none alone provides us with much confidence in our answer. Below, we briefly outline the different information sources we use to help us in identifying salmon populations. They are discussed in order of the strength of inference we believe it is possible to make about population structure from each indicator, beginning with relatively high inference that can be made with geographic and migration-rate indicators. Depending on the particular data quality and the genetic and demographic history of salmon in different regions, the usefulness of these indicators in any one area can vary.

1. Geography. The boundaries of a salmon population will be defined, in part, by the spatial distribution of its spawning habitat. Physical features such as a river basin's topographical and hydrological characteristics dictate to a large degree where and when salmon can spawn and delimit the spatial area over which a single group of fish can be expected to interact. Geographic constraints on population boundaries (such as distance between streams) can provide a useful starting point, but will not generally support strong inferences at a fine scale (e.g., distinguishing separate populations within a small river basin). In addition, biogeographic characteristics and historical connections between river basins on geological time scales can also be informative in defining population boundaries.

2. Migration rates. The extent to which individuals move between populations will determine the degree of reproductive isolation, and therefore demographic independence, among sites. Estimates of stray rates are particular to the group of fish, season, and streams in which they are made; thus, they provide useful information about straying under current conditions. In contrast, it is not possible to obtain estimates of the magnitude of their variation over long time periods (e.g., 100 years). Furthermore, there have been substantial changes in fish density within populations and geographic connectivity between populations during the last century. Migration rates are usually calculated through the recovery of tagged adults. Fish are tagged using a variety of external tags or internal coded-wire tags (CWTs) or passive integrated transponder (PIT) tags. Compared to mark-recapture and other direct estimates of straying, genetically based estimates of intergroup isolation can be used to estimate straying that has occurred between fish groups, integrated over longer time periods than direct estimates.

3. Genetic attributes. Neutral genetic markers are useful in identifying salmon populations because they indicate the extent of reproductive isolation among groups. Neutral markers can be difficult to interpret because patterns may reflect hatchery practices or nonequilibrium conditions, so they should be interpreted with caution. Neutral and adaptive genetic differences among fish groups (as indicated by quantitative traits or molecular markers) are more difficult to document than discrete marker differences. Since the degree of isolation necessary to maintain genetic independence is much higher than that for demographic independence, genetic information will tend to give a more conservative measure of demographic population structure. That is, some populations that appear to be linked genetically may be largely independent demographically.

4. Patterns of life-history and phenotypic characteristics. Technically, only those phenotypic traits based on underlying genetic variation (rather than environmentally induced variation) are informative in identifying populations (defined on the basis of reproductive isolation and demographic independence). Variations in spawning time, age at juvenile emigration, age at maturation and ocean distribution are under some degree of genetic influence (Myers et al. 1998). Environmental conditions may restrict variability in the life-history traits expressed. Hydrological conditions (i.e., water temperature, times of peak and low flows, etc.) influence the time of emigration and return migration and spawning. Conditions in many rivers (especially short coastal rivers) during the summer months do not provide suitable habitat for juvenile fish to extend their freshwater rearing beyond the late spring. Similarly, if habitat is not available for returning adults to oversummer prior to spawning, the spring- or summer-run life-history strategies would not be feasible. Phenotypic variation can be used as a proxy for genetically based variation, and it may indicate similarities in the selective environments experienced by salmon in different streams. In some cases, similarities in phenotype may arise independently in distinct populations (i.e., spring run-timing or possibly resistance to the parasite *Ceratomyxa shasta*). Alternatively, phenotypic differences in life-history traits between populations (especially those that have recently diverged) could be the result of differences in habitat utilization and geographic separation.

5. Population dynamics. Abundance data can be used to explore the degree to which demographic trajectories of two groups of fish are independent of one another. All else being equal, the less correlated time series of abundance are between two fish groups, the less likely they are to be part of the same population. Complicating interpretation of correlations in abundance between fish groups is the potentially confounding influence of correlated environmental characteristics, such as shared ocean conditions or regionwide drought. Additionally, harvest effects may result in correlations of abundance when distinct populations share oceanic and inshore migratory routes. When fish groups that are in close proximity are not correlated in abundance over time, they are not likely to be linked demographically. The reverse is not always easy to argue—when correlations in abundance between fish groups are detected, more work is needed to rule out confounding sources of correlation.

6. Environmental and habitat characteristics. In identifying independent, demographic populations, environmental characteristics can influence population structure in two ways. First, environmental characteristics can directly isolate populations. Thermal or flow conditions in a river can create migrational barriers that prevent interactions between populations (e.g., Willamette Falls and Lyle Falls). Second, environmental conditions may exert a selective influence on salmon populations, which in turn may influence the expression of life-history characteristics. The strength of the correlation between habitat and life-history characteristics may be related to homing fidelity and the degree to which populations in ecologically different freshwater habitats are effectively reproductively isolated. If immigrants are less fit, they will not contribute to the long-term demographics of the receiving population.

1.3 Identifying Historical Populations of Salmonids

The first goal of the WLC-TRT's Population Identification Subcommittee is to identify historical populations of salmonids in the listed ESUs. An understanding of the number, abundance, life-history diversity, and distribution of historical populations is an important step in formulating recovery scenarios. It is understood that the historical organization and status of populations in an ESU were not static, but dynamic; however, the historical structure does provide the only proven prototype of sustainability. It is not the TRT's task to completely restore historical conditions, but to determine, in general, the population structure necessary to restore the needed aspects of life-history diversity, population distribution, and abundance in order to provide for a sustainable ESU into the foreseeable future.

Criteria for Identifying the Distribution of Historical Populations

The task of identifying historical populations in the Lower Columbia and Upper Willamette River ESUs is challenging, because anthropogenic factors (e.g., hatchery operations, stock transfers, harvest effects, and habitat degradation and elimination) have significantly influenced population structure and interaction. Few extant populations in these ESUs provide information directly relevant to the determination of historical population structure and number. Where available, information concerning salmonid populations in the Lower Columbia and Upper Willamette Rivers and others (primarily Puget Sound) was useful in developing a template for the general geographic and ecological characteristics of an independent population. A geographic template was developed to infer selective and isolating factors that may have led to demographically independent populations (DIPs) in lieu of relevant biological information for historical salmonid populations. In general, four criteria were used to establish the distribution of historical populations: (1) documented historical use, (2) temporal isolation (different run or spawn timing), (3) geographic isolation (geographic template), and (4) basin specific information (barrier falls, etc.). In some instances, presumptive populations that did not meet the criteria for DIPs, but exhibited one or more of the characteristics of distinct populations, were designated as subpopulations. Subpopulation designations were intended to highlight areas where some level of population structuring may exist and where further study should be directed, rather than identify true biological subpopulations.

Geographic Template Criteria

For an independent population to persist in the face of environmental fluctuations it must maintain a sufficiently large population size. Whether an independent population must contain hundreds or thousands of individuals is still under debate, but at a minimum, hundreds of individuals are probably necessary. One measure of the potential for a watershed to sustain an independent population is its size. Basin size estimates were generally acquired from U.S. Geologic Survey (USGS) stream-gauge databases (Table 1). The size of a basin and the topography of the river to which it belongs may also influence homing accuracy. The presence of seasonal or complete migration barrier(s) provides an added degree of reproductive isolation.

Minimum basin size was derived from the examination of other ESUs where native, naturally produced populations (primarily chinook salmon) still exist. Additionally, boundaries between distinct populations could be inferred where rivers diverge into distinct major tributaries. Tributary basins, if large enough, may provide ecologically distinctive habitats and characteristic homing (olfactory) cues that promote the establishment of independent populations. For example, based on genetic analysis alone there are several reproductively isolated chinook salmon groups in northern Puget Sound. The Nooksack River basin contains two populations of chinook salmon that each represents a different Washington Department of Fish and Wildlife (WDFW) genetic diversity unit (GDU): the North Fork (743 km^2) and South Fork (477 km^2) (Marshall et al. 1995).

Table 1. Lower Columbia River tributary basin size (km^2) and distance (km) from river mouth.

Lower Columbia River ESU	**RKm**[a]	**Basin (km^2)**[b]	**USGS Gauge**
Lower Columbia River (coastal tributaries)			
Lewis and Clark River	12.90		
Youngs River	16.10	103.80	14251500
Walluski River	22.50		
Klaskanine River	27.40	36.20	14252000
Chinook River	9.60	30.20	CBIC 1967
Deep River	32.30	32.40	CBIC 1967
Grays River	33.80	156.90	14250000
Big Creek	37.00	82.60	14248500
Bear Creek	40.00	8.60	14248700
Skamokawa Creek	54.70	45.00	14248000
Elochoman River	60.00	170.30	14247500
Plympton Creek	63.00		
Clatskanie River		137.20	14247000
Beaver Creek			
Mill Creek	85.20	73.30	14246500
Abernathy Creek	86.90	52.60	14246000
Germany Creek	90.10	59.30	14245500
Coal Creek	99.80	69.60	Hymer et al. 1992
Tide Creek			
Goble Creek			
Milton Creek	144.00		
McNulty Creek			
Scappoose Creek			
Cowlitz River basins	106.20	6,420.40	14245150
Cispus River	+148.00	831.00	14231900
Tilton River	+102.00	403.90	14236500
Upper Cowlitz River		3,008.30	14235000
Ohanapecosh River	+214.00	261.50	14224000
Toutle River	+27.40	1,322.90	14242690
North Fork Toutle River (with Green River)	+20.90	735.20	14241101
North Fork Toutle River (without Green River)	+20.90	396.10	14241101
Green River	+41.80	339.10	14241000
South Fork Toutle River	+20.90	310.70	14241500
Coweeman River	+12.10	308.10	14245000
Kalama River	115.80	523.00	14223600
Little Kalama River	+21.90	29.80	CBIC 1967
Gobar Creek	+31.40	54.90	CBIC 1967

[a] Distances (RKm) are given from the mouth of the Columbia River to the mouth of the tributary. Distances with a "+" sign indicate the distance from the mouth of the parent stream to branching of the tributary.

[b] Basin sizes were obtained from information describing USGS flow-monitoring stations (where given); otherwise, basin sizes were obtained from CIBC (1967).

Lower Columbia River ESU	RKm[a]	Basin (km^2)[b]	USGS Gauge
Lewis River	141.00	2,718.40	CBIC 1967
North Fork Lewis River	+8.00	1,892.50	14220500
Cedar Creek	+25.30	143.70	CBIC 1967
Muddy River	+96.70	349.50	14216350
East Fork Lewis River	+8.00	390.90	14216500
Willamette River			
Johnson Creek		134.10	04211550
Kellogg Creek			14211130
Clackamas River	+39.90	2,4180	
Mainstem and upper Clackamas River			
Oakgrove Fork		>310.00	
Collawash River		>368.00	
Salmon Creek	151.20	208.90	14144000
Sandy River	193.60	1,315.00	
Bull Run	+25.70	277.00	14140000
Little Sandy River	+	46.30	14140500
Salmon River	+56.00	274.40	14135500
Zigzag River	+64.40	80.30	14131500
Washougal River	194.90	279.60	14143500
Mainstem Washougal River			
Little Washougal River	+9.10	60.10	14144000
West Fork Washougal River	+23.10	78.50	14143000
Columbia Gorge tributaries			
Mainstem Columbia River			
Bridal Veil Creek			
Wahkeena Creek			
Hardy Creek	228.20		CBIC 1967
Hamilton Creek	229.00	30.50	
Multnomah Creek			
Moffer Creek			
Tanner Creek			
Eagle Creek	236.50		
Rock Creek	243.00	106.10	CBIC 1967
Herman Creek	243.00		
Gorton Creek			
Viento Creek			
Lindsey Creek			
Phelps Creek			
Wind River	249.40	582.50	14128500
Panther Creek	+6.90	106.10	CBIC 1967
Trout Creek	+17.40	78.40	CBIC 1967
Little White Salmon	260.70	346.96	14125500
Big White Salmon River	270.30	696.40	14123000
Rattlesnake Creek	+12.10	144.20	CBIC 1967
Trout Lake Creek	+41.80	179.40	CBIC 1967
Hood River	271.90	722.30	14120000
East Fork Hood River summer run	+18.50	279.60	14115500
West Fork Hood River summer run	+18.50	247.50	14118500

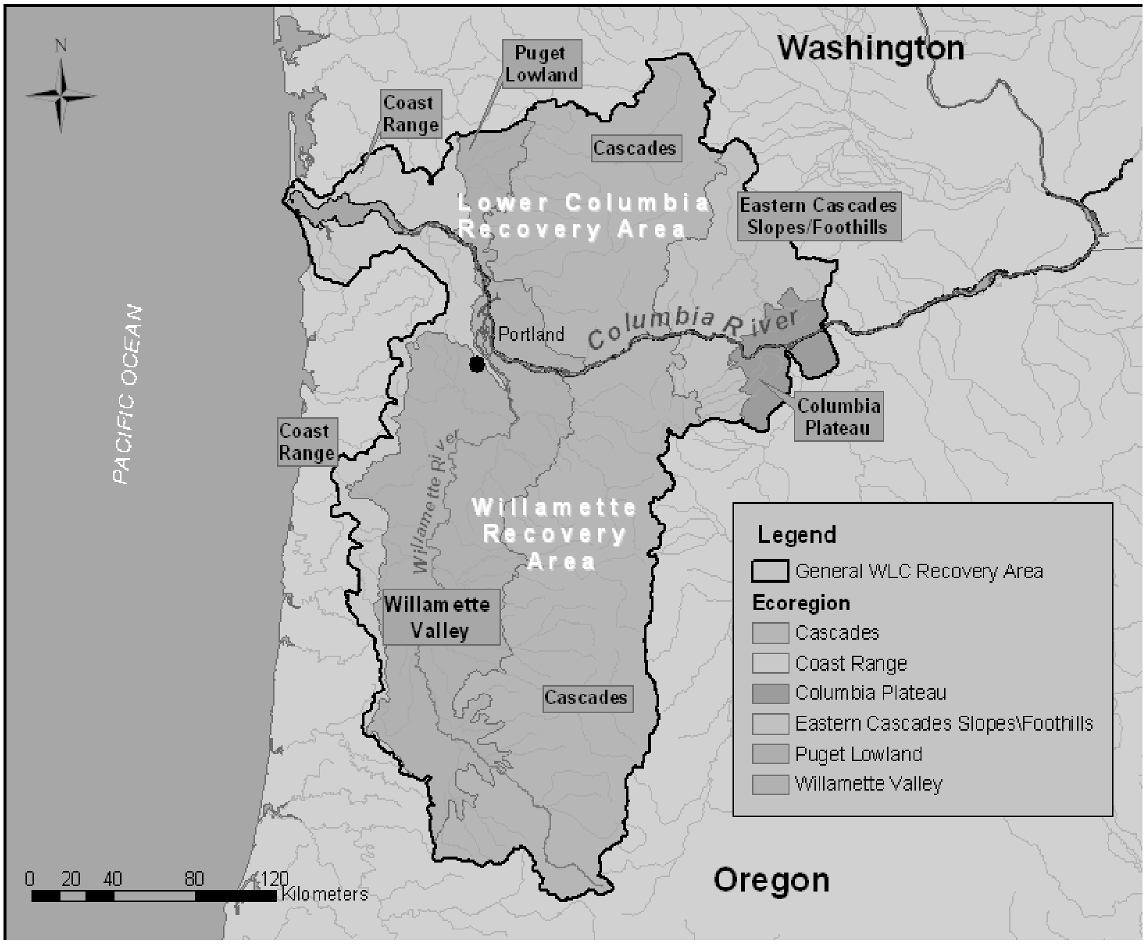

Figure 1. Environmental Protection Agency (EPA) Level III ecoregions for the Lower Columbia and Upper Willamette Rivers.

Within the Stillaguamish River basin (1,774 km^2), the North Fork drainage covers 738 km^2 and contains a population of chinook salmon with significant genetic and life-history differences relative to chinook salmon in the main stem and South Fork (Marshall et al. 1995). The Skagit River basin is the largest in Puget Sound (8,270 km^2, slightly larger than the Cowlitz River basin), and may presently contain as many as six DIPs. Historically the Skagit could have contained an additional two or three (now extinct) independent populations (WDF et al. 1993). The Puget Sound Technical Recovery Team (PSTRT 2001) identified three spring-run populations in the Skagit River basin: the Cascade, Suiattle, and Upper Sauk spring-run stocks, which originate from basins with areas of 390, 873, and 762 km^2, respectively. Other basins that may have historically contained independent populations all have basin areas larger than 250 km^2 (e.g., North Fork Skokomish [304 km^2] and Dungeness River [524 km^2]). Basin productivity depends on a variety of factors other than size; however, it would require special circumstances for rivers with basin areas smaller than 250 km^2 to sustain a population large enough to be demographically independent under variable environmental conditions. Differences in life-history characteristics among chinook and chum salmon and winter- and summer-run steelhead probably significantly influence the minimum basin size described above. These differences will be discussed below in the appropriate species sections.

Ecological Information

The fidelity with which salmonids return to their natal stream implies a close association between a specific stock and its freshwater environment. The selective pressures of different freshwater environments may be responsible for differences in life-history strategies among stocks. Miller and Brannon (1982) hypothesized that local temperature regimes are the major factor influencing life-history traits. If the boundaries of distinct freshwater habitats coincide with differences in life histories it would suggest a certain degree of reproductive isolation. Therefore, identifying distinct freshwater, terrestrial, and climatic regions may be useful in identifying distinct populations. As a first step in identifying historical independent populations of salmonids, the Lower Columbia River was divided into three geographic/ecological subregions: coastal, western Cascades, and Columbia Gorge (eastern Cascades). Differences in geography, hydrology, precipitation, vegetation, and geology are probably substantial enough to have differentially selected for variations in life-history strategy and provided the geographic separation for reproductive isolation. Within these large subregions, identifying historical independent populations is more problematical.

The U.S. Environmental Protection Agency (EPA) has established a system of ecoregion designations (Figure 1) based on soil content, topography, climate, potential vegetation, and land use (Omernik 1987). These ecoregions are similar to the physiographic provinces determined by the Pacific Northwest River Basins Commission (PNRBC 1969) for the Pacific Northwest. Similarly, there is a strong relationship between ecoregions and freshwater fish assemblages (Hughes et al. 1987). Also included in the physiographic descriptions for each region is information presented in PNRBC (1969), present-day water use information (USGS 1993), river flow information (Hydrosphere Products, Inc. 1993), and climate data from the U.S. Department of Commerce (USDOC 1968).

Biological Data

Homing fidelity is a major determinant of population structure and plays a key role in defining the geographic bounds of a population. Migration rates (homing fidelity) were estimated using CWT-marked releases of fish (primarily from hatcheries) (PFMC 2000). Spatial homing fidelity was measured as the relative proportion of freshwater recoveries that occurred in the river basin of origin. Methods for calculating migration (stray) rates followed that used by Haegen and Doty (1995). Freshwater recoveries of adults at hatcheries, fish traps, terminal (tributary) fisheries, and spawner surveys were considered in the estimation of migration. In general, only CWT releases during the 1980s that produced over 100 expanded freshwater recoveries were used. At least three CWT release groups were used for each release location. Only releases of fish that had been produced from adults returning to that release site (hatchery) were considered. Since many hatcheries were originally founded by transfers from other sites, genetically determined aspects of their oceanic migration may reduce the precision with which they return to their "new" natal stream. Furthermore, many aspects of hatchery rearing and release programs probably reduce the homing fidelity of returning hatchery fish. Additionally, although the proportion of freshwater recoveries at a nonnatal site may be high, the impact on the population receiving the strays is related to the number of strays, the number of indigenous spawners, and the relative reproductive success of the strays.

The marine distribution of chinook salmon groups was estimated through recoveries of CWT-marked fish in ocean fisheries. There is a strong genetic basis for ocean migration patterns, which has been supported by CWT information. These patterns represent an important form of resource partitioning and are based on ancestral feeding routes that are significant to the evolutionary success of the species. To minimize variability in ocean conditions and fishery effort, recoveries were analyzed for a minimum of three groups from any release site, only groups released from 1980 to 1989 that had at least 100 oceanic recoveries (expanded) were considered, and no groups from one site could be released during the same year. Recoveries were assigned to six regional oceanic areas: Alaska, British Columbia, Washington coast, Puget Sound, Oregon coast, and California coast. The marine distributions were compared using hierarchical clustering analysis (JMP V3.0, SAS Institute, Cary, N.C.). With few exceptions, groups came from hatchery populations, which may not be representative of historical populations depending on the history of stock transfers for each hatchery. Because of the difficulties in relating current oceanic distribution to historical patterns, this analysis was only used to ascertain whether general patterns of oceanic distribution were correlated to geographic proximity or life-history similarities.

Analysis of the scales from naturally spawning adults was utilized to identify similarities in the age at marine emigration and maturation of proposed populations. This information was used with caution, due to the unknown origin of unmarked naturally spawning fish, the impact of harvest on age structure, and the modification or loss of habitats that would preclude specific juvenile life-history strategies.

Historical documentation of fish presence and abundance (Table 2) was based on U.S. Fish and Wildlife Service (USFWS) surveys carried out in the 1930s and 1940s (Bryant 1949 and Parkhurst et al. 1950) and additional reports by Mattson (1948, 1955), Craig and Townsend (1946), Wallis (1961), and others. Hatchery and fisheries records also provided valuable insight into historical abundance and life-history characteristics.

Hatchery operations in the Lower Columbia and Upper Willamette Rivers have left a legacy of transplanted or homogenized stocks, with the exception of chum salmon. Very few remaining populations of salmonids are unchanged by these activities: thus it is difficult to estimate historical life-history characteristics from fish that are currently occupying river systems in this area. Furthermore, because of the magnitude of hatchery releases, similarities or differences in abundance trends do not necessarily indicate demographic independence or lack thereof. Hatchery fish influence demographic data in two ways. First, when present on natural spawning grounds they inflate the abundance of naturally spawning fish. Second, they reduce estimates of natural productivity by adding more adults to the adult-to-spawner relationship.

Table 2. Chinook, chum, and coho salmon and steelhead natural escapement estimates for Lower Columbia River tributaries.[a]

Lower Columbia River	Chinook	Coho	Chum	Steelhead
Lower Columbia River (coastal tributaries)				
Lewis and Clark River		rpt[b]	rpt	10
Youngs River	rpt	rpt	rpt	rpt
Walluski River				
Klaskanine River	rpt	rpt	rpt	12
Chinook River	rpt	rpt		
Deep River	nv	nv	nv	nv
Grays River	34	>100	6,286	>100
Big Creek	rpt	rpt	rpt	rpt
Bear Creek		rpt	rpt	
Skamokawa Creek		obs	rpt	obs
Elochoman River		371	158	7
Plympton Creek		rpt	rpt	
Clatskanie River	rpt	rpt	rpt	rpt
Beaver Creek		rpt	rpt	rpt
Mill Creek		rpt	rpt	1
Abernathy Creek			92	obs
Germany Creek		obs[c]	obs	obs
Coal Creek			rpt	rpt
Tide Creek			rpt	rpt
Goble Creek				
Milton Creek		rpt	rpt	rpt
McNulty Creek	nv	nv	nv	nv
Scappoose Creek	60	rpt	rpt	rpt
Cowlitz River basins				
Cispus River	130	120		obs
Tilton River	212	407		rpt
Upper Cowlitz River				
Ohanapecosh River	rpt	rpt		
Toutle River	rpt(S/F)	rpt	rpt	obs
North Fork Toutle River (without Green River)				
Green River				
South Fork Toutle River				
Coweeman River	1,746	2	rpt	rpt
Kalama River	20,000[d]	1,422	rpt	37
Lewis River	rpt	rpt	rpt	rpt
North Fork Lewis River	259	7,919	259	

[a] The numbers presented represent fish counted during surveys and are not expanded to estimate run size. Surveys did not necessarily correspond to the time of peak spawning. USFWS Columbia River surveys were done intermittently from 1936 to 1946 (Bryant 1949, Parkhurst et al. 1950).
[b] rpt = species presence reported to the survey teams by local biologists
[c] obs = juveniles or adults that were observed but not enumerated
[d] The hatchery superintendent, Parsons, reported that 13,000 chinook had been collected at the hatchery rack, and a further 7,000 passed over the rack to spawn naturally in 1936.

Table 2. cont.

Lower Columbia River	**Chinook**	**Coho**	**Chum**	**Steelhead**
Muddy River				
East Fork Lewis River	40	1,166		
Mainstem and upper Clackamas River	obs	obs		obs
Oakgrove Fork				
Collawash River				
Johnson Creek	rpt			rpt
Salmon Creek	19	16	rpt	rpt
Sandy River				
Bull Run			rpt	rpt
Little Sandy River				
Salmon River	rpt	rpt		rpt
Zigzag River				rpt
Washougal River	rpt	rpt		539
Mainstem Washougal River				
Little Washougal River				
West Fork Washougal River				
Columbia Gorge tributaries				
Mainstem Columbia River				
Bridal Veil Creek				
Wahkeena Creek				
Hardy Creek				
Hamilton Creek				rpt
Multnomah Creek				
Moffer Creek				
Tanner Creek	rpt			
Eagle Creek	rpt			
Rock Creek	rpt			rpt
Herman Creek	rpt			
Wind River	200			obs
Gorton Creek				
Little White Salmon	rpt			rpt
Viento Creek				
Lindsey Creek				
Big White Salmon River				
Hood River	rpt			rpt
East Fork Hood River				
West Fork Hood River	rpt			rpt

2. CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

2.1 Life History

Chinook salmon—also commonly referred to as king, spring, quinnat, Sacramento, California, or tyee salmon—is the largest of the Pacific salmon (Netboy 1958). The species distribution historically ranged from the Ventura River, California, to Point Hope, Alaska, in North America; and in northeastern Asia from Hokkaido, Japan, to the Anadyr River in Russia (Healey 1991). Additionally, chinook salmon have been reported in the Mackenzie River area of northern Canada (McPhail and Lindsey 1970). The Lower Columbia and Upper Willamette Rivers chinook salmon ESUs lie near the center of the species' North American distribution.

Of the Pacific salmon, chinook salmon exhibit arguably the most diverse and complex life-history strategies. Healey (1986) described 16 age categories for chinook salmon, 7 total ages with 3 possible freshwater ages. Two generalized freshwater life-history types were initially described by Gilbert (1912): stream-type chinook salmon reside in freshwater for a year or more following emergence, whereas ocean-type chinook salmon migrate to the ocean within their first year. Healey (1983, 1991) has promoted the use of broader definitions for ocean type and stream type to describe two distinct races of chinook salmon. Using Healey's definition, chinook salmon native to the Lower Columbia and Upper Willamette Rivers are considered to be ocean type (Myers et al. 1998).

Juvenile Emigration

Ocean-type juveniles enter saltwater during one of three phases. Immediate fry migrate to the ocean soon after yolk resorption, at 30–45 mm in length (Lister et al. 1971, Healey 1991). In most river systems, however, fry, which migrate at 60–150 days post-hatching, and fingerlings, which migrate in the late summer or autumn of their first year, represent the majority of ocean-type emigrants. When environmental conditions are not conducive to subyearling emigration, ocean-type chinook salmon may remain in freshwater for their entire first year, emigrating to the ocean during their second spring. Distance of migration to the marine environment, stream stability, stream flow and temperature regimes, stream and estuary productivity, and general weather regimes have been implicated in the evolution and expression of specific emigration timing.

The majority of naturally produced fall-run chinook salmon from the Lower Columbia and Lower Willamette Rivers emigrate to the marine environment as subyearlings (Reimers and Loeffel 1967, Howell et al. 1985, Hymer et al. 1992, Olsen et al. 1992, WDF et al. 1993). A portion of returning adults whose scales indicate a yearling smolt migration may be the result of extended hatchery-rearing programs rather than natural volitional yearling emigration (Table 3). It is also possible that modifications in the river environment may have altered the duration of

Table 3. Summary of the number and source (fraction of total) of chinook salmon juveniles released into selected rivers in the Lower Columbia River and Upper Willamette River ESUs.

River	Run	Native/Local[a]	In ESU[b]	Out of ESU	Total Releases
Chinook River	Fall	0.477	0.518	0.006	17,621,483
Youngs River	Fall	0.000	0.618	0.382	1,245,379
Grays River	Fall	0.269	0.731	0.000	83,901,280
Big Creek	Fall	0.611	0.363	0.027	202,843,377
Elochoman River	Fall	0.654	0.345	0.001	120,559,102
Cowlitz River	Fall	0.926	0.074	0.000	164,273,295
Toutle River	Fall	0.635	0.365	0.000	87,615,600
Kalama River	Fall	0.941	0.046	0.012	235,348,662
Lewis River	Fall	0.762	0.184	0.054	21,785,757
Clackamas River	Fall	0.000	0.913	0.087	60,051,486
Washougal River	Fall	0.485	0.508	0.007	172,296,250
Sandy River	Fall	0.067	0.933	0.000	32,815,098
Tanner	Fall	0.000	0.911	0.089	673,455,947
Hood River	Fall	0.000	1.000	0.000	2,656,380
Cowlitz River	Spring	0.959	0.027	0.014	71,004,079
Toutle River	Spring	0.996	0.004	0.000	2,672,655
Kalama River	Spring	0.881	0.119	0.000	10,367,665
Lewis River	Spring	0.621	0.322	0.057	15,809,691
Sandy River	Spring	0.151	0.189	0.660	14,533,110
Molalla River	Spring	0.000	0.000	0.000	10,987,335
Santiam River	Spring	0.793	0.191	0.016	193,191,761
North Santiam River	Spring	0.673	0.313	0.014	113,735,118
South Santiam River	Spring	0.700	0.300	0.000	39,619,551
McKenzie River	Spring	0.967	0.027	0.007	218,331,567
Middle Fork Willamette River	Spring	0.311	0.654	0.035	57,693,187

[a] Releases designated as "native/local" include the progeny of nonnative fish (and their descendants) that returned to a local hatchery and were incorporated into the hatchery broodstock.

[b] "In ESU" includes the proportion of the fish that originated from within the ESU, not including the local population.

Source: Data from Myers et al. (1998).

freshwater residence. The natural timing of spring-run chinook salmon emigration is similarly obscured by hatchery releases of spring-run chinook salmon juveniles late in their first autumn or early in their second spring. Age analysis based on scales from naturally spawning spring-run adults from the Kalama and Lewis Rivers indicated a significant contribution to escapement by fish that entered saltwater as subyearlings (Hymer et al. 1992). This subyearling smoltification pattern may also be indicative of life-history patterns for the Cowlitz River spring run, because both the Kalama and Lewis Rivers have received considerable numbers of transplanted fish from the Cowlitz River. Life-history data from the Clackamas and Sandy Rivers is very limited, and transplantation records indicate that these rivers have received overwhelmingly large numbers of Upper Willamette River spring-run chinook salmon (Nicholas 1995).

Recent analysis of scales from adults returning to the Upper Willamette River basin indicated that the majority of fish had emigrated to saltwater as yearlings (Table 8). This estimate is biased by the overwhelming hatchery contribution to escapement, over 90% of total escapement (Myers et al. 1998). Hatchery fish are released late in their first autumn or second spring (Nicholas 1995, Willis et al. 1995). Scales sampled from returning adults in 1941 indicated that the fish had entered saltwater no earlier than the autumn of their first year (Craig and Townsend 1946). Mattson (1963) found that returning adults that had emigrated as fingerling (subyearling) smolts made up a significant proportion of the 3-year-old age class, with fingerling emigrants making up a smaller proportion of the older age classes. A recent study indicated that Willamette River spring-run chinook salmon have a physiological smoltification window during their first autumn. Large numbers of fry and fingerlings have been observed migrating downriver from the Willamette River and its tributaries (Craig and Townsend 1946, Mattson 1962, Howell et al. 1988). Based on the examination of scale patterns from returning adults, it appears that these fry do not immediately enter the estuary or do not survive the emigration. Emigrating fry have been severely affected by high water temperatures and industrial waste discharges in the Lower Willamette River throughout much of this century, especially during periods of low river flow in late spring and early summer (Craig and Townsend 1946, Mattson 1962, USGS 1993). More recently, fry migrants constitute a relatively small proportion of the smolt emigration (especially compared to the artificially propagated fingerling and yearling contribution); thus their potential contribution to returning adults would be expected to be quite low. In a 1998 offshore study, subyearling Willamette River spring-run juveniles were identified through genetic mixed-stocks analysis in the Columbia River plume.[1] Alternatively, many of these fry migrants could be rearing in the Columbia River prior to emigrating to the marine environment (Craig and Townsend 1946, Mattson 1962).

Ocean Distribution

Ocean-type chinook salmon tend to migrate along the coast, while stream-type chinook salmon appear to move far off the coast into the central North Pacific (Healey 1983 and 1991, Myers et al. 1984). Studies of prerecruit (<71 cm) fish in the marine fisheries off southeastern Alaska indicated that differences in migration speed, timing, and growth were related to the life-history type, age, and general geographic origin of the stocks (Orsi and Jaenicke 1996). The causal basis for these differences is unknown, but may be based on poor coastal feeding conditions during past glacial events for the more northerly (stream-type) populations.

Marine CWT recoveries for Lower Columbia River stocks tend to occur off the British Columbia and Washington coasts, with a small proportion of tags recovered from Alaska (Table 4). Marine recoveries of CWT-marked, Willamette River spring-run fish occur off the British Columbia and Alaska coasts, with a much larger component (>30%) of recoveries being from Alaska relative to Lower Columbia River stocks (Table 5). Age of release (subyearling versus yearling) does not appear to influence the general oceanic distribution of fish (Myers et al. 1998).

[1]David Teel, NMFS, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112, pers. commun., January 2000.

Table 4. Distribution of coded-wire tagged (CWT) recoveries from chinook salmon in ocean fisheries.[a]

Hatchery Stock (Release Site)	Alaska	British Columbia	Washington Coast	Puget Sound	Oregon Coast	California
Grays River fall	0.10	0.62	0.20	0.00	0.07	0.00
Elochoman River fall	0.07	0.46	0.22	0.06	0.17	0.02
Big Creek fall (SAB[b])	0.00	0.31	0.15	0.03	0.43	0.09
Big Creek fall	0.05	0.63	0.27	0.00	0.05	0.00
Cowlitz River spring	0.05	0.44	0.32	0.06	0.11	0.00
Cowlitz River fall	0.12	0.44	0.23	0.02	0.18	0.00
Kalama River fall	0.10	0.72	0.16	0.00	0.02	0.00
Lewis River late fall	0.19	0.54	0.12	0.03	0.09	0.02
Lewis River summer	0.19	0.46	0.29	0.00	0.06	0.00
Washougal River fall	0.08	0.63	0.24	0.00	0.06	0.00
Bonneville Hatchery fall	0.00	0.55	0.24	0.08	0.11	0.00
Spring Creek fall	0.05	0.47	0.24	0.13	0.11	0.00
South Santiam River spring(1)[c]	0.30	0.55	0.14	0.00	0.01	0.00
North Santiam River spring(1)[c]	0.42	0.40	0.17	0.00	0.01	0.00
McKenzie River Hatchery spring (0)[d]	0.52	0.41	0.07	0.00	0.00	0.00
McKenzie River Hatchery spring (1)[c]	0.41	0.48	0.09	0.00	0.02	0.00
Clackamas River spring (1)[c]	0.24	0.47	0.20	0.00	0.09	0.00
Clackamas River spring (90s)[e]	0.46	0.23	0.11	0.00	0.18	0.02
North Santiam River spring (90s)[e]	0.77	0.21	0.01	0.00	0.00	0.00
South Santiam River spring (90s)[e]	0.67	0.23	0.09	0.00	0.01	0.00
McKenzie River Hatchery spring (90s)[e]	0.59	0.25	0.10	0.00	0.02	0.05
Upper Columbia River fall	0.33	0.62	0.02	0.02	0.01	0.00

[a] Tagged chinook salmon were released from hatcheries in the Lower Columbia and Upper Willamette Rivers. Recoveries for each release site are based on at least three release groups, each of which had at least 100 tag recoveries (expanded) in ocean fisheries. Except where noted, all tagged groups were released between 1980 and 1989.

[b] SAB = select area bright fall-run (Rogue River)

[c] 1 = yearling release

[d] 0 = subyearling release

[e] 90s = yearlings released 1990–1994.

Table 5. Age structure for Lower Columbia River chinook salmon.[a]

Age Designation	Subyearling Migrants					Yearling Migrants					Source
	2.0	3.0	4.0	5.0	6.0	2.1	3.1	4.1	5.1	6.1	
Klaskanine River fall	0.000	0.306	0.694	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Plympton Creek fall	0.084	0.708	0.193	0.016	0.000	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Big Creek fall	0.013	0.371	0.567	0.044	0.000	0.000	0.000	0.004	0.000	0.000	Olsen et al. 1992
Gnat Creek fall	0.006	0.651	0.283	0.030	0.030	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Lewis and Clark River fall	0.050	0.469	0.481	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Olsen et al. 1992
Grays River fall	0.137	0.294	0.510	0.057	0.000	0.000	0.000	0.000	0.000	0.000	Hymer et al. 1992
Elochoman River fall	0.132	0.501	0.340	0.027	0.000	0.000	0.000	0.000	0.000	0.000	Hymer et al. 1992
Cowlitz River spring	0.000	0.000	0.000	0.000	0.000	0.175	0.100	0.528	0.191	0.006	Hymer et al. 1992
Cowlitz River fall	0.032	0.165	0.580	0.193	0.004	0.001	0.016	0.008	0.000	0.000	Hymer et al. 1992
Coweeman River fall	0.015	0.007	0.312	0.645	0.022	0.000	0.000	0.000	0.000	0.000	Hymer et al. 1992
Kalama River late fall[b]	0.029	0.330	0.424	0.162	0.000	0.000	0.009	0.036	0.009	0.000	Hymer et al. 1992
Lewis River late fall[b]	0.132	0.196	0.419	0.212	0.008	0.000	0.003	0.018	0.009	0.001	Hymer et al. 1992
Lewis River fall	0.123	0.193	0.468	0.202	0.005	0.000	0.004	0.000	0.004	0.000	Hymer et al. 1992
Washougal River fall	0.022	0.198	0.628	0.151	0.000	0.000	0.000	0.001	0.000	0.000	Hymer et al. 1992
Sandy River late fall[b, c]	0.043	0.182	0.533	0.236	0.005	0.000	0.000	0.000	0.000	0.000	Fulop 2000
Sandy River fall	0.026	0.283	0.592	0.100	0.000	0.000	0.000	0.000	0.000	0.000	Fulop 2000

[a] Age information is based on scales recovered from naturally spawning chinook salmon. Age designation (X, Y): X is the age at maturation, and Y is the age at ocean emigration (0 = subyearling, 1 = yearling, 2 = 2-year-old smolt…).

[b] Late fall or bright

[c] Juvenile age structure was not available for Sandy River fish, but is assumed to be mostly subyearling migrants (partially based on data presented in Howell et al. 1985).

Return Migration

The timing of return to freshwater, and ultimately spawning, provides a temporal isolating mechanism for populations. Furthermore, return timing is often correlated with spawning location. Salmonids that return in the early spring often take advantage of high flows from snowmelt to access the upper reaches of many rivers. Differences in return migration timing provide a geographic isolating mechanism.

The freshwater component of the adult returning migratory process is under a significant genetic influence. The underlying genetic influence on run-timing was initially demonstrated by Rich and Holmes (1928), when spring-run chinook salmon from the McKenzie River (Oregon) were reared, marked, and released from a predominantly fall-run watershed. The transplanted chinook salmon displayed no apparent alteration in their normal time of return or spawning, although there was an apparent decrease in fidelity. Subsequent stock transplantations have further substantiated the heritable nature of run-timing. Heritability estimates for return timing among early- and late-returning pink salmon (*Oncorhynchus gorbuscha*) runs in Alaska were 0.4 and 0.2 for females and males, respectively (Gharrett and Smoker 1993). In one experiment, upriver fall-run chinook salmon were captured, spawned, and the subsequent progeny reared and released from a downriver site (McIsaac and Quinn 1988). A significant fraction of the returning adults from the upriver bright progeny group bypassed their rearing site and returned to their "traditional" spawning ground 370 km farther up the Columbia River. This migration pattern may be related to the relative timing of freshwater entry and spawning rather than a geographic sense of where the salmon's traditional home is. Returning to the home stream may reflect local adaptation and reproductive isolation.

Runs are designated on the basis of when adults enter freshwater; however, distinct runs may also differ in the degree of maturation at river entry and time of spawning. Early, spring-run (stream-maturing) chinook salmon tend to enter freshwater as immature or bright fish, migrate upriver (holding in suitable thermal refuges for several months), and finally spawn in late summer and early autumn. Late, fall-run (ocean maturing) chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the main stem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Fulton 1968, Healey 1991). Summer-run fish show intermediate characteristics of spring and fall runs, spawning in large- and medium-sized tributaries and not showing the extensive delay in maturation exhibited by spring-run chinook salmon (Fulton 1968). There is no record of summer-run fish historically spawning within the Lower Columbia or Upper Willamette River ESU boundaries. All temporal runs, and especially those that migrate into freshwater well in advance of spawning, utilize resting pools. These pools provide an energetic refuge from river currents, a thermal refuge from high summer and autumn temperatures, and a refuge from potential predators (Berman and Quinn 1991, Hockersmith et al. 1994). Furthermore, the utilization of resting pools may maximize the success of the spawning migration through decreases in metabolic rate and the potential reduction in susceptibility to pathogens (Bouck et al. 1975, Berman and Quinn 1991). Therefore, the existence or absence of resting pools may be an important determinant in the success of certain run times in specific basins.

Run-timing is also, in part, a response to stream-flow characteristics. Rivers such as the Klickitat or Willamette historically had waterfalls that were impassable to upstream migration, except during high late-winter or spring flows, while other falls are passable only during low flows (WDF et al. 1993). Low river flows on the south Oregon coast during the summer result in barrier sandbars that block migration. The timing of migration and, ultimately, spawning must also be cued to the local thermal regime. Egg deposition must be done at a time that will ensure fry emerge during the following spring when river or estuary productivity is sufficient for juvenile survival and growth. The strong association between run-timing and ecological conditions made this trait useful in considering potential ESU boundaries.

The fall run is currently predominant in the Lower Columbia River, although historically, spring-run fish may have been nearly as numerous as fall run. Fall-run fish return to the river in mid-August and spawn within a few weeks (WDF et al. 1993, Kostow 1995). These fall-run chinook salmon are often called tules; they are distinguished by their dark-skin coloration and advanced state of maturation at the time of freshwater entry. Tule fall-run chinook salmon populations may have historically spawned from the mouth of the Columbia River to the White Salmon and Hood Rivers. There is substantial disagreement on whether fall-run chinook salmon historically existed in the lower Klickitat River. Among other fall-run populations, a later returning component of the fall chinook salmon run exists in the Lewis and Sandy Rivers (WDF et al. 1993, Kostow 1995, Marshall et al. 1995). Because of the longer time interval between freshwater entry and spawning, Lewis River and Sandy River fall-run chinook salmon are less mature at freshwater entry than tule fall chinook salmon at river entry; they are commonly termed lower river brights (Marshall et al. 1995). There are presently a number of other fall-run chinook salmon in the Lower Columbia River that are generally referred to as brights. Hatchery records and genetic analyses indicate that these fish are the descendants of introduced fall-run chinook salmon from the Rogue River (Oregon coast) and the Upper Columbia River (Priest Rapids Hatchery). With the exception of the late fall-run chinook salmon in the Lewis and Sandy Rivers we know of no information to indicate that this life-history form was historically present anywhere in the ESU.

Spring-run chinook salmon on the Lower Columbia River, like those from coastal stocks, enter freshwater in March and April, well in advance of spawning in August and September. According to an early report:

> This variety is known the world over as the "Royal Chinook," and may truly be called the king of the salmon. Those taken from the Columbia River during the months of April, May and June are claimed to be superior to any found elsewhere. (ODF 1900)

Historically, fish migrations were synchronized with periods of high rainfall or snowmelt to provide access to upper reaches of most tributaries where fish would hold until spawning (Fulton 1968, Olsen et al. 1992, WDF et al. 1993). The relationship between flow and run-timing was recognized by early fishery biologists: "Another peculiarity in connection with the habits of this species of salmon is that they will not enter any stream which is not fed by snow water . . ." (ODF 1900).

Willamette Falls (RKm 42) historically limited access to the upper river, thus it defines the boundary of a distinct geographic region. High flows over the falls provided a window for returning chinook salmon in the spring, while low flows prevented fish from ascending the falls in the autumn (Howell et al. 1985). Returning Willamette River spring-run chinook salmon enter the Columbia River in February and March, but they do not ascend the Willamette Falls until April and May. The migration past the falls generally coincides with a rise in river temperatures above 10°C (Mattson 1948, Howell et al. 1985, Nicholas 1995). Spawning generally begins in late August and continues into early October, with spawning peaks in September (Mattson 1948, Nicholas 1995, Willis et al. 1995).

Run-timing was used as a criterion for distinguishing independent populations. Freshwater entry timing differences resulted in geographic separation, due to flow-related access windows at barrier falls or cascades. Furthermore, spring-run chinook salmon utilize upper watershed areas with distinct thermal regimes, resulting in spawn timing (and possibly embryonic development) differences relative to fall-run fish in the same watershed.

Age at Maturation

Adults return to tributaries in the Lower Columbia River predominately at 3 and 4 years of age for fall-run fish and 4 to 5 years of age for spring-run fish. This may be related to the predominance of yearling smolts among spring-run stocks. In general, Willamette River spring-run chinook salmon mature in their fourth and fifth year of life, with slightly more 4-year-old fish. Historically, 5-year-old fish comprised the dominant portion of the run (Mattson 1963).

Differences in age at maturation were of limited use in distinguishing independent populations. It is possible that older, larger fish are more successful at ascending barriers, or younger, smaller fish may be able to utilize off-side-channel habitat more effectively, but there was no conclusive information to substantiate this, and age structure was highly variable in most populations. Given the high degree of hatchery intervention in most river systems, the intensity of selective forces on many life-history traits may have been reduced or redirected to an unknown degree.

2.2 Lower Columbia River Chinook Salmon ESU

Historical Independent Populations

Coast Range Tributaries

This region extends from the mouth of the Columbia River to Coal Creek (RKm 99.8) on the Washington State side of the Columbia River and Scappoose Creek (RKm 140) on the Oregon side (Figure 2). Chinook salmon spawning in this region were placed in seven population clusters, based on historical population abundance estimates and watershed size.

Coast Range tributaries are all relatively short; less than 40 km (Table 1). The lower reaches tend to be low-gradient, slow-moving systems that are under tidal influences. Many tributaries enter the Columbia River through a series of sloughs that offer little useable spawning habitat. The rivers and creeks drain low-elevation hills, with peaks less than 1,000 m. Rainfall averages 200–240 cm per year. In the absence of substantial snowpack or groundwater sources, the river flows are strongly correlated with rainfall (peak flows occurring in December and

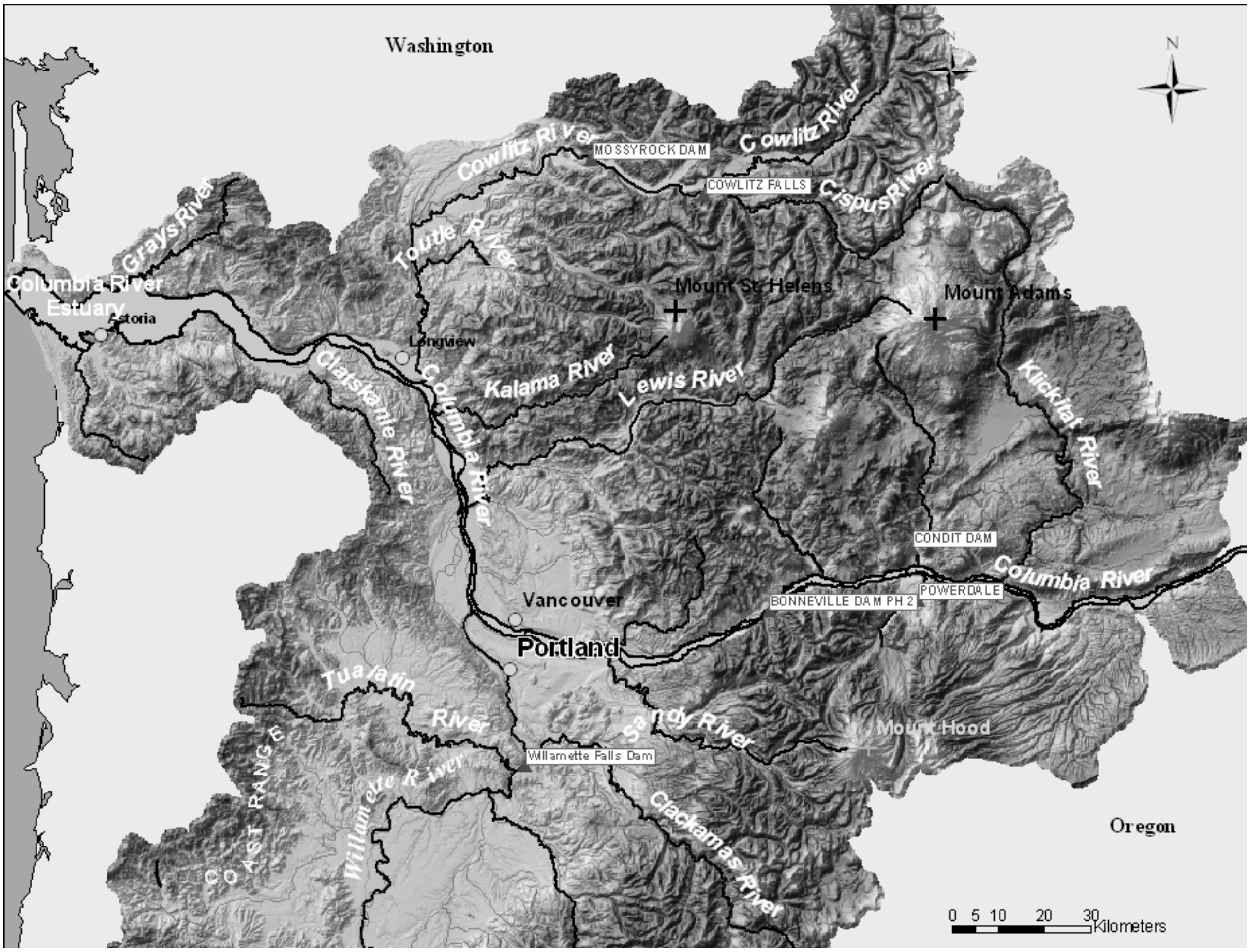

Figure 2. Lower Columbia River Basin.

January), and summer flows can be very low (low flows occur in August). Presently, there are no naturally spawning, spring-run chinook salmon in this subregion, and given the relatively short length of these rivers and creeks and their rainfall-dominated hydrology, there is little suitable habitat for spring-run chinook salmon. It is unlikely that distinctive run times or geographically isolated populations could have developed in one of these systems. Furthermore, it is possible that during extended periods of poor ocean conditions or extremes in climate (floods or droughts) many of the smaller systems may experience short-term extirpations.

The distribution of historical populations in this portion of the Lower Columbia River was initially derived using the geographic clustering of the watersheds listed (those historically known to contain chinook salmon). In some cases it is unclear whether chinook salmon historically were present (Table 2). For example, spawner surveys done in the 1930s and 1940s documented chinook salmon in the Chinook River. However, a hatchery was established in the watershed in 1894 using adults captured in the mainstem mouth of the Columbia River, and the fish observed are most likely descendants of those hatchery fish. The Washington Department of Fish and Game (WDFG 1916) suggested the Chinook River did not have an indigenous chinook salmon population prior to establishment of the hatchery run. Marshall et al. (1995) suggest that many rivers in this region did not support chinook salmon populations. Collins (1892), in his surveys of Pacific coast fisheries, specifically lists the Lewis and Clark River and Youngs River as supporting runs of chinook salmon. Gilbert and Evermann (1895) note that, "Fish of the fall run enter the Columbia a short time only before they are ready to spawn. So far as we now know, the most of these turn directly into streams near the mouth of the river and spawn a short time after their entrance into the Columbia." The absence of detailed historical documentation may be related to the emphasis on fisheries (and studies) targeting spring-run chinook salmon. In contrast to the spring run, fall-run chinook salmon entered freshwater at an advanced stage of maturation, and there was initially little demand for these poor quality fish. Spring-run chinook salmon sold to salmon packers in 1894 were worth \$.05 a pound, whereas fall-run chinook salmon and chum salmon were worth \$.03–.05 per fish (Smith 1895). The preference for spring-run chinook salmon also influenced hatchery policies. "The opinion also prevails that the fish hatched from the eggs of the fall run will return to the river in the fall and be the undesirable fish, and the hope is general that no attempts will be made to propagate the late fish, but that the efforts will be centered on the spring and summer broods, which alone are suitable for canning" (Smith 1895).

Chinook salmon studies studies were conducted on Gnat Creek from 1956 to 1962 (Willis 1962). In 1955, construction of a weir on the lower portion of the creek enabled biologists to enumerate and measure returning adults, as well as sample emigrating juveniles, except during high flow periods. During the study, average chinook escapement was only 39 fish. Peak juvenile outmigration by subyearling juveniles was observed during February and March; no yearling migrants were observed.

Genetic analysis was of limited utility due to the large numbers of hatchery-origin fish released into these basins from outside the specific watershed (see Appendix B, Tables B.6 and B.7). Straying between these spawning aggregations was estimated using CWT recoveries from naturally spawning fish, fish returning to hatchery racks, or fishery recoveries from the tributaries. In general, it is believed that there was a high degree of exchange between all the populations in the smaller coastal tributaries of the Lower Columbia River, but less so between populations in this region and those in other regions within this ESU. For example, of the freshwater recoveries of marked fish released from the Grays River Hatchery, only 32.3% were recovered back in the Grays River basin, 10.3% in Skamokawa Creek, 23.0% in the Elochoman River, 33.0% in Big Creek, and less than 1.0% of recoveries were upstream of the Cowlitz River (Figure 3). Low levels of homing fidelity were also observed for fish released from Abernathy Creek Salmon Culture Technology Center (SCTC), and the Elochoman River and Big Creek hatcheries. In general, a significant proportion (>10%) of the freshwater recoveries occurred up to 50 km away from the release site. These rates may be substantially higher than historical levels due to (1) use of mixed-origin Lower Columbia River fish by most hatchery programs, (2) poor water quality or low attraction flows in many of the rivers or hatcheries, and (3) attraction of fish to assemblages of fish (i.e., fish in hatchery holding ponds). Additionally, fish that enter hatchery traps or are intercepted in terminal fisheries are considered strays, despite the fact that fish naturally often hold only temporarily in nonnatal streams or may test tributaries for homing cues. In general, fall-run chinook salmon spawn in the lower reaches of the tributaries, just above the extent of tidal influence (Parkhurst et al. 1950, Merrell 1951). This may increase the likelihood of movement by spawning adults between basins.

Life-history information (spawn timing, age at maturation, ocean migration) was relatively useful, given the degree of hatchery transplantation and the high apparent rate of interchange (Figures 3 and 4, Table 6, Appendix A, Table A.1). In general, there were slight differences in peak spawning time for populations in this subregion, and presently considerable overlap exists in the spawning distribution for populations in this subregion (Figure 5). Similarly, there is no clear overall trend in age at maturation. However, fall-run chinook salmon from the Grays and Klaskanine Rivers and Big Creek tend to cluster together in the UPGMA dendrogram (Figure 6, Table 3) of Lower Columbia River chinook salmon, as do fall-run chinook salmon from Plympton and Gnat Creeks and the Lewis and Clark and Elochoman Rivers. Analysis of CWT recoveries in marine fisheries was not informative in life-history distinctions beyond the level of run-timing (Figure 7), except that ocean recovery distribution was similar among hatcheries that had exchanged large numbers of fish.

Very little information is available for the cluster of populations from Tide Creek to Scappoose Creek, other than information indicating that fall-run chinook salmon were historically present in most of these systems. Fall-run chinook salmon were thought to be spawning in Milton Creek during the late 1950s (Willis et al. 1960). Scappoose Creek is the only basin that contains enough habitat to potentially sustain large numbers of fish (Table 1). Willis et al. (1960) reported that 100 fall chinook salmon were observed spawning in the lower two miles of Scappoose Creek. Ecologically, the tributaries on the Oregon side, which drain the Coast Range, are very different from the larger tributaries on the Washington side (e.g., Cowlitz and Kalama Rivers, etc.), which drain the Cascade Range (Figure 1).

The seven DIPs proposed (see below) in this region are distinct based solely on geographic separation. In general, genetic information from recently collected fish is of limited value due to the high proportion of hatchery fish on the spawning grounds (Figure 4) and the large numbers of nonnative hatchery fish introduced into the region (Table A.1). Whether these clusters were historically reproductively isolated is difficult to establish, but to have maintained demographic independence, homing fidelity would have likely been substantially higher than is currently observed. Additionally, it is assumed that fish tend to orient along the riverbank, and in the Lower Columbia River a fish was more likely to stray to an adjacent system rather than across the river. It is fairly reasonable to assume that distinct independent populations did not exist on a scale smaller than the seven clusters. It may also be reasonable to assume that because of geographic and ecological factors, these clusters did form at least one independent population relative to other populations in the ESU.

Table 6. Salmon escapement estimates for Sandy River tributaries.[a]

Chinook Salmon	Historical[b]	1954[c]	1995[d]	1998[e]
Spring Run				
Mainstem Sandy River	5,000	750	1,900	2,606
Salmon River	2,000	<50		
Zigzag River	Fair	Unknown		
Bull Run River	5,000	200		
Little Sandy River	Unknown	0		
Fall Run		2,830		
Mainstem Sandy River	10,000	2,500		700
Salmon River	500	0		
Bull Run River	Unknown	500		
Gordon Creek	Unknown	200		
Chum Salmon				
Mainstem Sandy River	Unknown	200		
Beaver Creek	Unknown	<100		
Coho Salmon				
Mainstem Sandy River	15,000	3,000		
Bull Run River	5,000	400		
Little Sandy River	Good	few		
Salmon River	Good	300		
Zigzag River	Good	Unknown		
Gordon Creek	Good	250		
Cedar Creek	Unknown	500		
Beaver Creek	Unknown	250		
Steelhead				
Mainstem Sandy River	20,000	6,000		
Bull Run River	5,000	400		
Little Sandy River	Good	few		
Salmon River	2,000	600		
Zigzag River	Excellent	200		
Gordon Creek	Good	400		
Cedar Creek	Unknown	400		
Beaver Creek	Good	300		

[a] Numbers estimate naturally spawning escapement and may include hatchery-reared chinook salmon.
[b] Mattson (1955)
[c] Mattson (1955)
[d] Nicholas (1995)
[e] Based on a 5-year average (ODFW 1998).

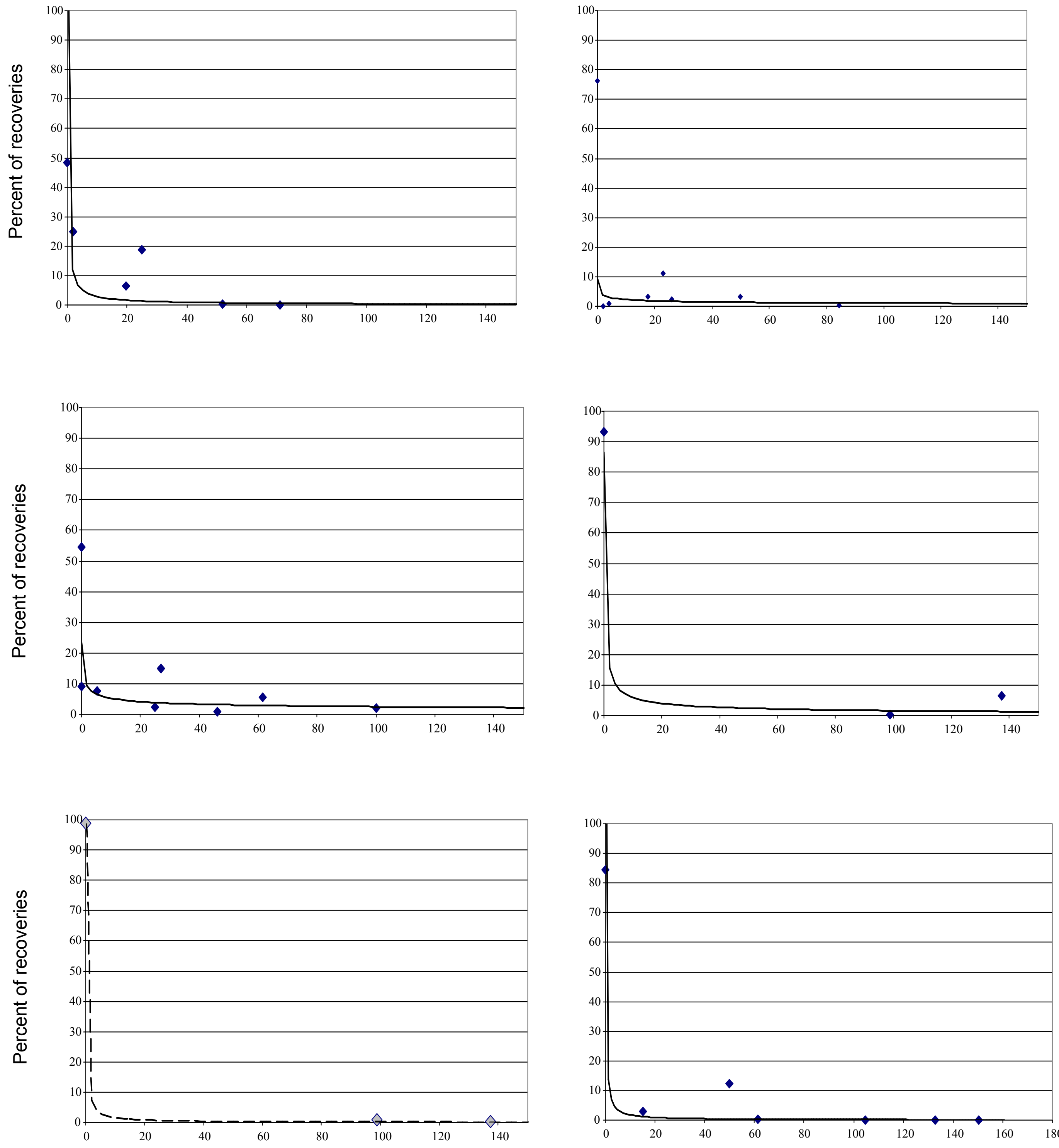

Figure 3. Incidence, as a percentage of all freshwater recoveries, and distance or adult recovery to juvenile release location of chinook salmon returning to the Lower Columbia River. Each graph represents the averaged results from at least three coded-wire tag groups (each with at least 100 freshwater recoveries) released from a specific hatchery from 1980 to 1990. Data from PSMFC (2000) and WDFW (2000).

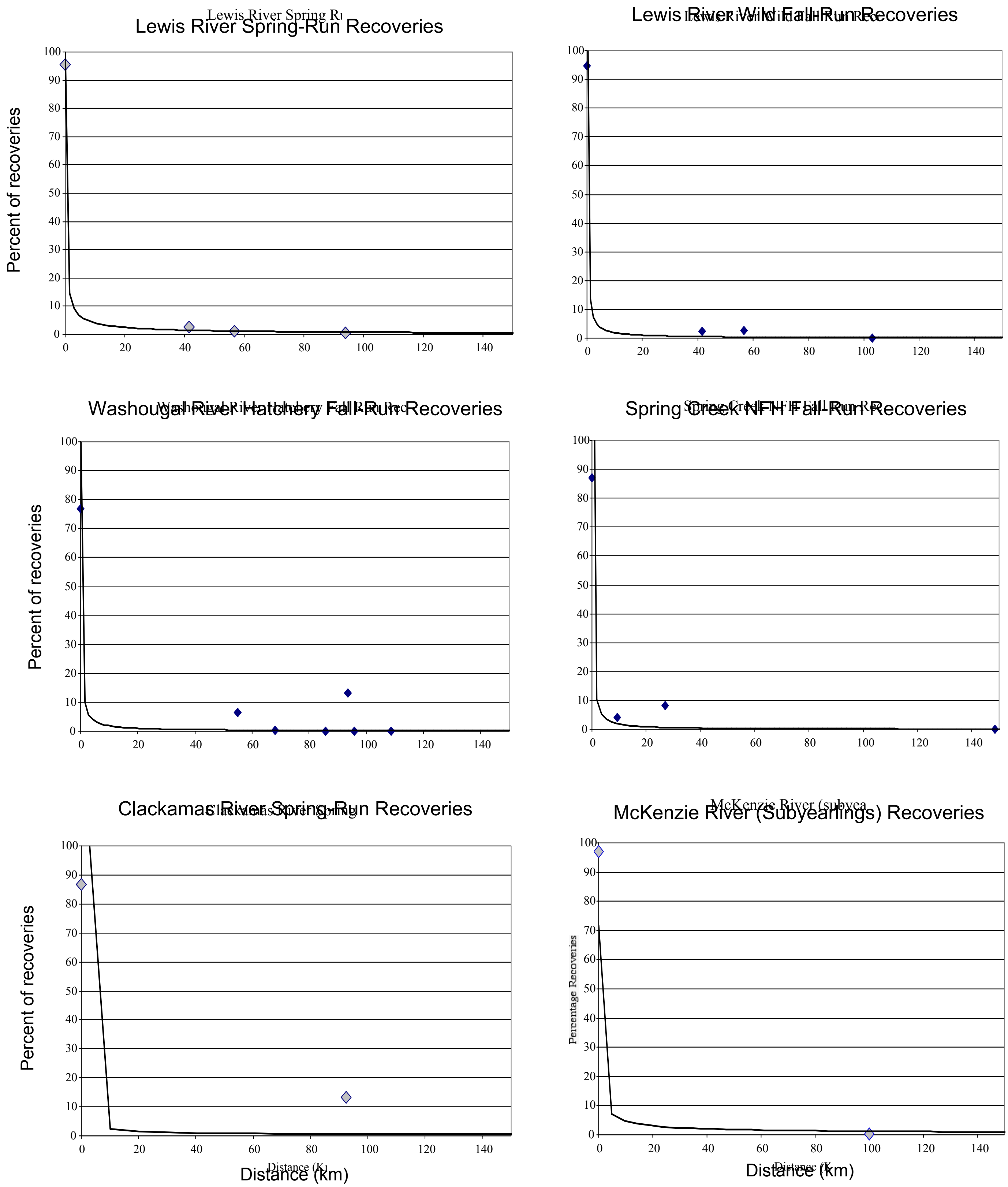

Figure 3. (cont)

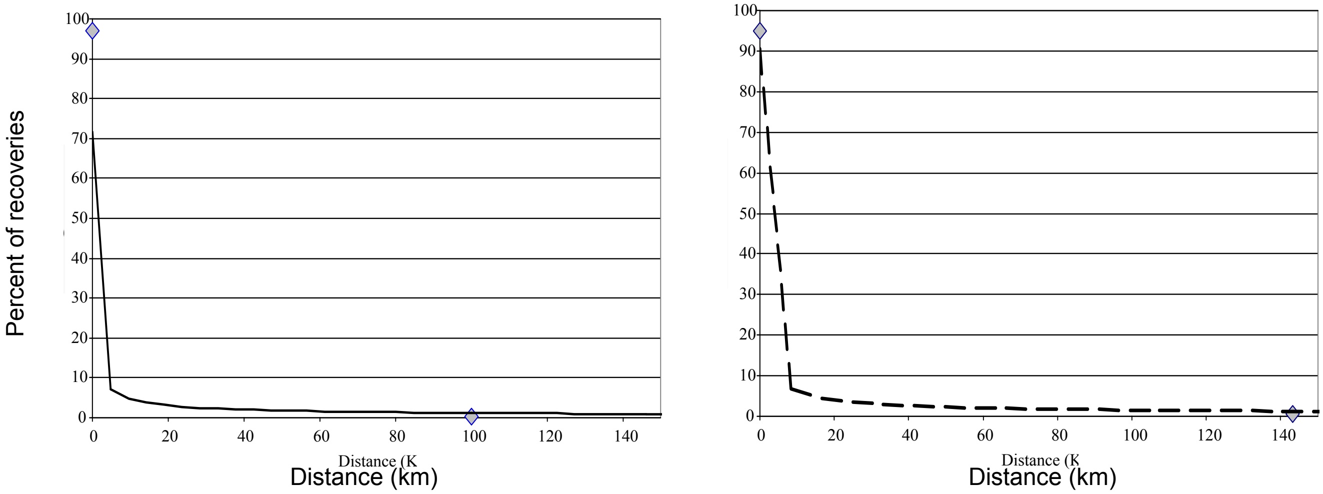

Figure 3. (cont)

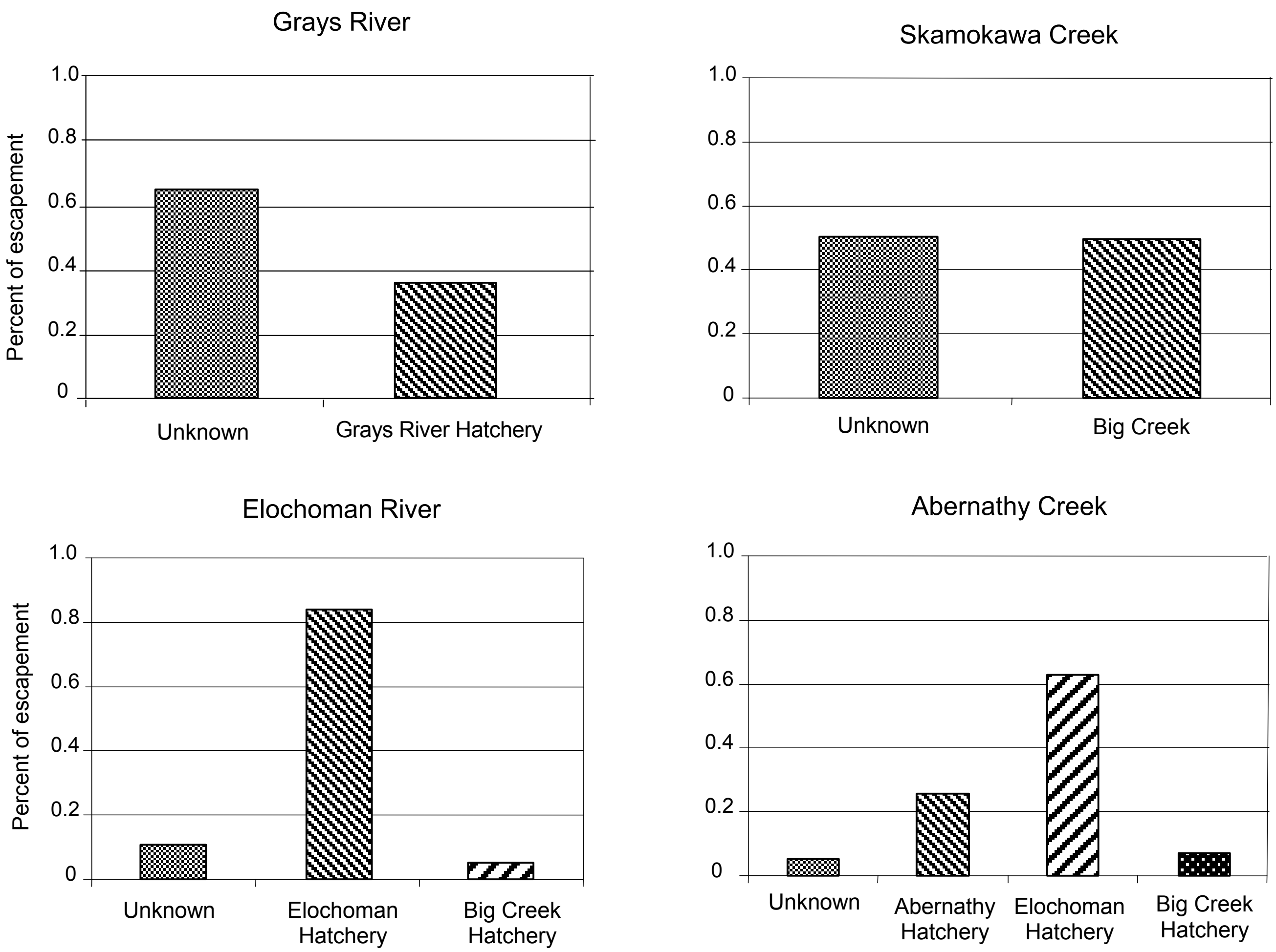

Figure 4. Estimated origin of naturally spawning chinook salmon in Columbia River tributaries based on recoveries of adults in spawner surveys. Unknown fish may consist of naturally produced (unmarked) fish or unmarked hatchery fish for which no CWTs were recovered. Source: Harlan (1999).

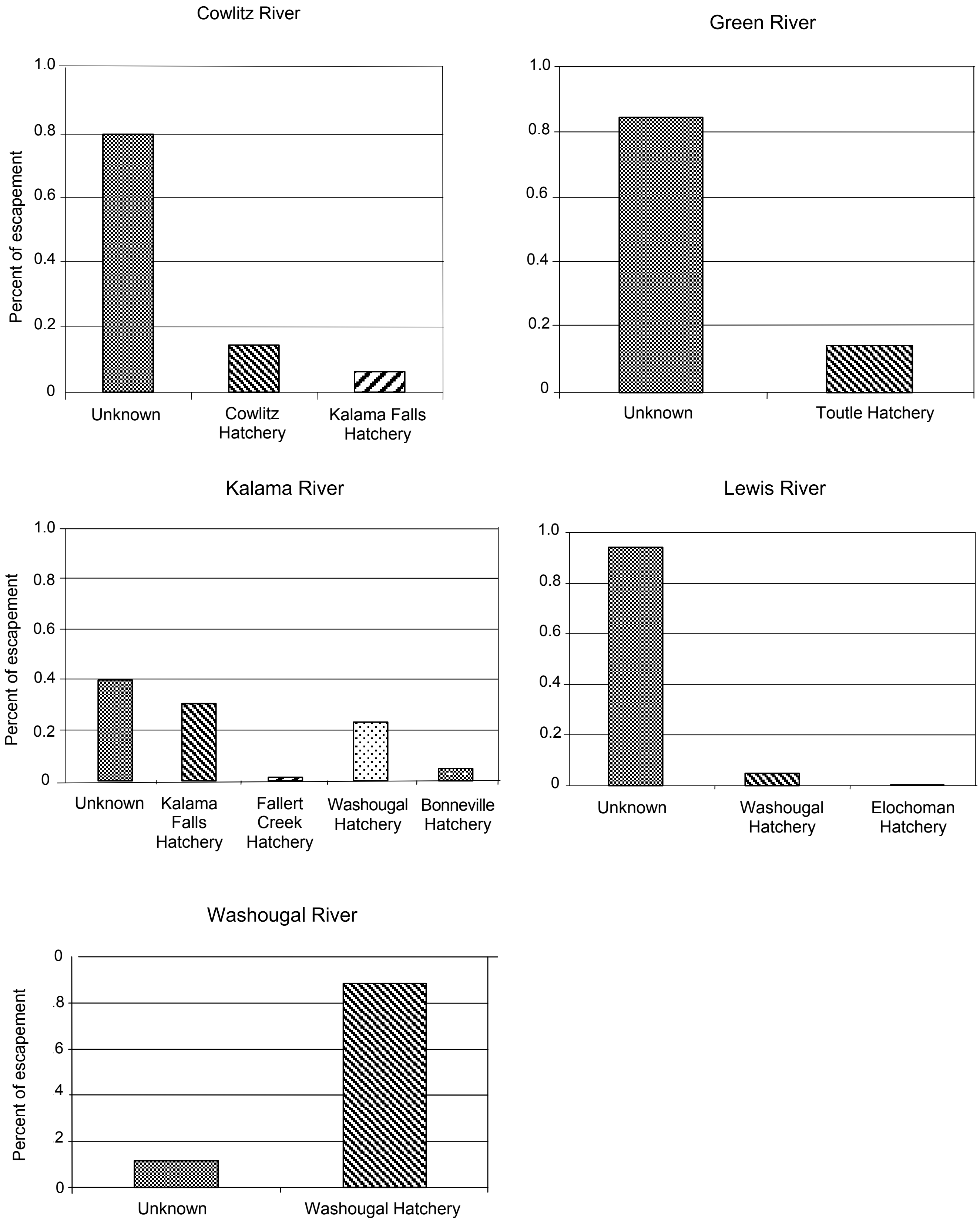

Figure 4. cont.

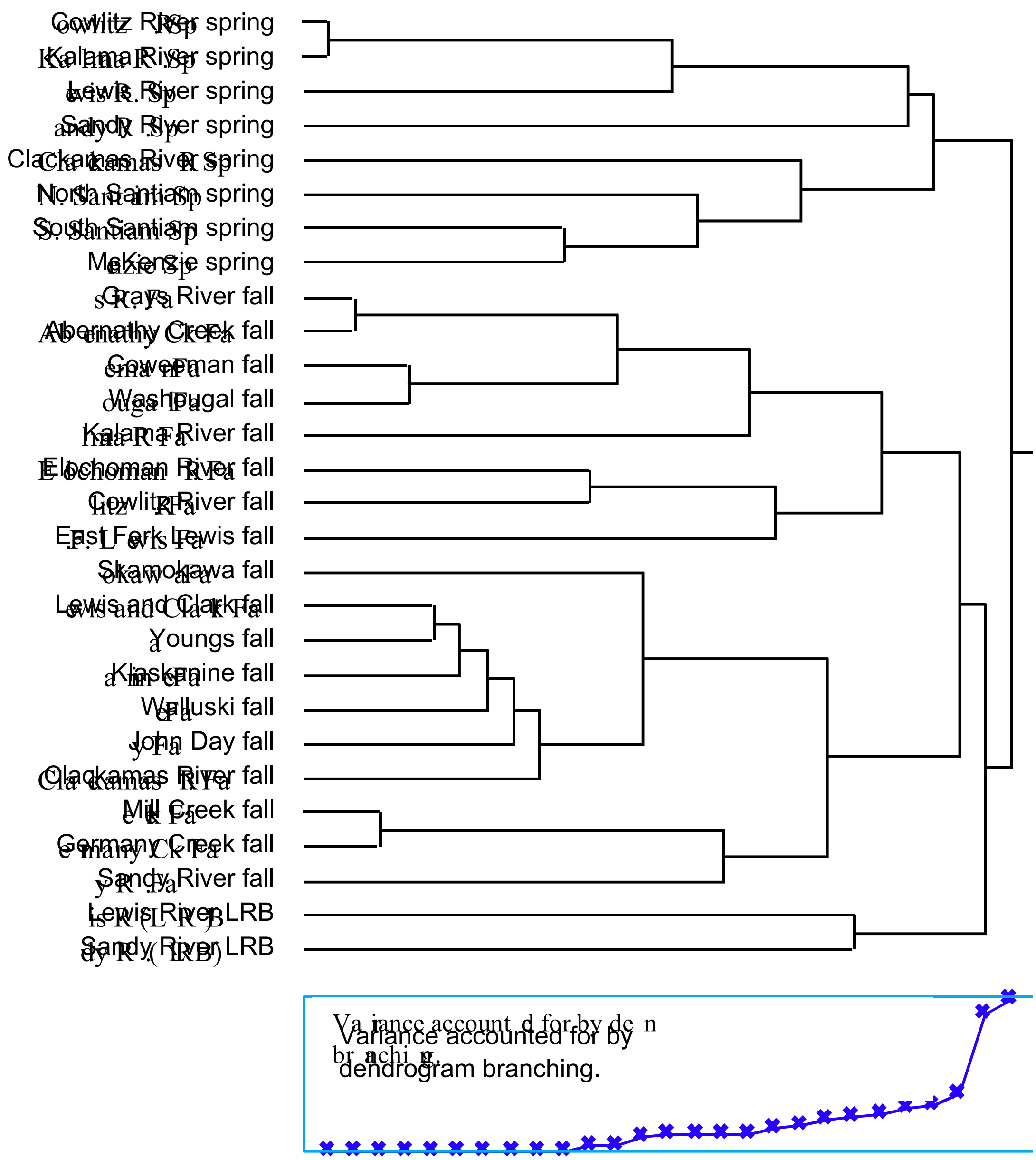

Figure 5. Standardized dendrogram for migration timing and spawning for Lower Columbia River and Upper Willamette River chinook salmon stocks. Distributions for each stock were based on estimated time of freshwater entry (by week) and time of peak spawning activity (by week). Migration and spawning time were based on data from various sources compiled during the 1980s. 0 = subyearling release, 1 = yearling release, LRB = lower river brights.

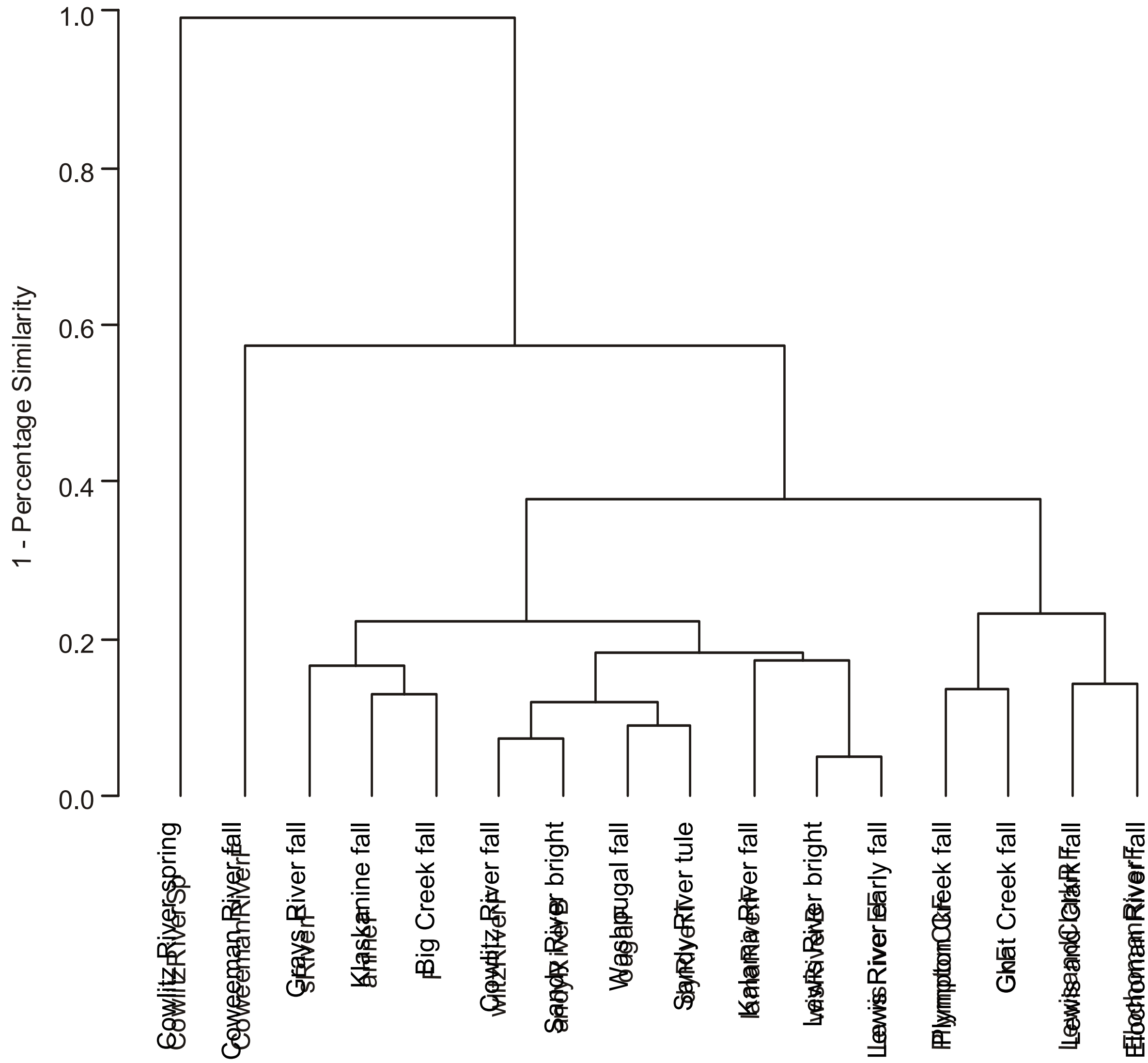

Figure 6. Unweighted pair group method with arithmetic averages (UPGMA) dendrogram for Lower Columbia chinook salmon based on percentage overlap in spawner age distributions (age at maturation and age at ocean emigration). Age structure is based on scales from naturally spawning fish.

Historical demographically independent populations (Figure 7). Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are indicated by SASSI.

1. Youngs Bay fall run
   a. Lewis and Clark River
   b. Youngs River
   c. Walluski River
   d. Klaskanine River
2. Grays River fall run SASSI
   a. Deep River
   b. Grays River
3. Big Creek fall run
   a. John Day River
   b. Mill Creek (Oregon)
   c. Big Creek
   d. Bear Creek
4. Elochoman River fall run
   a. Skamokawa Creek SASSI
   b. Elochoman River SASSI
5. Clatskanie River fall run
   a. Plympton Creek
   b. Clatskanie River
   c. Beaver Creek
6. Mill Creek fall run
   a. Mill Creek SASSI
   b. Abernathy Creek SASSI
   c. Germany Creek SASSI
   d. Coal Creek
7. Scappoose Creek fall run
   a. Tide Creek
   b. Goble Creek
   c. Milton Creek
   d. McNulty Creek
   e. Scappoose Creek

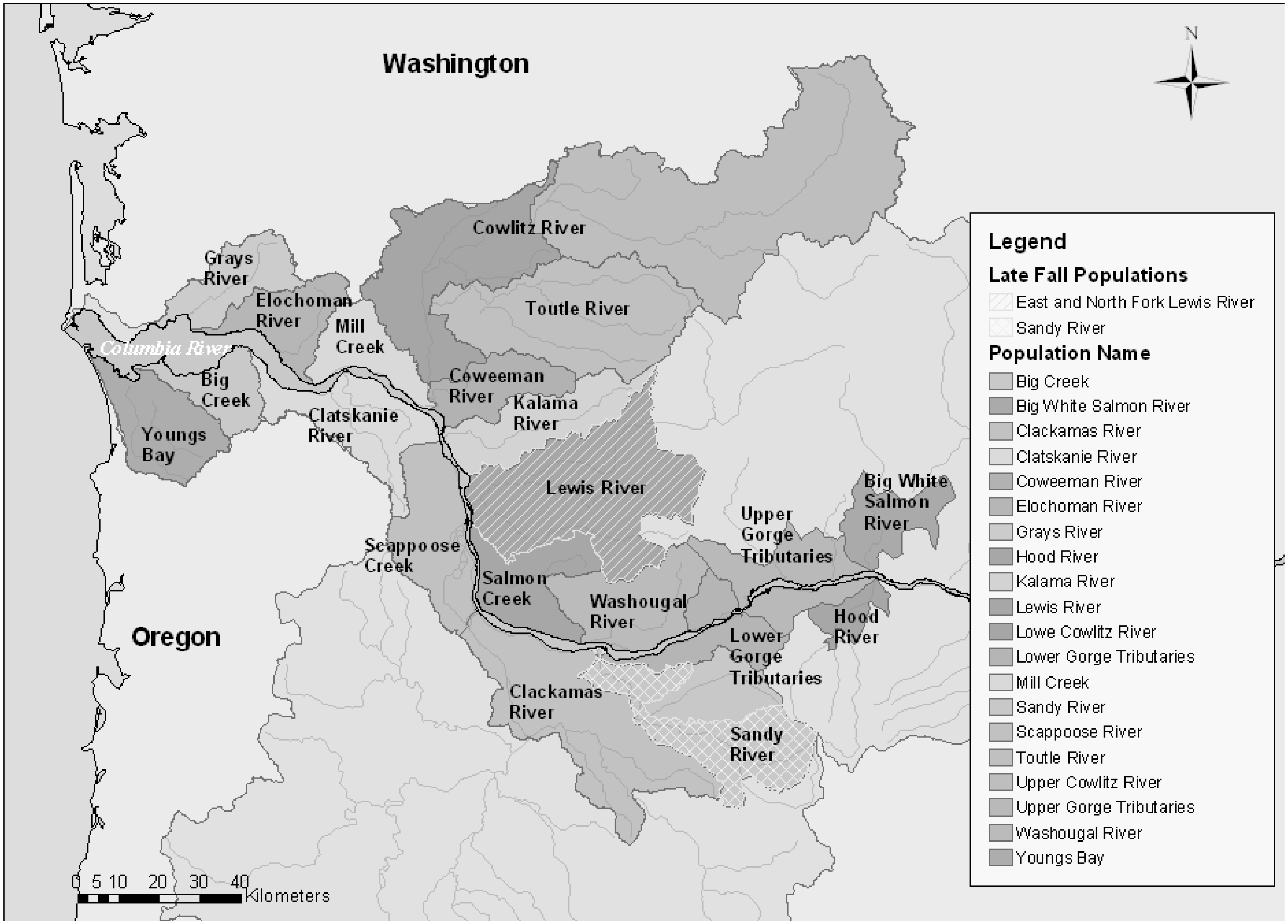

Figure 7. Historical demographically independent fall-run chinook salmon populations in the Lower Columbia River ESU.

Western Cascade Range Tributaries

Rivers in the western Cascade Range are larger than those found in the coastal region, with headwaters high in the Cascade Mountains. Many rivers are over 100 km long, with basins covering 1,000 km^2 or more (Table 1). Snowmelt and groundwater sources are substantial, maintain good year-round flows and cool water temperatures. River flows peak in December or January, and sustain at least 50% of peak for 6 months or more. The lower reaches of rivers are relatively low gradient, but high-gradient sections are common in the middle and upper reaches. Elevation plays a relatively important role in delineating the boundaries of EPA ecological regions (Figure 1).

This region extends from the Cowlitz River (RKm 106.2) to the Washougal River (RKm 194.9) on the Washington State side of the Columbia River and from the Willamette River (RKm 162.5) to the Sandy River (RKm 193.6) on the Oregon side. There appear to have been several major spawning aggregations in this region, based on historical population abundance information and watershed size (Tables 1 and 2).

Considerable biological information is available for populations in this region. More importantly, this information is less affected by hatchery influences relative to populations in the coastal region. This is due, in part, to the larger size of chinook salmon populations, making them more resilient to the effects of hatchery transfers. Several populations have had little or no direct hatchery influence (e.g., Coweeman River fall run, Lewis River late-fall run(s), and Sandy River late-fall run) (Tables 6 and A.1) and give some indication of the historical diversity in genetic and life-history characteristics.

Three basic life-history types of chinook salmon are found in this region: spring run, early-fall (tule) run, and late-fall (bright) run. Spring-run chinook salmon were historically found in the Cowlitz, Kalama, Lewis, and Sandy Rivers, tule fall-run fish were found throughout the region, and late-fall run fish were found in the Lewis and Sandy Rivers. Spring-run chinook salmon in the Clackamas River are part of the Upper Willamette River ESU and are discussed in that section. Spring-run and early fall-run spawning adults were historically separated both geographically and temporally, whereas the early-fall and late-fall run spawners were primarily temporally separated. Rivers in this region also provide sufficient habitat for juvenile chinook salmon to extend their rearing through the summer months. Analysis of scales collected from naturally spawning fall-run adults indicated that a small proportion (<10%) of fish do not emigrate until their second spring. Spring-run fish probably emigrated as both subyearlings and yearlings. However, recent scale collections are heavily biased by releases of primarily yearling hatchery fish. It is apparent that spring-run juveniles in this region are capable of emigrating to saltwater during their first year, in contrast to spring-run populations above the Cascade Crest, which appear to be obligate yearling migrants. In 1955 and 1956, juvenile chinook salmon were sampled emigrating from the upper Cowlitz River basin as fry during their first spring, fingerlings during the autumn, and yearling smolts during their second spring (Stockley 1961). The majority of downstream migrants were fry, and the mode of emigration took place during June. However, it is not known if these fry were migrating to ocean or downstream rearing sites. Analysis of ocean distribution, based on the CWT recovery location and age, indicates that only the Lewis River late-fall run of chinook salmon was distinct, with a more northerly distribution

(Figure 8, Table 5). Late-fall run populations in the Lewis River and Sandy River also tend to mature at an older age than early fall-run (tule) chinook salmon (Table 4).

Fall- and spring-run chinook salmon in the Cowlitz River are genetically similar to populations in the Kalama and Lewis River. This similarity may be due to the geographical proximity of the rivers. However, in the case of spring-run populations, this similarity is more likely related to the infusion of Cowlitz Hatchery spring-run chinook salmon into the hatchery programs in the Kalama and Lewis Rivers (see Appendix B). Dams on the Cowlitz and Lewis Rivers have eliminated migration access to the majority of historical spring-run spawning habitat. Genetic analysis of spring-run chinook salmon from the Sandy River indicates that they are genetically intermediate between spring-run fish in the Lewis River and Upper Willamette River (see Appendix B). Any present association between fish in the Sandy and Upper Willamette Rivers is due, in part, to extensive introductions of Willamette River fish into the Sandy River (Table 6).

Genetic similarities between spring-run and early-fall run fish may be due to the monophyletic nature of temporal runs in Lower Columbia River tributaries (Myers et al. 1998). Alternatively, there may have been natural hybridization between the temporal runs, due to the loss of geographic separation following dam construction or artificial hybridization in the hatchery due to the overlap in spawning time between the runs (Marshall et al. 1995, Myers et al. 1998). Cowlitz, Kalama, and Lewis River spring-run chinook salmon are all part of WDFW's mid- and Lower Columbia spring-run chinook salmon GDU (Marshall et al. 1995).

Migration between basins in this region is substantially lower than between populations in the coastal region (Figure 3). This may be due to a higher degree of homing fidelity for fish returning to larger-sized basins. Overall, for the hatchery releases analyzed from this region, more than 90% of the freshwater recoveries occurred in their natal river basin, and there were few recoveries of any significance beyond 25 km from the release site (Figure 3).

Suckley (1858) cited reports of "banks and sand bars of the Cowlitz River—a stream emptying the Columbia at a comparatively short distance from the ocean—lined with dead and dying salmon." Gilbert and Evermann (1895) reported that quinnat (chinook) salmon were obtained from the Cowlitz River in great numbers. Fall-run chinook salmon populations still exist in the Cowlitz River basin, although much of the current escapement is the result of hatchery production. Historically, the Cowlitz River was the primary producer of chinook salmon in the Lower Columbia River ESU (Bryant 1949); however, little information is available on the size of various tributary runs prior to the 1940s. In 1946, WDF and WDG estimated that 14,000 fall-run chinook salmon were spawning in the Cowlitz River above the proposed site of Mayfield Dam (RKm 84), representing a total run of 63,612.

Fall-run chinook salmon in the Coweeman River represent one of the few remaining populations in the ESU sustained through natural production. In 1951, it was estimated that 5,000 spawning fall-run chinook were in the Coweeman River, with a total spawning escapement of 31,000 fall-run chinook salmon throughout the Cowlitz basin (WDF, 1951). Recently, escapement into the Coweeman River has averaged 800 fish. However, there has been minimal contribution to escapement by hatchery strays (ODFW 1998). Fall-run chinook salmon populations in the Toutle River basin were nearly extirpated as a result of the Mount St. Helens

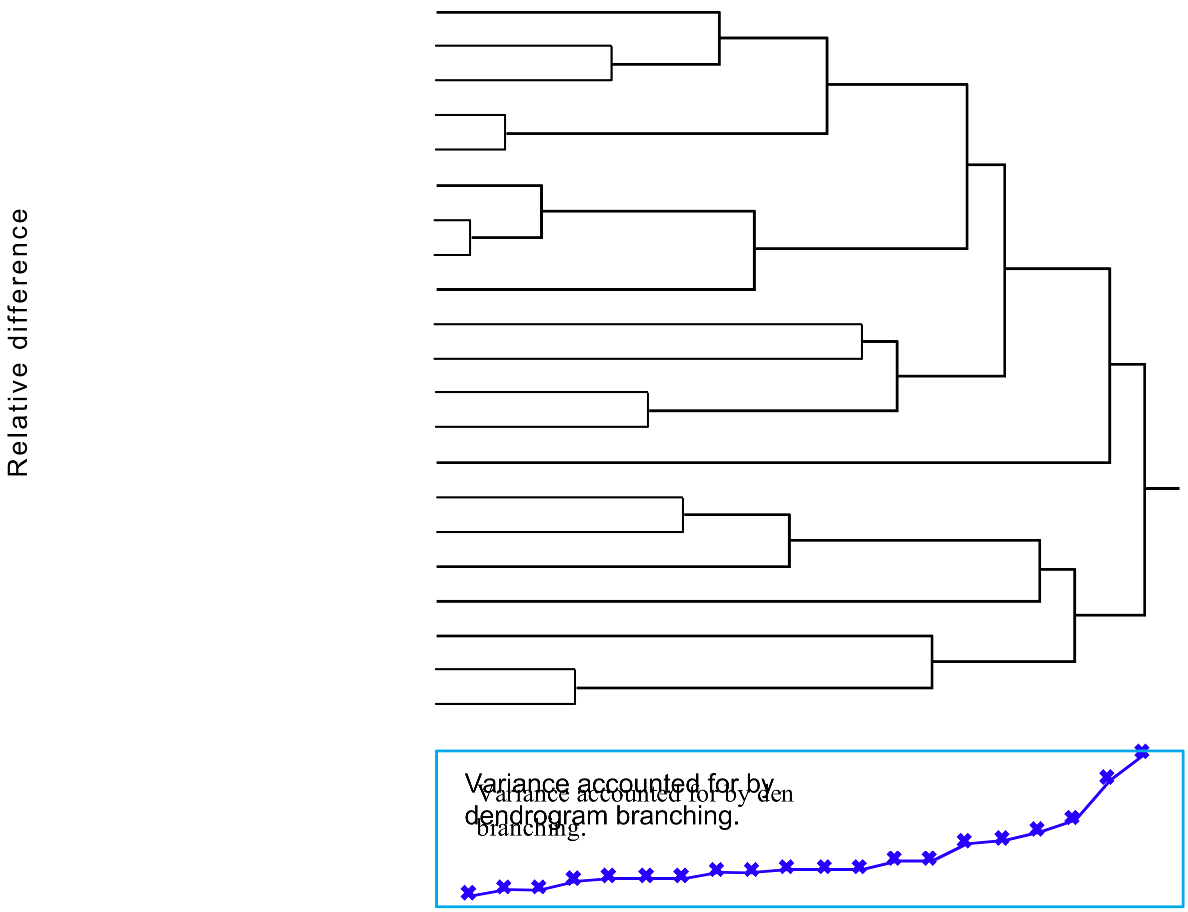

Figure 8. Standardized dendrogram of coded-wire tagged (CWT) ocean recovery distributions for Lower Columbia River and Upper Willamette River chinook salmon stocks. Distributions for each stock were based on at least three release groups (with 100 ocean recoveries [expanded]). Uness indicated all groups were released from 1981 to 1990: 0 = subyearling release, 1 = yearling release, 90s = release groups from 1991 to 1994, select area brights (SAB) = Rogue River fall-run chinook salmon released from Big Creek.

eruption in 1980. The reestablishment of chinook salmon runs in the basin has been achieved through natural recolonization and introductions of fish from the Cowlitz Salmon Hatchery. In the Cowlitz River spawner surveys, Bryant (1949) found fall-run fish spawning as far upriver as the lower reaches of the Tilton and Cispus Rivers (RKm 102 and 148, respectively) (WDF 1951). Evermann and Meek (1898) reported that fall-run chinook salmon entered the Toutle River in "considerable numbers," and could be expected after the first of September. Fall-run chinook salmon were also observed in the Toutle (RKm 27.4) and Coweeman River (RKm 12.1) basins. Given the distinctiveness of the existing Coweeman River fall-run chinook salmon population relative to the mainstem Cowlitz River fall-run population(s) (which is heavily influenced by hatchery releases), it is proposed that historically distinct populations of fall-run chinook salmon existed in the Coweeman, Toutle, and mainstem Cowlitz Rivers. It is possible that more than one population existed in the mainstem Cowlitz River, with the steep canyons that existed near the site of the present-day Mayfield Dam providing some degree of geographic separation. Furthermore, given the large size of the Toutle River basin (1,200 km^2), distinct populations may have also existed in the North and South Forks Toutle River (Table 1).

Substantial numbers of naturally spawning spring-run chinook salmon returned to the Cowlitz River basin through the 1960s. Geographically, the Cispus, Tilton, upper Cowlitz, and Toutle Rivers are large enough to have had enough production capacity to be self-sustaining. Habitat capacity estimates for these basins ranged from the thousands to tens of thousands of fish (Bryant 1949). In 1946, the spawning escapement for spring-run chinook salmon in the Cowlitz River basin above the then-proposed Mayfield Dam site was estimated to be 9,000 fish. Adjusting for harvest, this estimate represented a total run size of 32,490 fish (WDF and WDG 1946). WDF (1951) estimated that the spawning escapement for the entire Cowlitz River basin was 10,400 spring-run chinook salmon, with 8,100 spawning in the Cispus River, 400 in the upper Toutle River, 200 in the Tilton River, and 1,700 in the Upper Cowlitz River. Peak spawner counts for the Ohanapecosh (upper Cowlitz) and Cispus Rivers averaged 145.2 and 140.6 for the years 1950–1962, based on index survey areas of 5.6 km and 40 km, respectively (Birtchet and Meekin 1962). There may have been three or more independent populations of spring-run chinook salmon in the Cowlitz River basin. The Cispus and upper Cowlitz Rivers appear to have the geographic and abundance criteria necessary to have supported independent populations. It is less clear whether habitats in the Tilton and Toutle River basins are suited to spring-run chinook salmon life-history needs. In contrast to the Cispus and upper Cowlitz River basins, the Tilton River basin lacks extensive mainstem spawning areas and is not glacially influenced. Thus, there is some uncertainty whether spring-run chinook salmon in the Tilton River constituted their own historical DIP or were part of either the Cispus or upper Cowlitz River DIPs. Geographically, the Toutle River basin is large enough to have sustained a spring-run population, but it may have lacked the persistent cold-water sources that normally distinguish spring-run chinook salmon spawning habitat. Gilbert and Evermann (1895) described the Toutle River as being highly suitable for establishing a salmon hatchery (they based this assessment on reports of a large run of salmon in the river and observed water conditions, 15°C on 27 August). Evermann and Meek (1897) reported that salmon were present in the Toutle River in August, but residents indicated that the run increased after September 1. If spring-run chinook salmon were present they would have been located in headwater areas at the time of the survey. Furthermore, it is unlikely that residents could have observed returning spring-run chinook salmon during high spring flows.

The Kalama River historically had, and currently maintains, a very large population of fall-run chinook salmon. Although only a small spring-run population exists in the Kalama River, anecdotal information suggests that the run was considerably larger (WDF 1951). There is, however, considerable debate on this matter. A hatchery was established in the Kalama River basin in 1895 (located 7 km from the town of Kalama); however, this site was upstream of the primary fall-run chinook salmon spawning ground (WDFG 1902). Geographically, there are few large tributaries to the Kalama, and none with the capacity to support a spawning aggregation large enough to be considered an independent population.

The Lewis River currently supports three temporal runs: spring-run, early fall-run, and late fall-run chinook salmon. The early fall-run chinook salmon return primarily to the East Fork Lewis River in August and September, and spawn from late September to November (Marshall et al. 1995). Included in the provisional historical population with the early fall-run chinook salmon in the Lewis River are fall-run chinook salmon that returned to Salmon Creek (Figure 8). Salmon Creek is a low-gradient stream located 15 km upstream of the Lewis River. By itself, it may not have had sufficient habitat or the sustained water resources needed for an independent chinook salmon run, but could have clustered with the lower Lewis River and other smaller tributary or mainstem spawner aggregations. Late fall-run chinook salmon return to the North and East Forks Lewis River from August to October, and spawning extends from October to January. Evermann and Meek (1898) reported that chinook salmon were not seen in the Lewis River until after August 10 (the beginning of the closed fishing season). Marshall et al. (1995) report chinook salmon spawning as late as April. A late fall-run chinook salmon population also exists in the Sandy River (Oregon), and it is genetically similar to the Lewis River populations. In 1906, John Crawford visited the Lewis River to establish a new hatchery (WDFG 1907). He surveyed some 16 km upstream of Woodland, Washington, on September 3 and October 2 (peak spawning time for early fall-run chinook) and did not observe any chinook salmon. This would suggest that early fall-run chinook salmon might not be native to the Lewis River. An alternative explanation would be that river conditions were not conducive for surveying salmon in the lower river. Historically, spring-run chinook salmon were found in the North Fork Lewis River; however, access to historical habitat was eliminated following the construction of Merwin Dam (RKm 31) in 1931. Evermann and Meek (1897) reported that river conditions in the South Fork [East Fork] Lewis River were very different from the North Fork, and that only fall-run chinook salmon were present. WDFG (1913) reported that the majority of spring-run chinook salmon spawning occurred in tributaries to the Muddy Fork (also called “The Muddy”) of the Lewis River. Furthermore, there was little apparent spawning by fall-run chinook salmon above the hatchery location (Cedar Creek). In April 1926, WDF biologists surveyed the confluence of the Muddy Fork and North Fork Lewis River (WDFG 1928). They observed a “goodly number” of large steelhead spawning, in addition to spring “royal” chinook salmon. During the summers of 1926 and 1927, hatchery personnel returned to the site and were able to capture and spawn 48 and 72 female spring-run chinook salmon, respectively (273,000 and 407,050 eggs). There are no distinctive geographic features or major tributaries to suggest that more than one spring-run independent population existed in the Lewis River.

Fall-run chinook salmon were also native to the Lower Willamette River and its principal tributary, the Clackamas River. A tule fall-run existed in the lower Clackamas River until the 1930s, when poor water-quality conditions below Willamette Falls presented a barrier to returning fall-run chinook salmon (Parkhurst et al. 1950, Gleeson 1972). Stone (1878) reported intercepting salmon on 1 September 1877 just above Clear Creek (RKm 13), which “appeared to lack a week or two yet of being ripe.” Ripe fish were observed by Stone on 12 September 1877, with fish spawning above and below the Clear Creek site (Stone 1878). In 1902, following construction of a new weir across the river, 10,018,000 fall chinook salmon eggs were collected between 22 September and 8 November 1902 (Titcomb 1904). Egg take peaked on 15 October 1902, when 412,000 eggs were taken from 94 females. Dimick and Merryfield (1945) reported that these fish entered the Willamette River in September and October and spawned soon after entering the Clackamas River. Willis et al. (1960) speculated that fall-run chinook salmon spawned throughout the length of the Clackamas River and in nearly all accessible large tributaries. Fall-run chinook salmon from Lower Columbia River hatchery stocks were introduced into the Clackamas River from 1952 to 1981 to reestablish the run. Available data on fall-run chinook salmon in the Clackamas River were collected after reestablishment of the run and therefore were of little use in characterizing the historical run. Fall-run chinook salmon probably spawned in the lower reaches of the Clackamas River and other Willamette River tributaries below Willamette Falls (e.g., Johnson and Abernathy Creeks); they may have collectively comprised a single demographic population.

The Washougal River is 59 km long and drains a basin of 413 km^2. Salmon Falls (RKm 23) and Dougan Falls (RKm 34) may have been migration barriers to fall-run chinook salmon during low-water periods. Currently, the majority of chinook salmon spawn in a 6-km reach below Salmon Falls. Parkhurst et al. (1950) estimated that sufficient habitat existed below Salmon Falls for approximately 5,000 pairs of spawning salmon. The Washougal River branches into the Little Washougal and West Fork Washougal Rivers. However, neither tributary appears to be large enough to maintain independent populations of fall-run chinook salmon. Estimates of stray rates for fish released from the Washougal Hatchery are relatively high, with 27% of the recoveries in basins other than the Washougal (Figure 3). Given the large number of nonnative, fall-run chinook salmon released from the Washougal Hatchery, this may not be reflective of an historical homing fidelity. Despite the potential influence of hatchery transfers, fall-run chinook salmon sampled from the Washougal River were genetically different from fish from other basins. Furthermore, there is a general correlation between the geographic proximity of other basins and the genetic similarity among fish spawning in those basins. Historically, fall-run chinook salmon returning to the Washougal River may have constituted an independent population.

Fall- and spring-run chinook salmon are native to the Sandy River. As in the Lewis River, there are two types of fall-run chinook salmon: early-returning (tule) fall run and late-returning (bright) fall run. There is some debate about whether the tule fall-run fish are native to the basin or are descendants of hatchery releases from Lower Columbia River hatcheries. The late fall-run returns in September and October and spawns throughout December and January (Howell et al. 1985). There are reports of a winter run in the Sandy River, although Kostow (1995) suggests that they have been extirpated. It is also possible that the winter-run chinook salmon observed are the “tail-end” of the late-returning fall-run fish. Late-returning bright fish in the Lewis River have been observed spawning in April (Marshall et al. 1995). The run of late-returning fall-run fish may have historically exceeded 5,000 fish, compared with a recent survey (1997) that observed 1,125 adults (Whisler et al. 1998). There has been no artificial supplementation of the late-returning fall run. Genetic analysis indicates a strong association between Lewis and Sandy River late fall-run chinook salmon, and that these two populations form a cluster within the general group of other Lower Columbia River populations.

The Sandy River historically had a very large run of spring-run chinook salmon (Table 7). Run size for the Sandy River basin may have been in excess of 12,000 fish (Mattson 1955). Furthermore, Mattson (1955) estimated that the main stem and tributaries to the Sandy sustained large numbers of spring-run chinook salmon: Bull Run (5,000), Salmon River (3,000–4,000), and mainstem Sandy River (3,000–5,000). Oregon Department of Fisheries (ODF) described the Salmon River ". . . as a natural spawning stream from its confluence with the Sandy River to its source" (ODF 1903).

Genetic analysis of naturally spawning spring-run chinook salmon from the Sandy River suggested that the Sandy River population is genetically intermediate between Upper Willamette River populations and Lower Columbia River spring-run populations (NMFS 1998a). Furthermore, there was little genetic resemblance between the spring-run and bright fall-run fish in the Sandy River basin. In other Lower Columbia River and Coast Range basins, different run times in a basin tend to have evolved from a common source. The Sandy River basin is a deviation from this pattern, although it is probable that the existing spring run is not representative of the historical population. Microsatellite DNA data indicated that Sandy River spring-run chinook salmon are genetically distinguishable from the Clackamas Hatchery spring-run broodstock; however, the degree of differentiation was much less than that between spring runs in the Sandy and Yakima Rivers. Bentzen et al. (1998) concluded that although some interbreeding between the Upper Willamette River and Sandy River stocks has occurred, the Sandy River population still retains some of its original genetic characteristics. The NMFS Biological Review Team (BRT) concluded that although fish from the Upper Willamette River ESU have probably interbred with indigenous spring-run fish in the Sandy River, this population still retains some genetic characteristics from the native population (NMFS 1998a).

Information on life-history characteristics for spring-run fish from the Sandy River basin is limited. Hatchery collections of spring-run chinook salmon in the Salmon River began in 1896. Fish were observed spawning from mid July to early September, somewhat earlier than spring-run fish in the Cowlitz, Kalama, and Lewis Rivers. During the first year of operation (1896), the hatchery collected 2.6 million eggs (2.6 million eggs @ 5,000 eggs/female = 520 females [Craig and Suomela 1940]). In 1901, 413 chinook salmon females were spawned between 18 July and 3 September, with peak spawning occurring between 15 and 24 August 1901 (ODF 1903). Fall-run chinook salmon were also observed migrating as far as the hatchery weir on the Salmon River (Mattson 1955). A few fall-run chinook salmon were spawned between 1 and 16 October 1904 (ODF 1904).

A distinct population of spring-run chinook salmon certainly existed in the Sandy River basin. However, it is unclear whether spawning aggregations in the Salmon and Zigzag Rivers and Bull Run constituted independent populations or subpopulations. Late fall-run chinook salmon were temporally and geographically separated from spring-run fish. Since the late fall-run fish spawn in the lower portions of the Sandy River, it is unlikely that more than one population existed. There is some uncertainty regarding the historical existence of early fall-run chinook in the Sandy River basin.

Table 7. Chinook Salmon escapement estimates for Willamette River tributaries.[a]

Chinook Salmon	1936–46[b]	1947	1960[c]	1995[d]	1999[e]
Fall Run					
Clackamas River					
Spring Run					
Clackamas River	800		433	1,000	818
Willamette Falls		45,000			
Tualatin River (Gales Creek)	rpt				
Mollala River basin		550		Insignificant	
Mollala River	993	500			
Pudding River (Abiqua Creek)	200	50			
North Santiam River basin		2,830	2,100	<300	
Little North Santiam River	500	380	287		11 redds
North Santiam River	2200	2,450			176 redds
South Santiam River basin		1,300		Insignificant	
South Santiam River	392	1100			15 redds
Thomas and Crabtree Creek	155	200			
Calapooia River	20	30			
McKenzie River (above racks)	250	4,780		1,000	
Blue River	rpt				
Middle Fork Willamette River basin		2,550		Insignificant	
Middle Fork Willamette River	500	2,490			
Fall Creek	rpt	60			

[a] Numbers estimate naturally spawning escapement and may include hatchery-reared chinook salmon.
[b] Parkhurst et al. (1950)
[c] Willis et al. 1960
[d] Nicholas (1995)
[e] Schroeder et al. (2000)

Provisional historical demographically independent populations (Figures 7 and 9). Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are indicated by SASSI.

1. Upper Cowlitz River fall run [SASSI]
2. Lower Cowlitz River fall run [SASSI]
3. Coweeman River fall run [SASSI]
4. Toutle River fall run
   a. North Fork Toutle (Green) River fall run [SASSI]
   b. South Fork Toutle River fall run [SASSI]
5. Upper Cowlitz River spring run [SASSI]
6. Cispus River spring run
7. Tilton River spring run
8. Toutle River spring run

   a. North Fork Toutle (Green) River spring run
   b. South Fork Toutle River spring run
9. Kalama fall run [SASSI]
10. Kalama spring run [SASSI]
11. Salmon Creek/Lewis River fall run
   a. Salmon Creek fall run
   b. Lewis River early fall run
12. Lewis River late fall run (brights)
   a. East Fork Lewis River late fall run [SASSI]
   b. North Fork Lewis River late fall run [SASSI]
13. Lewis River spring run [SASSI]
14. Clackamas River fall run
15. Washougal River fall fun [SASSI]
16. Sandy River early fall run
   a. Bull Run early fall run
   b. Little Sandy River early fall run
   c. Mainstem Sandy River early fall run
   d. Sandy River late fall run
17. Sandy River spring run
   a. Bull Run spring run
   b. Salmon River spring run
   c. Mainstem Sandy River spring run

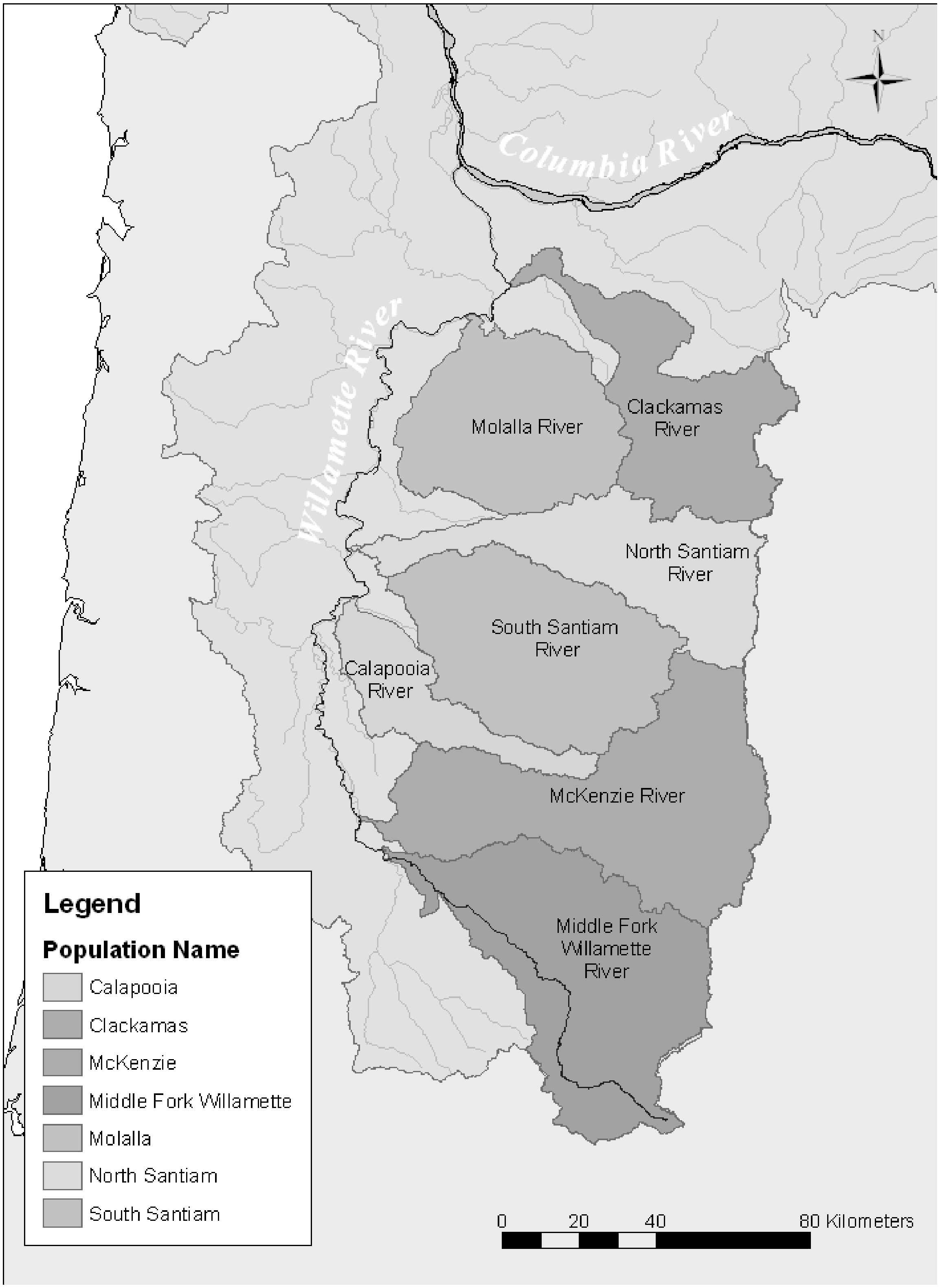

Figure 9. Historical, demographically independent spring-run chinook salmon populations in the Lower Columbia River ESU.

Columbia River Gorge Tributaries

This region extends from east of the Washougal River (RKm 194.9) to the White Salmon River (RKm 270) and from east of the Sandy River (RKm 193.6) to the Hood River (RKm 272). Rivers in this region of the ESU are heavily influenced by the steeply sloped sides of the Columbia Gorge. Most streams are relatively short. Impassable falls limit accessible habitat to less than a half mile on most small creeks. Larger rivers contain falls or a series of cascades in their lower reaches, which may present migrational barriers during all or most of the year. Physiographically, this region marks a transition between the high-rainfall areas of the Cascades and the drier areas to the east. Streamflows can be intermittent, especially during the summer.

Little information is available on the chinook salmon populations that inhabited this region. The majority of the river systems historically had little accessible habitat for chinook salmon. Much of what was historically available was inundated with the filling of the Bonneville Pool. Furthermore, after nearly a century of hatchery releases from a variety of sources into this region there may be little resemblance between fish currently utilizing many of the smaller creeks and those that were present historically. Shipherd Falls on the Wind River eliminated access to all but the lower 5 or 6 km of the river. Little is known of the fall run that utilized this area. U.S. Bureau of Fisheries hatchery records indicate that several million eggs were collected annually.

The Big White Salmon River (RKm 270) historically supported runs of both spring- and fall-run chinook salmon prior to the construction of Condit Dam (RKm 4) in 1913 (Fulton 1968). Evermann and Meek (1898) observed the beginning of the tribal fishery at the mouth of the Big White Salmon River. Hatchery records indicate that fall-run chinook salmon in the Little and Big White Salmon Rivers began spawning in early September, with peak egg takes in the later part of the month (21 September 1901); 12,840,700 eggs were collected in 1901 (Bowers, 1902). Historically, anadromous fish may have been able to ascend the Big White Salmon River as far as Trout Lake (RKm 45.4) (WDF 1951). Fall-run fish from the Big White Salmon River were used to establish the nearby Spring Creek National Fish Hatchery (NFH) broodstock in 1901 (Hymer et al. 1992). Although a number of different hatchery stocks were transferred to the Spring Creek NFH, this stock is still most closely affiliated with other Lower Columbia River fall-run populations (NMFS 1999a). The Spring Creek NFH stock of fall-run chinook salmon may still retain some historical genetic and life-history characteristics. The life-history characteristics of fall-run chinook salmon from the Spring Creek NFH do differ somewhat from other Lower Columbia River chinook salmon stocks. Furthermore, Spring Creek fall-run chinook salmon are somewhat distinct genetically from the cluster of Lower Columbia River populations. Historical information would indicate that all of the fall-run populations exhibited an early fall-run (tule) life history. Furthermore, existing late fall-run (bright) chinook salmon that spawn in this region appear to be the descendants of hatchery transfers from Upper Columbia River populations (Marshall et al. 1995).

Fall- and spring-run chinook salmon are native to the Hood River basin. Historically, large runs of chinook salmon existed in the Hood River basin. However, these runs have declined dramatically and, despite supplementation efforts, remain at critically low levels. Currently, fish from the Round Butte Hatchery (Deschutes River, Middle Columbia River

Spring-Run ESU) are being released into the Hood River basin as part of a reintroduction program. Fish from the Round Butte introductions and their descendants are not considered part of the Lower Columbia River ESU. Differences in water conditions in the East and West Forks of the Hood River may have provided a selective force for local adaptation, resulting in differences in spawning time and other factors. There is some question as to whether large numbers of spring-run chinook salmon were ever in the East Fork Hood River. Finally, differences in the timing and duration of peak flows, temperature, and headwater source between the Hood and White Salmon Rivers probably limited any substantial gene flow between the two rivers.

A number of smaller creeks in this region would have provided spawning habitat for fall-run chinook salmon from Columbia RKm 194 to 270. With the exception of the White Salmon and Hood Rivers, no single creek appears to provide enough habitat or the geographic separation necessary to support a DIP. Evermann and Meek (1898) observed "considerable numbers" of chinook in the Little White and Big White Salmon Rivers and Eagle and Tanner Creeks. No chinook salmon were observed at the mouth of the Big White Salmon River during a visit on 6 August 1896, but "quite a number" were observed during a return visit on 4 September 1896, at which time the Indians had already established fishing camps (Evermann and Meek 1898). A salmon culture station was established on the Little White Salmon River in 1896, and during its first year of full operation (1897) 12 million eggs were collected (12 million eggs @ 5,000 female = 2,400 females). Bowers (1902) reported that chinook salmon had entered Eagle and Tanner Creeks by 18 September 1901 and that enough fish were present to provide 2 to 3 million eggs (3 million eggs @ 5,000 eggs/female = 600 females). Furthermore, these spawning areas would be susceptible to flooding by the Columbia River, and many may have occasionally suffered short-term extinctions in the past. Evermann and Meek (1898) noted that Hamilton and Hardy Creeks, which normally contained a "good many salmon," were blocked to salmon by large quantities of wood. Also included are fall-run chinook salmon that may have historically spawned in the mainstem Columbia River. There is substantial evidence that chinook salmon historically (and presently) spawned in the mainstem Columbia River upstream of the site of the former Celilo Falls (Fulton 1968); however, little historical documentation exists for spawning populations in the main stem below the falls. Stone (1878) reported that the fall-run chinook salmon frequently spawned on the "sand beds" of the main river, within 80.5 km of the sea (approximately the limit of tidal influence in the Columbia River). Currently, there are spawning aggregations of early fall-run and late (bright) fall-run chinook salmon and chum salmon spawning below Bonneville Dam in the vicinity of Ives Island (Van Der Naald et al. 2001). Although the original source of these spawning fish is unclear, the ability of salmon to use mainstem habitat is well established. The late fall-run chinook appear to be most closely related to the upriver fall-run chinook populations (Upper Columbia River Summer and Fall-Run Chinook Salmon ESU), and are probably the progeny of hatchery strays (Marshall 1998, NMFS 1998a). Whether historical flow conditions in the main stem would have created similar situations is unknown. Additionally, if mainstem spawning was a significant component of the ESU, the relationship between fish spawning in the main stem and nearby tributaries would need to be established.

Provisional historical demographically independent populations (Figures 7 and 9). Letter designations indicate possible subpopulations designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are indicated by SASSI.

1. Lower Gorge tributary fall run
   a. Mainstem Columbia River
   b. Bridal Veil Creek
   c. Wahkeena Creek
   d. Hardy Creek
   e. Hamilton Creek
   f. Multnomah Creek
   g. Moffer Creek
   h. Tanner Creek
   i. Eagle Creek
   j. Rock Creek
2. Upper gorge tributaries fall-run
   a. Main stem
   b. Herman Creek
   c. Wind River [SASSI (Tule)]
   d. Gorton Creek
   e. Little White Salmon
   f. Viento Creek
   g. Lindsey Creek
   h. Phelps Creek
3. Big White Salmon River fall run [SASSI (Tule)]
4. Big White Salmon River spring run
5. Hood River fall run
6. Hood River spring run
   a. West Fork Hood River

2.3 Upper Willamette River Chinook Salmon ESU

Historical Independent Populations

Historically, the Willamette River basin provided sufficient spawning and rearing habitat for large numbers of spring-run chinook salmon. The predominant tributaries to the Willamette River that historically supported spring-run chinook salmon include the Molalla (RKm 58), Calapooia (RKm 192), Santiam (RKm 174), McKenzie (RKm 282), and Middle Fork Willamette Rivers (RKm 301)—all drain the Cascade Range to the east (Figure 10) (Mattson 1948, Nicholas 1995). There are no direct estimates of the size of chinook salmon runs in the Willamette River basin prior to the 1940s (Table 8). Wilkes (1845) estimated that the fishery at Willamette Falls could yield up to 800 barrels (122,000 kg) of salmon. Collins (1892) reported that 16,874 salmon (303,732) were shipped to Portland from the Willamette Falls fishery in April and May 1889. This estimate would not include tribal harvest or harvest that was shipped to markets other than

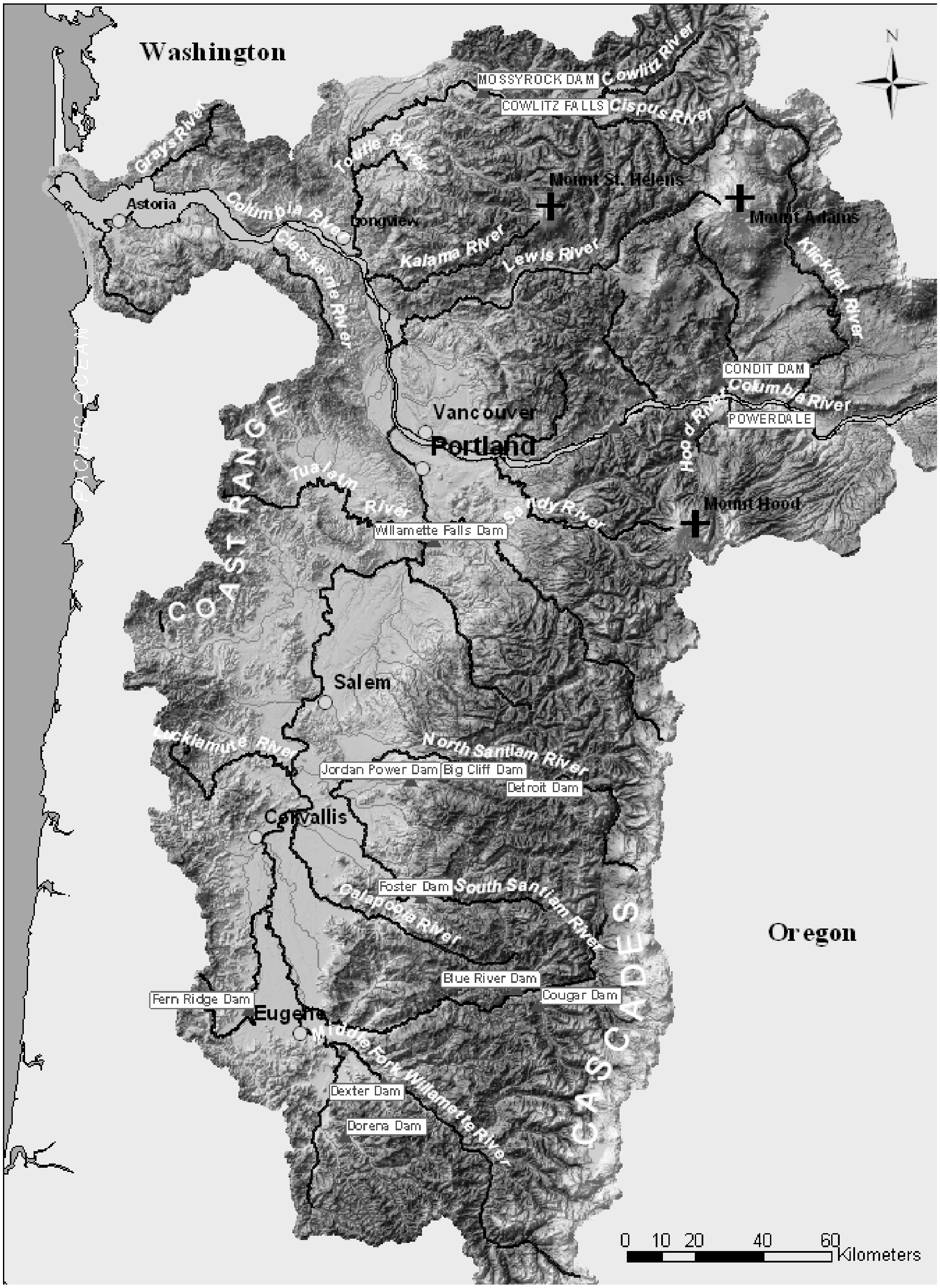

Figure 10. Willamette River basin.

Table 8. Age structure for Upper Willamette River spring-run chinook salmon.

Collection Site	Year	N	Age Designation[a]										Source
			2-year-old		3-year-old		4-year-old		5-year-old		6-year-old		
			2.0	2.1	3.0	3.1	4.0	4.1	5.0	5.1	6.0	6.1	
Lower Willamette River (sport fishery)	1946–51	590	—	—	0.017	0.015	0.082	0.148	0.055	0.554	0.001	0.101	Mattson 1963
Willamette River (sport fishery)	1970–77	8,936	—	—	—	0.024	—	0.484	—	0.476	—	0.016	Collins 1980
Willamette River (sport fishery)	1978–88	13,070	—	—	—	0.018	—	0.559	—	0.412	—	0.011	Bennett 1988
Willamette River (escapement[b])	1968–80	—		0.080	—	0.025	—	0.448	—	0.434	—	0.014	Bennett 1987
Clackamas River (sport fishery)	1979–88	3,033		—	—	0.045	—	0.668	—	0.285	—	0.003	Bennett 1988
Clackamas River (escapement)	1976–80	—		—	—	0.039	—	0.649	—	0.307	—	0.005	Bennett 1987
North Santiam River (spawning grounds)	1996–97	125[c]		0.000	—	0.000	—	0.414	—	0.555	—	0.020	Lindsay et al. 1997
McKenzie River (spawning grounds)	1996–97	63[d]		0.000	—	0.000	—	0.444	—	0.556	—	0.000	Lindsay et al. 1997

[a] Age information is based on scales recovered from returning adults. Age designation (X,Y): X is the age at maturation, and Y is the age at ocean emigration (0—subyearling, 1—yearling, 2—2-year-old smolt, etc.).
[b] Escapement estimates based on age data from hatchery and naturally spawning adults.
[c] Fish exhibiting subyearling emigration (N = 50) were classified as fall-run chinook salmon and not included, all but two were 3-year-old fish.
[d] Does not include marked hatchery fish.

Portland. McKernan and Mattson (1950) presented anecdotal information that the Native American fishery at Willamette Falls may have yielded 908,000 kg of salmon (454,000 fish @ 9.08 kg). Mattson (1948) estimated that the spring chinook salmon run in the 1920s may have been five times the existing run size of 55,000 fish (in 1947) or 275,000 fish, based on egg collections at salmon hatcheries. Additionally, much of the early historical information on salmon runs in the Upper Willamette River basin comes from state and federal hatchery reports.

Prior to the laddering of Willamette Falls, passage by returning adult salmonids (RKm 37) was only possible during winter and spring high-flow periods. The early run-timing of Willamette River spring-run chinook salmon relative to other Lower Columbia River spring-run populations is viewed as an adaptation to flow conditions at Willamette Falls. Chinook salmon begin appearing in the Lower Willamette River in February, but the majority of the run ascends Willamette Falls in April and May, with a peak in mid May. Wilkes (1845) reported that the salmon run over the falls peaked in late May. Low flows during the summer and autumn months prevented fall-run salmon from accessing the Upper Willamette River basin. Since the Willamette Valley was not glaciated during the last epoch (McPhail and Lindsey 1970), the reproductive isolation provided by the falls probably has been uninterrupted for a considerable time. Willamette Falls may have been formed by the receding floodwaters of the Bretz Floods (12,000–15,000 years before present) (Nigro 2001). This isolation has provided the potential for significant local adaptation relative to other Columbia River populations.

Mattson (1963) discussed the existence of a late spring-run chinook salmon that ascended the falls in June. These fish were apparently much larger (11.4–13.6 kg) and older (presumably 6-year-olds) than the earlier part of the run. Furthermore, Mattson (1963) speculated that this portion of the run "intermingled" with the earlier-run fish on the spawning ground and did not represent a distinct run. The disappearance of the June run in the 1920s and 1930s was associated with the dramatic decline in water quality in the Lower Willamette River. Similarly, the extirpation of the fall-run in the Clackamas River during this time period was associated with pollution in the Lower Willamette River. Currently, the migration of spring-run chinook salmon over Willamette Falls extends into July and August (overlapping with the beginning of the introduced fall run of chinook salmon); however, present-day salmon ascend the falls via a fish ladder. Historically, passage over the falls may have been marginal in June, due to diminishing flows, and only larger fish would have been able to ascend.

The juvenile life-history characteristics of Upper Willamette River spring-run salmon appear to be highly variable. Mattson (1962) determined that fry emerge from February to March, although sometimes as late as June. Emigration out of the tributaries and into the mainstem Willamette River occurred in three distinct phases: from late winter to early spring as fry, fall- to early-winter (October through December) migration as fingerlings, and late winter to spring (February through early May) as yearlings. Dimick and Merryfield (1945) reported that large numbers of fry were observed in the mainstem Willamette River from February through early April. It is possible that emigration also occurred during the summer, but pollution (specifically eutrophication and hypoxia) in the Lower Willamette River from the 1920s to 1940s may have extirpated that life-history form. In general, chinook salmon returning to the Upper Willamette River basin currently mature at 4 and 5 years old (Table 4).

Spring-run chinook salmon populations in the Upper Willamette River basin and Clackamas River have been strongly influenced by extensive hatchery transfers of fish throughout the ESU for nearly 100 years (Table A.2). Much of the genetic diversity that existed between populations has been homogenized. Historical spawning times can be inferred from hatchery records, but much of the life-history data that was collected in the 1940s was already biased by hatchery operations. Ecologically, all major spring-run-bearing waters drain the Cascades to the east and share the same Level IV EPA ecoregions. Historical population distribution for the spring-run chinook salmon in this region was determined using biogeographic information, life-history information, and historical estimates of abundance and habitat productivity.

The Willamette River basin covers approximately 29,800 km^2 (11,500 mi^2). Major tributaries include the Clackamas, Molalla, Santiam, Calapooia,[2] and McKenzie, and Middle Fork Rivers (Cascade Range); and Tualatin, Yamhill, Luckiamute, Marys, and Long Tom Rivers (Coast Range) (Figure 10, Table 9). The basin is composed of 30% valley floor (below 154 m) and 60% Cascade Mountain foothills and slopes (up to 3,000 m); the remaining area consists of part of the Coast Range (up to 1,200 m). The Upper Willamette River ESU is biogeographically different from many other Pacific Northwest ESUs in that it was not glaciated during the late Pleistocene. Climatically, a rain shadow effect, similar to the one influencing the Puget Lowland, limits rainfall to about 120 cm per year, with minimum rainfalls in July, August, and September. River flows peak in December and January and are sustained at 50% of peak flow for 6 or 7 months of the year. Low flows occur in August and September, although the volume is generally 20% of the peak flow. Summer flows in Coast Range tributaries are especially low due to the general absence of any substantial snowpack and may never have historically sustained chinook salmon populations (Dimick and Merryfield 1945).

The Clackamas River historically contained spring-run chinook salmon, but relatively little information about that native run exists. ODF (1903) reported that, "the Clackamas River is, as has always been conceded, the greatest salmon breeding stream of water that our state affords . . ." Barin (1886) observed a run of chinook salmon that "commences in March or April, sometimes even in February." Smith (1895) estimated that 140 tons of chinook were caught in the Clackamas River between April and May 1893 (127,270 kg @ 10.34 kg = 12,302 fish). Abernethy (1886) reported that some 3,500 chinook salmon were caught in the Clackamas River between 10 April and 10 July 1885; however, he noted that no fishing was done in the river in March when the run was apparently very large. There are various accounts of when the spring-run adults spawned in the Clackamas River. Barin (1886) mentioned fish spawning in September, although his observations were in the vicinity of Clear Creek (RKm 13), and the most likely observed fall-run fish spawning. The U.S. Fish Commission operated two hatcheries, one on the upper Clackamas River, Oak Grove Fork (RKm 95), and the other on the lower

[2] The Calapooia River (Willamette River basin) is also spelled Calapooya in a number of historical documents, it should not be confused with the Calapooya River in the Umpqua River basin.

Table 9. Willamette River tributary basin size (km^2) and distance (RKm) from river mouth.

	RKm[a]	Basin (km^2)	USGS Gauge
Willamette River (mouth of Columbia River to Willamette River)	162.5		
Clackamas River	39.9	2418	14211000
Collawash River		>368	14208300
Oakgrove Fork		320	14209000
Molalla River	57.9	2273	
Molalla River	+0.0[b]	901	14200000
Pudding River	+1.2	1372	14202000
Santiam River	173.6	4730	
North Santiam River	173.6+18.8	1905	14184100
Breitenbush River	+91.7	280	14179000
North Santiam above Detroit Dam	+91.7	558	14178000
Little North Santiam River	+45.1	290	14182500
South Santiam River	173.6+18.8	>1657	
South Santiam River (above Foster)	173.6+18.8	449	14185000
Middle Santiam River	+67.6	741	14186000
Quartzville Creek	+79.7	256	14185900
Calapooia River	192.3	968	14173500
McKenzie River	281.6	3366	14159000
Mohawk Creek	+16.1	458	14165000
Blue River	+88.5	277	14162200
South Fork McKenzie River	+93.3	>539	14159500
Horse Creek	+103.0	386	14159100
Middle Fork Willamette River	304.1	3495	14152000
Fall Creek	+17.7	>481	14151000
North Fork Middle Fork	+57.9	637	14147500
Salt Creek	+66.0	293	14146500
Middle Fork (above Oakridge)		668	14144800

[a] Distances (Rkm) are given from the mouth of the Willamette River to the mouth of the tributary, unless otherwise noted.

[b] Distances with a "+" sign indicate the distance from the mouth of a tributary to its secondary tributary.

Clackamas River (RKm 6). Eggs were collected at the upper Clackamas Station beginning 17 July and ending 26 August, with some 5 million eggs collected (Ravenel 1898). At the lower Clackamas Station, ripe fish were not collected until 15 September and by 7 November 1897 only spawned-out fish were collected (Ravenel 1898). Murtagh et al. (1992) suggested that fish collected at the lower Clackamas Station were probably fall-run (tule) chinook salmon. The State of Oregon took over operation of the Upper Clackamas station at the turn of the century and spawned 1,121 female spring-run chinook salmon between 12 July and 4 September 1901, with peak spawning occurring between 2 and 16 August 1901 (ODF 1903). Currently, naturally spawning spring-run chinook salmon spawn from September to October (Olsen et al. 1992).

Historically, the majority of spring-run chinook salmon production probably came from the mainstem Clackamas River and Collawash Fork (Willis et al. 1960). Historically, the Warm Springs Tribe considered the Big Bottom area of the Collawash River to contain the choicest salmon spawning grounds. Only the lower 3.8 km of the North Fork Clackamas River, 1.0 km of South Fork Clackamas River, and 4.8 km of the Oak Grove Fork were accessible (Willis et al. 1960).

Genetic analysis by NMFS of naturally produced fish from the upper Clackamas River indicated that this stock was similar to hatchery stocks from the Upper Willamette River basin (Myers et al. 1998, see Appendix B). This finding agrees with an earlier comparison of naturally produced fish from the Collawash River (a tributary to the upper Clackamas River) and Upper Willamette River hatchery stocks (Schreck et al. 1986). Fish introduced from the Upper Willamette River have significantly introgressed into, if not overwhelmed, spring-run fish native to the Clackamas River basin and obscured any genetic differences that existed prior to hatchery transfers.

ODFW (1998) suggested that spring-run fish returning to the Upper Willamette River basin historically may have strayed into the Clackamas River when conditions at Willamette Falls prevented upstream passage. Therefore, similarities between Clackamas River and Upper Willamette River spring-run fish may reflect an historical/evolutionary association between the two groups, rather than a recent artifact of human intervention. Recoveries of returning adults released from the Clackamas River have occurred at a number of sites outside the Clackamas River. This may reflect the introgression of other Upper Willamette River spring-run hatchery stocks into the Clackamas Hatchery, the relative downriver location of the releases (relative to historical spawning sites), or other aspects of the propagation of these fish prior to release.

The Molalla River is located just above Willamette Falls, 50 km from the mouth of the Willamette River (Figure 10). By 1903, the abundance of chinook salmon in the Molalla River had already decreased dramatically (ODF 1903). Surveys in 1940 and 1941 recorded 882 and 993 spring-run chinook salmon, respectively (Parkhurst et al. 1950). Craig and Townsend (1946) collected a number of juveniles moving downstream from the Molalla River. Mattson (1948) estimated the run size to be 500 in 1947 (Table 8). Surveys in 1940 observed 250 spring-run chinook salmon in Abiqua Creek (Pudding River) (Figure 9) (Parkhurst et al. 1950). Parkhurst et al. 1950 estimated that there was sufficient habitat in the Molalla to accommodate at least 5,000 salmon adults (Figure 10). Dimick and Merryfield (1945) reported that spring-run chinook salmon spawn from early September into October, but some spawning may take place in the Clackamas and Mollala Rivers as early as late July.

Spring-run chinook salmon are native to the Santiam River basin. The Oregon Fish Commission (OFC) attempted egg-taking operations in 1906 and 1909, but it was not until 1911 that adults were captured for spawning (Wallis 1963a). The hatchery rack was located near Jefferson, below the confluence of the North Santiam and Breitenbush Rivers and below most of the natural-spawning areas (except for the Little North Santiam River). It was general hatchery policy to capture as much broodstock as possible. In 1911, 1.5 million eggs were collected. The largest egg collection was 13.2 million in 1934. This would correspond to 4,125 females @ 3,200 eggs/female (Wallis 1963a). The estimated run size for the entire North Santiam River basin was 2,830 in 1947 (Mattson 1948). Within the North Santiam River, the principal spawning areas were located from 2 km above the town of Stayton up through the Breitenbush

River (Mattson 1948). Between 1911 and 1960, the overwhelming majority of hatchery fish released into the North Santiam basin have come from adults captured in the watershed. Other introductions have come from the South Santiam, McKenzie, and Willamette River hatcheries (Wallis 1963c). Parkhurst et al. (1950) estimated that there was sufficient habitat in the North Santiam to accommodate at least 30,000 salmon adults.

The earliest recorded observation of spawning occurred at the North Fork Santiam rack on 22 August 1947, which is earlier than was observed at the McKenzie or Middle Willamette River hatchery racks (Mattson 1948). These spawning differences were ascribed to lower temperatures at the Santiam racks relative to the other sites. During spawner surveys in 1998, no redds were observed prior to 1 September 1998 (Lindsay et al. 1999). In 1998, 115 redds were observed in the North Santiam River, with an additional 39 redds in the Little North Santiam River.

Historically, juvenile spring-run chinook salmon began downstream emigration at various ages and sizes. Studies by Craig and Townsend (1946) in 1941 indicated that juveniles in the North Santiam River began moving downstream in March, soon after emergence. There appeared to be more or less continuous emigration through summer and autumn, with no previous-year juveniles present in tributaries by March of the following year. Analysis of scales from adults returning to the North Santiam indicated that only 10% (6 out of 65) had entered the ocean as subyearlings, suggesting that a large proportion of juveniles observed emigrating downstream overwintered in the mainstem Willamette or Columbia Rivers (Mattson 1963).

Genetic analysis of naturally produced juveniles from the North Santiam River indicated that the naturally produced fish were most closely related to, although still significantly distinct from, other naturally and hatchery-produced spring-run chinook from the Upper Willamette and Clackamas Rivers (NMFS 1998a, see Appendix B). Recoveries of returning fish occur primarily in the North Santiam River (95%), and there are few recoveries outside the Upper Willamette River basin (Figure 3).

Spring-run chinook salmon are native to the South Santiam River. Egg collection activities began in 1923 with a weir placed across the river near the town of Foster (Wallis 1961), well below the natural holding and spawning areas (Mattson 1948). River conditions did not allow the weir to be put in place until June, and it is possible that a considerable portion of the run had already moved upstream at that time. Furthermore, Wallis (1961) noted that the inefficient operation of the weir often allowed a number of adults to move upstream. Additionally, in some years the weir was not put in place at all. Escapement to the South Santiam River was estimated to be 1,300 in 1947 (Mattson 1948). Spawning was also reported by Mattson (1948) in Thomas Creek (above the Jordan Dam), and Crabtree Creek (above the State Game hatchery). Chinook salmon were observed as far upstream as Tamolitsh Falls (Craig and Townsend 1946, Mattson 1948). Wallis (1961) estimated that because of poor husbandry practices, releases from the South Santiam Hatchery did not significantly contribute to escapements. In fact, the hatchery may have been mining returning naturally produced adults for broodstock each year.

There is little historical information on the life-history characteristics of spring-run chinook salmon from the South Santiam River. Juvenile studies by Craig and Townsend (1946) indicated more or less continuous downstream migration of fish from the time of emergence through the winter. Other life-history characteristics are assumed to be similar to other populations in the Upper Willamette River basin. In 1976, Foster Dam (RKm 77) blocked access to nearly all historical spring-run chinook salmon spawning areas (Middle Santiam River, Quartzville Creek, and South Santiam River [Mattson 1948]).

A population of spring-run chinook salmon historically existed in the Calapooia River. Parkhurst et al. (1950) estimated suitable habitat for 9,000 fish (Figure 10), although Willis et al. (1960) estimated that the run at only 100 to 500 fish. Parkhurst et al. (1950) reported the 1941 run was approximately 200 adults; Mattson (1948) estimated the run at 30 in 1947. More recently, Nicholas (1995) considered the run extinct, with limited future production potential.

Spring-run chinook salmon are native to the McKenzie River basin. Historical natural-spawning areas included the mainstem McKenzie River, Smith River, Lost Creek, Horse Creek, South Fork, Blue River, and Gate Creek (Figure 9) (Mattson 1948, Parkhurst et al. 1950). ODF (1903) surveyed much of the M'Kenzie [sic] River to site a hatchery and collection rack. The report states, "It has been generally reported by settlers and those living along the river that salmon can be seen spawning during the months of August and September all along the river, but principally from Leaburg post office up to its source." Currently, the McKenzie River is the only basin above Willamette Falls to sustain any level of natural production. The McKenzie River Hatchery (RKm 52), which began egg-taking operations in 1902, obtained a peak collection of 25.1 million eggs in 1935 (Wallis 1961), from an estimated 7,844 females (@ 3,200 eggs per female). Mattson (1948) estimated 4,780 adults returned to the McKenzie River, which constituted 40% of the entire run above the Willamette Falls. Parkhurst et al. (1950) estimated there was suitable habitat for 80,000 fish in the entire McKenzie River basin. In 1958, the OFC survey observed 3,198 chinook salmon redds in the McKenzie River basin (Willis et al. 1960).

The construction of the Cougar Mountain Dam (RKm 101) in 1963 eliminated 56 km of spawning habitat on the South Fork McKenzie River. The South Fork was generally believed to be the best salmon-producing stream in the McKenzie drainage (USFWS 1948). Mattson (1948) reported that the principal spawning area in the South Fork McKenzie River was located 7 to 13 km from the mouth. In 1956, 805 chinook salmon redds were observed in the South Fork McKenzie River (Willis et al. 1960). The Blue River Dam (1968, RKm 88) prevented access to an additional 32 km of spawning habitat.

McKenzie River spring-run chinook salmon historically began spawning in mid-August through mid-October, with peak spawning occurring around 10 September (Willis et al. 1995). In 1902, the Oregon State Hatchery spawned 138 females between 19 August and 20 October, peaking in mid-September (ODF 1903). Mattson (1963) reported that a female was spawned as early as 14 August 1935 at the McKenzie River Hatchery. Furthermore, stream surveys in the McKenzie River observed redds as early as 15 August and as late as 20 October. Juveniles are observed moving downstream beginning in February and continuing throughout the year (Craig and Townsend 1946, Cramer et al. 1996). Analysis of scales from adults returning to the McKenzie River in 1947 indicated that 13.5% (8 out of 59) entered the ocean as subyearlings.

Genetic analysis of juveniles from the McKenzie River indicated that the naturally produced fish were most closely related to other natural and hatchery-produced spring-run chinook from the Upper Willamette and Clackamas Rivers (NMFS 1998a, see Appendix B).

There is very little apparent straying, based on the recoveries of CWT fish released from the McKenzie River Hatchery, with more than 97% of all freshwater recoveries occurring in the McKenzie River basin.

The Middle Fork Willamette River also supported historical populations of spring-run chinook salmon. There were spawning aggregations in Fall Creek, Salmon Creek, North Fork Middle Willamette River, mainstem Middle Fork Willamette River, and Salt Creek (Mattson 1948, Parkhurst et al. 1950). Based on records (1909–present) from the Willamette River Hatchery (Dexter Ponds), the largest egg collection, 11,389,000 in 1918 (Wallis 1962), would correspond to 3,559 females (@ 3,200 eggs/female). Mattson (1948) estimated the run size to the Middle Fork Willamette River to be 2,550 in 1947.

The construction of Lookout Point and Dexter Dams (RKm 328) in 1953 eliminated access to almost 345 km of salmon habitat (Cramer et al. 1996). Only the Fall Creek basin remains accessible to anadromous salmonids. Although Parkhurst et al. (1950) estimated the Fall Creek basin could support several thousand salmon, by 1938 the run had already been severely depleted. In 1947, the run had dwindled to an estimated 60 fish (Mattson 1948). Construction of the Fall Creek Dam (1965) included fish passage facilities, but efficient passage is only possible during high-flow years (Connolly et al. 1992). Nicholas (1995) concluded that the native spring-run population was extinct, although some natural production, presumably by hatchery-origin adults, may still occur.

Studies of juvenile emigration from the Middle Fork Willamette River in 1941 indicated that downstream migration occurred on a more or less continuous basis from March through autumn (Craig and Townsend 1946). Genetic analysis of naturally produced juveniles from the Dexter Ponds trap indicated that the fish were most closely related to other naturally and hatchery-produced spring-run chinook from the Upper Willamette and Clackamas Rivers (NMFS 1998a, see Appendix B).

Dimick and Merryfield (1945) reported occasional sightings of adult chinook salmon in westside tributaries (draining the Coast Range), however they concluded that these fish were accidental strays and that several years of extensive sampling had failed to observe any young salmon. Parkhurst et al. (1950) also failed to observe chinook salmon in any tributaries draining the Coast Range during their surveys in the 1930s and 1940s. Reports of chinook salmon in westside tributaries have continued to the present; however it is unlikely the abundance of spawners in any of these tributaries constitutes a DIP.

There is little life-history or genetic information for Willamette River spring-run chinook salmon populations that is not potentially influenced by artificial propagation programs, migration barriers, and habitat destruction or degradation. In a comparison of the size and age structure of spring-run chinook salmon returning to hatcheries in the Upper Willamette River, Mattson (1963) observed a larger proportion of 3-year-old jacks returning to the Willamette Hatchery: 19.3% (Middle Fork Willamette River), relative to the McKenzie Station (7.6%) or North Santiam Hatchery (10.6%). Mattson (1963) noted some discrepancy in the identification of jacks at the different hatcheries. Furthermore, differences in hatchery-rearing protocols could easily have affected the age structure of returning fish. There was no apparent difference in the body size of fish returning to the McKenzie or North Santiam Rivers, although the sample sizes were rather small (18 to 33 fish) (Mattson 1963).

The size of the Willamette River and its constituent tributaries, combined with the preference of spring-run chinook salmon to spawn in headwater areas, provides a strong geographic mechanism for reproductive and demographic isolation. Furthermore, current straying rates for hatchery-reared Willamette River chinook salmon indicate a high degree of homing fidelity. Therefore, it is possible that there were a number of historically independent demographic populations in this ESU.

Provisional historical demographically independent populations (Figure 11). Letter designations indicate possible subpopulation designations within the numbered populations.

1. Clackamas River
    a. Collawash River
    b. Upper Clackamas River
2. Molalla River
    a. Molalla River
    b. Pudding River
3. North Santiam River
    a. Breitenbush River
    b. Marion Fork
    c. Little North Santiam River
    d. Mainstem North Santiam River
4. South Santiam River
    a. South Santiam River
    b. Middle Santiam River
    c. Quartzville Creek
5. Calapooia River
6. McKenzie River
    a. Mohawk Creek
    b. Blue River
    c. South Fork McKenzie River
    d. Horse Creek
7. Middle Fork Willamette River
    a. Fall Creek
    b. North Fork Middle Fork
    c. Salt Creek
    d. Mainstem Middle Fork Willamette River

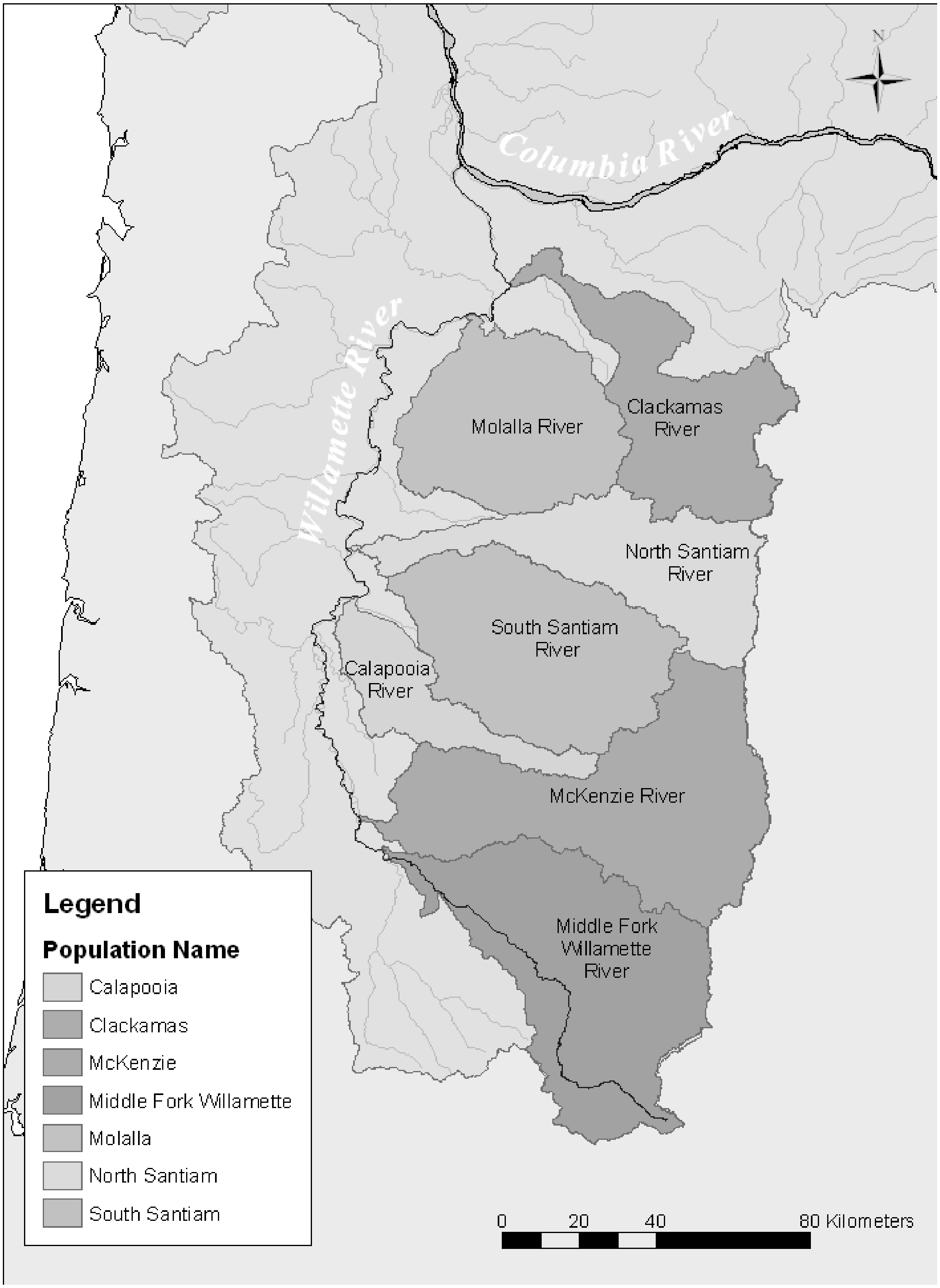

Figure 11. Historical demographically independent populations of spring-run chinook in the Upper Willamette River ESU.

3. STEELHEAD (*ONCORHYNCHUS MYKISS*)

3.1 Life History

The life history of steelhead trout is highly variable. In the Lower Columbia River, most wild steelhead are 4 to 6 years of age at first spawning, 50 to 91 cm in length, and 2 to 8 kg in weight (Table 10). However, they can attain ages of 9 years and reach lengths of over 100 cm (12 kg) (Busby et al. 1996). Steelhead may spawn more than once, although the frequency of repeat spawners is relatively low. At least 9 different initial and 13 different repeat age classes have been identified for Lower Columbia River steelhead (Leider et al. 1986).

Two distinct races of steelhead were historically, and are presently, found in the Lower Columbia River: summer run and winter run. However, while both summer- and winter-run life-history types currently exist in the Upper Willamette River, only winter steelhead were present historically. The life histories of summer- and winter-run steelhead have considerable overlap. Both rear in freshwater for 1 to 4 years prior to smolting, select similar habitat for freshwater rearing, and spend 1 to 4 years in the ocean. However, substantial differences separate these

Table 10. Most common (primary) and second most common (secondary) age-structure patterns reported for steelhead populations in the Lower Columbia River and Upper Willamette River ESUs.

Population[a]	Run Type[b]	Age Structure (frequency)[c]				Sample	Reference
		Primary		Secondary			
Toutle River	O	2/2	(0.73)	2/3	(0.11)	37	Howell et al. 1985
Cowlitz River	O	2/2	(0.55)	2/3	(0.34)	56	Howell et al. 1985
Kalama River	O	2/2	(0.65)	2/3	(0.18)	1363	Howell et al. 1985
Kalama River	S	2/2	(0.67)	2/1	(0.17)	909	Howell et al. 1985
Willamette River	O	2/2	(0.92)	3/2	(0.08)	141	Howell et al. 1985
Clackamas River	O	4	(0.71)	5	(0.26)	na	Chilcote 1997
Sandy River	O	4	(0.71)	5	(0.26)	na	Chilcote 1997
Washougal River	S	2/2	(0.71)	2/1 & 2/3[d]	(0.14)	7	Howell et al. 1985
Wind River	S	2/2	(0.58)	2/3	(0.26)	19	Howell et al. 1985
Hood River	O	2/2	(0.58)	2/3	(0.19)	1018	Olsen et al. 1994
Hood River	S	2/2	(0.65)	3/2	(0.16)	467	Olsen et al. 1994
Klickitat River	S	2/2	(0.75)	2/1	(0.14)	148	Howell et al. 1985

[a] Populations are generally arranged from north to south.
[b] O = ocean maturing (winter run); S = stream maturing (summer run).
[c] The frequency of occurrence in the sample is shown in parentheses. Format used is freshwater age/ocean age at first spawning migration.
[d] Both age structures are equally common.
Source: From Busby et al. 1996, Chilcote 1997.

races at the time of adult freshwater entry, degree of sexual maturity at entry, spawning time, and frequency of repeat spawning.

Each year, the majority of naturally produced Lower Columbia River summer steelhead enter freshwater between May and October. These fish are sexually immature upon return to their natal streams. Fish spawn between January and June, with peak spawning between late February and early April (Leider et al. 1986, Busby et al. 1996). The repeat spawner rate is about 5.9% for wild summer steelhead (Hulett et al. 1993). In contrast, wild winter steelhead enter freshwater as sexually mature fish between December and May. Spawning occurs between February and June, with peak spawning time in late April and early May, almost 2 months later than wild summer steelhead (Leider et al. 1986, Busby et al. 1996). The repeat spawner rate for wild winter steelhead is 8.1% on the Kalama River, double that of wild summer steelhead (Hulett et al. 1993).

On average, there is a 2-month difference in peak spawning time between winter- and summer-run steelhead, although there is probably some overlap in the spawning distribution. (Busby et al. 1996). Furthermore, within the same watershed, winter and summer steelhead spawn in geographically distinct areas. Summer steelhead populations occur above barrier falls, which are generally impassable during the winter-run migration. Watersheds that historically had summer steelhead populations include the Kalama, North Fork Lewis, East Fork Lewis, Washougal, Wind, and Hood Rivers (Figure 2). The long duration of prespawning holding in freshwater may result in a high mortality, putting summer steelhead at a competitive disadvantage relative to winter steelhead. Therefore, in basins where both winter and summer-run steelhead are present, the summer steelhead life-history strategy appears only able to persist above barrier falls. Furthermore, because summer-run steelhead return to specific areas above barrier falls, they require a higher homing fidelity relative to chinook salmon or winter-run steelhead. Both winter- and summer-run steelhead prefer to spawn in smaller streams and side channels as compared to chinook salmon. This may result in a finer level of population structuring than occurs in chinook salmon. Additionally, utilizing smaller stream systems provides more spawning and rearing habitat for steelhead than may be available to chinook salmon. These factors suggest that the minimum basin size for steelhead may be smaller than the 250 km^2 derived for chinook salmon.

Phelps et al. (1997) examined the relationship between coastal summer and winter steelhead populations. In their genetic analysis, the summer and winter runs within the GDU were more closely related to each other than to collections from other GDUs, indicating that the run-timing characteristics evolved from a single evolutionary line within basins. However, significant differences in allele frequencies indicate that summer and winter runs in the same basin should be treated as separate populations. Recent work by Sharpe et al. (2000) detected significant genetic differences between Kalama River wild winter and summer steelhead, confirming the earlier work by Phelps et al. (1997).

Parkinson (1984) indicated that significant differences in genetic variation were observed among steelhead populations in adjacent streams, and this pattern of variation supports the view that steelhead are subdivided into a large number of semi-isolated populations. Analysis of the historical distribution of summer steelhead in the Lower Columbia River indicate that self-sustaining populations were present in relatively small drainage areas, such as the East Fork Lewis River above Horseshoe Falls (130 km^2). The East Fork Lewis River summer steelhead population is considered reproductively isolated from adjacent spawning populations in the Kalama River, North Fork Lewis River, and Washougal River (93.3 km, 109.4 km, and 138.4 km distant, respectively). It is unclear whether the larger basins, such as the Kalama, Wind, Washougal, and North Fork Lewis Rivers, supported more than one summer steelhead population. However, the East Fork Lewis River population is an indication that steelhead populations may persist in drainages as small as 130 km^2, half the minimum drainage area estimated for chinook salmon.

In identifying historical independent populations of steelhead salmon, the Lower Columbia River was divided into two geographic/ecological subregions: western Cascade Range and Columbia Gorge. The Lower Columbia River Steelhead ESU does not include the coastal areas of the Columbia River basin or the White Salmon River (Busby et al. 1996).

3.2 Lower Columbia River Steelhead ESU

Historical Independent Populations

Western Cascade Range Tributaries

Rivers in this region are larger than those found in the coastal region, with headwaters high in the Cascade Mountains. Many rivers are over 100 km long, with basins covering 1,000 km^2 or more. Snowmelt and groundwater sources are substantial and maintain good year-round flows and cool water temperatures. River flows peak in December or January and sustain at least 50% of peak for 6 months or more. The lower reaches of these rivers are relatively low gradient, but high-gradient sections are common in the mid and upper reaches.

This region extends from the Cowlitz River (RKm 106.2) to the Washougal River (RKm 194.9) on the Washington State side of the Columbia River and from the Willamette River (RKm 162.5) to the Sandy River (RKm 193.6) on the Oregon side. There appear to have been several major populations in this region, based on historical population abundance estimates and watershed size (Figure 1).

In general, little life-history information is available to distinguish steelhead populations, other than traits associated with winter and summer run-timing. Historical references to steelhead rarely made any distinction between summer and winter runs. The majority of steelhead are believed to have emigrated to saltwater as 2-year-old fish and returned to spawn as 4-year-old adults (e.g., having spent 2 years in the ocean). The ability of steelhead to ascend waterfalls and cascades has given them a wide distribution in many basins that are not readily accessible to other anadromous salmonids. There is a considerable genetics database for Lower Columbia River steelhead. However, a number of the naturally spawning and hatchery populations have been strongly influenced by transfers of fish from Puget Sound hatcheries (Puget Sound ESU), the Big Creek Hatchery (Southwest Washington ESU), and the Skamania Hatchery (Phelps et al. 1995).

Historically, there were at least 20,000 winter steelhead in the Cowlitz River (Hymer et al. 1992). The Cowlitz River basin covers approximately 6,000 km^2 and drains the slopes of Mt. Rainier, Mount St. Helens, and Mt. Adams (Table 1). The construction of Mossyrock and Mayfield Dams eliminated approximately 50% of the historical spawning habitat. WDF and WDG (1946) estimated the steelhead spawning escapement above the Mayfield Dam site at 11,000 fish (including harvest, this represented a total run of 22,000 fish). The eruption of Mount St. Helens in 1980 dramatically altered habitat in the Toutle River basin. However, naturally spawning populations still exist in the lower mainstem Cowlitz, Coweeman, and Toutle River basins. Based on the observed distribution of steelhead throughout the basin in the 1930s and 1940s (Table 2), it was concluded that suitable habitat was available (Table 1) and geographically arranged for a number of large independent populations of steelhead to have historically existed in the Cowlitz River basin.

Analysis of allozyme variation indicates that there are significant differences between late-run, native, winter-run steelhead in the mainstem Cowlitz, Green (North Fork Toutle), and South Fork Toutle Rivers (Phelps et al. 1997, see Appendix B). The mainstem Cowlitz River population may represent the homogenized genetic resources of all winter-run populations from the upper and lower Cowlitz, Cispus, and Tilton basins. Furthermore, samples from the Green River (Cowlitz River basin) steelhead clustered with hatchery samples known to be strongly influenced by introductions of Chambers Creek (Puget Sound) winter-run steelhead. Therefore, the Green River winter steelhead may not be representative of the historical population.

Summer and winter steelhead are native to the Kalama River basin. A waterfall (Lower Kalama Falls) at RKm 17.7 may have historically been accessible only during periods of low flow. A set of high falls at RKm 56.3 (e.g., Kalama Falls) marks the limit of upstream migration.[3] The entire Kalama River basin covers 523 km^2, with 226 km^2 of basin lying between Lower Kalama Falls and Kalama Falls. In the absence of major geographic features, such as tributaries and others, it was estimated that only one independent population of summer and winter steelhead existed in the Kalama River basin.

Both summer and winter steelhead are native to the Lewis River basin. A large part of the historical spawning habitat on the North Fork Lewis River was blocked following construction of the Ariel-Merwin (1931), Yale (1953), and Swift (1958) Dams. For a number of years prior to the construction of the Yale Dam, adult steelhead were passed over the Ariel Dam to spawn (Parkhurst et al. 1950). Currently, some spawning takes place in the main stem below the dam and in Cedar Creek, a tributary to the Lewis River below the dam (Howell et al. 1985). Smoker et al. (1951) estimated that, prior to construction of the dams, the combined escapement of summer and winter steelhead was more than 1,000 fish. In the East Fork Lewis River, steelhead historically migrated above Sunset Falls (RKm 51). Modifications to the falls have improved steelhead access to the upper watershed.

[3] Passage at various falls is determined by flow conditions and the structure of the falls. Some falls (e.g., Willamette Falls) are passable during periods of high flow, when the lower portion of the falls is flooded or nearshore routes become available. Other falls (Kalama, Horseshoe, Duggan, and Shipherd Falls) present a jump/velocity barrier during high-flow periods, but are passable during low flows.

Winter steelhead are native to the Clackamas River basin. Although summer steelhead are currently present and naturally spawning in this system, they originated from releases of Skamania Hatchery summer steelhead stock (Table A.3) (Murtagh et al. 1992, Chilcote 1997). It was determined that of the artificially propagated steelhead stocks released into the Clackamas basin only the Clackamas Hatchery stock (#122) is part of the Lower Columbia River ESU (NMFS 1999a). The Big Creek Hatchery stock of winter steelhead return to the Clackamas River earlier (October to early March) than the native winter steelhead (February to June) (Murtagh et al. 1992). Furthermore, the peak spawning period for Big Creek–derived fish is January to early March, compared with May and June for native Clackamas River winter steelhead. Stone (1878) reported that steelhead spawning in the Willamette River peaks in May, but may extend as late as August in the Klackamas [sic] River. Barin (1886) observed that “the steel-head [sic] salmon commences its run from the middle of October, and begins spawning about the first of May.” Several population configurations have been suggested for the Clackamas River. One alternative includes the main stem and tributaries of the Clackamas River below North Fork as the Lower Clackamas River winter steelhead DIP. Upper tributaries to the Clackamas River may have had the capacity to sustain large populations of steelhead; whether the Upper Clackamas River (above North Fork Dam), including the Collawash River, was able to sustain a DIP is unclear.

Johnson Creek and Mt. Scott Creek were included as a subpopulation of the Clackamas River winter steelhead historical DIP. Although these creeks are not tributaries to the Clackamas River, their proximity to the mouth of the Clackamas River and the relatively large abundance of Clackamas River steelhead may have historically resulted in a substantial exchange of individuals between these water basins. It has also been suggested that Johnson Creek and Mt. Scott Creek were historically part of a DIP that included small tributaries to the Willamette River, below the Clackamas River, and along the Columbia River. Steelhead were noted in both creeks during surveys conducted in the 1930s (Bryant 1949) and 1950s (Willis et al. 1960). The Oregon Game Commission collected steelhead broodstock from Crystal Springs Creek, a tributary to Johnson Creek (Willis et al. 1960).

Both summer and winter steelhead are native to the Washougal River basin (Bryant 1949). Two sets of falls, Salmon Falls (RKm 28) and Dougan Falls (RKm 34), present barriers to returning adult steelhead during low-water periods (Parkhurst et al. 1950, Hymer et al. 1992). The U.S. Bureau of Commercial Fisheries operated an egg-taking station on the Washougal River during the 1920s. From 13 April to 23 May 1923, 834,000 eggs were collected (presumably from winter-run fish). This would represent 417 females, based on 4,000 eggs per female (Howell et al. 1985). Additionally, a large number of immature (most likely summer-run steelhead) were passed over the weir (Mitchell 1924). In July 1935, a survey counted 539 summer steelhead in resting holes below Salmon Falls (Parkhurst et al. 1950). WDF (1951) provided no escapement estimates, but did estimate that the Washougal River basin contributed 55,000 kg to the fishery (prior to construction of the Skamania Hatchery). The West Fork Washougal (RKm 20.9) is 37 km long, but a 5.5-m waterfall at RKm 8.9 is considered impassable. Bryant (1949) estimated there was suitable spawning habitat for approximately 2,000 fish in the West Fork Washougal River.

Winter and summer steelhead are present in the Sandy River basin, although only winter steelhead are recognized as being native (Kostow 1995). Anecdotal reports exist of a population of summer-run steelhead historically occurring in the Sandy River; however, we know of no documentation to substantiate this. Historically, winter steelhead escapement may have been in excess of 20,000 fish (Mattson 1955). Late steelhead were spawned at the Salmon River Hatchery from 25 February to 28 May 1902, although the vast majority were spawned after 2 April 1902 (ODF 1903). Loss of spawning habitat in the Bull Run and Little Sandy River basins, in combination with the effects of dams on the mainstem Sandy River, had reduced the run to 4,400 in 1954. The Bull Run alone may have historically produced 5,000 adults (Table 7) (Mattson 1955). More recently, the estimated wild escapement of hatchery fish over Marmot Dam (RKm 43) was 851 in 1997, although there has been considerable difficulty in distinguishing between naturally produced and hatchery-derived winter steelhead (Chilcote 1997). ODF (1903) identified a number of tributaries to the upper Sandy River that supported steelhead: "The Salmon River, which is a fork of the Sandy River, I found to be a good stream for artificial work . . . is frequented by the Winter Steelheads." The ODF (1903) report further stated that Zigzag "Creek" and Still Creek are "very desirable steelhead streams, and could be worked nicely for that variety of fish in connection with a work that may be going on at the eyeing station." Mattson (1955) estimated that the Salmon River historically produced 2,000 steelhead and simply concluded that the Zigzag River was an "excellent producer of steelhead."

There are potentially four or five subpopulations of winter-run steelhead in the Sandy River basin: mainstem Sandy River, Bull Run, Little Sandy River, Zigzag River, and Salmon River. It is possible that the geographic separation (Table 1) and physiographic differences (e.g., elevation, temperature, and hydrology) (Figure 1) between the lower river (Bull Run and Little Sandy) and upper river tributaries (Zigzag and Salmon Rivers) could have resulted in demographic and reproductive isolation between the two areas.

Provisional historical demographically independent populations (Figures 12 and 13). Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are indicated by SASSI. WDFW (1997) proposed revisions to the SASSI; the original stocks are listed as SASSI (1993), and the proposed changes are listed as SASSI (1997).

1. Cispus River winter run
2. Tilton River winter run
3. Upper Cowlitz River winter run
4. Lower Cowlitz River winter run [SASSI]
5. North Fork Toutle River (Green River) winter run [SASSI]
    a. North Fork Toutle River winter run [SASSI]
    b. Green River winter run [SASSI]
6. South Fork Toutle River winter run [SASSI]
7. Coweeman River winter run [SASSI]
8. Kalama River winter run [SASSI]
9. Kalama River summer run [SASSI]
10. North Fork Lewis river winter
11. East Fork Lewis River winter run [SASSI]
12. North Fork Lewis River summer run [SASSI]
13. East Fork Lewis River summer run [SASSI]
14. Clackamas River winter run

   a. Johnson Creek
   b. Eagle Creek
   c. Mainstem and upper Clackamas River winter run
   d. Collawash River
15. Salmon Creek winter run [SASSI]
16. Sandy River winter run
   a. Bull Run winter run
   b. Little Sandy winter run
   c. Salmon River winter run
   d. Zigzag River winter run
17. Washougal River winter run [SASSI]
   a. Mainstem Washougal River
   b. West (North) Fork Washougal River
18. Washougal River summer run [SASSI (1997)]
   a. Mainstem Washougal River [SASSI (1993)]
   b. West (North) Fork Washougal River [SASSI (1993)]

Columbia River Gorge Tributaries

This region extends from east of the Washougal River (RKm 195) to the Wind River (RKm 250) and from east of the Sandy River (RKm 194) to the Hood River (RKm 272). River basins in this region of the ESU are influenced by the steeply sloped sides of the Columbia Gorge. Most streams are relatively short. Impassable waterfalls limit accessible habitat to less than a half mile on most small creeks. Larger rivers contain falls or cascades in their lower reaches, which may present migrational barriers during all or most of the year. Furthermore, this region marks a transition between the high-rainfall areas of the Cascades and the drier areas to the east. Streamflows can be intermittent, especially during the summer.

Spawning steelhead were observed in several small creeks that line the Columbia Gorge during surveys conducted in the 1930s and 1940s. None provides sufficient habitat for large spawning aggregations of fish, and it is unlikely that there were any independent populations.

Summer and winter steelhead are native to the Wind River basin. Shipherd Falls (RKm 3) presented a migratory barrier to chinook salmon, but not to steelhead (Hymer et al. 1992). Winter steelhead were apparently less common in the upper watershed than summer steelhead. Shipherd Falls historically prevented winter steelhead from reaching the upper watershed; there was not sufficient habitat to support a DIP in the lower portion of the Wind River. Wind River winter steelhead would have been part of the upper gorge winter steelhead DIP. WDFW (1997) consolidated winter steelhead in the Wind and Washougal Rivers into one population and included the lower gorge tributaries into a separate population centered around Hamilton Creek. At the time of the USFWS surveys (Bryant 1949), summer steelhead abundance was already greatly depressed, but information gathered during interviews indicated that Panther and Cedar Creeks were historically “good producers” of summer steelhead. A lumber mill dam at RKm 22.5 on the mainstem Wind River blocked upstream passage until 1947. In 1956, fish passage facilities were constructed at Shipherd Falls, and additional modifications were made to a number of other falls and cascades in order to provide greater access throughout the watershed.

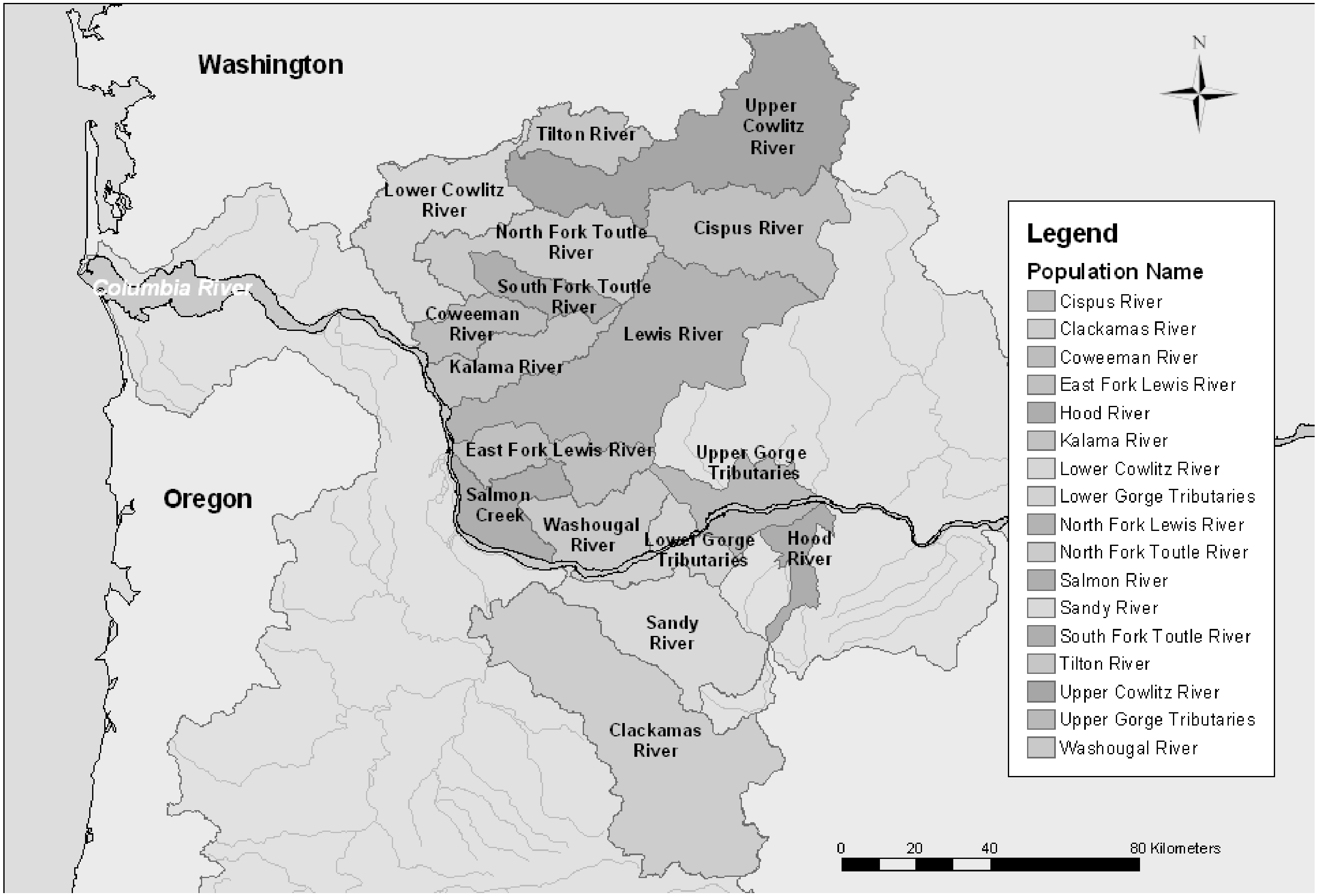

Figure 12. Historical, demographically independent, winter steelhead populations in the Lower Columbia River ESU.

Steelhead escapement for the Wind River in 1951 was estimated at 2,000 fish. Busby et al. (1996) reported summer steelhead escapement to the Wind River averaged 600 fish, half of which were of hatchery origin. Genetic analysis indicates the Wind River summer and winter steelhead most closely resemble fish from the Kalama River (NMFS 1997).

Winter and summer steelhead are native to the Hood River basin (Kostow 1995). The combined escapement for both winter and summer steelhead (excluding known hatchery fish) averaged around 1,000 fish during the 1950s and 1960s (Howell et al. 1985). Native summer steelhead escapement was 181 in 1997 and may have been as low as 80 in 1998 (Chilcote 1997). Winter steelhead are not found in the West Fork Hood River. Punchbowl Falls (RKm 0.6) prevents winter-run fish from ascending into the West Fork (Olsen et al. 1992).

Provisional historical demographically independent populations. (Some creeks listed may not have historically sustained steelhead, but may have occasionally—historically and currently—been utilized by steelhead sometime during their life history, and are included for general inventory purposes.) Letter designations indicate possible subpopulations within the numbered population. Populations identified in WDF et al. (1993) as a SASSI stock are indicated by [SASSI]. WDFW (1997) proposed revisions to the SASSI; the original stocks are listed as SASSI (1993), and the proposed changes are listed as SASSI (1997).

Columbia River Gorge Tributaries (Figures 12 and 13)

1. Lower gorge tributaries (winter run)[SASSI (1997)]
    a. Duncan Creek
    b. Bridal Veil Creek
    c. Wahkeena Creek
    d. Hardy Creek
    e. Hamilton Creek[SASSI (1993)]
    f. Multnomah Creek
    g. Moffer Creek
    h. Tanner Creek
2. Upper gorge tributaries (winter run)
    a. Eagle Creek
    b. Rock Creek
    c. Wind River
    d. Herman Creek
    e. Gorton Creek
    f. Viento Creek
    g. Lindsey Creek
    h. Phelps Creek
3. Wind River summer run[SASSI (1997)]
    a. Little Wind River
    b. Panther Creek[SASSI (1993)]
    c. Trout Creek[SASSI (1993)]
4. Hood River winter run
5. Hood River summer run

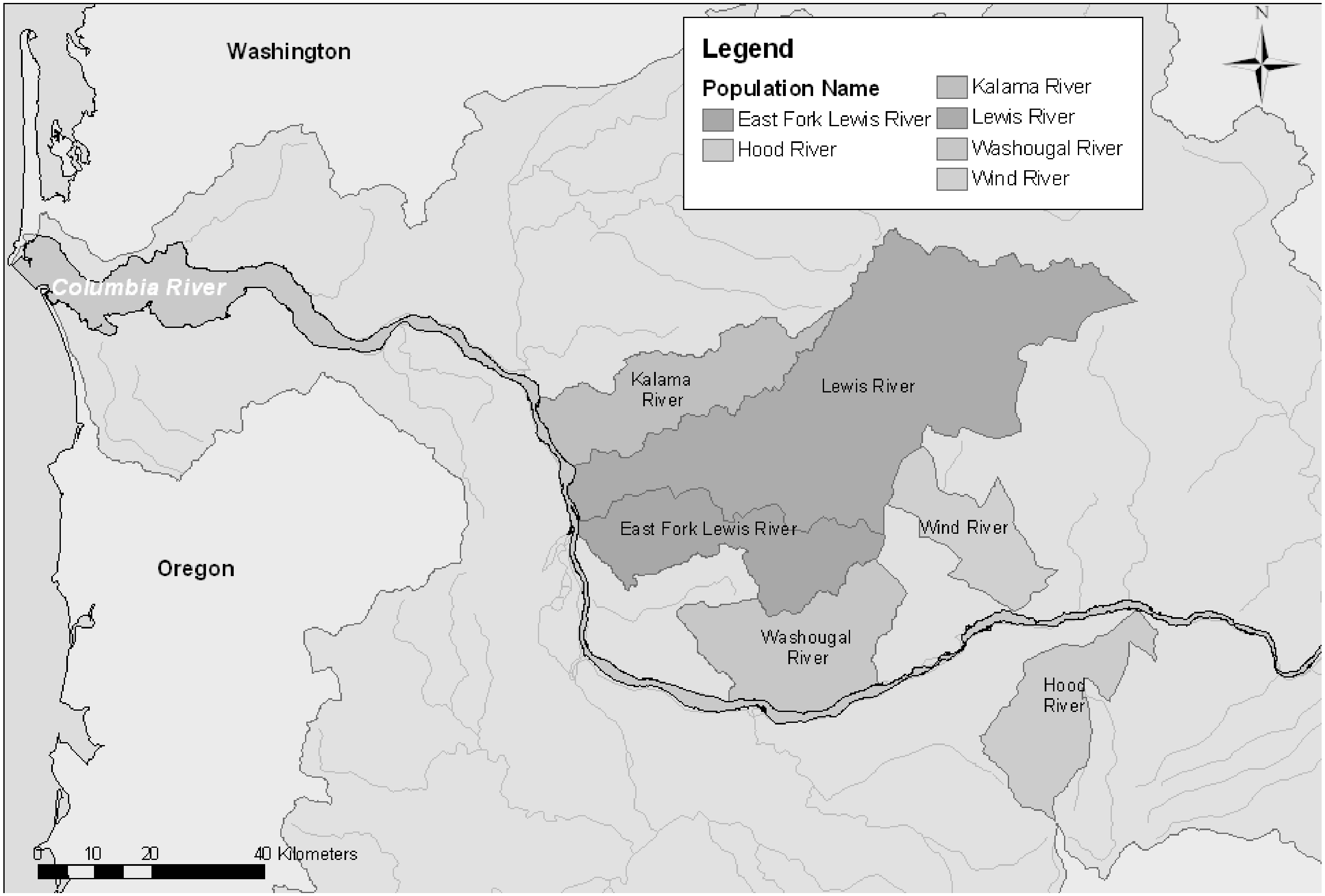

Figure 13. Historical, demographically independent, summer steelhead populations in the Lower Columbia River ESU.

3.3 Upper Willamette River Steelhead ESU

Historical Independent Populations

Of the three temporal runs of steelhead currently found in the Upper Willamette River ESU only the late-run winter steelhead is considered to be native. The same flow conditions at Willamette Falls that only provided access for spring-run chinook salmon also provided an isolating mechanism for this unique run time of steelhead. Late-run winter steelhead enter the Willamette River beginning in January and February, but do not ascend to their spawning areas until late March or April (Dimick and Merryfield 1945). Spawning takes place from April to the first of June. Redd counts for late-run winter steelhead in the Willamette River basin are conducted in May (Howell et al. 1985). The Oregon Department of Fish and Wildlife (ODFW) currently uses February 15 to discriminate between native and nonnative (Big Creek) winter steelhead at Willamette Falls (Kostow 1995). It is generally agreed that steelhead did not historically emigrate farther upstream than the Calapooia River (Dimick and Merryfield 1945, Fulton 1970). Historically, the character of the Willamette River at Albany changed from a highly braided, relatively shallow system upstream, to a more centralized channel, deep-river system downstream (Benner and Sedell 1997). Returning winter steelhead may have found upstream passage difficult past the confluence of the Calapooia River, whereas spring-run chinook salmon (which delay final maturation until the late-summer/early fall) could hold in mainstem, or off-channel, habitat until passage upstream was possible. Stone (1878) reported that steelhead began arriving at the base of Willamette Falls around Christmas, but were most abundant in April. Additionally, the spawning peak was reported to be in May, with spawning complete by June.

Presently, native steelhead are distributed in a few, relatively small, naturally spawning aggregations. In 1982, it was estimated that 15% of the late-run winter steelhead ascending Willamette Falls were of hatchery origin (Howell et al. 1985). Counts of native late-run winter steelhead past Willamette Falls had a 5-year geometric mean abundance of just over 3,000 fish through 1997 (ODFW 1998).

Surveys in 1940 reported anecdotal information that steelhead spawned in Gales Creek, a tributary to the Tualatin River (Parkhurst et al. 1950). Numerous introductions of early-run winter steelhead (Big Creek stock) and late-run (North Santiam stock) winter steelhead have been made into the Tualatin River, but it is unclear whether the existing fish represent native or introduced lineages, or whether steelhead even existed historically in the Tualatin River. Naturally spawning winter-run steelhead are currently found in several westside tributaries of the Willamette River; however, there is considerable debate on the origin of these fish. With the exception of Gales Creek, a tributary to the Tualatin River, Parkhurst et al. (1950) did not report the presence of any salmon or steelhead in these systems. Most of the surveys were conducted during the summer, when adult steelhead would not be present. Hatchery records indicate that large numbers of early-run winter steelhead were stocked into the Luckiamute and Yamhill Rivers. ODFW suggests that, based on spawn timing, late-run winter steelhead may have recently colonized the Yamhill River (NMFS 1999a). Other than cutthroat trout and the occasional (introduced) coho salmon, surveys conducted during the 1950s did not observe any anadromous salmonids (e.g., chinook salmon and steelhead), nor were any reported in the North

ForkYamhill River, Marys River, or Long Tom River basins (Willis et al. 1960). Recent genetic analysis of presumptive steelhead from the westside tributaries indicated that fish from the Yamhill River and Rickreall Creek were most genetically similar to steelhead populations from the Lower Columbia River basin, suggesting the influence of Big Creek winter steelhead or Skamania summer steelhead (NMFS 1999b, see Appendix B). The sample from the Luckiamute River had no clear affinity with any other steelhead population, and may be descended from native resident rainbow trout. Because of the ecological similarities among the Willamette River westside tributaries, fish occurring in these basins were grouped together. With the exception of the Tualatin River, there is little evidence to suggest that sustained spawning aggregations of steelhead may have existed historically in the westside tributaries of the Willamette River basin. Furthermore, it is unlikely that these tributaries, individually or collectively were large enough to constitute a DIP.

The Molalla River currently contains three distinct steelhead runs: native late-run winter steelhead, introduced early-run winter steelhead (from Lower Columbia River populations), and introduced Skamania summer-run steelhead (Chilcote 1997). In 1957, a spawning ground survey observed 370 adult steelhead and 623 redds in the 94.1 km of the Molalla River basin surveyed (Willis et al. 1960). Additionally, Willis et al. (1960) noted that several hundred steelhead entered Abiqua Creek annually. Historically, small tributaries above Willamette Falls (e.g., Abernathy Creek) would most likely have been part of the Mollala River winter steelhead population.

Native late-winter and introduced Skamania summer-run steelhead are both present in the North Santiam River (Chilcote 1997). In 1940, surveys estimated the steelhead run was at least 2,000 fish (Parkhurst et al. 1950). Parkhurst et al. (1950) also reported that larger steelhead runs existed in the Breitenbush, Little North Santiam, and Marion Fork Rivers. Native steelhead were artificially propagated at the North Santiam Hatchery beginning in 1930, when a record 2,860,500 eggs (686 females @ 4,170 eggs/female) were taken (Wallis 1963a). The release of hatchery-propagated steelhead (late-winter run) in the North Santiam was discontinued in 1998 (NMFS 1999a). Recent (through 1994) average escapements to the North Santiam averaged 1,800 fish of mixed hatchery and natural origin (Busby et al. 1996).

Native late-winter and introduced Skamania summer-run steelhead are both present in the South Santiam River. Hatchery operations began in 1926, and in 1940 a record 3,335,000 eggs were taken (800 females @ 4,170 eggs/female). However, river conditions did not allow the weir to be set in place until after a portion of the steelhead run had already passed (Wallis 1961).

ODFW considers the late-run winter steelhead in the South Santiam River to be one population of native origin. However, the abundance trends for populations above and below Foster Dam are very different. The number of redds below Foster Dam has remained relatively stable (albeit at a low level), while the redd count above Foster Dam declined dramatically in recent years. Live counts of naturally produced (unmarked) fish passing Foster Dam (1996–2000) have averaged 296 fish, with 728 fish passed above Foster Dam in 2001 (Nigro 2001).

Genetic analysis indicates a close genetic affinity between winter steelhead populations in the Santiam, Molalla, and Calapooia Rivers. Steelhead descended from summer-run

(Skamania) and early-run winter (Big Creek) hatchery populations are distinct from the native steelhead (NMFS 1997, see Appendix B).

Late-run winter steelhead are native to the Calapooia River. Parkhurst et al. (1950) reported that steelhead ascended the Calapooia as far as 87 km upstream, although passage at the Finley Mill Dam (RKm 42) may have not have been possible during periods of low flow. A survey conducted in 1958 from the town of Holley to the mouth of Potts Creek (31.7 km) recorded 73 steelhead adults (live and dead) and 427 redds (Willis et al. 1960). There is no hatchery program on the Calapooia River. Chilcote (1997) estimated that contribution of hatchery fish to escapement (strays from other Upper Willamette River releases) is less than 5%. This population has declined to very low levels since the late 1980s.

Provisional historical demographically independent winter-run steelhead populations (Figure 14). Letter designations indicate possible subpopulation designations within the numbered populations.

1. Molalla River
   a. Pudding River
   b. Molalla River
2. North Santiam River
   a. Breitenbush River
   b. Marion Fork
   c. Little North Santiam River
3. South Santiam River
   a. South Santiam River
   b. Thomas and Crabtree Creeks
   c. Middle Santiam River
   d. Quartzville Creek
4. Calapooia River
5. Westside tributaries[4]
   a. Tualatin/Gales Creek
   b. South Fork Yamhill River
   c. Rickreall Creek
   d. Luckiamute River

[4] Spawning winter steelhead have been reported the tributaries listed below; however the westside tributaries are not considered to have historically constituted a DIP.

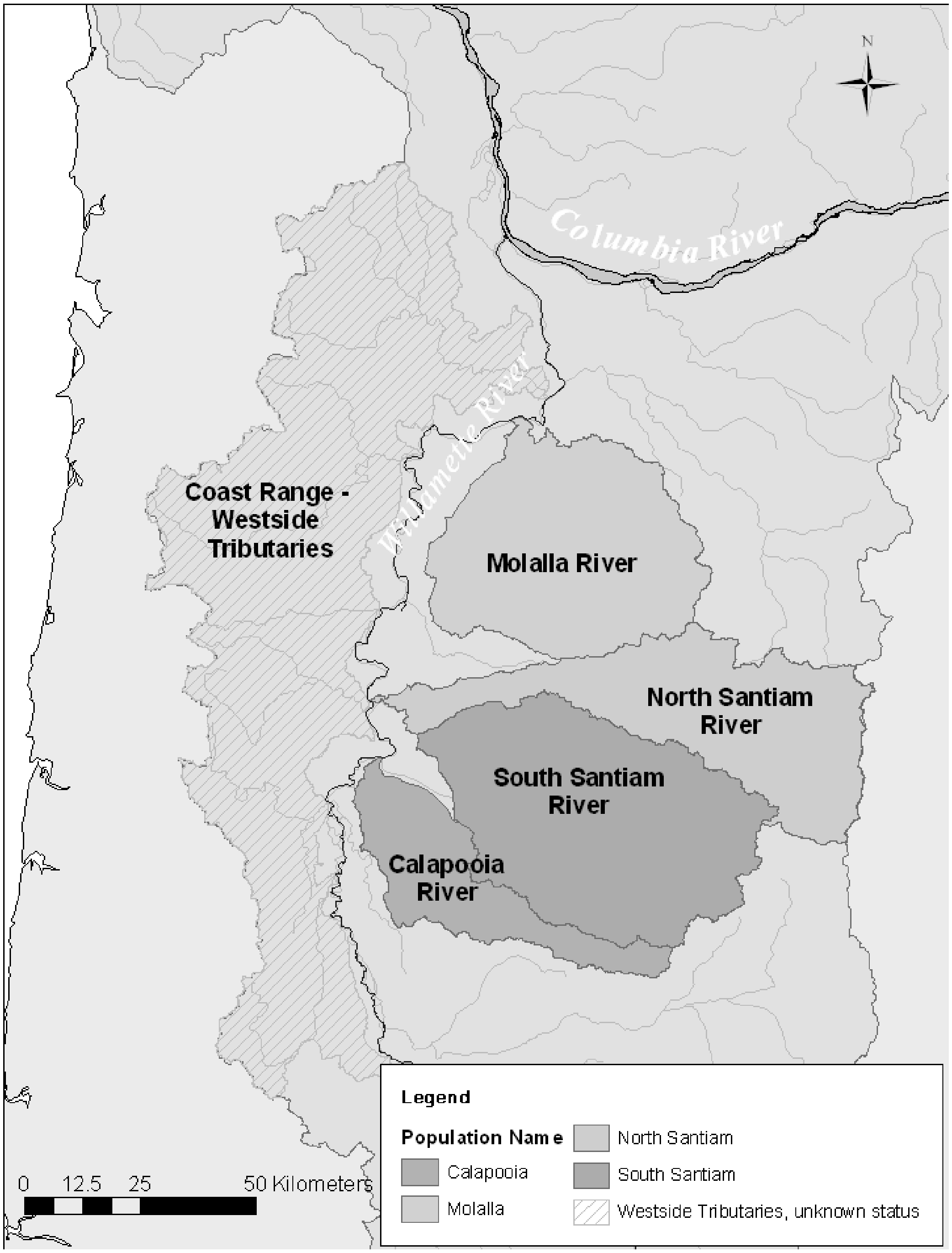

Figure 14. Historical, demographically independent, winter steelhead populations in the Upper Willamette River ESU.

4. CHUM SALMON (*ONCORHYNCHUS KETA*)

4.1 Life History

Chum salmon have the widest natural geographic and spawning distribution of any Pacific salmonid, primarily because its range extends farther along the shores of the Arctic Ocean than other salmonids (Groot and Margolis 1991). Chum salmon have been documented to spawn from Korea and the Island of Honshu, Japan, east around the rim of the North Pacific Ocean to Monterey Bay, California. Chum salmon also grow to be among the largest of Pacific salmon, second only to chinook salmon in adult size, with individuals reported up to 108.9 cm in length and 20.8 kg in weight (*Pacific Fisherman* 1928). Average size for the species is around 3.6 to 6.8 kg (Salo 1991).

Chum salmon usually spawn in coastal areas, and juveniles emigrate almost immediately after emerging from the gravel (Salo 1991). This ocean-rearing migratory behavior contrasts with the stream-rearing behavior of some other species of *Oncorhynchus* (e.g., coastal cutthroat trout, steelhead, coho salmon, and most types of chinook and sockeye salmon), which usually migrate to sea at a larger size, after months or years of freshwater rearing. This means that survival and growth in the first year depend less on freshwater conditions than on favorable estuarine conditions, unlike other salmonids (coho, steelhead, and stream-type chinook), which depend heavily on freshwater habitats. Another behavioral difference between chum salmon and species that rear extensively in freshwater is that chum salmon form schools, presumably to reduce predation (Pitcher 1986).

In both Asia and North America, chum salmon spawn commonly in the lower reaches of rivers, with redds usually dug in the main stem or side channels of rivers from just above tidal influence to nearly 100 km from the sea. In some areas they typically spawn where groundwater percolates through the redds (Bakkala 1970, Salo 1991). Some chum salmon even spawn in intertidal zones of streams, especially in Alaska, where tidal fluctuation is extensive and upwelling of groundwater in intertidal areas may provide preferred spawning sites.[5] Bailey (1964) reported that chum salmon eggs in Olsen Creek, Alaska, could survive exposure to tidewater up to 55% of the time during embryonic development. Chum salmon were observed spawning in the intertidal zone of Walcott Slough in Hood Canal, Washington (O'Malley 1922). It was also noted that the chum salmon spawn where springwater seepage occurs and the developing embryos may be exposed to relatively low concentrations of saltwater.

Chum salmon are believed to spawn primarily in the lower reaches of rivers because they usually show little persistence in surmounting river blockages and falls. However, in some Pacific Northwest streams, such as the Skagit River, Washington, chum salmon routinely

[5] Jack Helle, NMFS, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801, pers. commun., April 1995.

migrate over long distances, at least 170 km.[6] In the Yukon River, Alaska, and the Amur River, Russia, chum salmon migrate more than 2,500 km inland. Although these distances are impressive, both rivers have low gradients and no extensive falls or other blockages to migration. In the Columbia River basin, reports indicate that chum salmon may historically have spawned in the Umatilla and Walla Walla Rivers, more than 500 km from the sea (Nehlsen et al. 1991). However, these fish would have had to pass Celilo Falls, a web of rapids and cascades that once existed in the Columbia River, which would have presented a considerable migration obstacle. In the Columbia River, adults typically enter freshwater in October with spawning activity extending from early November through December (Johnson et al. 1997). Chum salmon returning to the Grays River (and the Columbia River in general) mature at 3 years of age.

Observations of chum salmon behavior have suggested to some that the species may have a broader geographic perspective of their natal stream than other species of *Oncorhynchus* (reviewed in Lister et al. 1981). There are a number of reasons why this perception could have developed.

- Chum salmon spawn near the mouths of streams, and their young do not conduct the long, downstream, freshwater migrations that are common in some salmonid species. It has been hypothesized that juvenile salmonids, which conduct long freshwater migrations, may sequentially imprint on a chain of migratory cues that assist them as adults in returning to their natal streams (Lister et al. 1981).
- Observations of the reluctance of adult chum salmon to surmount small falls or rapids have suggested to some that they may go upstream as far as they can toward natal areas, but once they reach a barrier, they spawn.
- Adult chum salmon also are more sexually mature when they enter freshwater than most species of anadromous salmonids, thus they may not be able to endure delays in reaching their natal areas. If delayed, they may be forced to spawn at the first available location.
- It has been observed (McNeil 1969, Lister et al. 1981) that when spawning densities of chum salmon become high in some rivers (especially those with hatchery runs), straying to nearby streams may increase. A few experimental studies that directly addressed this issue (Lister et al. 1981, Quinn 1984 and 1993, Salo 1991, Altukhov and Salmenkova 1994, Tallman and Healey 1994) concluded that under normal circumstances, straying in chum salmon is no greater than in any other *Oncorhynchus* species.

The Columbia River historically contained large runs of chum salmon, which supported a substantial commercial fishery in the first half of the twentieth century. These landings represented a harvest of more than 500,000 chum salmon in some years. There are presently neither recreational nor directed commercial fisheries for chum salmon in the Columbia River, although some chum salmon are taken incidentally in the gill-net fisheries for coho and chinook salmon, and there has been minor recreational harvest in some tributaries (WDF et al. 1993). Hymer (1993, 1994) and WDF et al. (1993) monitored returns of chum salmon to three streams in the Columbia River basin and suggested that there may be a few thousand, perhaps up to

[6] Doug Hendrick, Washington Department of Fish and Wildlife, 333 East Blackburn Rd., Mt. Vernon, WA 98273, pers. commun., January 1996.

10,000, chum salmon spawning annually in the basin. Kostow (1995) identified 23 spawning populations on the Oregon side of the Columbia River but provided no estimates of the number of spawners in these populations. Spawner surveys conducted by ODFW during the autumn and winter of 2000/2001 only found a single chum in the 29 streams surveyed (Naald 2001), although a number of chum were apparently observed at hatchery weirs on the Oregon side of the Columbia River during the 2000/2001 return year.

An estimate of the minimum run size for chum salmon returning to both the Oregon and Washington sides of the Columbia River has been calculated by summing harvest, spawner surveys, Bonneville Dam counts, and returns to the Sea Resources Hatchery on the Chinook River in Washington (ODFW and WDFW 1995). This estimate suggests that the chum salmon run size in the Columbia River has been relatively stable (albeit at a very low level) since the run collapsed in the mid-1950s (Figure 15). The minimum estimate for the Columbia River run size in 1999 was 2,400 adult fish (Keller 2001).

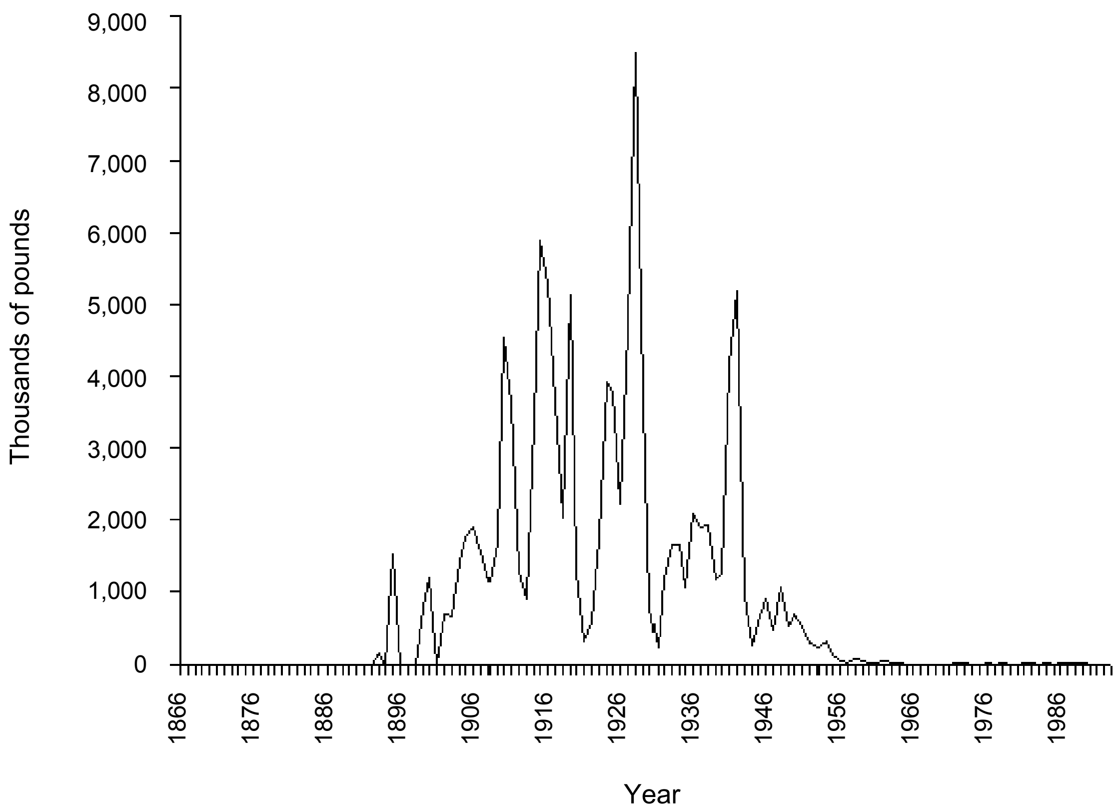

Figure 15. Commercial landings of chum salmon in the Columbia River, 1886–1993. Data from NMFS (1995).

4.2 Columbia River ESU

Historical Independent Populations

Coast Range Tributaries

Chum salmon are native to rivers and creeks near the mouth of the Columbia River. There is little information on the size or distribution of chum salmon populations in specific river basins prior to the 1930s, and by that time chum abundance was already severely in decline.

From 1936 to 1945, chum salmon were observed in the Chinook, Deep, and Grays Rivers, and Mill, Elochoman, Abernathy, and Germany Creeks (Table 2) (Parkhurst et al. 1950). The Chinook River is relatively small, but geographically isolated from the Grays River basin. It may have represented an important transition between the Washington coast and Columbia River populations, but there is no historical information to establish its relationship with the other populations. It is tentatively identified as a DIP. The Grays River is the most important tributary remaining for chum salmon in this area. In 1936, survey crews observed over 6,200 chum adults in the Grays River (Parkhurst et al. 1950). WDF (1951) estimated that average chum escapement to the Grays River was 7,500, with an additional 1,200 fish spawning in nearby tributaries to the Columbia River. Spawning chum salmon were also observed in the Elochoman River and Abernathy Creek during the 1936 survey. In general, spawning chum salmon were reported in most rivers and creeks in this area. WDF (1951) estimated average escapement for the Elochoman River and Abernathy Creek basins at 4,000 and 2,700 adults, respectively. Recent genetic analysis of samples from the Grays River were similar to other samples from the Columbia River (Hardy and Hamilton Creeks), but distinct from coastal and Puget Sound populations (Phelps et al. 1994b).

Lewis and Clark River to Scappoose Creek. Parkhurst et al. (1950) reported that chum salmon were present in almost every watershed in this area (Table 2), but no abundance estimates were presented, and the majority of the information was anecdotal. Records from Big Creek Hatchery show that between 1950 and 1960, an average of 607 chum salmon were intercepted at the hatchery rack annually, with a maximum of 2,430 chum salmon encountered in 1958 (Wallis 1963b). Chum salmon were also captured at the Klaskanine Hatchery rack. Although no adult numbers were recorded, a maximum of 1,481,294 eggs was obtained in 1940, for an estimated 530 females @ 2,800 eggs/female (Wallis 1963c). Additionally, Wallis (1963c) notes that chum salmon utilized the South Fork Klaskanine, but not the North Fork. Willis et al. (1960) reported that Milton Creek was the greatest producer of chum salmon (about 200 chum per year) in the area surrounding Scappoose Creek. ODFW identified 23 populations on the Oregon side of the Lower Columbia River, although this inventory was apparently based on incidental observations rather than set criteria for populations (Kostow 1995).

Western Cascade Range Tributaries and Columbia River Gorge Tributaries

Chum salmon were historically widely distributed in tributaries below Celilo Falls. Barin (1886) observed that dog salmon (chum salmon) appeared in the Clackamas River by November and spawned soon afterward. By 1944, chum salmon were not found during biological surveys of the Clackamas (Dimick and Merryfield 1945). Probably the same water-quality problems that had extirpated the early-run fall chinook salmon also eliminated chum salmon. Chum salmon were also historically present in the Sandy River basin (Mattson 1955). At the time of his review, Mattson estimated that approximately 200 chum returned annually to the Sandy. Although there are no current estimates, chum salmon have been reported in recent surveys of the Sandy River.[7]

Chum salmon are native to tributaries in this area, although their current abundance is a fraction of historical levels. Hatcheries in the Lower Columbia River made little effort to collect chum salmon, primarily due to their low market value in the fishery. The majority of eggs were collected at the Lewis River Hatchery (up to 750 females being spawned in any one year). Transfers of chum from outside of the Columbia River basin, however, were substantial. Between 1913 and 1918 some 30 million chum fry (predominately from the Chehalis River) were released throughout the Columbia River (including a number of sites above Celilo Falls, and in the Methow and Walla Walla Rivers) (WDFG 1916, 1918). Hatchery practices at the time emphasized releasing unfed fry, and the success of many of these transfers, especially those far upriver, is doubtful.

Estimates of annual escapement to the Cowlitz, Kalama, Lewis, and Washougal Rivers in 1951 (when chum salmon populations were already in decline) were 1,000, 600, 3,000, and 1,000 fish, respectively (WDF 1951). Within the Cowlitz River basin, chum salmon migrated as far as Mayfield Dam and spawned in the lower tributaries of the Cowlitz River: Coweeman River, Ostrander Creek, Arkansas Creek, Toutle River, Salmon Creek, Olequa Creek, and Lacamas Creek (WDF 1951). Emigrating chum salmon fry were sampled at the Mayfield Dam site in 1955 and 1956 (Stockley 1961). Chum salmon have been recently recovered in the mainstem Cowlitz below the Cowlitz Salmon Hatchery and at the hatchery rack. Currently, naturally spawning populations of chum salmon exist in Hardy (RKm 228) and Hamilton Creeks (RKm 229), and in man-made spawning channels associated with these creeks. These small tributaries to the Columbia River are located just downstream of Bonneville Dam. Returning chum salmon adults were spawned incidentally at the Bonneville and Oxbow hatcheries (Tanner and Herman Creeks) from the 1930s to the 1950s. Chum salmon were also incidentally spawned at the U.S. Bureau of Fisheries' Little White Salmon Hatchery, especially when chinook salmon egg collections did not fill incubation capacity. In 1917, the Little White Salmon Hatchery collected 1,447,500 chum salmon eggs (Smith 1919). This collection represents approximately 643 females (@ 2,250 eggs/female Howell et al. 1985). There is no indication what proportion of the run was collected.

There are few current estimates of chum abundance in the tributaries to the Lower Columbia River. Aside from the Grays River and Hamilton and Hardy Creeks, chum salmon

[7] Orlay Johnson, NMFS, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112, pers. commun., January 2000.

have been observed in a number of rivers (Cowlitz, Lewis, and mainstem Columbia River) on the Washington State side of the Columbia River (Keller 2001). It is probable that chum salmon exist at low abundance levels in many of their historical watersheds. In 1998 and 1999, only 195 and 135 chum salmon, respectively, were observed ascending the fish ladder at Bonneville Dam (Keller 2001, NMFS 2000).

Little genetic or life-history information for chum salmon is available with which to reconstruct the historical population structure in the Lower Columbia River. Genetic information currently exists only for the Grays River and Hamilton and Hardy Creek populations. Similarities between fish from Hamilton and Hardy Creeks relative to Grays River samples would be expected given the proximity of these watersheds and the relatively small size of the populations. No differences in the age structure of the three spawning aggregations are apparent, with 3-year-old fish predominating (Keller 2001). Analysis of scales taken from chum salmon returning to the Columbia River in 1914 also indicated that 3-year-old fish constituted the majority of the run, 70.4% (Marr 1943). Peak spawning activity for chum salmon in the Grays River and Hamilton and Hardy Creeks differs by about a month (November 8 and December 8 or 10 each year, respectively) providing considerable geographic and temporal isolation (Keller 2001). Differences in the time of spawning may be related to differences in water sources for Grays River and Hamilton and Hardy Creeks (rainfall versus groundwater, respectively). The preference of chum salmon to spawn in the lower river reaches and mainstem Columbia River increases the likelihood of migration between local populations, especially given the large historical populations that existed in the Columbia River. However, it is also possible that if salmon were returning to a specific site, such as a mainstem groundwater seep, they would need a high degree of homing fidelity. Furthermore, tributaries to the Columbia River in the coastal region are under tidal influence and salmon would have to move some distance upstream to find adequate spawning areas, providing some degree of geographic isolation between basins.

Analysis of the correlation between allozyme allelic frequencies for fall-run chum salmon populations in British Columbia, and the distance between populations, suggested that populations greater than 250 km apart do not genetically influence one another through migration (Johnson et al. 1997). This distance should be considered an upper bound, since the genetic independence is much more sensitive to migration than demographic independence. Furthermore, the British Columbia data may not be not be applicable to the current situation in the Lower Columbia River due to the proximity of neighboring populations in British Columbia relative to the Lower Columbia River.

It is clear from the historical record that chum salmon were present in most tributaries to the Lower Columbia River and to an unknown extent present in the main stem. However, without an understanding of the dynamics of migration between populations, it is difficult to identify discrete populations. Life-history similarities between fall-run chinook salmon and chum salmon were used to establish the population boundaries in the Lower Columbia River. Additionally, since chum salmon prefer lower mainstem and off-channel spawning areas, no attempt was made to establish multiple-population boundaries within a single basin. Further study is needed to establish the relationship of chum salmon spawning in the mainstem Columbia River and to tributary spawners. It is currently assumed that there is a close association between mainstem spawners and geographically proximate basins.

Historical demographically independent chum salmon populations (Figure 16). Letter designations indicate possible subpopulation designations within the numbered populations. Populations identified in WDF et al. (1993) as a SASSI stock are indicated by SASSI.

1. Youngs Bay (RKm 15)
    a. Lewis and Clark River
    b. Youngs River
    c. Walluski River
    d. Klaskanine River
2. Grays River (RKm 35)[SASSI]
    a. Chinook River
    b. Deep River
    c. Grays River
3. Big Creek
    a. Big Creek
    b. Bear Creek
4. Elochoman River (RKm 60)
    a. Skamokawa Creek
    b. Elochoman River
5. Clatskanie River (RKm 85)
    a. Plympton Creek
    b. Clatskanie River
    c. Beaver Creek
6. Mill Creek (RKm 85)
    a. Mill Creek
    b. Abernathy Creek
    c. Germany Creek
    d. Coal Creek
7. Scappoose Creek (RKm 140)
    a. Tide Creek
    b. Goble Creek
    c. Milton Creek
    d. McNulty Creek
    e. Scappoose Creek
8. Cowlitz River fall run/summer run
9. Kalama fall run
10. Salmon Creek fall run
11. Lewis River fall run
12. Clackamas River fall run
13. Washougal River fall run
14. Sandy River fall run
15. Lower gorge tributaries fall run
    a. Mainstem Columbia River
    b. Bridal Veil Creek
    c. Wahkeena Creek
    d. Hardy Creek [SASSI]

   e. Hamilton Creek [SASSI]
   f. Multnomah Creek
   g. Moffer Creek
   h. Tanner Creek
16. Upper gorge tributaries fall run
   a. Eagle Creek
   b. Rock Creek
   c. Herman Creek
   d. Wind River
   e. Gorton Creek
   f. Little White Salmon River
   g. Viento Creek
   h. Lindsey Creek
   i. Phelps Creek
   j. Big White Salmon River
   k. Hood River

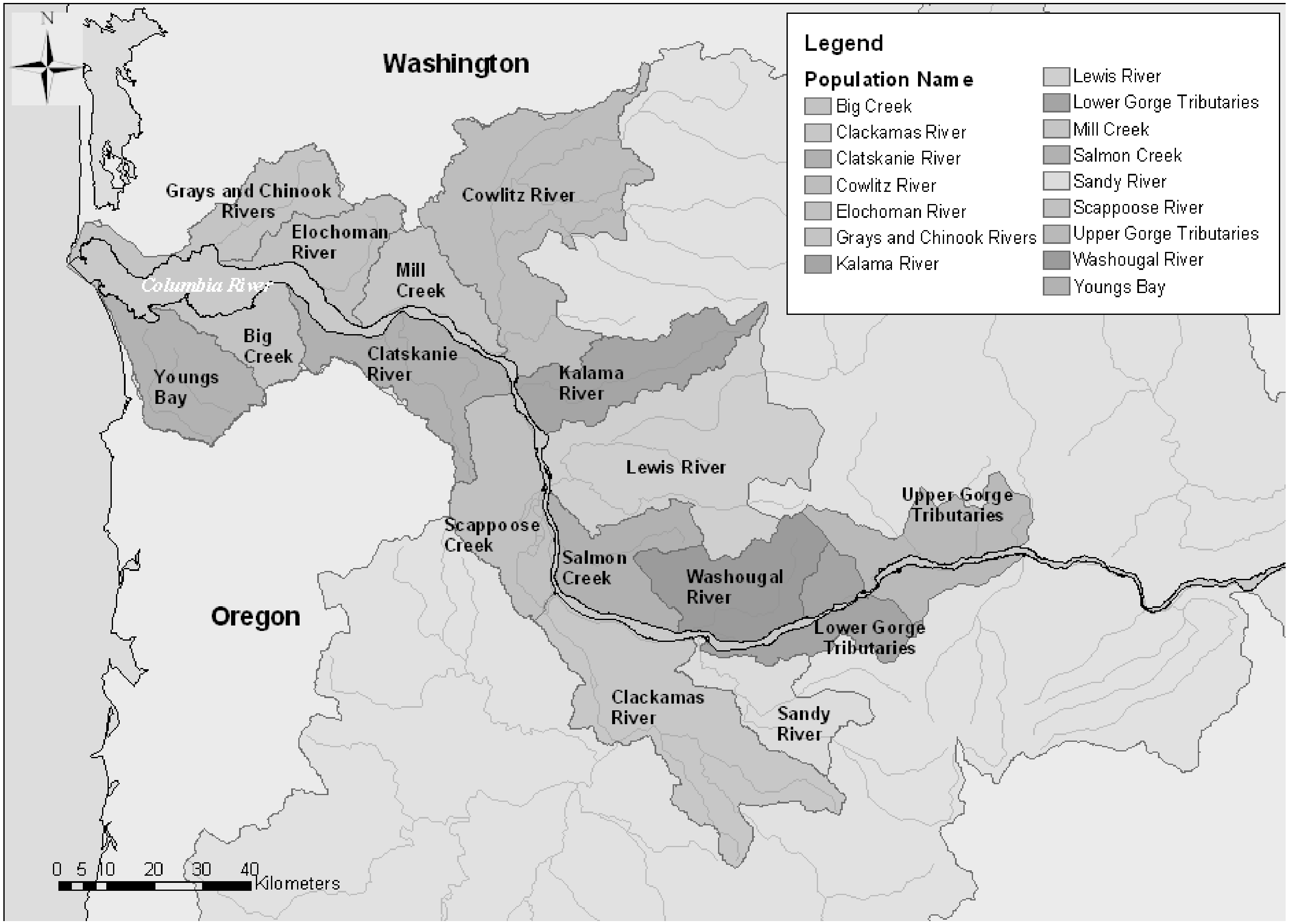

Figure 16. Historical, demographically independent chum salmon populations in the Lower Columbia River ESU.

APPENDIX A

HATCHERY CHINOOK SALMON AND STEELHEAD RELEASES FOR THE LOWER COLUMBIA RIVER ESU

Table A.1. Hatchery chinook salmon releases for the Lower Columbia River ESU.

ESU 9. Lower Columbia River ESU (Fall Run)				**Total Releases[d]**	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Chinook River	1964, 1971	2	Big Creek Hatchery	1,150,865	
	1981–93	12	Chinook Hatchery	8,403,778	
	1989	1	Elochoman Hatchery	124,700	
	1970	**1**	**Issaquah Creek Hatchery**		**97,511**
	1982	1	Lower Columbia River (WA)	830,589	
	1953, 1988–89	3	Lower Kalama Hatchery and Kalama Falls Hatchery	1,105,550	
	1965–83	4	Spring Creek NFH	3,146,137	
	1970–80	3	Toutle Hatchery	1,177,853	
	1972–79	4	Unknown	2,473,102	
	1987, 1990	2	Washougal Hatchery	1,584,500	
			Total	19,997,074	**97,511**
Deep River	1980, 1993	2	Cowlitz Hatchery/Kalama River	960,456	
			Total	960,456	0
Grays River	1968–83	9	Abernathy NFH	8,795,726	
	1977–84	2	Big Creek Hatchery	1,406,632	
	1981–84	3	Bonneville Hatchery	4,970,683	
	1980, 1986	2	Cowlitz Hatchery	4,018,755	
	1967–89	5	Elochoman Hatchery	3,434,258	
	1966–93	26	Grays River Hatchery	22,542,491	

[a] Duration = the time frame of the releases

[b] Years = the total number of years that fish were actually released within the time frame. The majority of spring-run chinook salmon were released as yearling smolts. The majority of ocean-type, fall- and summer-run chinook salmon were released as subyearlings. No releases of eggs or fry (<5 g) are included here. Data before 1950 are not necessarily complete (NRC 1996).

[c] Release source = origin of broodstock used to produce the juveniles released. Plain text indicates that the source was from within the ESU, while bold text indicates a source from outside the ESU.

[d] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river are also assumed to be native regardless of past introductions, unless the hatchery broodstock is known to be from outside the ESU.

KEY:
mix a mix of two or more stocks from the same area
NFH National Fish Hatchery
/ a mix of stocks from different areas
USFWS U.S. Fish and Wildlife Service

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Grays River cont.	1986	1	Grays River Hatchery/Elochoman Hatchery	102,000	
	1981, 1993	2	Kalama River/Grays River Hatchery	190,073	
	1981	1	Klickitat Hatchery	225,134	
	1981, 1982	2	Lower Columbia River (WA)	5,768,516	
	1957, 1966	2	Lewis River Hatchery	1,400,329	
	1953, 1954	2	Lower Kalama Hatchery	399,997	
	1968–93	8	Lower Kalama Hatchery	9,578,125	
	1987	1	Skamokawa Creek	107,000	
	1953–92	15	Spring Creek NFH	17,437,295	
	1980	1	Toutle Hatchery	1,951,871	
	1984–87	4	Washougal Hatchery	1,572,395	
			Total	83,901,280	0
Skamokawa Creek	1958	1	Klickitat Hatchery	237,380	
			Total	237,380	
Elochoman River	1966–78	3	Abernathy NFH	709,546	
	1981	1	Basin Stocks	2,928,957	
	1964	1	Big Creek Hatchery	2,049,806	
	1980	1	Cowlitz Hatchery	2,310,420	
	1974	**1**	**Elk River Hatchery**		**30,070**
	1956–93	26	Elochoman Hatchery	78,855,922	
	1986	1	Elochoman Hatchery/Kalama River	1,194,177	
	1980	1	Elochoman Hatchery/Toutle Hatchery	2,411,131	
	1956	1	Green River Hatchery	67,484	
	1975–93	5	Kalama Falls Hatchery	5,392,994	
	1958, 1982	2	Klickitat Hatchery	1,759,005	
	1982	1	Lower Columbia River (WA)	1,300,072	
	1956–66	3	Lewis River Hatchery	3,007,696	
	1953–54	2	Lower Kalama Hatchery	400,080	
	1971	1	Nemah Hatchery	132,750	
	1987	1	Skamokawa Creek	511,300	
	1953–67	12	Spring Creek NFH	14,699,029	
	1975, 1980	2	Toutle Hatchery	2,337,931	
	1974	**1**	**Trask Hatchery**		**38,974**
	1955	1	Unknown	3,758	
	1988	1	Washougal Hatchery	418,000	
			Total	120,490,058	**69,044**
Abernathy Creek	1974–94	21	Abernathy NFH	29,120,068	
	1977	1	Spring Creek NFH	5,090	
	1960–77	18	Unknown	15,273,548	
			Total	44,398,706	0

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Columbia River - RM 29	1971, 1977, 1979	2	Abernathy NFH	3,481,359	
	1979	1	Carson NFH	966,240	
	1979	1	Cascade Hatchery	25,617	
	1980	1	Cowlitz Hatchery	7,565,885	
	1957, 1958	2	Klickitat Hatchery	731,595	
	1980	1	Lower Columbia River (WA)	50,414	
	1968	1	Lower Kalama Hatchery	77,693	
	1971	**1**	**Priest Rapids Hatchery**		**1,804,000**
	1957–69	4	Spring Creek NFH	5,183,331	
.	1969	1	Toutle Hatchery	500,396	
	1990, 1991	2	Tule stocks	1,000	
	1960–85	10	Unknown	471,660,276	
	1971	**1**	**Wells Hatchery**		**1,784,000**
	1979	1	Willard NFH	148,575	
			Total	490,392,381	**3,588,000**
Cowlitz River	1981	1	Big Creek Hatchery (OR)	807,000	
	1981	1	Bonneville Hatchery	4,217,937	
	1961–93	27	Cowlitz Hatchery	152,192,405	
	1953–81	3	Lower Kalama Hatchery	2,830,087	
	1953, 1955	2	Spring Creek NFH	586,673	
	1968, 1979	2	Toutle Hatchery	1,008,357	
	1978, 1990	2	Washougal Hatchery	2,606,330	
	1952	1	Carson NFH	24,506	
			Total	164,273,295	0
Toutle River	1967	1	Big Creek Hatchery (OR)	463,459	
	1952	1	Carson NFH	1,164,070	
	1991, 1993	2	Cowlitz Hatchery	641,382	
	1989	1	Elochoman Hatchery	868,700	
	1988	1	Grays River Hatchery	3,937,000	
	1966–75	4	Green River Hatchery	8,024,234	
	1957	1	Lewis River Hatchery	348,799	
	1953–93	5	Lower Kalama Hatchery and Kalama Falls Hatchery	6,880,135	
	1953–60, 1993	8	Spring Creek NFH	9,400,907	
	1953–93	28	Toutle Hatchery	55,647,988	
	1964, 1965	2	Unknown	6,479,628	
	1987, 1993	2	Washougal Hatchery	987,600	
	1960	1	Willard NFH	795,932	
			Total	95,639,834	0
Kalama River	1978	1	Big Creek Hatchery (OR)	88,568	
	1977, 1982	2	Bonneville Hatchery	734,074	
	1958–93	31	Kalama Falls Hatchery	169,592,860	
	1956	1	Lewis River Hatchery	661,447	
	1952–84	28	Lower Kalama Hatchery	51,969,100	
	1976–81	**3**	**Priest Rapids Hatchery**		**280,209**

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Kalama River cont.	**1972**	**1**	**Ringold Hatchery**		**190,316**
	1978–84	**6**	**Snake River**		**2,194,002**
	1959, 1960	2	Spring Creek NFH	5,168,368	
	1978, 1979	2	Toutle Hatchery	4,286,684	
	1980	**1**	**Tucannon River**		**183,034**
			Total	232,684,135	**2,847,561**
Lewis River	1979	1	Grays River Hatchery	23,567	
	1952–93	30	Lewis River Hatchery	15,283,070	
	1954	1	Lower Kalama Hatchery	41,128	
	1954, 1974	2	Lower Kalama Hatchery	274,978	
	1961–79	3	Speelyai Hatchery	1,315,749	
	1959–81	3	Spring Creek NFH	3,121,717	
	1948–51	4	Unknown	510,252	
	1984, 1985	**2**	**Upriver brights**		**1,187,029**
	1980	1	Washougal Hatchery	28,267	
			Total	20,598,728	**1,187,029**
Salmon Creek	1969	1	Lower Kalama Hatchery	3,000	
	1969	1	Toutle Hatchery	3,000	
			Total	6,000	0
Washougal River	1967, 1986	2	Abernathy NFH	2,239,237	
	1971	1	Big Creek Hatchery (OR)	856,650	
	1977–83	3	Bonneville Hatchery	4,437,019	
	1980, 1986	2	Cowlitz Hatchery	7,489,190	
	1986	1	Elochoman Hatchery	75,600	
	1985	1	Grays River Hatchery	79,750	
	1966–85	7	Kalama Falls Hatchery	8,996,220	
	1981	1	Lower Columbia River (OR/WA)	5,509,822	
	1955–66	4	Lewis River Hatchery	2,449,402	
	1953	1	Lower Kalama Hatchery	175,000	
	1989	**1**	**Priest Rapids Hatchery**		**1,216,800**
	1958–65	8	Spring Creek NFH	21,186,454	
	1992	1	Spring Creek/Toutle Hatchery	5,522,700	
	1969–80	5	Toutle Hatchery	7,451,494	
	1979	1	Toutle Hatchery/Washougal Hatchery	5,342,147	
	1964, 1967	**2**	**Unknown**	**4,776,903**	
	1959–93	24	Washougal Hatchery	83,605,011	
			Total	160,192,599	**1,216,800**
Columbia River-RM 141	1992, 1993	2	Bonneville Hatchery	857,601	
	1978–88	9	Lower Columbia River (WA)	653,305	
	1992	**1**	**Little White Salmon NFH (URB)**		**1,628,987**
	1977	**1**	**Priest Rapids Hatchery**		**241,000**
	1977	**1**	**Snake River (WA)**		**3,326**
	1955–79	4	Unknown	1,510,096	
	1982	1	Washougal Hatchery	49,034	

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Columbia RM 141 cont.			Total	3,070,036	**1,873,313**
Hamilton Creek	1977	1	Spring Creek NFH	50,160	
			Total	50,160	0
Wind River	1952–68	11	Unknown	54,803,553	
	1976	1	Carson NFH	668,692	
			Total	55,472,245	0
Spring Creek NFH	1979–84	5	Abernathy NFH	29,113,699	
	1985–91	7	Bonneville Hatchery	44,276,578	
	1991	1	Clackamas River (early)	3,292,304	
	1987, 1988	2	Lower Columbia River (WA)	10,771,008	
	1987	1	Little White Salmon NFH	973,610	
	1987	**1**	**Priest Rapids Hatchery**		**1,100,000**
	1973–94	18	Spring Creek NFH	228,514,095	
	1988	1	Tule stock	1,084,816	
	1988	1	Unknown	217,350	
			Total	318,243,460	**1,100,000**
Little White Salmon River	1985	1	Bonneville Hatchery	203,996	
	1994	1	Carson NFH	1,797,922	
	1976–85	9	Little White Salmon NFH	86,649,137	
	1978, 1994	2	Spring Creek NFH	5,937,253	
	1983	1	Tule stock	8,430,082	
	1951–79	16	Unknown	152,096,514	
	1983–93	**11**	**Upriver brights**		**20,708,020**
			Total	255,114,904	**20,708,020**
Columbia River - RM 164	1994	1	Carson NFH	325	
	1981	1	Little White Salmon NFH	37,400	
	1979	1	Unknown	265,472	
			Total	303,197	0
Big White Salmon River	1976–84	4	Abernathy NFH	8,231,545	
	1979	1	Lower Columbia River (WA)	101,896	
	1981	1	Little White Salmon NFH	1,084,839	
	1954, 1979	2	Spring Creek NFH	3,082,047	
	1950–79	18	Unknown	74,351,025	
	1979	1	Willard NFH	98,597	
			Total	86,949,949	0
Skipanon River	1987	1	Klaskanine Hatchery	15,500	
			Total	15,500	0
Lewis and Clark River	1951, 1952	2	Lower Columbia River (OR)	146,230	
	1950	1	Unknown	61,600	
			Total	207,830	0
Youngs River	1988, 1991	2	Big Creek Hatchery	621,005	
	1986	1	Bonneville Hatchery	26,397	
	1989–92	**3**	**Cole Rivers Hatchery**		**475,352**
	1961, 1989	2	Klaskanine Hatchery	122,625	
			Total	770,027	**475,352**

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Klaskanine River	1979	1	Abernathy NFH	56,260	
	1950–89	10	Big Creek Hatchery	33,173,221	
	1931	1	Big White Salmon River	737,702	
	1929, 1936	2	Bonneville Hatchery	5,955,830	
	1978–86	9	Bonneville Hatchery	32,704,826	
	1975	**1**	**Chetco River**		**41,079**
	1983–88	**6**	**Cole Rivers Hatchery**		**572,601**
	1925–78	13	Klaskanine Hatchery	16,042,881	
	1927, 1928	2	Klaskanine Hatchery/USBF	2,145,108	
	1960, 1962	1	Klaskanine Hatchery/Willard NFH	1,993,540	
	1932–66	8	Lower Columbia River (OR)	11,302,002	
	1933, 1942	**2**	**Lower Columbia River (OR)/Willamette Hatchery**		**7,371,078**
	1931–39	**4**	**Lower Columbia River (WA)/ Willamette Hatchery**		**9,209,991**
	1946, 1958	2	Oxbow Hatchery	860,537	
	1959	1	Spring Creek NFH	965,428	
	1975	**1**	**Trask Hatchery**		**39,369**
	1923–77	5	Unknown	13,334,263	
			Total	119,271,598	**17,234,118**
Big Creek	1944–93	31	Big Creek Hatchery	123,924,819	
	1946, 1948	2	Big Creek Hatchery/Bonneville Hatchery	1,573,622	
	1959, 1960	2	Big Creek Hatchery/Willard NFH	3,171,214	
	1943	1	Bonneville Hatchery	338,500	
	1981–87	3	Bonneville Hatchery	14,313,343	
	1984–94	**11**	**Cole Rivers Hatchery**		**3,519,553**
	1941	**1**	**McKenzie River Hatchery**		**1,290,875**
	1950, 1968–76	9	Unknown	54,142,951	
	1942	**1**	**Willamette Hatchery**		**568,500**
			Total	197,464,449	**5,378,928**
Gnat Creek	1952	1	Big Creek Hatchery	29,520	
	1954–57	4	Bonneville Hatchery	150,769	
	1957, 1958	**2**	**Trask Hatchery**		**52,220**
			Total	180,289	52,220
Clatskanie River	1951–53	3	Big Creek Hatchery	208,200	
			Total	208,200	0
Mid-Columbia River OR	1979–84	5	Abernathy NFH	965,896	
	1964, 1987	2	Big Creek Hatchery	1,949,466	
	1978–83	4	Bonneville Hatchery	5,806,919	
	1939, 1954	2	Bonneville Hatchery/Oxbow Hatchery	2,714,025	
	1965	1	Carson NFH	411,965	
	1978, 1981	2	Cascade Hatchery	5,625,444	
	1978	**1**	**Deschutes River (OR)**		**73,092**

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Mid-Columbia River OR cont.	1910	1	Lower Columbia River (OR)	15,170,324	
	1981	1	Little White Salmon NFH	25,933	
	1940, 1941, 1963	3	Oxbow Hatchery	5,246,079	
	1977–80	3	Spring Creek NFH	3,359,797	
	1966	1	Tule stock	377,520	
	1940, 69, 70		Unknown	1,119,151	
	1987–91	**5**	**Upriver brights**		**1,804,107**
	1966	**1**	**Willamette Hatchery**		**11,025**
			Total	42,772,519	1,888,224
Scappoose Creek	1952, 1953	2	Big Creek Hatchery	69,450	
			Total	69,450	0
Clackamas River	1952–54	3	Bonneville Hatchery	2,160,060	
	1981	1	Bonneville Hatchery	4,080	
	1965	1	Lower Columbia River (OR)	921,545	
	1955, 1965	2	Oxbow Hatchery	1,214,851	
	1960	1	Spring Creek NFH	1,012,607	
	1960–72	7	Unknown	16,585,148	
			Total	21,898,291	0
Eagle Creek	1938, 1953	2	Bonneville Hatchery	630,000	
	1961, 1967	2	Cascade Hatchery	10,923,441	
	1949, 1960–65	4	Lower Columbia River (OR)	20,420,776	
	1962	**1**	**Lower Columbia River (OR)/ Mt. Shasta Hatchery**		**4,853,922**
	1929	**1**	**Lower Columbia River (OR)/ Willamette Hatchery**		**347,000**
	1934–65	7	Unknown	978,056	
			Total	32,952,273	**5,200,922**
Sandy River	1938–54	3	Bonneville Hatchery	4,057,279	
	1966	1	Cascade Hatchery	174,648	
	1945–65	8	Lower Columbia River (OR)	18,696,769	
	1960	1	Lower Columbia River (OR/WA)	2,919,481	
	1955–64	5	Sandy Hatchery	2,207,995	
	1934–77	12	Unknown	4,758,926	
			Total	32,815,098	0
Multnomah Creek	1951	1	Lower Columbia River (OR)	50,400	
	1953	1	Oxbow Hatchery	152,064	
			Total	65,832,660	0
Tanner Creek	1990–92	3	Big Creek Hatchery	14,585,543	
	1928–66	14	Bonneville Hatchery	106,965,953	
	1977–93	17	Bonneville Hatchery	130,296,696	
	1912–61	14	Bonneville Hatchery mix	80,763,654	
	1945	**1**	**Bonneville Hatchery and Rock Creek Hatchery**		**4,601,000**
	1958	**1**	**Bonneville Hatchery/Trask Hatchery**		**4,225,234**
	1965	1	Bonneville Hatchery/unknown	9,601,000	

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Tanner Creek cont.	1940–67	6	Lower Columbia River (OR)	34,203,415	
	1955–62	3	Lower Columbia River (OR/WA)	27,961,223	
	1979–81	**3**	**Snake River (OR)**		**512,440**
	1957	**1**	**Trask Hatchery**		**3,756,712**
	1986–91	3	Tule stock	2,894,909	
	1918–77	21	Unknown	206,351,204	
	1978–93	**16**	**Priest Rapids**		**46,736,964**
			Total	613,623,597	59,832,350
Herman Creek	1918	1	Bonneville Hatchery	3,937,598	
	1928–54	4	Lower Columbia River (OR)	4,402,471	
	1958	1	Lower Columbia River (OR/WA)	2,348,962	
	1951–67	12	Oxbow Hatchery	39,619,232	
	1925–68	3	Unknown	8,998,412	
			Total	59,306,675	0
Hood River	1938–54	7	Bonneville Hatchery	1,473,180	
	1951	1	Lower Columbia River (OR)	503,200	
	1934–37	4	Unknown	680,000	
			Total	2,656,380	0
Fifteenmile Creek	1949	1	Lower Columbia River (OR)	80,500	
			Total	80,500	0
Grays River	1977	1	Kalama Falls Hatchery	116,800	
			Total	116,800	**0**
Abernathy Creek	1975	1	Abernathy NFH	91,744	
	1969, 1975		Unknown	90,050	
			Total	181,794	**0**
Cowlitz River	1968–93	26	Cowlitz Hatchery	68,063,606	
	1979	1	Little White Salmon NFH	224,590	
	1948–70	4	Unknown	1,716,588	
	1968, 1969	**2**	**Willamette Hatchery**		**999,295**
			Total	70,004,784	**999,295**
Toutle River	1974–84	7	Cowlitz Hatchery	2,661,471	
	1953	1	Unknown	11,184	
			Total	2,672,655	**0**
Kalama River	1964	1	Ancient wild stocks	46,657	
	1964, 1966	2	Bitter Creek	147,074	
	1967, 1981	2	Cowlitz Hatchery	525,909	
	1969–93	25	Kalama Falls Hatchery	9,084,007	
	1965	1	Klaskanine Hatchery	195,800	
	1972, 1973	2	Lower Columbia River mix	99,175	
	1978	1	Little White Salmon NFH	136,989	
	1964	1	Sherwood Creek	132,054	
			Total	10,367,665	**0**
Lewis River	**1973–81**	**4**	**Carson NFH**		**702,708**
	1972–87	9	Cowlitz Hatchery	2,476,235	
	1981–93	5	Kalama Falls Hatchery	2,415,550	

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Lewis River cont.	**1975, 1976**	**2**	**Klickitat Hatchery**		**203,660**
	1977–93	11	Lewis River Hatchery	6,999,862	
	1980	1	Lewis River Hatchery/Kalama River	807,408	
	1977–82	4	Speelyai Hatchery	2,011,325	
	1948–51	4	Unknown	192,943	
			Total	14,903,323	**906,368**
Columbia River (Beacon Rock)	1978–88	8	Lower Columbia River (WA)	959,953	
	1973–90	**14**	**Snake River (WA)**		**1,412,152**
			Total	959,953	**1,412,152**
North Hatchery Bonneville Dam (bypass system tests)	**1978**	**1**	**Carson NFH**		**76,060**
	1980	**1**	**Kooskia Hatchery**		**62,300**
	1978, 1980	**2**	**Rapid River Hatchery**		**35,000**
	1973–77	**4**	**Snake River (WA)**		**425,801**
			Total	0	**599,161**
Columbia River - RM 164	**1974, 1994**	**2**	**Carson NFH**		**5,350**
			Total	0	**5,350**
Wind River	1976	1	Abernathy NFH	82,697	
	1979	1	Lower Columbia River (WA)	45,014	
	1956–75	19	Unknown	27,098,613	
			Total	27,226,324	**0**
Spring Creek NFH	**1993**	**1**	**Kalama Falls Hatchery/Ringold Hatchery and Carson NFH**		**669,400**
			Total	0	**669,400**
Little White Salmon River	1985	1	Abernathy NFH	946,959	
	1986–94	**7**	**Carson NFH**		**9,819,820**
	1976–89	**13**	**Little White Salmon NFH**		**13,759,232**
	1966–75	8	Unknown	4,807,330	
			Total	5,754,289	**23,579,052**
Big White Salmon River	**1986–94**	**8**	**Carson NFH**		**4,880,790**
	1982	1	Cowlitz Hatchery	149,071	
	1991	**1**	**Little White Salmon NFH**		**942,804**
			Total	149,071	**5,823,594**
Youngs River	**1991, 1992**	**2**	**Clackamas River early**		**242,534**
	1994	**1**	**Marion Forks Hatchery**		**301,361**
	1989–92	**4**	**Willamette Hatchery**		**1,048,266**
			Total	0	**1,592,161**
Klaskanine River	**1931**	**1**	**Big White Salmon River and McKenzie River Hatchery**		**158,643**
	1991	**1**	**Clackamas River (early)**		**119,627**
	1994	**1**	**Marion Forks Hatchery**		**109,974**
	1928–34	**3**	**McKenzie River Hatchery**		**4,404,514**
	1994	**1**	**Santiam River**		**100,000**
	1930	**1**	**Trask Hatchery**		**953,400**
	1920–24	3	Unknown	14,548,862	

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Klaskanine River cont.	**1989–92**	**3**	**Willamette Hatchery**		**577,944**
	1927	**1**	**Willamette Hatchery mixed**		**2,101,000**
			Total	14,548,862	**8,525,102**
Big Creek	1985	**1**	**Clackamas River (early)**		**20,449**
			Total	0	**20,449**
Mid-Columbia River OR	**1980**	**1**	**Carson NFH**		**44,344**
	1979, 1990	**2**	**Clackamas River (early)**		**17,909**
	1991	**1**	**Lookingglass Hatchery**		**8,398**
	1946	1	Unknown	605,750	
			Total	605,750	**70,651**
Scappoose Creek	1930		**Marion Forks Hatchery/Trask Hatchery**		**60,000**
			Total	0	**60,000**
Clackamas River	**1975**	**1**	**Carson NFH**		**289,710**
	1977, 1978	2	Cascade Hatchery	195,203	
	1985, 1992	**2**	**Clackamas River**		**232,947**
	1978–94	**14**	**Clackamas River (early)**		**11,595,754**
	1979	**1**	**Clackamas River (late)**		**98,461**
	1975–87	**5**	**Eagle Creek NFH**		**1,294,822**
	1978	**1**	**Marion Forks Hatchery**		**188,261**
	1979–88	**4**	**Santiam River**		**1,653,231**
	1939–89	30	Unknown	25,649,266	
	1982–89	**6**	**Willamette Hatchery**		**4,319,098**
			Total	25,844,469	**19,672,284**
Sandy River	1990	1	Bonneville Hatchery	258,629	
	1978	**1**	**Carson NFH**		**57,861**
	1979–93	**11**	**Clackamas River (early)**		**3,067,038**
	1948, 1949	2	Lower Columbia River (OR)	441,169	
	1942, 1959	**2**	**McKenzie River Hatchery**		**1,066,949**
	1952–60	7	Sandy Hatchery	2,192,294	
	1939–47	**4**	**Sandy Hatchery/McKenzie River Hatchery**		**3,903,646**
	1957	**1**	**Sandy Hatchery/Willamette Hatchery**		**40,475**
	1979, 1981, 19**86**	**3**	**Santiam River**		**305,729**
	1920–84	8	Unknown	2,007,960	
	1973, 1974	2	USFWS-unspecified	37,483	
	1982–88	**4**	**Willamette Hatchery**		**1,153,877**
			Total	4,937,535	**9,595,575**
Tanner Creek	**1925–45**	**8**	**Bonneville Hatchery/Willamette Hatchery**		**27,815,501**
	1930	**1**	**Marion Forks Hatchery/Trask Hatchery**		**1,710,240**
	1920–22	3	Unknown	15,861,909	
			Total	15,861,909	**29,525,741**
Herman Creek	1920–35	3	Bonneville Hatchery	7,119,680	
	1924	1	Oxbow Hatchery	3,963,540	
	1921–72	19	Unknown	50,327,069	
			Total	61,410,289	**0**

Table A.1 cont.

ESU 9. Lower Columbia River ESU (Fall Run)				**Total Releases[d]**	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Hood River	1919	1	Bonneville Hatchery	291,860	
	1946–47	2	Oxbow Hatchery	680,750	
	1984–85	**2**	**Clackamas Hatchery**		**53,920**
	1985–92	**6**	**Carson Hatchery**		**871,406**
	1993–94	**2**	**Deschutes River**		**69,127**
			Total	972,610	**994,453**
			Totals for ESU #9	3,607,547,163	**226,965,239**

Table A.2. Hatchery chinook salmon releases for the Upper Willamette River ESU.

ESU 10. Upper Willamette River ESU (Spring Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Clackamas River	1975	1	Carson NFH	289,710	
	1977, 1978	**2**	**Cascade Hatchery**		**195,203**
	1985, 1992	2	Clackamas River	232,947	
	1978–94	14	Clackamas River (early)	11,595,754	
	1979	1	Clackamas River (late)	98,461	
	1975–87	5	Eagle Creek NFH	1,294,822	
	1978	1	Marion Forks Hatchery	188,261	
	1979–88	4	Santiam River	1,653,231	
	1939–89	30	Unknown	25,649,266	
	1982–89	6	Willamette Hatchery	4,319,098	
			Total	45,321,550	**195,203**
Molalla River	1991	1	Clackamas River (early)	469,890	
	1964	1	McKenzie River Hatchery	72,975	
	1981–92	3	Santiam River	2,032,335	
	1964–65	2	Unknown	375,209	
	1982–92	10	Willamette Hatchery	7,520,897	
			Total	10,471,306	
Pudding River	1964	1	McKenzie River Hatchery	62,550	
	1983–85	3	Willamette Hatchery	453,479	
			Total	516,029	0
Luckiamute River	1968	1	Unknown	88,128	
			Total	88,128	0
Santiam River	**1965–82**	**7**	**Carson NFH**		**1,416,271**
	1980, 1981	2	Clackamas River (early)	752,939	
	1967–75	**4**	**Hagerman NFH***	645,175	**645,175**
	1923–94	53	Marion Forks Hatchery	87,932,370	

[a] Duration = time frame of the releases,

[b] Years = the total number of years that fish were actually released within the time frame. The majority of spring-run chinook salmon were released as yearling smolts. The majority of ocean-type, fall- and summer-run chinook salmon were released as subyearlings. No releases of eggs or fry (<5 g) are included here. Data before 1950 are not necessarily complete (NRC 1995).

[c] Release source = the origin of the broodstock used to produce the juveniles released. Plain text indicates that the source was from within the ESU, while bold text indicates a source from outside the ESU.

[d] Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river are also assumed to be native regardless of past introductions, unless the hatchery broodstock is known to be from outside the ESU.

KEY:

mix	a mix of two or more stocks from the same area
NFH	National Fish Hatchery
/	a mix of stocks from different areas

Table A.2 cont.

ESU 10. Upper Willamette River ESU (Spring Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Santiam River cont.	1936, 1937	2	Marion Forks Hatchery/McKenzie River Hatchery	8,441,800	
	1961–78	7	McKenzie River Hatchery	1,009,442	
	1941, 1948	2	McKenzie River Hatchery/ Santiam River	1,663,717	
	1932–94	46	Santiam River	61,605,990	
	1963, 1964	2	Santiam River/Willamette Hatchery	1,989,604	
	1962	**1**	**Spring Creek NFH**		**191,298**
	1918–81	26	Unknown	16,976,462	
	1981–86	6	Willamette Hatchery	10,566,693	
			Total	191,584,192	**2,252,744**
Willamette River	1952, 1962–67	4	Marion Forks Hatchery	343,676	
	1949, 1978	2	McKenzie Hatchery	50,003	
	1955	1	McKenzie Hatchery/ Willamette Hatchery	1,173,991	
	1953, 1987	2	Santiam River	420,240	
	1916–77	14	Unknown	12,567,419	
	1955–67	7	Willamette Hatchery	9,457,376	
	1979–92	11	Willamette Hatchery	10,089,414	
			Total	34,102,119	0
Calapooia River	1981, 1985	2	Santiam River	46,188	
	1982–85	4	Willamette Hatchery	500,522	
			Total	546,710	0
McKenzie River	**1969–75**	**7**	**Hagerman NFH***		**1,424,563**
	1966	1	Marion Forks Hatchery	47,418	
	1952	1	Marion Forks Hatchery and McKenzie Hatchery	1,125,897	
	1966	1	Marion Forks Hatchery/Willamette Hatchery	3,030	
	1902–69	62	McKenzie Hatchery	192,671,426	
	1978–94	17	McKenzie Hatchery	15,997,516	
	1951–65	4	McKenzie Hatchery/Willamette Hatchery	1,309,620	
	1972–91	4	Santiam River	288,820	
	1918–77	17	Unknown	4,144,703	
	1966–84	4	Willamette Hatchery	1,318,574	
			Total	216,907,004	**1,424,563**
Middle Fork Willamette River	**1974**	**1**	**Hagerman NFH***		**41,379**
	1920–76	**4**	**LCR (OR)/Willamette Hatchery**		**1,885,217**
	1983, 1990	1	Marion Forks Hatchery	290,174	
	1979–90	4	McKenzie Hatchery	1,038,153	
	1928, 1952	2	McKenzie Hatchery and Willamette Hatchery	8,310,778	
	1958	**1**	**Nehalem River/Willamette Hatchery**		**19,962**

Table A.2 cont.

ESU 10. Upper Willamette River ESU (Spring Run)				Total Releases[d]	
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**
Middle Fork	1978–91	7	Santiam River	3,439,419	
Willamette cont.	1952–66	6	Santiam River/Willamette Hatchery	6,984,701	
	1950–77	9	Unknown	17,681,493	
	1958	**1**	**Wenatchee River/Willamette Hatchery**		**67,827**
	1921–94	59	Willamette Hatchery	17,934,084	
			Total	55,678,802	2,014,385
Molalla River	**1965, 1967**	**2**	**Big Creek Hatchery**		**1,397,158**
	1958	**1**	**Bonneville Hatchery/Trask Hatchery**		**100,000**
	1978	**1**	**Cascade Hatchery**		**2,111,600**
	1959, 1960	**2**	**Lower Columbia River (OR)/Willamette Hatchery**		**401,858**
	1967	**1**	**Oxbow Hatchery**		**500,132**
	1957	**1**	**Trask River (Bonneville Hatchery)**		**75,000**
	1964–76	**11**	**Unknown**		**9,310,823**
			Total	0	13,896,571
Luckiamute River	**1974, 1976**	**2**	**Unknown**		**1,945,098**
			Total	0	1,945,098
Mary's River	**1970**	**1**	**Hagerman NFH***		**176,400**
			Total	0	176,400
Santiam River	**1966**	**1**	**Big Creek Hatchery**		**1,000,848**
	1921, 1951	**2**	**Bonneville Hatchery/ Oxbow Hatchery**		**1,669,444**
	1966	**1**	**Cascade Hatchery**		**350,000**
	1956, 1957	**2**	**Klickitat Hatchery**		**175,974**
	1958, 1966	**2**	**Oxbow Hatchery**		**599,911**
	1964–76	**11**	**Unknown**		**54,236,434**
			Total	0	**58,032,611**
Willamette River	**1953–56**	**4**	**Bonneville Hatchery**		**2,922,337**
	1977–93	**16**	**Bonneville Hatchery**		**88,960,581**
	1949	**1**	**Bonneville Hatchery/Trask Hatchery**		**8,776**
	1970	**1**	**Hagerman NFH***		**14,560**
	1965–85	**13**	**Willamette Hatchery**		**34,294,598**
			Total	0	**126,200,852**
McKenzie River	**1966**	**1**	**Bonneville Hatchery**		**510,150**
	1966	**1**	**Cascade Hatchery**		**650,454**
	1964–68	**3**	**Unknown**		**3,399,591**
			Total	0	**4,560,195**
			Totals for ESU #10:	555,215,840	210,698,622

Table A.3. Hatchery steelhead releases, listed by ESU.

ESU 3. Southwest Washington ESU				Total Releases[d]		
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**	**Run**
Beaver Creek (WA)	1959–1973	12	Unknown	834,116		NA
	1986, 1987	**2**	**Elochoman River**		**64,964**	**S**
	1983	**1**	**Kalama River**		**10,750**	**S**
	1993	**1**	**NF Lewis River**		**33,840**	**S**
	1968–1981	**4**	**Unknown**		**90,601**	**S**
	1984–1990	**7**	**Washougal River**		**1,115,045**	**S**
	1984–1994	**8**	**West Fork Washougal River**		**1,115,780**	**S**
	1986–1992	6	Beaver Creek (WA, Eloch)	457,833		W
	1982–1983	2	Bogachiel River	157,038		W
	1982–1994	13	Elochoman River	1,178,382		W
	1985	**1**	**Green River (WDFW)**		**19,976**	**W**
	1993	**1**	**Kalama River**		**19,040**	**W**
	1994	**1**	**North Fork Lewis River**		**43,538**	**W**
	1959–1981	19	Unknown	1,232,901		W
	1990	1	Washougal River	4,950		W
			Total	3,865,220	**2,513,534**	
Grays River	1993, 1994	2	Elochoman River	82,187		W
			Total	82,187		
Mayr Bros. RP	**1982–1991**	**7**	**Bogachiel River**		**1,403,619**	**W**
	1983–1988	4	Chehalis River (WA)	135,076		W
	1992	1	Humptulips River	242,346		W
	1984–1991	7	Quinault River	1,375,356		W
	1975–1981	7	Unknown	1,794,307		W
	1989	1	Van Winkle Creek	52,264		W
			Total	3,599,349	**1,403,619**	
Big Creek	1968–1975	5	Unknown	312,493		NA
	1976–1992	16	Big Creek	987,831		W
	1972–1977	4	Unknown	262,244		W
			Total	1,562,568		

[a] Duration = the time frame of the releases,
[b] Years = the total number of years that fish were actually released within the time frame.
[c] No releases of eggs or fry (<5 g) are included here. Data before 1950 are incomplete (NRC 1995).
[d] Releases in bold indicate introductions from outside the ESU. Stocks of unknown origin are assumed to be from within the ESU. Fish releases derived from adults returning to that river are also assumed to be native regardless of past introductions, unless the river historically never contained a run.

NOTES:
NFH National Fish Hatchery
X cross between two different stocks
/ mix of stocks from different areas
W winter run
S summer run
WDFW Washington Department of Fish and Wildlife

Table A.3 cont.

ESU 3. Southwest Washington ESU				Total Releases[d]		
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**	**Run**
Gnat Creek (OR)	**1965, 1966**	**2**	**Alsea River and tributaries**		**405,905**	**NA**
	1961	**1**	**Carson Hatchery**		**75,273**	**NA**
	1961–1964	**4**	**Columbia River (OR, early)**		**481,114**	**NA**
	1971	**1**	**Deschutes River**		**27,375**	**NA**
	1961–1971	**9**	**Hagerman**		**825,522**	**NA**
	1961–1966	**6**	**Hood River**		**375,461**	**NA**
	1968	**1**	**Nestucca River**		**1,498**	**NA**
	1971–1973	**4**	**Deschutes River**		**138,545**	**S**
	1974–1976	**3**	**Foster Reservoir**		**365,720**	**S**
	1978–1992	**15**	**South Santiam Hatchery**		**3,311,941**	**S**
	1977	**1**	**Unknown**		**204,949**	**S**
	1966	**1**	**Alsea River and tributaries**		**10,268**	**W**
	1976–1992	15	Big Creek	7,077,693		W
	1967–1975	**9**	**Hagerman**		**2,509,075**	**W**
	1982	**1**	**Marion Forks**		**23,492**	**W**
	1877	1	Unknown	354,942		W
			Total	7,432,635	**8,756,138**	
Klaskanine River	1978–199	15	Big Creek	875,134		W
	1972–1977	5	Unknown	228,231		W
			Total	1,103,365		
	1991–1993	2	West Fork Washougal River	42,000		S
Trojan Pond	1987–1990	4	Big Creek	240,137		W
Cowlitz River Basin						
Coweeman River Pond	**1984–1994**	**9**	**Elochoman River**		**944,779**	**W**
	1986	1	Mixed coastal	8,927		W
			Total	8,927	**944,779**	
South Fork Toutle River	1984–1990	4	Washougal River	359,850		S
	1986–1994	5	West Fork Washougal River	379,940		S
	1971–1981	11	Unknown	286,160		S
	1968–1985	2	Beaver Creek	58,079		W
			Total	1,084,029		
Cowlitz (Trout)	1976–1994	16	Cowlitz River (WDFW)	2,602,327		S
	1971–1981	11	Unknown	1,311,165		S
	1982–1994	13	Cowlitz River (WDFW)	2,650,929		W
	1967–1981	11	Unknown	2,400,399		W
			Total	11,150,732	**1,889,558**	
North Hatchery Fork	**1985**	**1**	**Elochoman**		**6,345**	**W**
Toutle River	**1980**	**1**	**Beaver Creek**		**19,729**	**W**
	1980	1	Cowlitz	27,436		W
	1988–1993	5	Washougal	183,671		S
	1972–1980	**3**	**Skamania**		**169,516**	**S**
			Total	211,107	**195,590**	
Kalama River Basin						
Gobar Pond	1985	1	Cowlitz River (WDFW)	50,726		S

Table A.3 cont.

ESU 3. Southwest Washington ESU				Total Releases[d]		
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**	**Run**
Gobar Pond cont.	1975–1981	7	Unknown	447,285		S
	1982–1990	3	Washougal River	231,415		S
	1986–1994	8	West Fork Washougal River	2,035,586		S
	1982	**1**	**Chambers Creek**		**219,746**	**W**
	1984–1994	**10**	**Elochoman River**		**2,093,308**	**W**
	1985	1	Green River (Cowlitz River tributary)	169,395		W
	1993	1	Kalama River	60,836		W
			Total	2,995,243	**2,313,054**	
Lewis River Basin						
Lewis River	1953–1958	5	Lewis River (WDFW)	274,253		NA
	1948–1951	4	Unknown	95,434		NA
			Total	369,687	**0**	
Merwin Net Pen	1979–1981	3	Unknown	93,944		S
	1984–1987	4	Washougal River	457,421		S
	1991–1993	2	West Fork Washougal River	42,000		S
	1983	**1**	**Chambers Creek**		**41,000**	**W**
	1988–1991	**3**	**Elochoman River**		**114,325**	**W**
	1979–1981	3	Unknown	104,100		W
	1984, 1986	2	Washougal River	29,730		W
	1990–1993	2	West Fork Washougal River	294,834		W
			Total	1,761,403	**155,325**	
Washougal River Basin						
Skamania	1953–1966	12	Unknown	145,158		NA
Hatchery	**1985**	**1**	**Chambers Creek**		**56,169**	**S**
	1983	**1**	**Columbia River (WA, upper)**		**39,492**	**S**
	1985	1	Cowlitz River (WDFW)	2,660		S
	1980–1988	4	Skamania (WDFW)	28,731		S
	1985	**1**	**Skykomish River (WDFW)**		**75,053**	**S**
	1957–1981	25	Unknown	3,564,653		S
	1982–1994	13	West Fork Washougal River	8,319,870		S
	1985	**1**	**Willamette River (ODFW)**	4,988		**S**
	1983	1	Wind River		**115,605**	S
	1983	**1**	**Bogachiel River**			**W**
	1982, 1986	**2**	**Chambers Creek**	214,731	**1,745,308**	**W**
	1985, 1986	2	Cowlitz River (WDFW)		**622,435**	W
	1984, 1991	**2**	**Elochoman River**	2,284,744		**W**
	1957–1981	13	Unknown		**1,908,187**	W
	1985	1	Washougal River	1,697		W
	1984–1994	11	West Fork Washougal River	4,506,909		W
			Total	19,074,141	**4,562,249**	
Vancouver	1950–1965	12	Unknown	751,528		NA
Hatchery	1951–1980	7	Unknown	1,033,052		S
	1982–1993	11	Washougal River	5,427,645		S
	1985, 1986	2	West Fork Washougal River	1,064,254		S
	1994	1	Skamania (WDFW)	60,667		W

Table A.3 cont.

ESU 3. Southwest Washington ESU				Total Releases[d]		
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**	**Run**
Vancouver	1964–1979	8	Unknown	618,829		W
Hatchery cont.			Total	8,955,975	0	
Wallace Pond	1989–1994	5	Cowlitz River (WDFW)	677,570		W
			Total	677,570		
Bonneville	**1979**	**1**	**Big Creek**		**12,323**	**W**
Hatchery			Total		**12,323**	
Clackamas River Basin						
Clackamas	**1992**	**1**	**South Santiam Hatchery**		**38,756**	**S**
	1981	**1**	**Big Creek**		**15,292**	**W**
	1986–1992	7	Clackamas River late	460,671		W
			Total	460,671	**54,048**	
Eagle Creek NFH	**1977**	**1**	**Big Creek**		**84,103**	**NA**
	1979	1	Clackamas River late	162,067		NA
	1959	1	Unknown	34,267		NA
	1978	**1**	**Big Creek**		**51,714**	**W**
	1989–1994	6	Clackamas River early	1,035,433		W
	1960–1988	27	Unknown	6,448,482		W
			Total	7,680,249	**135,817**	
Rock Creek Basin	1989–1994	3	West Fork Washougal	23,020		W
	1991	**1**	**Elochoman River**		**10,000**	**W**
			Total	23,020	**10,000**	
Sandy River	1939–1946	7	Marmot Dam	4,254,606		NA
Basin	1900–1909	9	Salmon River fry	2,644,018		NA
	1955–1958	4	Sandy +unknown			NA
	1976	**1**	**Marion Forks**		**9,758**	**W**
	1977	1	Unknown	7,980		W
			Total	6,906,604	**9,758**	
Wind River Basin						
	1964–1969	4	Goldendale Hatchery	241,080		S
	1965	1	Wild stock (?)	27,770		S
	1963–1994	**20**	**Skamania Hatchery**		**1,510,536**	**S**
	1985–1993	8	Vancouver Hatchery (Washougal)	297,715		S
	1956–1970	5	Carson NFH	145,731		NA
	1959–1962	3	Skamania Hatchery	101,245		NA
	1951	1	Vancouver Hatchery (unknown)	7,520		NA
	1961,1963	2	Skamania Hatchery	35,740		W
			Total	856,801	1,510,536	
Big White						
Salmon River	**1983**	**1**	**Upper Columbia River**		**21,001**	**S**
	1982–1987	2	Washougal	30,144		S
	1984–1993	5	West Fork Washougal	224,935		S
	1985	**1**	**Willamette River**		**10,006**	**S**
	1991–1992	**2**	**Beaver Creek**		**79,260**	**W**
	1982	**1**	**Chambers Creek (Puget Sound)**		**32,901**	**W**

Table A.3 cont.

ESU 3. Southwest Washington ESU				Total Releases[d]		
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**	**Run**
Big White Salmon River cont.	1985–1986	2	Cowlitz River	123,841		W
	1984	**1**	**Elochoman Hatchery**		**10,047**	**W**
	1994	1	North Fork Washougal	10,047		W
	1990–1994	4	Washougal River	129,838		W
			Total	518,805	**153,215**	
Hood River Hatchery	1958–1966	8	Hood River	147,375		
			Total	147,375	0	
Leaburg	**1970–1976**	**3**	**Foster Reservoir**		**107,650**	**S**
	1980–1992	**13**	**McKenzie River**	0	**1,139,387**	**S**
	1978–1985	**8**	**South Santiam Hatchery**		**677,723**	**S**
			Total		**1,924,760**	
Marion Forks	1931–1985	18	Marion Forks	11,528,482		NA
	1968–1975	4	Unknown	394,191		NA
	1983	1	South Santiam Hatchery	20,940		S
	1976–19992	16	Marion Forks	1,853,410		W
	1984	1	South Santiam Hatchery	21,064		W
	1969–1977	5	Unknown	354,692		W
			Total	14,172,779	0	
McKenzie Hatchery	**1913**	**1**	**Trask Hatchery fingerlings**		**90,551**	**NA**
	1911	1	Unknown	35,000		NA
	1983–1991	**9**	**McKenzie River**		**472,674**	**S**
	1982–1992	**10**	**South Santiam Hatchery**		**811,307**	**S**
			Total	35,000	**1,374,532**	
Roaring River	1971	1	Foster Reservoir	84		NA
	1975	1	Hagerman	8,022		NA
	1960	1	Roaring River	9,620		NA
	1965	1	Wickiup Reservoir	16,592		NA
	1973–1976	**4**	**Foster Reservoir**		**388,568**	**S**
	1978–1992	**15**	**South Santiam Hatchery**		**1,867,166**	**S**
	1977	**1**	**Unknown**		**2,750**	**S**
	1959	**1**	**Wickiup Reservoir**		**16,133**	**S**
	1968, 1969	**2**	**Wickiup Reservoir**		**54**	**S**
	1972, 1976	**2**	**Alsea River and tributaries**		**114,976**	**W**
	1976–1992	**12**	**Big Creek**		**1,630,062**	**W**
	1985–1988	**3**	**Klaskanine River**		**222,317**	**W**
	1972, 1977	2	Unknown	149,024		W
			Total	183,342	**4,242,026**	
South Santiam **[River or Hatchery?]**	**1929**	**1**	**Rogue River**		**411,056**	**NA**
	1928–1944	13	South Santiam Hatchery	13,697,599		NA
	1969–1975	3	Unknown	350,192		NA
	1976–1992	**16**	**South Santiam Hatchery**		**2,844,316**	**S**
	1972–1977	**4**	**Unknown**		**641,043**	**S**
	1981	1	Marion Forks	26,489		W
			Total	14,074,280	3,896,415	

Table A.3 cont.

ESU 3. Southwest Washington ESU				Total Releases[d]		
Watershed	**Duration[a]**	**Years[b]**	**Source[c]**	**Within ESU**	**Outside ESU**	**Run**
Willamette	**1957–1959**	**3**	**Alsea River and tributaries**		**182,218**	**NA**
Hatchery	1956	1	Oak Springs	1,069		NA
	1972	1	Unknown	20,936		NA
	1954–1961	6	WILL+MF+BONN **[??]**	Unknown		NA
	1955, 1957	2	Willamette River	102,271		NA
	1984, 1987	2	South Santiam Hatchery	206,466		S
	1987	1	Big Creek	82,211		W
			Total	412,953	182,218	

APPENDIX B

OVERVIEW OF GENETIC DATA AVAILABLE ON SALMONID POPULATIONS IN LISTED LOWER COLUMBIA AND UPPER WILLAMETTE ESUs

Introduction

This document describes and summarizes the genetic data currently available on chum salmon populations in the Columbia Chum ESU, chinook salmon and steelhead trout in the Lower Columbia ESU, and chinook salmon and steelhead trout in the Upper Willamette ESU. Although DNA data are likely to become available on at least some of these populations in the next few years, all the currently available data are from electrophoretic analysis of soluble enzymes (e.g., Aebersold et al. 1987), often called allozyme data. All data described herein were produced by the genetics labs of either the Washington Department of Fish and Wildlife (WDFW) in Olympia, Washington, or the National Marine Fisheries Service (NMFS) in Seattle/Manchester, Washington

Standards for data consistency and quality (informally called the coastwide process) between these two labs and others in the region have been developed over the past 15 years (Shaklee and Phelps 1990), ensuring that data from the two groups can be combined. The only exception is steelhead, for which some standardization work remains to be done (D. Teel[1]). Data from a number of labs throughout the region were combined to produce the NMFS status reviews on chum, chinook, and steelhead. The databases are described in tables in this appendix. Most of the data have already appeared in the status reviews, but there is a considerable amount of new data for some species/ESU combinations.

The collections available may seem to be a reasonably comprehensive sampling of the populations in the Lower Columbia/Upper Willamette region, but there is a subtle bias to sampling that can be potentially important in the TRT's review of these data. Genetic sampling has been done largely to characterize differences between groups that were already viewed as distinct stocks, not as a means of delineating populations. The reason for this is that the initial impetus for genetic work on these fish, especially chinook, was analysis of mixed-stock fisheries (e.g., Marshall et al. 1991). The bias results from the fact that the smaller the stock, the less important it would be to the fishery, and thus the less likely it would have been to be sampled. Thus there is a circularity here in that we have data because we thought groups of fish were different, and now we use those data to determine that these groups are different. Since ESA listings began, there has been some change in sampling strategy in terms of sampling small populations that, outside of ESA significance, would get little attention from fish management agencies, but it is important to consider how our view of populations may have been shaped by this sampling strategy.

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[1] David Teel, NMFS, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112, pers. commun.

The states of Washington and Oregon have both formally described populations (not necessarily genetically distinct) of chinook, steelhead, and chum; as well as genetic groupings of these populations. These population designations and genetic groupings may be of some use in TRT population identification work. The State of Washington and tribal comanagers (WDF et al. 1993) have defined stocks for salmon and steelhead in the Salmon and Steelhead Stock Inventory (SASSI; now known as the Salmonid Stock Inventory, SaSI). WDFW genetic groupings, called major ancestral lineages (MALs) and genetic diversity units (GDUs), are described for chinook in Marshall et al. (1995), for chum in Phelps et al. (1995), and for steelhead in Phelps et al. (1994a, 1997). Population designations and genetic management groups for salmon and steelhead occurring in Oregon are described in Kostow (1995).

Genetic population structure is usually a continuum rather than a set of discrete steps, so there are no established, widely accepted criteria for describing genetic groupings, just guidelines that can differ from place to place and can involve a fair degree of subjectivity. In Washington, biologists were asked to develop groupings that captured the “basic genetic essence” of the species (Busack and Marshall 1995), the idea being that if only one population per GDU survived, the basic genetic structure of the species would still be preserved. In the absence of distinctive life-history differences, population groups were often described based on cluster analysis of allozyme data. A similar process was followed in Oregon (Kostow 1995). To date, no attempt has been made below the ESU level to describe genetic groupings that include both Washington and Oregon populations.

A final important feature to be aware of in reviewing the genetic data is that more data are available on Washington populations of all three species than on Oregon populations.

Analyses

Two ways of looking at the data are presented here: (1) ordination of populations or collections and (2) testing for genetic differences between populations or collections. Both methods are based on allele frequency differences among populations, so to this extent are not independent.

A. Ordination

Allele frequency differences among collections or groups of collections are summarized as genetic distances. Two genetic distance statistics are presented in tables, Nei’s unbiased genetic distance (Nei 1978) and Cavalli-Sforza and Edwards chord distance (Cavalli-Sforza and Edwards 1967), hereafter called CSE chord distance. The genetic distances are then presented graphically as dendrograms, using unweighted pair-group method cluster analysis (Sneath and Sokal 1973) and/or in nonmetric multidimensional scaling (MDS) diagrams (Kruskal 1964). Genetic distances were calculated using the BIOSYS-1 program (Swofford and Selander 1981). Dendrograms were created using BIOSYS-1 or NTSYS (Rohlf 1994). MDS diagrams were created using NTSYS. Principal coordinate analysis (Gower 1966) was used to provide an initial ordination for generation of MDS diagrams.

The two types of genetic distance statistics assume two different modes of population differentiation, Nei's assumes differences arise primarily through mutation, and the CSE method assumes differences arise primarily through genetic drift. Nei distances have a long history in the literature, and the Nei unbiased difference has the advantage of being unbiased. The CSE chord distance does have some bias problems (Busack, WDFW, unpubl. data), but the drift mechanism it incorporates is probably a more accurate model for genetic differentiation in salmon and steelhead than mutation. CSE distances have been used extensively in the NMFS status reviews. In this document, we present Nei unbiased distances as well as CSE chord distances, but we use the latter exclusively for ordination.

The two ordination methods used here, dendrograms and MDS diagrams, both distort relationships between populations to some extent. Dendrograms are created by the stepwise addition of populations to clusters and then by recomputing distances between clusters and unclustered populations. Thus, distances change as the clustering proceeds. Also, the technique forces populations into clusters. Gradual allele frequencies over a geographical area cannot accurately be depicted in dendrograms (Lessa 1990). MDS is conceptually simpler: given all the pairwise distances, MDS attempts to draw a "map" of relationships in two- or three-dimensional space. MDS diagrams may be more challenging to interpret than dendrograms, but have the advantages of being able to depict allele-frequency clines and not generating artifactual clusters. On the other hand, the scaling of distances in dendrograms does not appear in MDS.

B. Tests of Allele-Frequency Heterogeneity

All pairwise combinations of populations/collections were tested for allele-frequency differences by log-likelihood tests using the G-statistic (Sokal and Rohlf 1981). The distribution of the G approximates the X^2 distribution. Williams's correction (Sokal and Rohlf 1981) is included in the tests to make the approximation closer. Tests are done for each locus and then summed for the final G value. Test results are presented as p-values; i.e., the probability of the null hypothesis of both samples representing random draws from the same gene population. Thus, we leave determining levels of statistical significance, including Bonferroni corrections (e.g., Rice 1989), for multiple tests to the reader.

Two caveats need to be considered in evaluating these test results. First, power is strongly influenced by sample size. Small samples may yield large p-values despite biologically meaningful allele-frequency differences: conversely, very large samples may yield small p-values that are not biologically meaningful. We have attempted in these analyses to avoid tests involving sample-size extremes. Second, low p-values indicate only that the null hypothesis of random draws from the same gene pool is probably violated, and there are a variety of reasons the null hypothesis can be untrue. There may be significant levels of gene flow between populations that show sizable allele-frequency differences. Also, different year classes from the same population may differ in allele frequency. This is actually to be expected (Waples 1990) and is thus not necessarily a reflection of the population being ill-defined genetically. This phenomenon makes comparisons of populations sampled in different years problematic. With enough information about the age structure of the populations being compared, test statistics can be adjusted for the temporal scale of allele frequency comparisons (Waples 1990). We have not attempted this here, however.

Results

Columbia River Chum Salmon

Chum probably occur in very low numbers in many streams on both sides of the lower Columbia River, but until recently were seen in numbers large enough for meaningful allozyme analysis only in two regions, Grays River and just downstream of Bonneville Dam. In the latter area, spawning was observed in Hamilton and Hardy Creeks. Several collections of spawning adults, totaling several hundred fish, were made from these sites over the last eight years (Table B.1). More recently, spawning was observed in the mainstem Columbia at Ives Island, a spot just off Hamilton and Hardy Creeks. Small numbers of Ives Island adults and juveniles were collected in 1998 and 1999, and a large number was collected in 2000. Recently, fish were also observed spawning in seep areas of the Columbia at Vancouver near the I-205 bridge, and a large collection was made in 2000–2001. Small numbers of chum, also not yet analyzed, were also collected in the Elochoman and Cowlitz Rivers in 2000.

Loci used in the genetic analysis are presented in Table B.2. Genetic distances among 11 chum collections are presented in Table B.3, and a dendrogram based on the CSE distances is presented in Figure B.1. Three small collections from the Ives Island area were not included in the analysis because we felt that small sample sizes might not adequately characterize the populations. Also, two collections from Hamilton Creek were pooled to avoid small-sample-size problems. The cluster analysis clearly separates the samples into three groups: Grays River, the below-Bonneville area (Hamilton and Hardy Creeks, Ives Island, and the I-205 seeps), and the Sea Resources Hatchery. At the time it was sampled, this hatchery was propagating a non

Columbia chum stock from southwestern Washington (it has since switched to Grays River stock. Thus, there appear to be two Columbia chum groups, in agreement with the GDU designations of Phelps et al. (1995). There is, however, no clear distinction among the below-Bonneville collections.

G-test results (Table B.4) support the cluster analysis. The maximum p-value between the Grays River collections and any other collection was 0.0001, showing good separation between this population and all others. Several comparisons within the below-Bonneville collections are undoubtedly nonsignificant. Especially important are comparisons of collections collected the same year. Similarly, there are several high p-value comparisons among the Hardy and Hamilton Creek collections. Thus, at this point there is good evidence that the Grays River and below-Bonneville populations are reproductively isolated to a large degree, but there is no such evidence for isolation among the below-Bonneville areas. Therefore, there appear to be at least two genetically distinct populations, Grays River and below-Bonneville mainstem and tributary spawners. The similarity between the collections from the I-205 seeps and the more upstream collections most likely indicates opportunistic colonization of a new area.

Table B.1. Chum collections from the Lower Columbia ESU included in the WDFW database used in this review.

Population Sampled	**State**	**Collection Codes**	**Collection Year**	**Life Stage**	**Sample Sizes**
Grays River	WA	W92HA	1992	A	100
Grays River	WA	W97FT	1997	A	136
Grays River	WA	W98KG	1998	A	79
Hamilton Creek	WA	W92HB	1992	A	100
Hamilton Creek	WA	W96FS	1996	A	38
Hamilton Creek	WA	W97FR	1997	A	65
Hamilton Creek	WA	W98LF	1998	A	100
Hardy Creek	WA	W96FR	1996	A	97
Hardy Creek	WA	W97FS	1997	A	100
I-205 Seeps	WA	W00KY W00PT	2000	A	86
Ives Island Area	WA	W00LC	2000	A	94
Sea Resources Hatchery	WA	W96EC	1996	A	100

Table B.2. Loci included in the WDFW chum database. Loci nomenclature follows conventions of Shaklee et al. (1990).

mAAT-1	LDH-A2
sAAT-1,2	LDH-B1
sAAT-3	mMDH-3
mAH-1	sMDHA-1,
mAH-2	sMDHB-1,2
mAH-3	mMEP-2
ALAT	sMEP-1
CKA-1	MPI
ESTD-2	PEPA
GAPDH-2	PEPB-1
GPI-A	PGDH
G3PDH-1	SSOD1
G3PDH-2	TPI-1
mIDHP-1	TPI-3
sIDHP-1	TPI-4
sIDHP-2	ESTD-1
LDH-A1	

Table B.3. Genetic distances among 10 Lower Columbia River chum collections, based on the WDFW database. Distances above diagonal are Nei's (1978) unbiased distances; below are Cavalli-Sforza and Edwards (1967) chord distances.

Population	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1 Columbia I-205 seeps	*****	0.0000	0.0029	0.0003	0.0070	0.0007	0.0007	0.0036	0.0010	0.0000
2 Columbia Ives Is.	0.0349	*****	0.0028	0.0006	0.0070	0.0000	0.0008	0.0035	0.0012	0.0000
3 Grays 92	0.0706	0.0692	*****	0.0025	0.0023	0.0020	0.0011	0.0000	0.0011	0.0018
4 Hamilton 92	0.0408	0.0420	0.0596	*****	0.0077	0.0011	0.0008	0.0026	0.0016	0.0003
5 Sea Resources 96	0.0755	0.0820	0.0701	0.0821	*****	0.0057	0.0039	0.0023	0.0036	0.0062
6 Hardy 96	0.0382	0.0304	0.0615	0.0391	0.0727	*****	0.0007	0.0023	0.0013	0.0000
7 Hardy 97	0.0431	0.0447	0.0510	0.0433	0.0691	0.0383	*****	0.0015	0.0000	0.0004
8 Grays 97	0.0685	0.0681	0.0293	0.0583	0.0664	0.0602	0.0515	*****	0.0019	0.0024
9 Hamilton 98	0.0447	0.0466	0.0578	0.0451	0.0708	0.0441	0.0272	0.0579	*****	0.0008
10 Hamilton 96/97	0.0351	0.0356	0.0601	0.0364	0.0764	0.0277	0.0400	0.0614	0.0374	*****

Table B.4. Pairwise G-test results for Lower Columbia chum. Only comparisons with p-values greater than 0.00005 are shown.

Comparisons for Columbia River I-205 Seeps 2000

Pair		p-value
Columbia I-205 seeps	vs. Columbia Ives Is.	0.2292
Columbia I-205 seeps	vs. Hamilton 1996/97	0.0652
Columbia I-205 seeps	vs. Hamilton 1992	0.0031
Columbia I-205 seeps	vs. Hardy 1996	0.0098
Columbia I-205 seeps	vs. Hardy 1997	0.0003
Columbia I-205 seeps	vs. Hamilton 1998	0.0001

Comparisons for Columbia River Ives Island 2000

Pair		p-value
Columbia Ives Is.	vs. Hardy 1996	0.4493
Columbia Ives Is.	vs. Hamilton 1996/97	0.1709
Columbia Ives Is.	vs. Hamilton 1992	0.0045
Columbia Ives Is.	vs. Hardy 1997	0.0005
Columbia Ives Is.	vs. Hamilton 1998	0.0001

Comparisons for Hardy and Hamilton Samples

Pair		p-value
Hardy 1996	vs. Hamilton 1996/97	0.5684
Hardy 1997	vs. Hamilton 1998	0.7875
Hamilton 1992	vs. Hardy 1996	0.0131
Hamilton 1992	vs. Hamilton 1996/97	0.0423
Hardy 1996	vs. Hardy 1997	0.0277
Hardy 97	vs. Hamilton 1996/97	0.0144
Hamilton 1998	vs. Hamilton 1996/97	0.0262
Hamilton 1992	vs. Hardy 1997	0.0014
Hardy 1996	vs. Hamilton 1998	0.0011
Hamilton 1992	vs. Hamilton 1998	.0001

Other Comparisons

Pair		p-value
Grays 1992	vs. Grays 1997	0.4458
Grays 1992	vs. Hardy 1997	0.0001

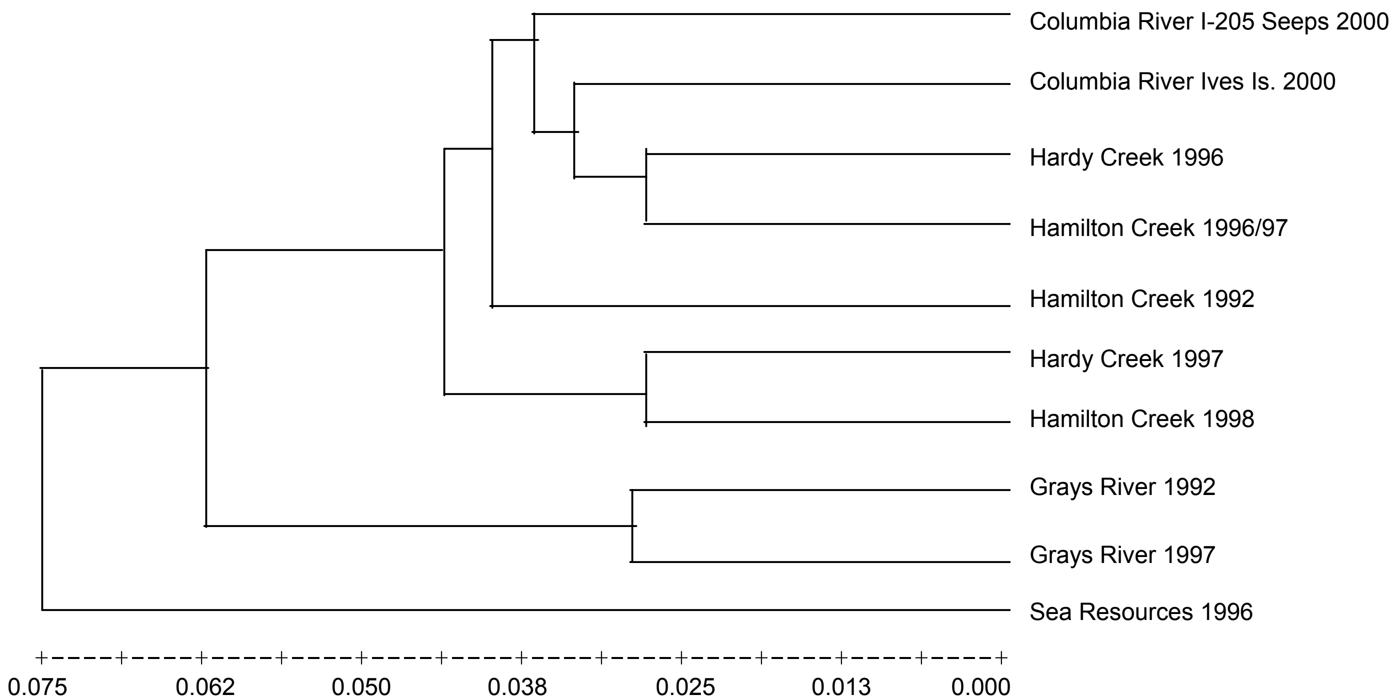

Figure B.1. UPGMA dendrogram of Cavalli-Sforza and Edwards (1967) chord distances among 10 collections of Lower Columbia chum.

Lower Columbia Chinook

Two databases were available for evaluation of the genetic structure of chinook in the Lower Columbia ESU, one from WDFW and one from NMFS (Table B.5). The overlap between the databases is large, with a substantial proportion of the data in the NMFS database contributed by WDFW. There is a major geographical difference in coverage, however, with the NMFS database also including data on populations in the Upper Willamette ESU. The WDFW database, on the other hand, also contains more recent data on Washington populations that are not included in the NMFS database. The two databases differ in locus and allele coverage (Table B.6). The WDFW database was developed specifically for TRT use, to provide the most complete set of genetic data for the Lower Columbia ESU currently possible. The WDFW database includes fewer loci than the NMFS database (29 versus 37), but the reduction resulted from excluding loci that were not variable in the Lower Columbia ESU. The WDFW database also includes alleles that are scored confidently at WDFW but not yet included in the coastwide database maintained by NMFS.

Table B.7 presents matrices of genetic distances among all pairwise combinations of populations in the WDFW database. The genetic distance relationship among these populations is summarized by a dendrogram (Figure B.2) and by multidimensional scaling (Figure B.3). The most conspicuous group on the dendrogram is the lower cluster consisting of the Abernathy, Big Creek, and Spring Creek hatcheries. Big Creek and Spring Creek are large hatcheries with a rich history of stock mixing, whereas Abernathy is a small research station that has received fish from several stocks. That this is a genetically distinct group (see also the group's position on the MDS in Figure B.3) is obvious, but exactly what it represents is unclear. It is possible that it represents an historical lineage, possibly reflecting the genetic composition of the Big White Salmon fall chinook founders of the Spring Creek Hatchery population, but it is more likely that it is just a genetically distinct amalgam of several populations. The ancestry of this group needs additional study through examination of hatchery records. This group is considered a GDU(mid-Columbia tule fall) by Marshall et al. (1995).

Excluding this cluster just discussed, two other major groups are apparent in both figures: spring chinook and all other fall chinook populations. In the spring chinook cluster, Cowlitz probably represents a blend of the pre-dam, Cowlitz spring chinook populations. This population has been large since the dams were constructed and has received very few introductions (Tables 3 and 4). However, because of incomplete separation by run timing, Cowlitz spring and fall chinook have been crossed at the hatchery. The similarity of the other two populations to Cowlitz may be natural. The case is easiest to make for the Kalama River, which has used 88% native fish (Tables 3 and 4) in the hatchery, and which also has a natural production component. The Lewis spring stock has received far more out-of-basin introductions, and it has long been thought that the original spring chinook run either died out or was largely replaced by introduced fish. The cluster of spring chinook makes geographical sense, however. The three basins are neighbors, and all three had spring runs historically.

In the fall chinook cluster, the most distinct population is Coweeman River. This distinctiveness likely reflects natural genetic variation. This is a wild population, with little or no hatchery influence, and it has remained distinctive from the Cowlitz Hatchery fall chinook run. This probably means that historically it was a separate population from the mainstem Cowlitz. The remaining fall chinook fall into two clusters that are not so apparent on the MDS diagram: one consisting of the Lewis, Sandy, and Washougal samples and the other consisting of

Table B.5. Chinook collections from the Lower Columbia and Upper Willamette ESUs included in the WDFW and NMFS databases used in this review.

Population Sampled	ESU	State	Collection Codes[a]	Collection Year	Life Stage	Sample Sizes	Database
Cowlitz Hatchery spring run	LC	WA	S0053	1982	A	50	NMFS
			W87QA	1987	A	102	BOTH
Cowlitz Hatchery fall run	LC	WA	W88QZ	1988	A	99	BOTH
			S0045	1982	A	50	NMFS
			S0049	1981	A	49	NMFS
North Fork Lewis River spring run	LC	WA	W88XF	1988	A	135	BOTH
North Fork Lewis River fall run (bright)	LC	WA	W90CZ	1990	A	120	BOTH
Kalama Hatchery spring run	LC	WA	W90BK	1990	A	109	BOTH
			S0113	1982	A	50	NMFS

Table B.5. (cont.)

Population Sampled	ESU	State	Collection Codes	Collection Year	Life Stage	Sample Sizes	Database
Big Creek Hatchery	LC	OR	W90CM	1990	A	100	BOTH
			S0012	1982	J	50	NMFS
Elochoman River fall run	LC	WA	W95EP	1995	A	35	WDFW
			W97EY	1997	A	84	WDFW
Abernathy Creek fall fun	LC	WA	W95EO	1995	A	43	WDFW
			W97EX	1997	A	41	WDFW
			W98DY	1998	A	30	WDFW
Abernathy Hatchery fall run	LC	WA	W95EK	1995	A	100	WDFW
Coweeman River fall run	LC	WA	W96CF	1996	A	76	WDFW
			W97FE	1997	A	14	WDFW
Kalama Hatchery fall fun	LC	WA	W88AB	1988	A	49	WDFW
			W89BG	1989	A	100	WDFW
			S0116	1982	J	50	BOTH
East Fork Lewis River fall run (early)	LC	WA	W95EQ	1995	A	12	WDFW
			W96DV	1996	A	63	WDFW
			W97FC	1997	A	33	WDFW
Washougal River fall run	LC	WA	W95ER	1995	A	65	WDFW
			W96EA	1996	A	39	WDFW
Sandy River fall run (bright)	LC	OR	W90DA	1990	A	54	BOTH
			W91FN	1991	A	36	BOTH
			W92FA	1992	A	50	BOTH
			W93ET	1993	A	14	WDFW
Spring Creek NFH fall run	LC	WA	W87AL	1987	A	104	BOTH
			W90CL	1990	A	150	BOTH
			S0012	1982	J	50	NMFS
			S0261	1982	J	50	NMFS
Sandy River spring run	LC	OR	S1099	1997	J	?	NMFS
Dexter Hatchery spring run	UW	OR	W87AJ	1987	A	100	NMFS
McKenzie Hatchery spring run	UW	OR	S0157	1982	A	38	NMFS
			W88QP	1988	A	110	NMFS
McKenzie River spring run	UW	OR	S1098	?	?	100	NMFS
North Santiam River spring run	UW	OR	S1135	1998	J	99	NMFS
Clackamas Hatchery spring run	UW	OR	W88AD	1988	A	100	NMFS
North Fork Clackamas River spring run	UW	OR	S1091	1997	J	80	NMFS
Marion Forks Hatchery spring run	UW	OR	W90CK	1990	A	100(?)	NMFS

[a] Codes beginning with S signify collections analyzed by NMFS; collection codes beginning with W signify collections analyzed by WDFW.

Table B.6. Loci included in the NMFS and WDFW chinook data sets used in this review. Loci nomenclature follows conventions of Shaklee et al. (1990).

Locus	Database	Locus	Database
mAAT-1	BOTH	PEPB-1	BOTH
mAAT-2	WDFW	PEPD-2	BOTH
sAAT-1,2	NMFS	PEP-LT	BOTH
sAAT-3	BOTH	PGDH	NMFS
sAAT-4	BOTH	PGK-2	BOTH
ADA-1	BOTH	PGM-1	BOTH
ADA-2	NMFS	PGM-2	BOTH
ADH	NMFS	mSOD	NMFS
mAH-1	NMFS	sSOD-1	BOTH
mAH-3	NMFS	sSOD-2	WDFW
mAH-4	BOTH	TPI-3	NMFS
sAH	BOTH	TPI-4	BOTH
ALAT	NMFS		
FDHG	BOTH		
GAPDH-2	NMFS		
GPI-A	BOTH		
GPI-B2	BOTH		
GPIB-2a	NMFS		
GPIr	NMFS		
GR	BOTH		
bHEX	NMFS		
IDDH1	NMFS		
mIDHP-2	BOTH		
sIDHP-1	BOTH		
sIDHP-2	BOTH		
LDHB-1	NMFS		
LDHB-2	NMFS		
LDH-C	BOTH		
mMDH-2	BOTH		
sMDHA-1,2	NMFS		
sMDH-B1,2	BOTH		
sMEP-1	BOTH		
sMEP-2	NMFS		
MPI	BOTH		
PEPA	BOTH		

Table B.7. Genetic distances among 15 Lower Columbia River chinook populations, based on the WDFW database. Distances above diagonal are Nei's (1978) unbiased distances; below are Cavalli-Sforza and Edwards (1967) chord distances.

Population	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Cowlitz Hatchery spring	*****	0.0033	0.0003	0.0083	0.0050	0.0032	0.0103	0.0107	0.0012	0.0037	0.0061	0.0035	0.0034	0.0052	0.0109
2 North Fork Lewis River spring	0.0614	*****	0.0025	0.0115	0.0032	0.0045	0.0134	0.0061	0.0027	0.0058	0.0032	0.0028	0.0036	0.0037	0.0145
3 Kalama Hatchery spring	0.0505	0.0569	*****	0.0088	0.0049	0.0035	0.0099	0.0115	0.0010	0.0040	0.0059	0.0036	0.0039	0.0055	0.0101
4 Big Creek Hatchery fall	0.0939	0.1018	0.0866	*****	0.0051	0.0019	0.0002	0.0169	0.0060	0.0020	0.0138	0.0106	0.0068	0.0090	0.0007
5 Elochoman River fall	0.0869	0.0765	0.0777	0.0771	*****	0.0008	0.0067	0.0040	0.0017	0.0013	0.0029	0.0016	0.0008	0.0017	0.0079
6 Abernathy Creek fall	0.0774	0.0786	0.0701	0.0550	0.0450	*****	0.0032	0.0073	0.0013	0.0000	0.0052	0.0028	0.0015	0.0026	0.0039
7 Abernathy Hatchery fall	0.1012	0.1075	0.0908	0.0371	0.0800	0.0575	*****	0.0206	0.0072	0.0032	0.0165	0.0127	0.0090	0.0115	0.0003
8 Coweeman River fall	0.1074	0.1023	0.1066	0.1143	0.0740	0.0839	0.1276	*****	0.0073	0.0084	0.0010	0.0022	0.0033	0.0018	0.0224
10 Kalama Hatcher fall	0.0771	0.0790	0.0692	0.0529	0.0438	0.0305	0.0619	0.0804	0.0516	*****	0.0057	0.0034	0.0015	0.0033	0.0042
11 East Fork Lewis River early fall	0.0861	0.0745	0.0780	0.1054	0.0642	0.0711	0.1124	0.0613	0.0659	0.0695	*****	0.0002	0.0016	0.0009	0.0181
12 North Fork Lewis River LRB fall	0.0781	0.0696	0.0695	0.0978	0.0543	0.0610	0.1039	0.0646	0.0548	0.0575	0.0423	*****	0.0006	0.0006	0.0138
13 Washougal River fall	0.0762	0.0718	0.0715	0.0877	0.0438	0.0581	0.0945	0.0682	0.0503	0.0495	0.0496	0.0412	*****	0.0007	0.0105
14 Sandy River LRB[a] fall	0.0901	0.0767	0.0822	0.0923	0.0601	0.0666	0.0995	0.0670	0.0682	0.0626	0.0550	0.0517	0.0520	*****	0.0128
15 Spring Creek NFH fall	0.1088	0.1166	0.0999	0.0377	0.0932	0.0685	0.0368	0.1334	0.0987	0.0718	0.1229	0.1141	0.1062	0.1105	*****

[a] LRB = lower river bright.

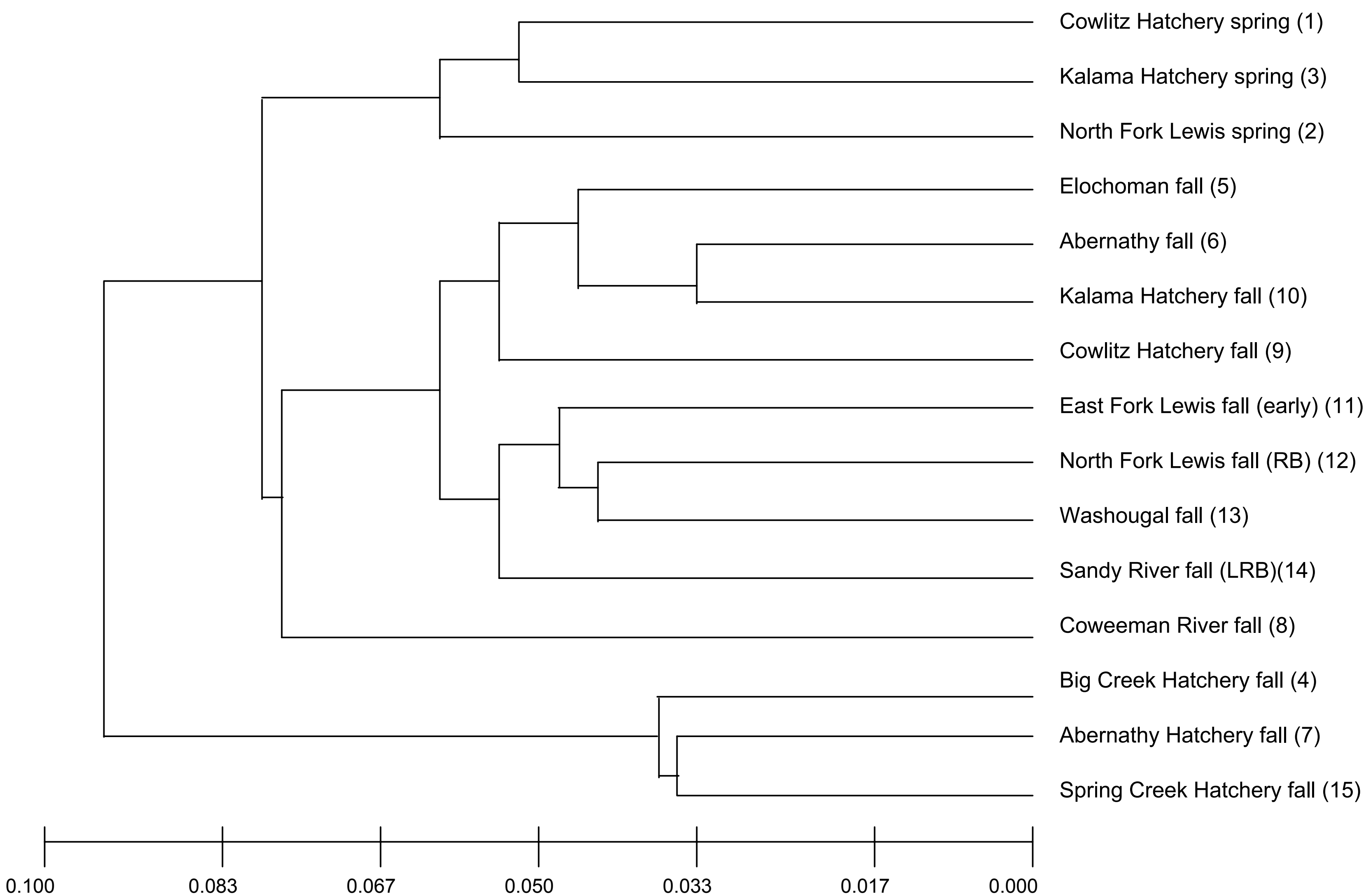

Figure B.2. UPGMA dendrogram of Cavalli-Sforza and Edwards (1967) chord distances among 15 populations of Washington Lower Columbia chinook. LRB = lower river bright. Numbers in parentheses correspond to numbers on Figure B-3.

Elochoman, Cowlitz, Kalama, and Abernathy. These patterns may reflect some level of natural differentiation over the geographical area sampled, but the lack of an obvious cline, coupled with the large amount of genetic exchange known to have occurred among hatcheries in the area makes any inferences risky about the resemblance of these patterns to original patterns. The only possible exception is the relationship between the two lower river bright populations (Lewis and Sandy) to the Lewis and Washougal tules. Either there is some gene flow (in one or both directions) or the bright populations have not diverged from the tule populations. The G-test results (Table B.8) offer additional insight in several respects. First, although most values were very low (less than 0.00005), the few high p-values help scale the diagrams. Although significance levels are not denoted explicitly in the table, any p-value greater than 0.05 can be taken as nonsignificant, no matter what level of correction for multiple tests is done. Thus, most clusters on the dendrogram created at a genetic distance of less than 0.05 are nonsignificant. Second, they back up the observation that at least the Lewis brights are not very different from the Washougal and Lewis tules: they are, in fact, not significantly different.

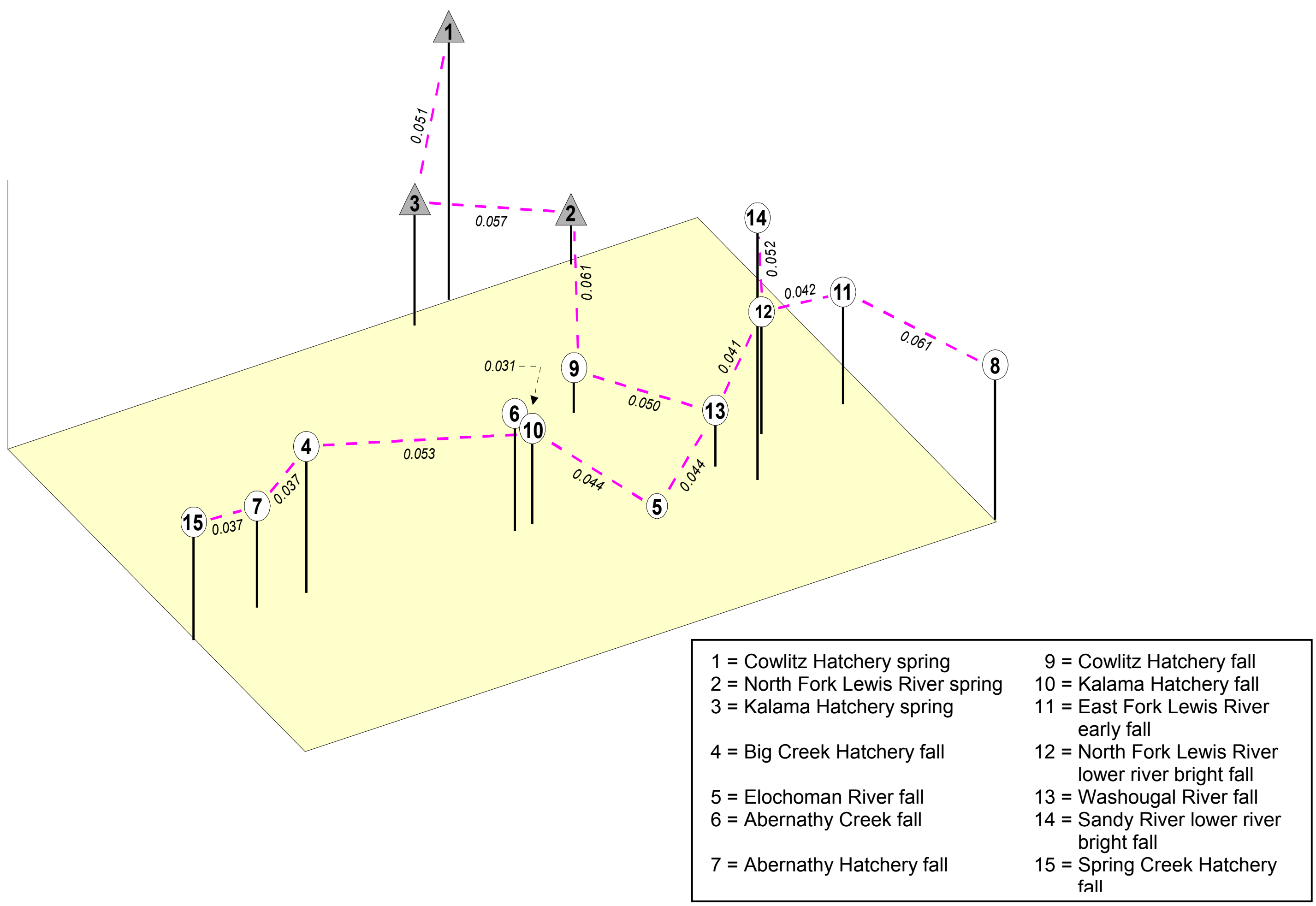

Figure B.3. Multidimensional scaling analysis with minimum spanning tree of Cavalli-Sforza and Edwards chord distances at 30 allozyme loci. Triangles denote spring populations; circles denote fall populations.

There are other data that could have been included here on presumed nonnative fish that have had some genetic impact on chinook in the Lower Columbia ESU. These include samples of “upriver brights” (URBs) spawning in the mainstem Columbia and from the Little White Salmon and Bonneville hatcheries, and also Rogue River bright fall chinook, which have been released both from Youngs Bay net pens and from Big Creek Hatchery for several years.

Relationships between some of the same populations are presented in an MDS diagram [need to include a dendrogram as well] based on the NMFS database (Figure B.4), along with the addition of Sandy River spring chinook. Sandy River is shown to be quite distinctive from the downstream populations and appears to be a transitional population between the Lower Columbia and Upper Willamette ESUs. However, the large number of releases of Willamette spring chinook from the Sandy River Hatchery (Tables 3 and 4) may account for much if not all of the resemblance to the Upper Willamette populations, making it unclear how different from more downstream populations the Sandy River population originally was.

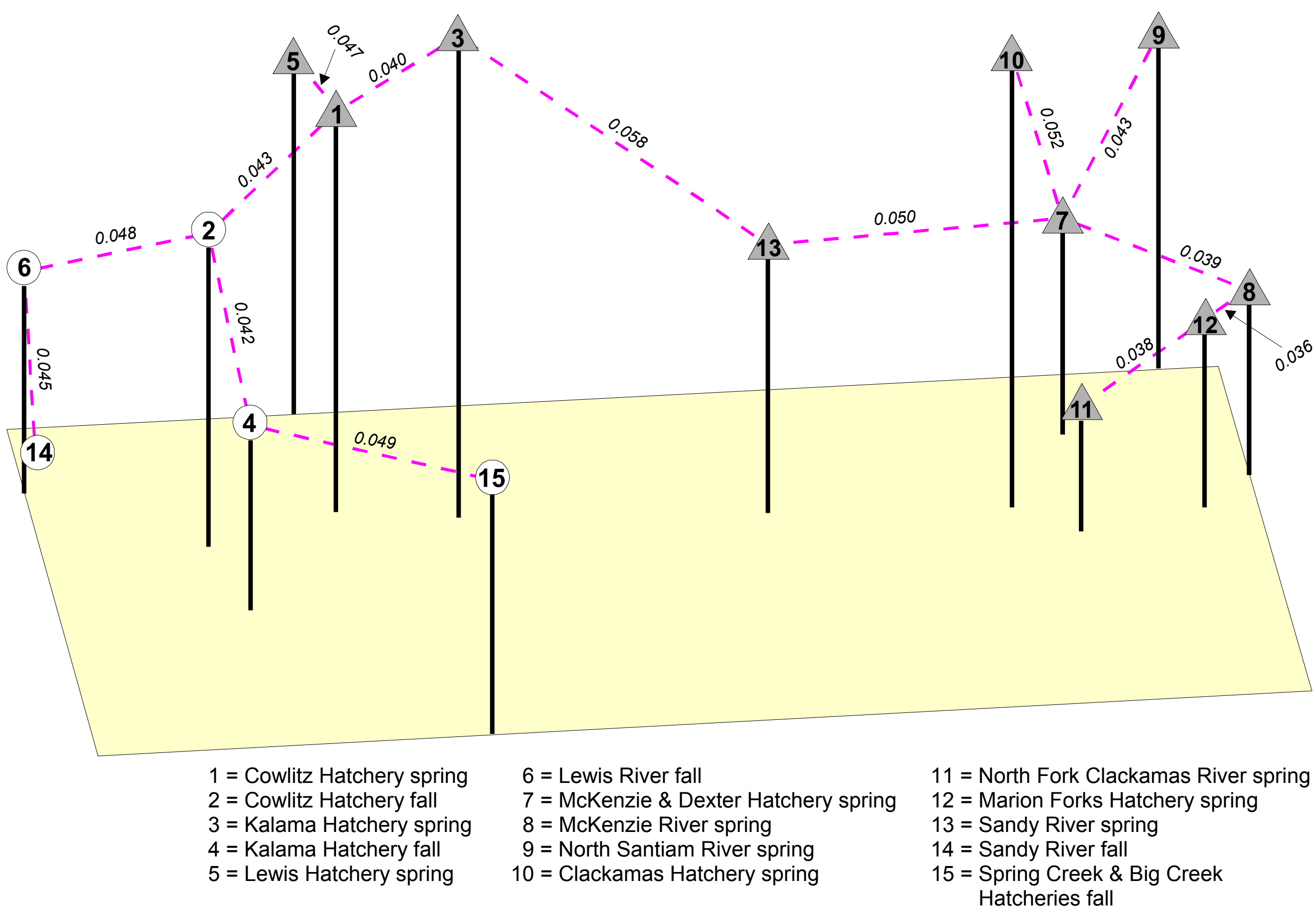

Figure B.4. Multidimensional scaling analysis with minimum spanning tree of Cavalli-Sforza and Edwards chord distances at 37 allozyme loci for Lower Columbia and Willamette chinook salmon. Triangles denote spring populations; circles denote fall populations.

Table B.8. Results of Williams-corrected G-tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity for all pairwise comparisons of 15 collections of Lower Columbia chinook in the WDFW database. Values shown are p-values. Only values greater than 0.00005 are shown.

Comparison		**p-value**
Big Creek Hatchery fall	vs. Abernathy Hatchery fall	0.2297
Abernathy Creek fall	vs. Kalama Hatchery fall	0.6238
East Fork Lewis River early fall	vs. North Fork Lewis River late bright fall	0.0699
North Fork Lewis River late bright fall	vs. Washougal River fall	0.0922
Big Creek Hatchery fall	vs. Spring Creek NFH fall	0.0190
Elochoman fall	vs. Abernathy Creek fall	0.0075
Elochoman fall	vs. Kalama Hatchery fall	0.0012
Elochoman fall	vs. Washougal River fall	0.0095
Abernathy Hatchery fall	vs. Spring Creek Hatchery fall	0.0096
Cowlitz Hatchery spring	vs. Kalama Hatchery spring	0.0004
Elochoman fall	vs. Cowlitz Hatchery fall	0.0001
Cowlitz Hatchery fall	vs. Washougal River fall	0.0007
East Fork Lewis River early fall	vs. Washougal River fall	0.0001

Figure B.5, a CSE dendrogram of most of the chinook populations in Washington, puts the genetic diversity observed among Lower Columbia chinook in perspective. Lower Columbia chinook are included in the grouping designated by WDFW as MAL II; Puget Sound chinook comprise MAL IV. Note that the Puget Sound populations fall in large part into major groupings that have a geographical basis: Nooksack, Skagit/Stillaguamish, Snohomish, White River, and South Sound/Hood Canal. Assuming that the distance at which branch points occur approximates the level of diversity among populations comprising the cluster, it can be seen that the diversity among Lower Columbia chinook is far less than that among Puget Sound chinook. Based only on this diagram, the diversity among Lower Columbia fall chinook appears to be about the same as that among South Sound/Hood Canal fall chinook, a group notable for extensive impacts of hatchery stocking. However, the Lower Columbia data included in the analysis that this diagram is based on does not include data from Coweeman River, one of the most distinctive Lower Columbia chinook populations, or from any of the Oregon populations. Thus, the Lower Columbia chinook populations are probably more differentiated than the southern Puget Sound populations.

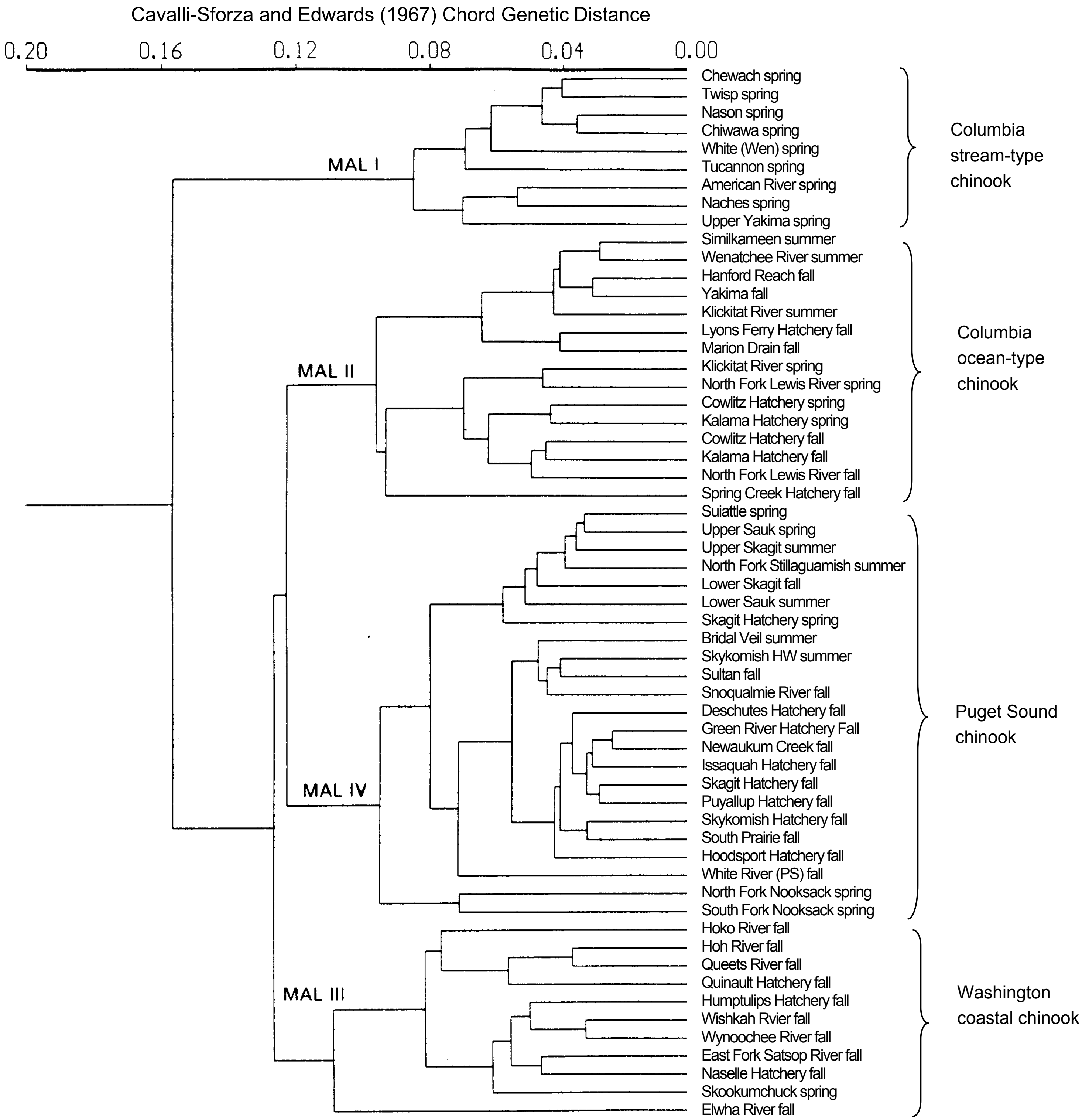

Figure B.5. UPGMA dendrogram of Washington chinook populations, based on Cavalli-Sforza and Edwards chord distances. Modified from Marshall et al. 1995.

Upper Willamette River Chinook Salmon

This ESU has not been sampled genetically nearly as extensively as the Lower Columbia ESU. Distances are shown in Table B.9, an MDS diagram is presented in Figure B.4, and G-test results are presented in Table B.10. All comparisons have fairly low p-values, indicating substantial differences, but there is no geographical pattern to the diversity. Moreover, the relationship between wild fish and hatchery fish is surprising. Clackamas wild fish appear to be very different from Clackamas hatchery fish. McKenzie wild appear very similar to fish from

Marion Forks Hatchery, a facility on the Santiam. North Santiam wild are quite distinct from Marion Forks fish. These results indicate either that the wild fish are genetically distinct from the hatchery fish, which seems unlikely given the low levels of wild production and high relative level of hatchery production, or that the wild fish samples have given misleading results. This could be the case if they were the progeny of few spawners, which is quite possible in these Willamette streams. The fact that at least two of these wild collections (Clackamas and North Santiam) were juveniles may also be a contributing factor. As juveniles, they likely represent a single year class. A population's year classes can vary significantly if effective size is low or if the adult age distribution is heavily weighted toward a single age. If the wild collections were excluded from Figure B.4, the remaining collections would show far less diversity, about as much as the spring chinook populations in the Lower Columbia ESU.

The available information on stock transfers suggests there has been enough genetic exchange among hatcheries in the Willamette basins to justify considering Upper Willamette spring chinook at present as a single gene pool (Kostow 1995 and Tables 3 and 4). If so, any diversity observed would be solely a reflection of small amounts of drift creating ephemeral genetic differences among the hatchery stocks. The amount of diversity observed, including the low p-values, is not inconsistent with this hypothesis. Alternatively, if the hatcheries are now attempting to limit transfers, they would presumably start drifting apart.

Table B.10. Results of Williams-corrected G-tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity for all pairwise comparisons of 15 collections of Lower Columbia and Upper Willamette chinook in the NMFS database. Values shown are p-values. Only values greater than 0.00005 are shown.

Comparison		**p-value**
Cowlitz Hatchery spring	vs. Cowlitz Hatchery fall	0.0001
Cowlitz Hatchery spring	vs. Kalama Hatchery spring	0.0004
Lewis fall	vs. Sandy fall	0.0001
McKenzie/Dexter Hatchery spring	vs. McKenzie spring	0.0005
McKenzie/Dexter Hatchery spring	vs. North Fork Clackamas spring	0.0001
McKenzie spring	vs. Marion Forks Hatchery spring	0.0091
McKenzie spring	vs. North Fork Clackamas spring	0.0069
North Fork Clackamas spring	vs. Marion Forks Hatchery spring	0.0039

Table B.9. Genetic distances among 15 Lower Columbia River and Upper Willamette chinook populations, based on the NMFS database. Distances above diagonal are Nei's (1978) unbiased distances; below are Cavalli-Sforza and Edwards (1967) chord distances.

Population	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Cowlitz Hatchery spring	*****	0.0005	0.0001	0.0016	0.0026	0.0023	0.0071	0.0087	0.0094	0.0059	0.0073	0.0089	0.0037	0.0033	0.0035
2 Cowlitz Hatchery fall	0.0432	*****	0.0007	0.0006	0.0019	0.0010	0.0067	0.0086	0.0084	0.0054	0.0066	0.0083	0.0032	0.0019	0.0030
3 Kalama Hatchery spring	0.0395	0.0541	*****	0.0022	0.0018	0.0022	0.0052	0.0070	0.0076	0.0045	0.0055	0.0072	0.0025	0.0035	0.0038
4 Kalama Hatchery fall	0.0510	0.0425	0.0607	*****	0.0037	0.0023	0.0089	0.0104	0.0110	0.0067	0.0076	0.0100	0.0049	0.0029	0.0014
5 Lewis Hatchery spring	0.0474	0.0531	0.0487	0.0656	*****	0.0017	0.0081	0.0113	0.0110	0.0080	0.0082	0.0109	0.0058	0.0018	0.0063
6 Lewis River fall	0.0602	0.0483	0.0621	0.0507	0.0602	*****	0.0109	0.0137	0.0128	0.0094	0.0117	0.0127	0.0068	0.0003	0.0069
7 McKenzie/ Dexter Hatchery spring	0.0846	0.0927	0.0760	0.0974	0.0850	0.1098	*****	0.0005	0.0009	0.0023	0.0015	0.0018	0.0011	0.0118	0.0088
8 McKenzie River spring	0.0977	0.1081	0.0901	0.1065	0.1041	0.1229	0.0386	*****	0.0015	0.0021	0.0009	0.0003	0.0016	0.0150	0.0092
9 North Santiam River spring	0.0969	0.1009	0.0894	0.1055	0.1001	0.1176	0.0432	0.0548	*****	0.0030	0.0030	0.0024	0.0018	0.0139	0.0112
10 Clackamas Hatchery spring	0.0781	0.0893	0.0709	0.0898	0.0851	0.1027	0.0524	0.0564	0.0595	*****	0.0018	0.0017	0.0014	0.0108	0.0063
11 North Fork Clackamas River spring	0.0872	0.0941	0.0812	0.0924	0.0893	0.1127	0.0435	0.0409	0.0633	0.0564	*****	0.0008	0.0015	0.0128	0.0053
12 Marion Forks Hatchery spring	0.0947	0.1019	0.0873	0.1016	0.0992	0.1140	0.0454	0.0360	0.0605	0.0553	0.0384	*****	0.0019	0.0142	0.0089
13 Sandy River spring	0.0646	0.0682	0.0585	0.0679	0.0730	0.0807	0.0501	0.0655	0.0624	0.0542	0.0604	0.0614	*****	0.0084	0.0052
14 Sandy River fall	0.0704	0.0631	0.0746	0.0606	0.0644	0.0448	0.1088	0.1212	0.1167	0.1051	0.1115	0.1158	0.0890	*****	0.0076
15 Spring/Big Creek Hatchery fall	0.0665	0.0720	0.0711	0.0491	0.0835	0.0869	0.0947	0.1011	0.1061	0.0861	0.0829	0.0976	0.0718	0.0914	*****

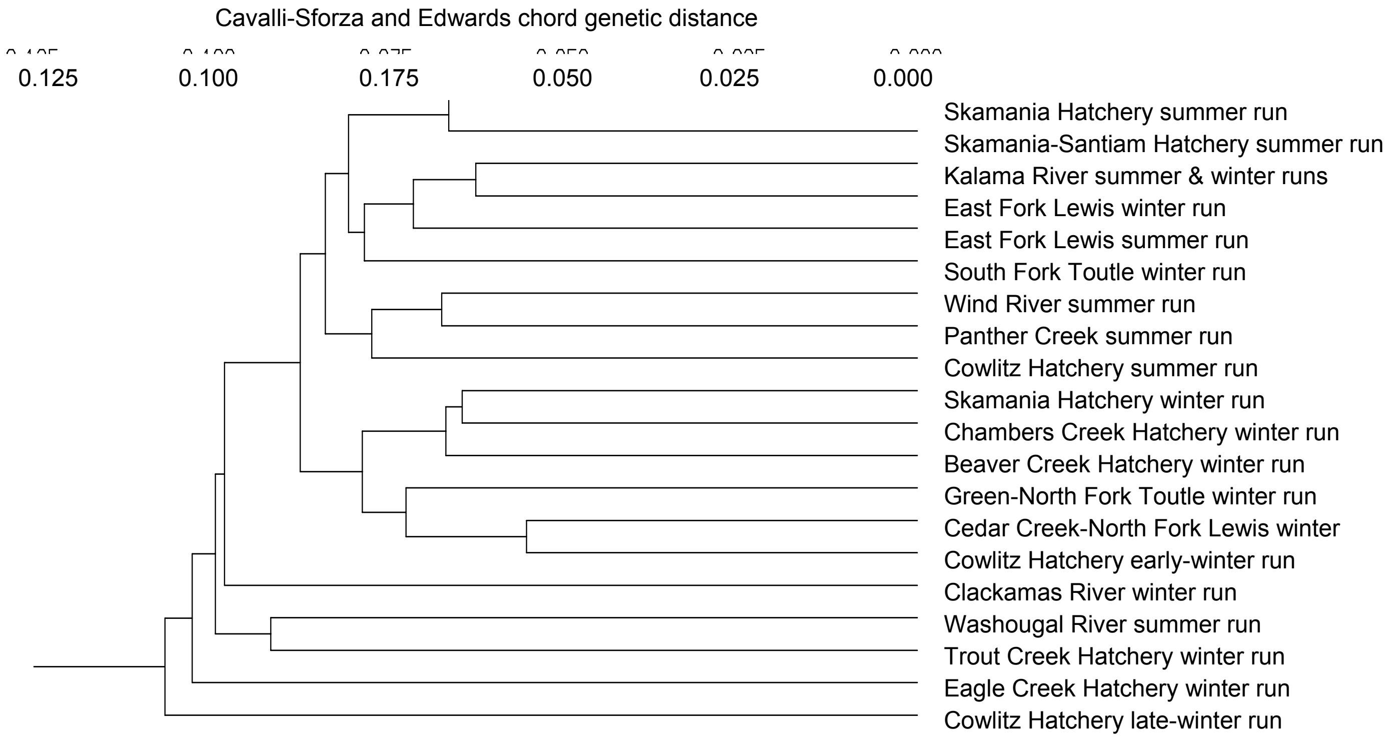

Figure B.6. Cluster analysis (UPGMA) of genetic distances among WDFW samples of steelhead populations within the boundaries of the Lower Columbia steelhead.

Lower Columbia River Steelhead

Again, two databases were used to examine genetic relationships among steelhead populations in the two ESUs, a WDFW database focusing on the Lower Columbia ESU, and an NMFS database covering both ESUs (Table B.11). Also, as in the case of chinook, overlap between the databases is considerable. Loci used are presented in Table B.12. Genetic distances among the Lower Columbia collections in the WDFW database are shown in Table B.13, and a dendrogram appears in Figure B.6. In cases in which populations were sampled more than once, data from the multiple collections were pooled.

Hatchery fish have been used extensively on the Washington side of the Lower Columbia ESU, but as in the case with steelhead hatchery plants all over western Washington, only two stocks have been used: the Chambers Creek winter stock from Puget Sound, based on fish from Chambers Creek, and the Skamania summer stock, based on fish from the Washougal and Klickitat Basins. A sample from Chambers Creek Hatchery and from Beaver Creek Hatchery, a Chambers Creek derivative in the southwest Washington ESU have been included in the analysis to provide insight on hatchery influences, along with two samples of the Skamania summer stock, one of them from the Santiam. Low reproductive success of the Skamania stock has been demonstrated in the Kalama Basin (Chilcote et al. 1986, Leider et al. 1990) and in the Clackamas Basin (Kostow and Phelps, in prep.).

Some caveats are in order before discussing the steelhead results. Unlike the case with chinook, most steelhead collections are of juveniles. Because of this, they tend to be of a single year class. If effective size is small and/or the population is dominated by a particular age class,

Table B.11. Steelhead collections from the Lower Columbia and Upper Willamette ESUs included in the WDFW and NMFS databases used in this review.

Population Sampled	Run[a]	ESU	State	Collection Codes[b]	Collection Year	Life Stage	Sample Size	Database
Clackamas at Eagle Creek Hatchery	W	LC	OR	W96ED	1996	J	50	WDFW
Clackamas River	W	LC	OR	C95AM	1995–1997	A	68	WDFW
Clatskanie River	W	LC	OR	CLATS	1996	?	40	NMFS
Cowlitz Hatchery	S	LC	WA	W96EM	1996	J	50	WDFW
Cowlitz Hatchery early	W	LC	WA	W96EN	1996	J	50	WDFW
Cowlitz Hatchery late	W	LC	WA	W96EO	1996	J	70	WDFW
East Fork Lewis	S	LC	WA	W96DK	1996	J	59	WDFW
East Fork Lewis	W	LC	WA	W96DL	1996	J	59	WDFW
Green River (Toutle)	W	LC	WA	W96DP	1996	J	50	WDFW
Kalama River	S,W	LC	WA	C94BR	1994	J	95	BOTH
North Fork Lewis (Cedar Creek)	W	LC	WA	W96DS	1996	J	59	WDFW
South Fork Toutle River	W	LC	WA	W96DM	1996	J	49	WDFW
Skamania Hatchery	W	LC	WA	W93CA	1993	J	50	BOTH
Skamania Hatchery	S	LC	WA	C91AA	1991,1994	A	197	BOTH
Washougal River	S	LC	WA	C93CS	1993	J	110	BOTH
Wind River (Panther Creek)	S	LC	WA	W94CU	1994	J	55	BOTH
Wind River (Trout Creek)	S	LC	WA	W93CR	1993	J	50	BOTH
Wind River	S	LC	WA	W94BU	1994	J	54	BOTH
Chambers Creek Hatchery	W	PS	WA	W93CD	1993	?	50	WDFW
Beaver Creek Hatchery	W	SWWa	WA	W93CB	1993	J	47	WDFW
Calapooia River	W	UW	OR	32445	1997	J	39	NMFS
Luckiamute River	W	UW	OR	32439	1997	J	31	NMFS
Marion Forks Hatchery	W	UW	OR	32548	1998	J	40	NMFS
Middle Fork Willamette River (resident trout)	R	UW	OR	32547	1998	J	31	NMFS
North Fork Molalla River	W	UW	OR	32311	1996	J	50	NMFS
North Santiam River	W	UW	OR	SANTI	1997	J	36	NMFS
Rickreall River (Canyon Creek)	W	UW	OR	32440	1997	J	34	NMFS
South Santiam (Wiley Creek)	W	UW	OR	32444	1997	J	40	NMFS
Skamania at South Santiam	S	UW	OR	W95AN	1995	J	51	WDFW
Upper McKenzie (Deer Creek) (resident trout)	R	UW	OR	32546	1998	J	33	NMFS
Yamhill River (Willamina Creek)	W	UW	OR	32442	1981	J	49	NMFS

[a] W = winter, S = summer, R = resident form.

[b] Entirely alphabetical or entirely numerical codes signify collections analyzed by NMFS; collections codes beginning with W signify collections analyzed by WDFW.

Table B.12. Loci included in the NMFS and WDFW steelhead databases. Loci nomenclature follows conventions of Shaklee et al. (1990).

Locus	Database	Locus	Database
mAAT-1	BOTH	mIDHP-1	NMFS
sAAT-12	BOTH	mIDHP-2	BOTH
sAAT-3	NMFS	sIDHP-1	BOTH
ADA-1	BOTH	sIDHP-2	BOTH
ADA-2	BOTH	LDH-B1	NMFS
ADH	BOTH	LDH-B2	BOTH
mAH-3	WDFW	sMDH-A12	BOTH
sAH	BOTH	sMDH-B12	BOTH
ALAT	BOTH	mMEP-1	BOTH
CK-A1	NMFS	MPI	BOTH
CK-A2	NMFS	NTP	BOTH
CK-C2	WDFW	PEPA	BOTH
FDHG	NMFS	PEPB-1	BOTH
FH	NMFS	PEPD-1	BOTH
GAPDH-3	BOTH	PEP-LT	NMFS
bGLUA	BOTH	PGK-2	BOTH
GPI-A	BOTH	PGM-1	BOTH
GPI-B1	BOTH	PGM-2	NMFS
GPI-B2	BOTH	sSOD-1	BOTH
G3PDH-1	BOTH	TPI-3	BOTH
IDDH-1	BOTH		
IDDH-2	BOTH		

there may be sizable differences in allele frequency among broodyears, and thus among annual samples of juveniles from a single population. Thus a single year's collection representing a single broodyear, which is often all that is available, may be inadequate for understanding genetic relationships between it and other populations. Also, juvenile steelhead samples may be mixed collections of resident and anadromous fish, or of different run times, if both occur in the same basin. A final consideration is that the sample sizes tend to be lower than for chinook, thus the variance of allele frequency estimates is higher

Several interesting population clusters are apparent on Figure B.6. The uppermost cluster consists of the two Skamania summer steelhead collections. The next cluster down, containing collections from the Kalama (a juvenile sample probably containing both winter and summer fish), the Lewis, and the Toutle, may also reflect Skamania Hatchery influence, as this stock is heavily used in all three basins. The next cluster consists of two summer-run collections from the Wind River and a collection of Cowlitz summers. The Skamania stock has been heavily used in both basins, but the inclusion of the Wind collections may also indicate a natural genetic affinity to the Skamania stock in that the Wind Basin neighbors the Washougal and the Klickitat, populations from which the Skamania stock is derived.

Table B.13. Genetic distances among 20 Lower Columbia River steelhead collections, based on the WDFW database. Distances above diagonal are Nei's (1978) unbiased distances; below are Cavalli-Sforza and Edwards (1967) chord distances.

Population	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Skamania Hatchery summer	*****	0.0081	0.0023	0.0055	0.0049	0.0056	0.005	0.0023	0.0041	0.0012
Washougal summer	0.0906	*****	0.0063	0.0051	0.0057	0.0036	0.0047	0.0058	0.0079	0.0071
Kalama River summer & winter	0.0797	0.0908	*****	0.0029	0.0017	0.0017	0.0029	0.0008	0.0008	0.0031
Skamania Hatchery winter	0.0861	0.0906	0.0854	*****	0.0019	0.0013	0.0053	0.0037	0.0025	0.0061
Beaver Creek Hatchery winter	0.1033	0.0955	0.0832	0.069	*****	0.0004	0.0055	0.0029	0.0023	0.0034
Chambers Creek Hatchery winter	0.0944	0.0894	0.072	0.0644	0.0644	*****	0.0046	0.0018	0.0019	0.0052
Trout-Wind summer	0.1012	0.0915	0.0985	0.1142	0.1194	0.1124	*****	0.0019	0.0029	0.0064
Wind River summer	0.0726	0.0919	0.0782	0.0911	0.1053	0.0935	0.074	*****	0.0003	0.0039
Panther Creek summer	0.087	0.0976	0.0769	0.09	0.1044	0.0904	0.0863	0.0673	*****	0.0058
Skamania@Santiam summer	0.0663	0.0814	0.0835	0.0864	0.0983	0.0955	0.1084	0.0812	0.0957	*****
East Fork Lewis summer	0.0758	0.0965	0.0739	0.0893	0.1042	0.0915	0.1071	0.0825	0.0866	0.0745
East Fork Lewis winter	0.0826	0.0883	0.0625	0.0922	0.094	0.0778	0.0995	0.0827	0.0837	0.0801
South Fork Toutle winter	0.0805	0.0874	0.0691	0.0823	0.0872	0.083	0.1018	0.0893	0.0992	0.0872
Green-North Fork Toutle winter	0.0916	0.0896	0.0765	0.0832	0.0837	0.0894	0.1101	0.0892	0.0836	0.0875
Cedar Creek winter NFLe	0.0801	0.1012	0.0707	0.0638	0.0707	0.0686	0.1068	0.0885	0.086	0.0915
Eagle Creek Hatchery winter CLK	0.1161	0.1071	0.0858	0.1031	0.0998	0.0963	0.1209	0.1132	0.1015	0.1162
Cowlitz Hatchery summer	0.0722	0.1051	0.0737	0.0838	0.0952	0.0802	0.11	0.0757	0.0787	0.0863
Cowlitz Hatchery early winter	0.087	0.1098	0.0772	0.0719	0.0858	0.0897	0.1177	0.0926	0.0918	0.0907
Cowlitz Hatchery late winter	0.1089	0.1179	0.0999	0.0939	0.115	0.1129	0.1304	0.1054	0.102	0.1106
Clackamas River winter	0.0987	0.0961	0.0801	0.107	0.1099	0.1019	0.1091	0.0911	0.095	0.0998

Table B.13 cont.

Population	11	12	13	14	15	16	17	18	19	20
Skamania Hatchery summer	0.0031	0.0041	0.0022	0.004	0.002	0.0069	0.0022	0.0027	0.0053	0.0052
Washougal summer	0.0076	0.0056	0.0033	0.0058	0.0074	0.0064	0.0087	0.0096	0.0109	0.0072
Kalama River summer & winter	0.0018	0.0006	0.0015	0.0003	0.0004	0.0014	0.001	0.0006	0.0033	0.0033
Skamania Hatchery winter	0.0045	0.0042	0.0031	0.0031	0.002	0.0043	0.0032	0.0025	0.006	0.0065
Beaver Creek Hatchery winter	0.0028	0.0018	0.0026	0.0009	0.0018	0.0027	0.0018	0.0017	0.005	0.0069
Chambers Creek Hatchery winter	0.003	0.0014	0.0023	0.0011	0.0017	0.0018	0.0028	0.003	0.0061	0.0038
Trout-Wind summer	0.0043	0.0038	0.0028	0.0035	0.0041	0.0041	0.0046	0.005	0.0063	0.005
Wind River summer	0.002	0.0012	0.0025	0.0008	0.0013	0.0027	0.0014	0.0024	0.0038	0.0023
Panther Creek summer	0.0023	0.0016	0.0044	0.0004	0.0013	0.0017	0.0005	0.0011	0.0026	0.0047
Skamania@Santiam summer	0.0042	0.0044	0.002	0.0045	0.0032	0.0078	0.0033	0.0032	0.0072	0.0078
East Fork Lewis summer	*****	0.0016	0.0029	0.0018	0.0022	0.0038	0.0015	0.0023	0.0044	0.0044
East Fork Lewis winter	0.0687	*****	0.0025	0.0004	0.0017	0.0017	0.0024	0.0024	0.0051	0.0032
South Fork Toutle winter	0.0841	0.0815	*****	0.0025	0.0017	0.0039	0.0037	0.0027	0.0059	0.0042
Green-North Fork Toutle winter	0.0814	0.0783	0.0817	*****	0.001	0.0008	0.0016	0.0011	0.0022	0.0039
Cedar Creek winter NFLe	0.0841	0.0798	0.0751	0.0727	*****	0.0027	0.0019	0.0001	0.0033	0.0034
Eagle Creek Hatchery winter CLK	0.104	0.098	0.0893	0.0872	0.0955	*****	0.0038	0.003	0.0054	0.004
Cowlitz Hatchery summer	0.0797	0.0852	0.0949	0.0881	0.0816	0.1147	*****	0.0007	0.0026	0.0064
Cowlitz Hatchery early winter	0.0874	0.0908	0.0815	0.072	0.0553	0.0968	0.0804	*****	0.0024	0.0062
Cowlitz Hatchery later winter	0.1013	0.1132	0.1018	0.0899	0.0914	0.1222	0.1025	0.0844	*****	0.0092
Clackamas River winter	0.1018	0.0867	0.0962	0.0934	0.0946	0.1013	0.1093	0.1051	0.119	*****

The next large cluster is of winter steelhead hatchery stocks, all Chambers Creek derivatives, and Green (Toutle) River and Cedar Creek. The latter two streams have received considerable numbers of hatchery winter steelhead, but the Green River has not been planted since 1980 (D. Rawding[2]). The remaining clusters on the dendrogram include populations that are more genetically distinct from the hatchery stocks than those discussed above. Forming a single-population cluster is Clackamas wild winter steelhead. The next cluster contains Trout Creek, a Wind River tributary where hatchery fish have been large excluded by a trap, and Washougal River, collected from above partial barriers where hatchery fish are unlikely to stray. The last two collections on the dendrogram probably reflect additional genetic distinctiveness from the Skamania–Chambers Creek hatchery stock complex, but not necessarily distinctiveness from hatchery stocks in general. The Clackamas at Eagle Creek collection is of Eagle Creek/Big Creek stock, possibly with some Clackamas influence (Kostow and Phelps in prep.), but the Cowlitz late winter run spawns sufficiently late that interbreeding with Chambers Creek fish is unlikely.

Overall, this figure is not overly informative, probably showing two genetically distinctive populations—Cowlitz and Clackamas winter steelhead—and some other possible reflections of original genetic relationships, but certainly not showing anything close to a good separation of several populations that correlates well with geography. The G-tests are not very informative. No inferences can be drawn from them about population groupings. Table B.15 displays genetic distances among collections in the NMFS database, and a dendrogram appears in Figure B.7. Two samples from outside the ESU, the Clatskanie and Grays Rivers, are included in this database. The clustering of Lower Columbia ESU collections provides no additional insight over that gleaned from the WDFW database.

Table B.14. Results of Williams-corrected G-tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity for all pairwise comparisons of 20 collections of Lower Columbia and Upper Willamette *Oncorhynchus mykiss* in the WDFW database.

Comparison		**p-value[a]**
Cedar Creek winter 96	vs. Cowlitz Hatchery early winter 96	0.0465
Skamania Hatchery winter 93	vs. Chambers Creek Hatchery winter 93	0.0026
Beaver Creek Hatchery winter 93	vs. Chambers Creek Hatchery winter 93	0.0064
Wind River summer 94	vs. Panther Creek SR 94	0.0063
Kalama River summer 94	vs. East Fork Lewis winter 96	0.0001
Kalama River summer 94	vs. South Fork Toutle winter 96	0.0002
Skamania Hatchery winter 93	vs. Beaver Creek Hatchery winter 93	0.0001
Skamania Hatchery winter 93	vs. Cedar Creek winter 96	0.0004
Chambers Creek Hatchery winter 93	vs. Cedar Creek winter 96	0.0001
Panther Creek summer 94	vs. Cowlitz Hatchery SR 96	0.0001
Green-North Fork Toutle winter 96	vs. Cowlitz Hatchery early winter 96	0.0005
South Fork Toutle winter 96	vs. Cedar Creek winter 96	0.0001
South Fork Toutle winter 96	vs. Green-North Fork Toutle winter	0.0001

[a] Values shown are p-values. Only values greater than 0.00005 are shown.

[2] Dan Rawding, WDFW, Region 5, 2108 Grand Blvd., Vancouver, WA 98661, pers. commun.

Table B.15. Genetic distances[a] among 19 Lower Columbia and Upper Willamette *Oncorhynchus mykiss* collections, based on the NMFS database.

Population	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Clatskanie 1996	*****	0.0012	0.0015	0.0057	0.0055	0.0035	0.0020	0.0012	0.0045	0.0002	0.0015	0.0065	0.0030	0.0019	0.0075
2 Grays 1994	0.0751	*****	0.0017	0.0094	0.0098	0.0062	0.0028	0.0012	0.0057	0.0019	0.0012	0.0061	0.0038	0.0047	0.0091
3 Kalama 1994	0.0850	0.0625	*****	0.0044	0.0040	0.0050	0.0010	0.0007	0.0018	0.0023	0.0013	0.0076	0.0066	0.0032	0.0067
4 North Fork Molalla 1993	0.0851	0.1002	0.0833	*****	0.0014	0.0099	0.0065	0.0065	0.0055	0.0061	0.0067	0.0117	0.0147	0.0035	0.0024
5 North Santiam 1997	0.0958	0.1138	0.0916	0.0754	*****	0.0080	0.0051	0.0067	0.0053	0.0056	0.0079	0.0134	0.0146	0.0026	0.0035
6 Washougal 1993-1994	0.0936	0.0841	0.0816	0.1048	0.0992	*****	0.0038	0.0063	0.0066	0.0042	0.0049	0.0165	0.0089	0.0070	0.0114
7 Wind 1993-1994	0.1002	0.0814	0.0717	0.1006	0.0993	0.0750	*****	0.0010	0.0024	0.0033	0.0032	0.0111	0.0061	0.0048	0.0079
8 Panther 1994	0.0911	0.0766	0.0676	0.0941	0.1029	0.0873	0.0595	*****	0.0033	0.0019	0.0018	0.0059	0.0041	0.0037	0.0086
9 Skamania Hatchery 1991 summer	0.0926	0.0850	0.0708	0.0883	0.0917	0.0816	0.0722	0.0778	*****	0.0046	0.0042	0.0132	0.0115	0.0061	0.0097
10 Skamania Hatchery 1991 winter	0.0722	0.0634	0.0793	0.0940	0.0984	0.0817	0.0899	0.0776	0.0768	*****	0.0016	0.0064	0.0061	0.0014	0.0078
11 Beaver Creek Hatchery 1993	0.0896	0.0609	0.0761	0.1025	0.1146	0.0841	0.0925	0.0860	0.0863	0.0593	*****	0.0069	0.0064	0.0049	0.0086
12 Luckiamute 1997	0.0916	0.1013	0.1095	0.1076	0.1258	0.1300	0.1256	0.1146	0.1221	0.1016	0.1088	*****	0.0097	0.0057	0.0149
13 Rickreall 1997	0.0777	0.0936	0.1104	0.1196	0.1209	0.1078	0.1134	0.1030	0.1128	0.0892	0.1075	0.1088	*****	0.0075	0.0144
14 Yamhill 1997	0.0715	0.0898	0.0931	0.0834	0.0878	0.1074	0.1066	0.1029	0.1029	0.0805	0.1031	0.0927	0.0921	*****	0.0046
15 South Santiam 1997	0.1013	0.0975	0.1016	0.0823	0.0896	0.1065	0.1061	0.1104	0.1130	0.0972	0.1049	0.1214	0.1184	0.0867	*****
16 Marion Forks Hatchery 1998	0.0947	0.1175	0.0925	0.0639	0.0707	0.1095	0.1049	0.1043	0.0975	0.1083	0.1167	0.1187	0.1263	0.0933	0.0999
17 Calapooia 1997	0.1113	0.1238	0.1081	0.0807	0.0857	0.1159	0.1101	0.1098	0.1088	0.1133	0.1269	0.1451	0.1367	0.1130	0.0948
18 Upper McKenzie 1998	0.1668	0.1764	0.1635	0.1480	0.1428	0.1772	0.1755	0.1688	0.1791	0.1637	0.1732	0.1741	0.1806	0.1536	0.1432
19 Middle Fork Willamette 1998	0.1604	0.1780	0.1682	0.1402	0.1400	0.1686	0.1726	0.1755	0.1772	0.1634	0.1733	0.1844	0.1741	0.1546	0.1315

[a] Distances above diagonal are Nei's (1978) unbiased distances; below are Cavalli-Sforza and Edwards (1967) chord distances.

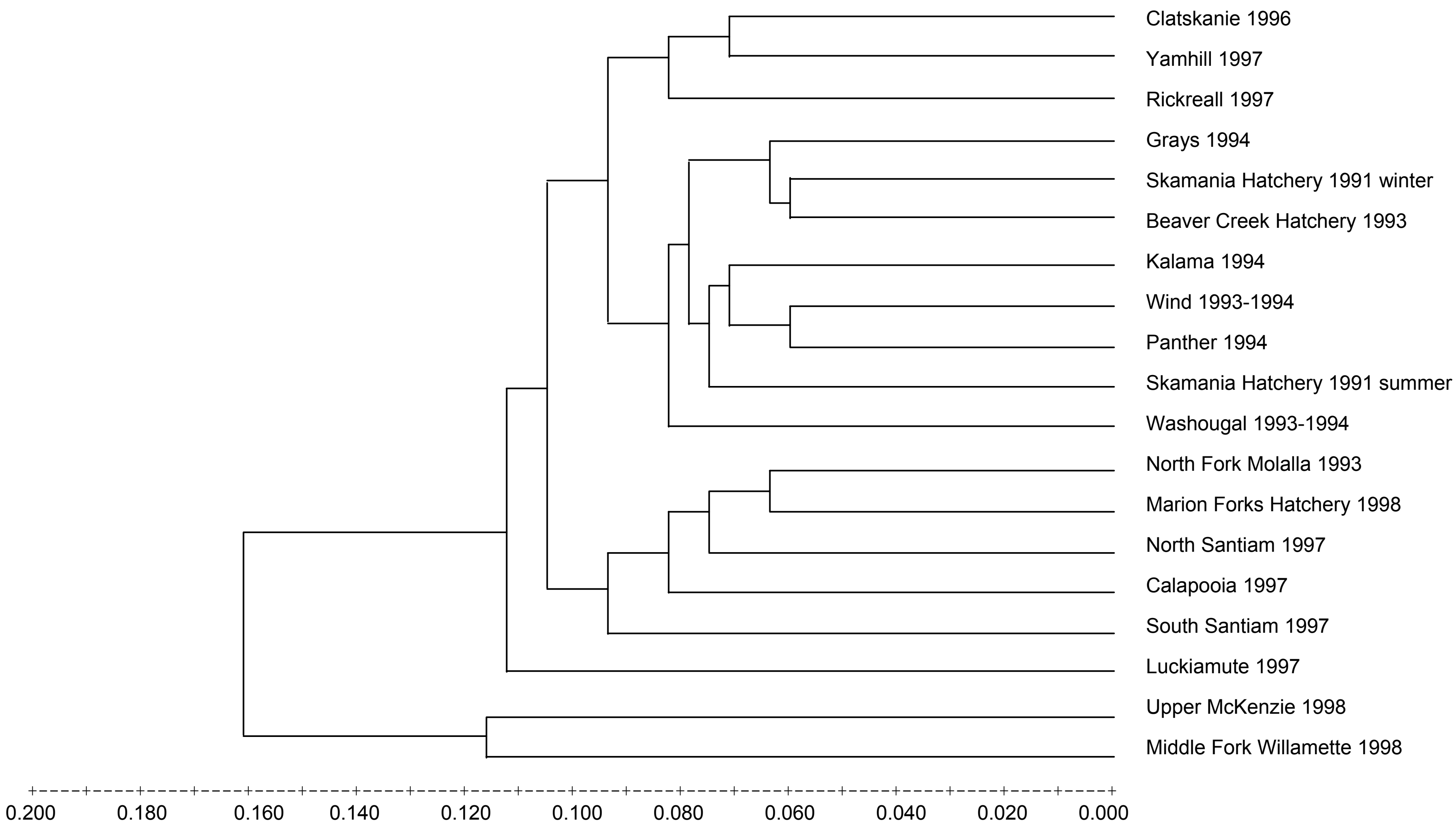

Figure B.7. UPGMA dendrogram of Cavalli-Sforza and Edwards (1967) chord distances among 19 collections of Lower Columbia and Upper Willamette *Oncorhynchus mykiss*.

Upper Willamette River Steelhead

Based on their placement in the dendrogram (Figure B.7), Upper Willamette collections appear more diverse genetically than those from the Lower Columbia ESU. Most distinctive (bottom cluster) are the two samples of resident trout from the upper Mackenzie and Middle Fork Willamette. The Luckiamute collection is quite distinctive from most other Willamette collections, and quite distinctive from the other westside collections (Rickreall and Yamhill), which cluster with the Clatskanie collection. Possibly this reflects lower-river hatchery influence. The remaining Upper Willamette collections cluster together. It is not clear how much the relationships among them may reflect hatchery activity, but they appear to be more distinct from each other than are the Lower Columbia collections.

As was the case with the collections in the WDFW database, G-test p-values (Table B.16) are almost all very low, and thus not informative.

Table B.16. Results of Williams-corrected G-tests (Sokal and Rohlf 1981) for allele-frequency heterogeneity for all pairwise comparisons of 19 collections of Lower Columbia and Upper Willamette *Oncorhynchus mykiss* in the NMFS database.

Comparison		p-value[a]
North Fork Molalla 1993	vs. Marion Forks Hatchery 1998	0.0152
Clatskanie 1996	vs. Grays 1994	0.0011
Clatskanie 1996	vs. Skamania Hatchery 1991 winter	0.0035
Grays 1994	vs. Beaver Creek Hatchery 1993	0.0086
North Santiam 1997	vs. Marion Forks Hatchery 1998	0.0042
Clatskanie 1996	vs. Yamhill 1997	0.0002
Grays 1994	vs. Kalama 1994	0.0004
Grays 1994	vs. Panther 1994	0.0001
Grays 1994	vs. Skamania Hatchery 1991 winter	0.0010
North Fork Molalla 1993	vs. North Santiam 1997	0.0008
Wind 1993& 1994	vs. Panther 1994	0.0006
Skamania Hatchery 1991 winter	vs. Beaver Creek Hatchery 1993	0.0003

[a] Values shown are p-values. Only values greater than 0.00005 are shown.

APPENDIX C

SUMMARY OF INFORMATION USED TO DETERMINE DEMOGRAPHICALLY INDEPENDENT HISTORICAL POPULATIONS IN LISTED LOWER COLUMBIA AND UPPER WILLAMETTE ESUs

Introduction

The following tables summarize the information utilized to determine demographically independent historical populations. Information categories address fundamental questions about the population.

- Historical presence: Is there documentation that the population in question occupied/utilized the river basin?
- Historical abundance: Is there evidence that the population in question was historically large enough to be demographically independent?
- Life-history characteristics: Is there evidence that the population in question exhibited life-history characteristics that would be indicative of local adaptation or provide reproductive isolation from other populations?
- Genetics: Is there genetic evidence that the population in question was (is?) genetically distinct from other populations (e.g., reproductively isolated to some degree)?
- Geography: Are there any aspects of river morphology that would promote population isolation, or is the basin large enough to produce a sustainable population, or is the population sufficiently distant from other populations to reduce the rate of migration between populations?

Each population is given a distinct code, which is used to identify watershed/population boundaries on maps in the document. Within each data category, information quantity and quality was scored on a scale from 0 to 3.

Information scale:

0 no information available

1 some information, but of limited quality and/or quantity

2 information available, but of limited used due to quality issues (i.e., hatchery, nonnative stock influences, environmental degradation, etc.)

3 good information directly pertaining to historical populations or to present populations that are representative of historical populations

Table C.1. Historical Lower Columbia River fall-run chinook salmon populations.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Youngs Bay	YOUN-KF	2	2	1	0	2
Grays River	GRAY-KF	3	2	1	1	3
Big Creek	BIGC-KF	2	1	1	1	2
Elochoman River	ELOC-KF	2	1	1	1	2
Clatskanie River	CLAT-KF	2	1	1	0	2
Mill Creek	MILL-KF	2	1	1	2	2
Scappoose Creek	SCAP-KF	2	1	0	0	2
Upper Cowlitz River	UCWL-KF	3	1	2	1	3
Lower Cowlitz River	LCWL-KF	3	2	2	2	3
Coweeman River	COWE-KF	3	2	3	3	3
Toutle River	TOUT-KF	3	2	1	0	3
Kalama River	KALA-KF	3	2	2	2	3
Salmon Creek	SALM-KF	2	1	0	1	2
Lewis River late	LEWL-KF	3	2	3	3	3
Clackamas River	CLCK-KF	2	1	1	2	3
Washougal River	WASH-KF	2	2	2	2	3
Sandy River early	SNDE-KF	1	0	0	0	2
Sandy River late	SNDL-KF	2	2	2	3	3
Lower gorge tributaries	LGRG-KF	2	2	1	0	2
Upper gorge tributaries	UGRG-KF	2	2	1	0	2
Big White Salmon River	BWSR-KF	2	1	1	2	3
Hood River	HOOD-KF	2	1	1	0	3

Table C.2. Historical Lower Columbia River spring-run chinook salmon populations.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Upper Cowlitz River	UCWL-KS	3	2	1	2	3
Cispus River	CISP-KS	3	2	1	0	3
Tilton River	TILT-KS	3	2	1	0	3
Toutle River	TOUT-KS	3	2	1	0	3
Kalama River	KALA-KS	2	1	0	2	3
Lewis River	LEWS-KS	3	2	1	1	3
Sandy River	SAND-KS	3	2	2	0	3
Big White Salmon	BWSR-KS	2	0	0	0	3
Hood River	HOOD-KS	3	2	1	0	3

Table C.3. Historical Upper Willamette River spring-run chinook salmon populations.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Clackamas River	CLCK-KS	3	2	2	1	3
Molalla River	MOLA-KS	3	1	1	0	3
North Santiam River	NSNT-KS	3	2	2	1	3
South Santiam River	SSNT-KS	2	2	1	1	3
Calapooia River	CALA-KS	3	1	1	0	3
McKenzie River	MCKZ-KS	3	2	2	2	3
Middle Fork Willamette River	MFWL-KS	3	2	2	0	3

Table C.4. Historical Lower Columbia River winter steelhead populations.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Cispus River	CISP-SW	3	1	0	0	3
Tilton River	TILT-SW	3	1	0	0	3
Upper Cowlitz River	UCWL-SW	3	2	0	0	2
Lower Cowlitz River	LCWL-SW	3	1	1	1	2
North Fork Toutle River (Green River)	NTOU-SW	3	1	0	1	2
South Fork Toutle River	STOU-SW	3	1	0	0	2
Coweeman River	COWE-SW	3	1	0	0	2
Kalama River	KALA-SW	3	2	2	1	3
North Fork Lewis River	NLEW-SW	3	2	1	1	3
East Fork Lewis River	ELEW-SW	3	2	1	1	3
Clackamas River	CLCK-SW	3	2	2	2	3
Salmon Creek	SALM-SW	2	0	0	0	2
Sandy River	SAND-SW	3	2	1	0	3
Washougal River	WASH-SW	3	1	1	0	3
Lower gorge tributaries	LRG-SW	2	0	0	0	3
Upper gorge tributaries	UGRG-SW	2	0	0	0	2
Hood River	HOOD-SW	3	2	1	0	3

Table C.5. Historical provisional Lower Columbia River summer-run steelhead populations.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Kalama River	KALA-SS	3	2	2	2	3
North Fork Lewis River	NLEW-SS	3	1	1	1	3
East Fork Lewis River	ELEW-SS	2	1	2	1	3
Washougal River	WASH-SS	3	2	1	1	3
Wind River	WIND-SS	3	1	1	1	3
Hood River	HOOD-SS	3	1	1	0	3

Table C.6. Historical provisional Upper Willamette River winter-run steelhead populations.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Westside tributaries	WEST-SW	1	1	0	1	2
Molalla River	MOLA-SW	3	1	1	2	3
North Santiam River	NSNT-SW	3	2	2	2	3
South Santiam River	SSNT-SW	3	2	2	2	3
Calapooia River	CALA-SW	3	1	1	2	3

Table C.7. Historical Lower Columbia River chum salmon.

Population	Map Code	Historical Presence	Historical Abundance	Life-History Characteristics	Genetics	Geography
Chinook River	CHIN-CM	2	1	0	0	1
Youngs Bay	YOUN-CM	3	1	0	0	2
Grays River	GRAY-CM	3	1	2	3	3
Big Creek	BIGC-CM	3	1	0	0	2
Elochoman River	ELOC-CM	3	1	0	0	2
Clatskanie River	CLAT-CM	3	1	0	0	2
Mill Creek	MILL-CM	3	1	0	0	2
Scappoose Creek	SCAP-CM	2	1	0	0	2
Cowlitz River fall/summer	COWL-CM	3	2	2	0	3
Kalama River	KALA-CM	3	1	0	0	3
Salmon Creek	SALM-CM	2	0	0	0	3
Lewis River	LEWS-CM	3	2	1	0	3
Clackamas River	CLCK-CM	3	1	1	0	3
Washougal River	WASH-CM	3	1		0	3
Sandy River	SAND-CM	3	1	1	0	3
Lower gorge tributaries	LGRG-CM	3	1	2	2(?)	2
Upper gorge tributaries	UGRG-CM	3	1	1	0	2

APPENDIX D

RELATIONSHIPS BETWEEN HISTORICAL, DEMOGRAPHICALLY INDEPENDENT AND PRESENT-DAY CHINOOK SALMON AND STEELHEAD POPULATIONS IN THE LOWER COLUMBIA RIVER AND UPPER WILLAMETTE RIVER

Introduction

In an earlier document, Myers et al. (2002) identified the putative historical, demographically independent populations (DIPs) of chum salmon, chinook salmon, and steelhead in the Lower Columbia River and Upper Willamette River evolutionarily significant units (ESUs). This provided a template for what a "total" recovery would look like. However, the current populations in this watershed in many cases differ a great deal from their historical counterparts due to habitat degradation and gene flow from hatchery programs, either through direct introductions or straying by returning hatchery fish. Recovery planning must be based in large part on these current populations, therefore, it is important to have a clear picture of the current status of the populations in the ESUs relative to the historical template. In this document we describe the current demographic and genetic status of the populations identified in the earlier document, as well as the associated hatchery populations that affect them. In addition, as much as is possible, we compare the current life-history patterns to those historically present.

The genetic status of existing populations is based on our knowledge of the history of hatchery releases (e.g., Myers et al. 1998) and the genetic structure revealed by recent genetic analyses (Appendix C). Demographic status is based on recent escapement information from the Washington Department of Fish and Wildlife (WDFW) Salmonid Stock Inventory (SaSI) database and from the Oregon Department of Fish and Wildlife (ODFW). Additionally, status ratings from the Washington Department of Fisheries (WDF) Salmon and Steelhead Stock Inventory (SASSI, WDF et al. 1993), an earlier version of the SaSI, and Kostow (1995) are used, as well as ratings from the National Marine Fisheries Service (NMFS) biological review teams (BRTs) involved in status reviews and listing decisions. During the status review process, the BRTs were charged with making several determinations concerning the status of hatchery populations:

- Was the hatchery population part of the ESU?
- If so, was the hatchery population considered essential for recovery?
- What was the genetic relationship between the hatchery population and the population that historically existed in the hatchery's watershed?

Chinook Salmon

Lower Columbia River (Coastal Tributaries)

The abundance and genetic composition of populations in this area have all been similarly impacted by artificial propagation and habitat degradation. During the 1930s and 1940s the abundance levels for chinook salmon fell to critically low levels. The release of nearly 250 million chinook into these watershed from the 1950s to mid-1990s probably overwhelmed those elements of the native DIPs that remained. Introductions of fall-run chinook salmon into these rivers and the founding population for the state and federal hatcheries primarily came from Spring Creek National Fish Hatchery (NFH), or those on western Cascade rivers: the Cowlitz Salmon Hatchery, Kalama Salmon Hatchery, and Lewis River Hatchery. Much of the existing genetic structure for this region can be related to the relative influence of Spring Creek NFH or western Cascade hatchery introductions. A significant number of adult strays from the ODFW Rogue River (Oregon coast) Bright Program based in Youngs Bay have been observed in a number of Washington tributaries. Habitat degradation has severely limited natural production, therefore the majority of returning adults have been first-generation, hatchery-derived fish. Furthermore, information on historical DIPs from Youngs Bay to Scappoose Creek is limited. Given the dramatic changes in habitat quality across the Washington and Oregon sides of this region, it is unlikely that historical life-history characteristics remained unchanged to the present.

Overall production at hatcheries within the Oregon portion of the coastal tributaries has focused on tule fall-run chinook salmon from within the ESU. Notable exceptions include large numbers of Willamette River spring-run chinook salmon and, more importantly, the relatively recent large releases of Rogue River fall-run chinook salmon from Big Creek and Youngs Bay. The absence of appropriate holding and spawning habitat for spring-run chinook salmon limits the long-term impact of Willamette River fish; however, Rogue River fall-run chinook salmon can successfully reproduce in Columbia River coastal tributaries and may become integrated into local spawning populations. Habitat degradation has constrained natural production, and the majority of naturally spawning fish appear to be the progeny of hatchery-propagated fish. The low probability of successful natural production minimizes the ability of the hatchery stocks to adapt to local habitat conditions. Furthermore, the low abundance of natural-origin recruits (NORs) relative to hatchery-produced fish (1:10), increases the likelihood that harvests directed on hatchery fish will disproportionately impact NORs. Hatchery stocks were established using introductions of fish from other Lower Columbia River hatcheries: Spring Creek NFH, Bonneville Hatchery, and unspecified mixes of Lower Columbia River stocks. Genetic analysis is limited to hatchery stocks, and the existing relationships reflect a long history of exchange between hatcheries, especially Big Creek and Spring Creek NFH. Kostow (1995) reported that ODFW harvest management staff concluded, based on expansions of coded-wire tag (CWT) recoveries from these fish, that a substantial proportion of the fish in these tributaries have been strays from Big Creek Hatchery tules along with some strays of Rogue River brights released into Big Creek. Available information indicates that the fall chinook populations in the Lower Columbia basin are much reduced from historical abundances, with natural spawning dominated by hatchery fish from the 11 Oregon and Washington fall-run chinook salmon hatcheries located in the Lower Columbia River.

WDFW (Marshall et al. 1995) groups fall-run tule populations in this region (with the exception of Mill, Germany, and Abernathy Creeks) into the larger Lower Columbia River tule fall chinook genetic diversity unit (GDU). This GDU also includes fall-run chinook salmon in the Cowlitz, Kalama, and Washougal Rivers. The result of hatchery transfers, straying hatchery fish, and diminished natural production, has been the development of widely mixed populations of largely hatchery origin.

Fall-run chinook salmon in Abernathy, Germany, and Mill Creeks are genetically similar to fall-run chinook stocks found between Bonneville and McNary Dams. Marshall et al. (1995) question whether chinook salmon were originally found in these systems. Furthermore, they assert that the existing natural spawners are a mix of natural and hatchery origins, primarily from Abernathy Creek (founded by Spring Creek NFH transfers) and Big Creek (founded largely by Spring Creek NFH transfers). SASSI (WDF et al. 1993) states that all the stocks in this region are a mixed stock of composite production. Naturally spawning stray adults from the Rogue River fall chinook programs have also been recovered.

Except where introduced Rogue River fall-run chinook salmon have become established, the majority of fall-run chinook salmon spawning in the coastal region of the Lower Columbia River ESU originated from stocks within the ESU. Although the genetic composition of fish spawning in the coastal tributaries may be representative of the ESU, existing conditions do not provide for reestablishment of locally adapted, self-sustaining populations.

Chinook River Fall-Run Chinook Salmon (CHNK-KF)

Historical accounts indicate that chinook salmon were not historically present in this basin. Given its small size (30.2 km^2), it is unlikely that a self-sustaining population could have existed in the Chinook River basin. Artificial propagation activities have been ongoing since the early 1900s, initially using fish captured from nearby fish traps. The majority of contributing stocks in recent years have been from the Lower Columbia River ESU (Myers et al. 1998). There is little successful natural production; the majority of the spawners are of hatchery origin, and there has been little potential for local adaptation.

NMFS Rating (Sea Resources Hatchery): In ESU, category 3
SASSI Rating (In River): Not rated

Youngs Bay Fall-Run Chinook Salmon (YOUN-KF)

Fall-run chinook salmon were historically present in most of the rivers within the boundaries of this DIP. Habitat degradation and overharvesting substantially depressed or extirpated fall-run chinook salmon from many of these basins. Additionally, there have been substantial releases of both spring- and fall-run chinook salmon into this area. Many of these releases came from outside the Lower Columbia River ESU. Most notable are introductions of spring-run chinook salmon from the Upper Willamette River (UWR) ESU and fall-run chinook salmon from the Oregon coast (Rogue River). It is unlikely that there are any remaining distinct spawning aggregations of native chinook salmon in this DIP. Additionally, there has been little potential for local adaptation by any hatchery stocks introduced into this DIP.

NMFS Rating (Youngs Bay–Rogue River Net-Pen Program): Out of ESU
NMFS Rating (Youngs Bay–UWR Spring-Run Net-Pen Program): Out of ESU
NMFS Rating (Klaskanine Hatchery Spring-Run Chinook Salmon): Out of ESU
ODFW Gene Conservation Group: Lower Columbia fall chinook

Grays River Fall-Run Chinook Salmon (GRAY-KF)

The Grays River basin historically had a large population of chinook salmon; however, by 1944 as few as 34 adults were observed in the basin (WDF 1951). Large-scale hatchery introductions began in the late 1950s from a number of Lower Columbia River hatcheries. By 1993, some 84 million fall-run chinook salmon had been released into the basin. The Grays River Hatchery fall-run chinook salmon program, which began in 1962, was recently terminated. Carcass recoveries from natural spawning surveys indicated that approximately 35% of the fish were first-generation strays from the Grays River Hatchery (Harlan 1999). It is probable that the native Grays River population was overwhelmed by hatchery introductions, and that a large proportion of the current natural spawners are first-generation, hatchery-origin fish. With the termination of in-basin releases of hatchery fish, it may be possible for the existing population to become more locally adapted, but only if suitable habitat conditions exist.

NMFS Rating (Terminated Grays River Hatchery Program): In ESU, category 3
SASSI Rating (In River): Mixed origin, composite production (1992), healthy
WDFW Lower Columbia River Tule Fall Chinook GDU

Big Creek Fall-Run Chinook Salmon (BIGC-KF)

Fall-run chinook salmon are native to the basin. A hatchery was established in the basin in 1941 using locally returning fish as broodstock. Since 1941, eight different stocks of fall-run chinook salmon have been released from this hatchery, in addition to a number of spring-run chinook salmon (primarily from the Upper Willamette River ESU). Through 1993, 193 million fall-run chinook salmon had been released into the Big Creek basin. For several years, releases of Rogue River bright fall-run chinook salmon were made out of the Big Creek Hatchery. Releases were terminated because of concerns regarding the straying of these nonnative fish into basins throughout the Lower Columbia River. A weir placed in the river for the collection of spawners also blocks access to much of the basin. Passage provided above the weir has been intermittent during the course of hatchery operations. It is unlikely that much of the native Big Creek population is represented by the existing hatchery or naturally spawning populations. Furthermore, given existing conditions, it is unlikely that the naturally spawning fall-run chinook salmon in this basin are self-sustaining or independent. Genetically, the Big Creek Hatchery population most closely resembles fall-run chinook salmon from the Spring Creek NFH, which was founded by fish from the White Salmon River.

NMFS Rating (Big Creek Hatchery): In ESU, category 3
ODFW Hatchery Program Type (Kostow 1995): 3
ODFW Gene Conservation Group: Lower Columbia fall chinook

Elochoman River Fall-Run Chinook Salmon (ELOC-KF)

Fall-run chinook salmon were historically present in the Elochoman River; however, it is unclear whether a persistent spawning aggregation existed in Skamokawa Creek. Extensive hatchery releases into the Elochoman River prior to and following the construction of the Elochoman Hatchery probably resulted in functional loss of the original population. Much of the existing spawning habitat has been substantially degraded. Additionally, upstream passage in the Elochoman River is partially blocked by the hatchery weir. The majority of naturally spawning adults in Skamokawa Creek and Elochoman River are first-generation hatchery fish, 50% and 82%, respectively (Harlan 1999). Genetic analysis of fall-run chinook salmon from the Elochoman River indicates that they are most similar to fall-run chinook salmon from Abernathy Creek and the Kalama River. There has been little potential for the progeny of naturally spawning fish to adapt to local conditions.

NMFS Rating (Elochoman Hatchery): In ESU, category 3
SASSI Rating (Skamokawa Creek): Mixed origin, composite production (1992), healthy
SASSI Rating (Elochoman River): Mixed origin, composite production (1992), healthy
WDFW Lower Columbia River Tule Fall Chinook GDU

Clatskanie River Fall-Run Chinook Salmon (CLAT-KF)

Fall-run chinook salmon were historically present in the main streams in this DIP: Plympton Creek, Clatskanie River, and Beaver Creek. Naturally spawning fall-run chinook salmon still occur in these streams; however, the majority of these fish appear to be first-generation hatchery strays (Theis and Melcher 1995). Genetic analysis of fall-run fish from these streams is not available; however, based on the marked hatchery strays recovered and geographic proximity, it is likely that there would be a strong similarity to stocks released from the Big Creek Hatchery and other local facilities.

ODFW Gene Conservation Group: Lower Columbia fall chinook

Mill Creek Fall-Run Chinook Salmon (MILL-KF)

There is little information on the fall-run chinook salmon that historically inhabited the boundaries of this DIP. Hatchery introductions, habitat degradation, and the straying of hatchery fish from outside DIP boundaries are likely to have overwhelmed native fall-run chinook salmon in this DIP. Presently, fall-run chinook salmon are observed spawning in Mill, Germany, and Abernathy Creeks, but the majority of these fish are apparently hatchery produced (Harlan 1999). Adults returning to Abernathy, Germany, and Mill Creeks were more similar to fall-run chinook salmon in the mid-Columbia River tule GDU, which includes fall-run fish from the Wind and White Salmon Rivers and Spring Creek NFH (Marshall et al. 1995).

NMFS Rating (Abernathy Hatchery): In ESU, Category 3
SASSI Rating (Abernathy River): Mixed origin, composite production (1992)
SASSI Rating (Germany Creek): Mixed origin, composite production (1992)

SASSI Rating (Mill Creek): Mixed origin, composite production (1992)
WDFW Mid-Columbia River Tule Fall Chinook GDU

Scappoose Creek Fall-Run Chinook Salmon (SCAP-KF)

Fall-run chinook salmon were historically present in Scappoose Creek and many of the other smaller tributaries in this ESU. There is, however, little information on historical or current life-history traits or genetic characteristics. Spawner surveys have been done intermittently and give little indication of run size or trends in abundance. Hatchery introductions and strays have probably had a substantial influence on the native population. Furthermore, habitat degradation constrains natural productivity in the DIP, and limits the development of a locally adapted population.

ODFW Gene Conservation Group: Lower Columbia fall chinook

Western Cascade Slope Tributaries

Western Cascade crest (Washington) tributaries include the Cowlitz, Kalama, Lewis, and Washougal Rivers. These rivers all have headwaters at high elevations in the Cascade Mountains. River flows peak in December or January and sustain at least 50% of peak for six months or more. Basin sizes are much larger and able to sustain larger populations than those found in the coastal region. In many basins, naturally produced salmon (except for summer steelhead and spring-run chinook salmon and chum) are still found in appreciable numbers, and make may up a significant portion of the spawning population. The lower reaches of these rivers are relatively low gradient, but high-gradient sections are common in the mid and upper reaches. Dams currently block access to spring-run chinook and steelhead habitat on the Lewis, Cowlitz, and Sandy River basins.

Upper Cowlitz River Fall-Run Chinook Salmon (UCWL-KF)

The Cowlitz River basin has been and still is a major producer of fall-run chinook salmon. Since 1963, upstream access has been limited by Mossyrock Dam (RKm 84). Fall-run chinook salmon that historically migrated into the upper watershed were incorporated into the Cowlitz (Salkum) Salmon Hatchery broodstock. Any population substructure that previously existed above the dam was effectively eliminated. There may be some population structure in tributaries below the dam, although hatchery-origin spawners are commonly found in the lower tributaries. Analysis of natural spawners in 1980 indicated that the majority of fish were hatchery strays (WDF et al. 1993). Additionally, an unknown proportion of spring-run fish may have been incorporated into the fall-run hatchery population. Overall, however, the hatchery program has limited direct introgression (through hatchery transfers) from out-of-basin populations and may retain much of the historical diversity.

This population no longer occurs in its historical range, and the population itself no longer exists as a distinct entity but as a mixture of upper and lower Cowlitz populations. It is still reasonable to assume that the Cowlitz Salmon Hatchery stock, or the naturally spawning fall-run chinook salmon that migrate to the barrier dam, would be the best candidates for any reintroduction programs.

Upper Cowlitz River Spring-Run Chinook Salmon (UCWL-KS), Cispus River Spring-Run Chinook Salmon (CISP-KS), Tilton River Spring-Run Chinook Salmon (TILT-KS)

Except for a few spring-run chinook salmon that have been passed above the Cowlitz Falls Dam, the historical spawning habitat for these three spring-run DIPs is no longer accessible. Downstream passage for chinook salmon smolts is limited. Furthermore, with the construction of Mayfield Dam in 1963, returning adults from the three DIPs were incorporated into a single spring-run broodstock at the Cowlitz (Salkum) Salmon Hatchery. The hatchery run has declined significantly since the construction of Mayfield Dam. A few spring-run chinook salmon are observed spawning naturally below the hatchery (average of 169 fish from 1980 to 1996). These are probably hatchery-origin fish. Furthermore, there is considerable potential for hybridization between fall-run and spring-run fish in the river, as well as possibly in the hatchery.

Spring-run chinook salmon are effectively no longer found within the historical population boundaries for the upper Cowlitz River, Cispus River, and Tilton River DIPs. The biological resources of the DIPs are still present, albeit in a homogenized form, in the Cowlitz Salmon Hatchery broodstocks, and to a less extent in the Kalama and Lewis River spring-run hatchery broodstocks. It is not known to what extent genetic variability has been lost or adaptive genetic complexes disrupted; however, the Cowlitz Salmon Hatchery stock must be considered the "stock of choice" for any recovery efforts in the Cowlitz River basin.

NMFS Rating (Cowlitz (Salkum) Salmon Hatchery): In ESU, category 2
WDFW Mid- and Lower Columbia River Spring Chinook GDU

Lower Cowlitz River Fall-Run Chinook Salmon (LCWL-KF)

The Cowlitz River basin has been and still is a major producer of fall-run chinook salmon. Since 1963, Mossyrock Dam (RKm 84) has limited upstream access. Fall-run chinook salmon that historically migrated into the upper watershed (see "Upper Cowlitz River Fall-Run Chinook Salmon, COWL-KF1") were incorporated into the Cowlitz (Salkum) Salmon Hatchery broodstock. A substantial number of spawners from the lower Cowlitz River fall-run chinook salmon DIP (COWL-KF2) have also been incorporated into the broodstock at the Cowlitz Salmon Hatchery. There may be some population structure in tributaries below the dam, although surveys indicate that hatchery strays occur at relatively high frequencies. Analysis of natural spawners in 1980 indicated that the majority of fish were hatchery strays (WDF et al. 1993). Additionally, an unknown proportion of spring-run fish may have been incorporated into the hatchery fall-run broodstock. Overall, however, the hatchery program has limited direct introgression (through hatchery transfers) from out-of-basin populations and may retain much of the historical diversity.

NMFS Rating (Cowlitz [Salkum] Salmon Hatchery): In ESU, category 2
SASSI Rating (Cowlitz River): Mixed origin, composite production (1992)
WDFW Lower Columbia River Tule Fall Chinook GDU

Toutle River Spring-Run Chinook Salmon (TOUT-KS)

There are historical accounts of spring-run chinook salmon in the Toutle River, although it is unclear how large a population existed prior to European settlement. WDF (1951) estimated that the spawning escapement for the entire Cowlitz River basin was 10,400 spring-run chinook salmon, with 8,100 spawning in the Cispus River, 200 in the Tilton River, 1,700 in the upper Cowlitz River, and 400 in the upper Toutle River. SASSI (WDF et al. 1992) does not recognize a spring-run stock in the Toutle River basin, although there are reports of early returning fish in the Toutle River. More than 2 million spring-run chinook salmon from the Cowlitz Hatchery were planted in the Toutle River between 1974 and 1984. Whether the existing fish in the Toutle River represent the progeny of hatchery transplants, hatchery strays, or the descendants of native fish remains to be established.

Toutle River Fall-Run Chinook Salmon (TOUT-KF)

Fall-run chinook salmon were historically present throughout the Toutle River basin: North Forth Toutle River, Green River, and South Fork Toutle River. Furthermore, given the large size of the Toutle River basin (1,200 km^2), several DIPs may have existed (Myers et al. 2002). Population(s) in the Toutle River basin were nearly extirpated as a result of the Mount St. Helens eruption. Reestablishment of chinook salmon runs in the basin was achieved through natural recolonization and introductions of fish from hatcheries in the Cowlitz, Kalama, Grays, and Washougal Rivers and Big Creek. SASSI (WDF et al. 1992) identifies two stocks in the Toutle River basin, the Green (Toutle) and South Fork Toutle fall chinook.

NMFS Rating Green River Hatchery: In ESU, category 2
SASSI Rating Green (Toutle) River: Unknown origin, composite production (WDF et al. 1992)
SASSI Rating South Fork Toutle River: Unknown origin, composite production (WDF et al. 1992)
WDFW Lower Columbia River Tule Fall Chinook GDU

Coweeman River Fall-Run Chinook Salmon (COWE-KF)

Fall-run chinook salmon in the Coweeman River represent one of the few remaining populations in the ESU sustained through natural production. In 1951, it was estimated that there were 5,000 spawning fall-run chinook in the Coweeman River, with a total spawning escapement of 31,000 fall-run chinook salmon throughout the Cowlitz basin (WDF 1951). Recently, escapement into the Coweeman River has averaged 800 fish; however, there has been minimal contribution to escapement by hatchery strays (ODFW 1998). Relatively few stray hatchery fish are recovered in the basin (based on CWT recoveries), and there have been limited introductions of hatchery fish into the Coweeman River. Genetic analysis indicates that Coweeman River fall-run chinook salmon are distinct from other populations sampled, including fall-run chinook salmon from the mainstem Cowlitz River.

SASSI Rating Coweeman Fall Chinook: Mixed origin, composite production (WDF et al. 1992).

Kalama River Spring-Run Chinook Salmon (KALA-KS)

Presently, only a small spring-run population exists in the Kalama River; however, anecdotal information suggests that the run may have been considerably larger (WDF 1951). Prior to 1950, there were limited reports of early returning fish in the Kalama River. Spring chinook were released from the Kalama Fall Hatchery beginning in 1959. A number of different spring-run stocks have been released into the Kalama River basin; however, genetically this population most closely resembles Cowlitz River spring-run chinook salmon.

NMFS Rating Kalama River Fall-Run Chinook (Kalama Falls Hatchery): In ESU, category 3
SASSI Rating Kalama Spring Chinook: Mixed origin, composite production
WDFW Mid- and Lower Columbia River Spring Chinook GDU

Kalama River Fall-Run Chinook Salmon (KALA-KF)

The Kalama River historically had, and currently maintains, a very large population of fall-run chinook salmon. Although an active hatchery program has been in the basin since 1895, there has been relatively little importation of fall-run chinook salmon into the basin. WDF et al. (1992) indicated that the Kalama River fall-run chinook exhibited distinctive biological and genetic characteristics.

NMFS Rating Kalama River Fall-Run Chinook (Kalama Falls and Fallert Creek Hatcheries): In ESU, category 2
SASSI Rating Kalama Fall Chinook: Mixed origin, composite production
WDFW Lower Columbia River Tule Fall Chinook GDU

Lewis River Spring-Run Chinook Salmon (LEWS-KS)

Historically, spring-run chinook salmon were found in the North Fork of the Lewis River. WDFG (1913) reported that the majority of the spring-run chinook salmon spawning occurred in tributaries to the Muddy Fork—“The Muddy”—of the Lewis River. Access to historical habitat was eliminated following the construction of Merwin Dam (RKm 31) in 1931. Few spring-run chinook salmon utilize the East Fork Lewis River. Despite attempts to maintain the run through hatchery supplementation, the native spring run dwindled and eventually was largely replaced by hatchery fish transferred from outside of the Lewis River basin. Introductions of spring-run chinook salmon from the Cowlitz, Kalama, Willamette, and Klickitat Rivers have been used to sustain the hatchery broodstock. Genetically, the Lewis River spring run most closely resembles populations from the Cowlitz and Kalama Rivers (NMFS 1998a). There is also a close association between the Lewis River and the Sandy River spring runs. Over the past five years, total (hatchery and natural) escapements of spring-run chinook salmon to the Lewis River have averaged 2,444 fish (PFMC 1999).

NMFS Rating Lewis River Spring-Run Chinook (Lewis River and Speelyai Hatcheries): In ESU, category 3
SASSI Rating Lewis Spring Chinook: Mixed origin, composite production
WDFW Mid- and Lower Columbia River Spring Chinook GDU

Salmon Creek Fall-Run Chinook Salmon (SALM-KF)

The Lewis River contains two types of fall-run chinook salmon: an early-returning, or tule, fall run and a late-returning, or bright, fall run. The tule fall run returns primarily to the East Fork Lewis River in August and September and spawns from late September to November (Marshall et al. 1995). This DIP also includes tule chinook salmon that spawn in Salmon Creek and other minor tributaries upriver to, but not including, the Washougal River. Historical documentation of tule chinook salmon utilizing these rivers is very limited, and it is possible that the run in the East Fork Lewis River was founded by hatchery introductions, although no hatchery program for these fish currently exists. Hatchery strays are uncommon in the East Fork Lewis River. Given the degraded condition of spawning habitat in Salmon Creek, spawning success is probably fairly low, and the majority of the returning adults are most likely of hatchery origin.

WDFW Lower Columbia River Tule Fall Chinook GDU

Lewis River Late Fall-Run Chinook Salmon (LEWL-KF)

The Lewis River contains two types of fall-run chinook salmon: a tule fall run and a bright fall run. The bright fall run returns to the North and East Forks of the Lewis River from August to October, and spawning extends from October to January, with reports of chinook salmon spawning as late as April (Marshall et al. 1995). A bright population, which is also genetically similar to the Lewis River brights, also exists in the Sandy River (Oregon). There has been limited hatchery propagation of fall-run chinook salmon in the Lewis River basin.

SASSI Rating Lewis Fall Chinook: Native origin, wild production
SASSI Rating East Fork Lewis Fall Chinook: Native origin, wild production
WDFW Lewis River (Lower Columbia) Bright Fall Chinook GDU

Clackamas River Fall-Run Chinook Salmon (CLCK-KF)

Fall-run chinook salmon were native to the Lower Willamette River and its principal tributary, the Clackamas River. A tule fall-run existed in the lower Clackamas River until the 1930s, when poor water quality conditions below Willamette Falls presented a barrier to returning fall-run chinook salmon (Parkhurst et al. 1950, Gleeson 1972). Dimick and Merryfield (1945) reported that these fish entered the Willamette River in September and October and spawned soon after entering the Clackamas River. Fall-run chinook salmon from Lower Columbia River hatchery stocks were introduced into the Clackamas River from 1952 to 1981 to reestablish the run. Hatchery releases of fall chinook salmon into the Clackamas River last occurred in the 1980s, allowing the existing population at least five generations to adapt to local conditions. Presently, the run appears to be maintained through natural reproduction: ODFW (1998) estimated that few if any hatchery fish were spawning in the Clackamas River.

ODFW Gene Conservation Group: Lower Columbia fall chinook

Washougal River Fall-Run Chinook Salmon (WASH-KF)

The Washougal River is 59 km long and drains a basin of 413 km^2. Salmon Falls (RKm 23) and Dougan Falls (RKm 34) may have been migration barriers to fall-run chinook salmon during low-water periods. Currently, the majority of the chinook salmon spawn in a 6-km reach below Salmon Falls. The average recent natural escapement to the Washougal (1992–1996) has been 3,638 fish (NMFS 1998a). Estimates of stray rates for fish released from the Washougal Hatchery are relatively high, with 27% of the recoveries in basins other than the Washougal. Among the adults surveyed spawning in the Washougal River, over 80% were from the Washougal Hatchery, suggesting that natural reproduction is relatively unsuccessful in the Washougal River basin.

Despite the potential influence of hatchery transfers, fall-run chinook salmon sampled from the Washougal River were genetically different from fish from other basins. WDFW biologists believe that conditions in the Washougal are unique enough to limit the success of these out-of-basin transfers. Furthermore, there is a general correlation between the geographic proximity of other basins and the genetic similarity among fish spawning in those basins.

NMFS Rating Washougal River Fall-Run Chinook (Washougal River Hatchery): In ESU, category 3
SASSI Rating Washougal Fall Chinook: Mixed origin, composite production
WDFW Lower Columbia River Tule Fall Chinook GDU

Sandy River Spring-Run Chinook Salmon (SNDE-KS)

The Sandy River historically had a very large run of spring-run chinook salmon. Run size for the Sandy River basin may have been in excess of 12,000 fish (Mattson 1955). Access to the upper Sandy River basin was severely impacted by the construction of Marmot Dam (at RKm 43) in 1913. Water from the Sandy River was diverted at Marmot Dam into the Little Sandy and Bull Run Rivers, and there was little, if any, flow into the Sandy River below Marmot from July to September (Craig and Suomela 1940). Furthermore, the diversion was unscreened until 1951, so a large proportion of the progeny of naturally spawning fish above the dam was diverted and killed by the turbines of the Bull Run powerhouse prior to that time (ODFW 1990). Propagation activities were terminated in 1925, due to the low size of the run.

The State of Oregon undertook artificial propagation activities with the collection of spring-run broodstock at the base of Marmot Dam from 1938 to 1955. Until the 1950s, introductions of Upper Willamette River spring-run chinook salmon were limited and intermittent. A hatchery was established on Cedar Creek, a tributary to the Sandy River, below Marmot Dam. Although releases of spring-run chinook salmon were made from the Cedar River site, there is some evidence that many returning spring-run fish were actually fall-run chinook salmon (Wallis 1966). Introductions of Upper Willamette River spring-run chinook salmon increased considerably during the 1960s and 1970s. Recently, releases of hatchery fish in the upper Sandy River (above Marmot Dam) were terminated. Hatchery fish now being released are externally marked and will be intercepted at Marmot Dam when they return (ODFW 1998). ODFW plans to convert its Sandy River broodstock from Upper Willamette River–derived spring-run chinook salmon to naturally produced spring-run adults returning to the Sandy. ODFW estimated that the average escapement of naturally produced spring-run salmon over Marmot Dam was 2,600 fish (ODFW 1998).

Genetic analysis of naturally spawning fish from the Sandy River suggested that the Sandy River population was genetically intermediate between Upper Willamette River populations and Lower Columbia River spring-run populations. Furthermore, there was little genetic resemblance between the spring-run and late bright fall-run fish in the Sandy River basin. In other Lower Columbia River and coastal basins there is a tendency for different run times in a basin to have evolved from a common source. The Sandy River basin would be a deviation from this pattern. Microsatellite DNA data indicated that the Sandy River spring-run was genetically distinguishable from the Clackamas Hatchery spring-run broodstock; however, the degree of differentiation was much less than that between spring runs in the Sandy and Yakima Rivers. Bentzen et al. (1998) concluded that although some interbreeding between the Upper Willamette River and Sandy River stocks had occurred, the Sandy River population still retained some of its original genetic characteristics.

NMFS Rating Sandy River-Run Chinook (Clackamas Stock #19): Out of ESU
ODFW Gene Conservation Group: Willamette/Sandy spring chinook

Sandy River Early (Tule) Fall-Run Chinook Salmon (SNDE-KF)

Fall-run chinook salmon are native to the Sandy River. As in the Lewis River, there are two types of fall-run chinook salmon: early-returning (tule) fall run and late-returning (bright) fall run. It has been suggested that only the bright fish are native to the basin, and that the tule fall-run fish are descendants of hatchery releases from Lower Columbia River hatcheries. Stocking of hatchery tules was discontinued in 1977, and many adults returning to the Sandy are thought to be hatchery strays (Kostow 1995).

ODFW Gene Conservation Group: Lower Columbia fall chinook

Sandy River Late Fall-Run Chinook Salmon (SNDL-KF)

Fall-run chinook salmon are native to the Sandy River. As in the Lewis River, there are two types of fall-run chinook salmon: early-returning (tule) fall run and late-returning (bright) fall run. The bright fall-run returns in September and October spawn throughout December and January (Howell et al. 1985). There are reports of a winter-run in the Sandy River, although Kostow (1995) suggested that they have been extirpated. It is also possible that the winter-run chinook salmon observed are the tail-end of the bright fall-run fish. Bright fish in the Lewis River have been observed spawning as late as April. The run of bright fall-run fish may have historically been over 5,000 fish. In 1997, the escapement estimate was 1,125 adults (Whisler et al. 1998). There has been no artificial supplementation of the bright fall run. Genetic analysis indicates a strong association between Lewis and Sandy River bright fall-run chinook salmon, and these two populations cluster with other Lower Columbia River populations.

ODFW Gene Conservation Group: Sandy fall chinook

Chinook Salmon (Columbia River Gorge Tributaries)

This region extends from east of the Washougal River (RKm 194.9) to the White Salmon River (RKm 270) and from east of the Sandy River (RKm 193.6) to the Hood River (RKm 272). Rivers in this region of the ESU are heavily influenced by the steeply sloped sides of the Columbia Gorge. Most streams are relatively short. Impassable falls limit accessible habitat to less than a half mile on most small creeks. Larger rivers contain falls or a series of cascades in their lower reaches, which may present migrational barriers during all or most of the year. Physiographically, this region marks a transition between the high-rainfall areas of the Cascades and the drier areas to the east. Stream flows can be intermittent, especially during the summer.

Lower Gorge Tributary Chinook Salmon (LGRG-KF), Upper Gorge Tributary Chinook Salmon (UGRG-KF)

There are a number of small creeks along the Columbia River upstream of the Sandy and Washougal Rivers. Some spawning habitat in the lowermost portion (approximately 1–3 km) of these creeks and in the mainstem Columbia River was lost with the construction of Bonneville Dam and the filling of Bonneville Pool. Currently, these creeks contain little suitable spawning habitat for chinook salmon, and it is thought that the fall-run chinook salmon observed in these tributaries are hatchery fish released from Bonneville Pool Hatchery programs. Currently, aggregations of early and late fall-run chinook salmon and chum salmon spawn below Bonneville Dam in the vicinity of Ives Island (Van Der Naald et al. 2001). Although the original source of these spawning fish is unclear, the ability of salmon to use mainstem habitat is well established. The late fall-run chinook appear to be most closely related to the upriver fall-run chinook populations (Upper Columbia River Summer and Fall-Run Chinook Salmon ESU), and are probably the progeny of hatchery strays (Marshall 1998, NMFS 1998a).

NMFS Rating Little White Salmon NFH Fall Run: Out of ESU
NMFS Rating Bonneville Hatchery (ODFW #14): Out of ESU
NMFS Rating Bonneville Hatchery (ODFW #95): Out of ESU
SASSI Rating Wind River Tule Fall Chinook: Mixed origin, composite production
SASSI Rating Wind River Bright Fall Chinook: Unknown origin, composite production
SASSI Rating White Salmon River Bright Fall Chinook: Mixed origin, composite production
WDFW Lower Columbia River Tule Fall Chinook GDU
WDFW Mid-Columbia River Tule Fall Chinook GDU

Wind River Spring-Run Chinook Salmon

Spring-run chinook salmon were not historically found in the Wind River basin. Shipherd Falls (RKm 5) prevented chinook salmon from accessing the upper watershed (Parkhurst et al. 1950). Only steelhead were apparently able to ascend the falls. The falls were laddered in 1956, and both spring- and fall-run chinook salmon have been introduced into the upper watershed. The existing spring run is a composite of Upper Columbia and Snake River spring-run salmon that were intercepted at Bonneville Dam and propagated at the Carson National Fish Hatchery (NFH) in the upper Wind River (RKm 24). This spring-run stock is not considered part of the Lower Columbia River ESU, nor any ESU.

NMFS Rating Carson NFH Spring Run: Out of ESU
SASSI Rating Wind River: Nonnative, composite

Big White Salmon River Spring-Run Chinook Salmon (BWSR-KS)

The Big White Salmon River (RKm 270) historically supported runs of both spring and fall chinook salmon prior to the construction of Condit Dam (RKm 4) in 1913 (Fulton 1968). Historically, anadromous fish may have been able to ascend the Big White Salmon River as far as Trout Lake (RKm 45.4) (WDF 1951). Spring-run chinook salmon in the Big White Salmon River were extirpated soon after the construction of Condit Dam, due to loss of accessibility to suitable habitat. A number of nonnative spring-run chinook salmon (Carson NFH) have been released from the Spring Creek and Little White Salmon NFHs.

NMFS Rating Little White Salmon NFH Spring Run: Out of ESU

Big White Salmon River Fall-Run Chinook Salmon (BWSR-KF)

The Big White Salmon River (RKm 270) historically supported runs of both spring and fall chinook salmon prior to the construction of Condit Dam (RKm 4) in 1913 (Fulton 1968). Records indicate that fall-run chinook salmon in the Little White Salmon and Big White Salmon Rivers began spawning in early September, with peak egg takes in the later part of the month (21 September), with a total of 12,840,700 eggs collected in 1901 (Bowers, 1902). Historically, anadromous fish may have been able to ascend the Big White Salmon River as far as Trout Lake (RKm 45.4) (WDF 1951). Fall-run fish from the Big White Salmon River were used to establish the nearby Spring Creek NFH broodstock in 1901 (Hymer et al. 1992). Although there have been a number of different hatchery stocks transferred to the Spring Creek hatchery, this stock is still most closely affiliated with other Lower Columbia River fall-run populations (NMFS 1999a). The Spring Creek NFH stock of fall-run chinook salmon may still retain some historical genetic and life-history characteristics. The life-history characteristics of fall-run chinook salmon from the Spring Creek NFH do differ somewhat from other Lower Columbia River chinook salmon stocks. Furthermore, Spring Creek fall-run chinook salmon are somewhat genetically distinct from the cluster of Lower Columbia River populations. Existing late fall-run (bright) chinook salmon that spawn in this region appear to be the descendants of hatchery transfers from Upper Columbia River populations (Marshall et al. 1995).

NMFS Rating Spring Creek NFH Fall Run: In ESU, category 3
SASSI White Salmon River Tule Fall Chinook: Mixed origin, composite production
WDFW Mid-Columbia River Tule Fall Chinook GDU

Hood River Spring-Run Chinook Salmon (HOOD-KS)

There were once spring-run chinook salmon in the Hood River basin; however, these runs have declined dramatically from historical levels and, despite supplementation efforts, remain at critically low levels. Spring-run chinook salmon in the Hood River are believed to have been extirpated (Kostow 1995, Kostow et al. 2000). Fish from a number of different hatcheries were released into the Hood River basin to reestablish a spring run. From 1985 to 1992, over one million fish were released into the basin from the Carson NFH and the ODFW Lookingglass Hatchery (ODFW Stock #81, a Carson NFH derivative). Currently, fish from the Round Butte Hatchery (Deschutes River, Middle Columbia River Spring-Run ESU) are being released into the Hood River basin as part of a reintroduction program. Fish from the Round Butte introductions and their descendants are not considered part of the Lower Columbia River ESU.

NMFS Rating Hood River Spring Run (ODFW #66): Out of ESU

Hood River Fall-Run Chinook Salmon (Hood-KF)

Fall- and spring-run chinook salmon were native to the Hood River basin. Currently, a very small spawning aggregation of fall-run chinook salmon remains in the Hood River basin. Spawning occurs in the mainstem and the West Fork Hood River to Punchbowl Falls (RKm 6). There is very limited information on the biological or genetic characteristics of this population. Hatchery releases directly into the basin have been very limited; however, the Hood River is located near a number of return facilities for large hatchery programs.

ODFW Gene Conservation Group Lower Columbia Fall

Chinook Salmon (Upper Willamette River)

Historically, the Willamette River basin provided sufficient spawning and rearing habitat for large numbers of spring-run chinook salmon. The predominant tributaries to the Willamette River that historically supported spring-run chinook salmon include the Molalla (RKm 58), Calapooia (RKm 192), Santiam (RKm 174), McKenzie (RKm 282), and Middle Fork Willamette Rivers (RKm 301)—all drain the Cascades to the east (Mattson 1948, Nicholas 1995). There are no direct estimates of the size of the chinook salmon runs in the Willamette River basin prior to the 1940s (Table 8). McKernan and Mattson (1950) present anecdotal information that the Native American fishery at Willamette Falls may have yielded 908,000 kg of salmon (454,000 fish @ 9.08 kg). Mattson (1948) estimated that the spring chinook salmon run in the 1920s may have been five times the existing run size of 55,000 fish (in 1947) or 275,000 fish, based on egg collections at salmon hatcheries.

Prior to the laddering of Willamette Falls, passage by returning adult salmonids (RKm 37) was only possible during the winter and spring high-flow periods. The early run timing of

Willamette River spring-run chinook salmon relative to other Lower Columbia River spring-run populations is viewed as an adaptation to flow conditions at Willamette Falls. Chinook salmon begin appearing in the Lower Willamette River in February, but the majority of the run ascends Willamette Falls in April and May, with a peak in mid-May. Low flows during the summer and autumn months prevent fall-run salmon from accessing the Upper Willamette River basin. Since the Willamette Valley was not glaciated during the last epoch (McPhail and Lindsey 1970), the reproductive isolation provided by the falls probably has been uninterrupted for a considerable time period. Willamette Falls may have been formed by the receding floodwaters of the Bretz Floods (12,000–15,000 years before present) (Nigro 2001). This isolation has provided the potential for significant local adaptation relative to other Columbia River populations.

Clackamas River Spring-Run Chinook Salmon (CLCK-KS)

The Clackamas River historically contained a spring run of chinook salmon, but relatively little information about that native run exists. ODF (1903) reports that, "the Clackamas River is, as has always been conceded, the greatest salmon breeding stream of water that our state affords . . ." Barin (1886) observed a run of chinook salmon that "commences in March or April, sometimes even in February."

Construction of the Cazadero Dam in 1904 (RKm 43) and River Mill Dam in 1911 (RKm 37) limited the spring run's migratory access to the majority of historical spawning habitat. In 1917, the fish ladder at Cazadero Dam was destroyed by floodwaters, eliminating fish passage to the upper basin (Murtagh et al. 1992). Hatchery production of spring-run chinook salmon in the basin continued, using broodstock captured at the Cazadero and River Mill Dams (Willis et al. 1995). Transfers of Upper Willamette River hatchery stocks (primarily the McKenzie River Hatchery) began in 1913, and between 1913 and 1959 over 21.3 million eggs were transferred to the Clackamas River basin (Wallis 1961, 1962, 1963). Furthermore, a large proportion of the transfers occurred during the late 1920s and early 1930s to supplement the failure of the runs in the Clackamas River basin at that time (Leach 1932). In 1942, spring-run chinook salmon propagation programs in the Clackamas River basin were discontinued. By 1939, when passage for spring-run chinook salmon was restored over the Clackamas River dams, the spring-run population had declined considerably from its numbers at the turn of the century. A spawner survey conducted in August 1940 observed 300 adults below Cazadero Dam and more than 500 below River Mill Dam (Parkhurst et al. 1950); however, unspecified conditions did not permit these fish to migrate above the dams. A further 500–700 spring-run chinook salmon were observed spawning in Eagle Creek (where the U.S. Bureau of Fisheries Station was sited) in September and October 1941 (Parkhurst et al. 1950).

The recolonization of the upper Clackamas River progressed very slowly. The average annual dam count (River Mill or North Fork Dam) from 1952 to 1959 was 461 (Murtagh et al. 1992). More importantly, 30% of the adult passage counts occurred in September and October. Artificial propagation activities were restarted at the Eagle Creek NFH in 1956 using eggs from a number of Upper Willamette River hatchery stocks. The program released approximately 600,000 smolts annually through 1985. In 1976, the ODFW Clackamas Hatchery (located below River Mill Dam) began releasing spring-run chinook salmon (Willamette River hatchery broodstocks were used, since it was believed that the returns from the local population were too small to meet the hatchery's needs [Murtagh et al. 1992]). Increases in adult returns over the North Fork Dam and increases in redd counts above the North Fork Reservoir corresponded to the initial return of adults to the hatchery in 1980 (Murtagh et al. 1992, Willis et al. 1995). Adult counts over North Fork Dam rose from 592 in 1979 to 2,122 in 1980 (Murtagh et al. 1992). Spawner surveys conducted in 1998 estimated that 380 redds were present above the North Fork Dam (this corresponded to the cumulative total of 1,382 adults passing the dam one week prior to the redd count) (Lindsay et al. 1999). Recent changes in management policy by ODFW (ODFW 1998) should reduce the number of hatchery-derived adults spawning above the North Fork Dam. These changes include releasing hatchery fish farther downstream and mass marking all hatchery releases to allow the removal of hatchery fish ascending the North Fork Dam.

Genetic analysis by NMFS of naturally produced fish from the upper Clackamas River indicated that this stock was similar to hatchery stocks from the Upper Willamette River basin (Myers et al. 1998, see Appendix B). This finding agrees with an earlier comparison of naturally produced fish from the Collawash River (a tributary to the upper Clackamas River) and Upper Willamette River hatchery stocks (Schreck et al. 1986). Fish introduced from the Upper Willamette River have significantly introgressed into, if not overwhelmed, spring-run fish native to the Clackamas River basin, and obscured any genetic differences that existed prior to hatchery transfers.

It was suggested by ODFW (1998) that spring-run fish returning to the Upper Willamette River basin historically may have strayed into the Clackamas River when conditions at Willamette Falls prevented upstream passage. Therefore, similarities between Clackamas River and Upper Willamette River spring-run fish may reflect an historical/evolutionary association between the two groups, rather than a recent artifact of human intervention. Recoveries of returning adults released from the Clackamas River have occurred at a number of sites outside of the Clackamas River. This may reflect the introgression of other Upper Willamette River spring-run hatchery stocks into the Clackamas Hatchery, the relative downriver location of the releases (relative to historical spawning sites), or other aspects of the propagation of these fish prior to release.

NMFS Rating Clackamas Hatchery Spring Run: In ESU, category 3
ODFW Willamette Spring Gene Conservation Group

Molalla River Spring-Run Chinook Salmon (MOLA-KS)

The Molalla River is located 50 km from the mouth of the Willamette River, just above Willamette Falls (Figure 9). By 1903, the abundance of chinook salmon in the Molalla River had already decreased dramatically (ODF 1903). Surveys in 1940 and 1941 recorded 882 and 993 spring-run chinook salmon present, respectively (Parkhurst et al. 1950). Craig and Townsend (1946) collected a number of juveniles moving downstream from the Molalla River. Mattson (1948) estimated the run size to be 500 in 1947. Surveys in 1940 observed 250 spring-run chinook salmon in Abiqua Creek (Pudding River) (Parkhurst et al. 1950). Kostow (1995) determined that the naturally spawning population in the Molalla River (including Abiqua Creek in the Pudding River basin) had been extirpated. Efforts are under way to reestablish natural production in the Molalla River basin using other Upper Willamette River spring-run populations. While much historical habitat was degraded, it remains accessible.

ODFW Willamette Spring Gene Conservation Group

North Santiam River Spring-Run Chinook Salmon (NSNT-KS)

Spring-run chinook salmon are native to the Santiam River basin. The Oregon Fish Commission began egg-taking operations in 1911, when adults were at the hatchery rack near Jefferson, below the confluence of the North Santiam and Breitenbush Rivers, and below most of the natural spawning areas (except for the Little North Santiam River). The largest egg collection was 13.2 million in 1934 (this corresponds to 4,125 females @ 3,200 eggs/female [Wallis 1963]). The estimated run size for the entire North Santiam River basin was 2,830 in 1947 (Mattson 1948). Between 1911 and 1960, the overwhelming majority of hatchery fish released into the North Santiam basin came from adults captured within the watershed; other introductions came from the South Santiam, McKenzie, and Willamette River hatcheries (Wallis 1963a). A program to introduce Carson Hatchery spring-run chinook salmon (Snake River and Upper Columbia River populations) at the North Santiam Hatchery during the 1970s was discontinued after several years and appears to have had little impact on the original hatchery population (Willis et al. 1995).

The construction of Detroit and Big Cliff Dams (RKm 79) in 1953 on the North Santiam River, eliminated access to approximately 70% of the spawning area for chinook salmon. Alteration in temperature and discharge rate from the dams probably had a significant impact on the survival of eggs deposited below the dam. Changes in the temperature regime have resulted in accelerated embryonic development rates and premature emergence. Cramer et al. (1996) reported chinook salmon fry in the North Santiam River moving downstream in late November, in contrast to normal emergence in February or March.

Genetic analysis of naturally produced juveniles from the North Santiam River indicated that the naturally produced fish were most closely related, although still significantly distinct ($P > 0.05$) from other naturally and hatchery-produced spring-run chinook from the Upper Willamette and Clackamas Rivers (NMFS 1998a).

NMFS Rating Marion Forks Hatchery Spring Run (ODFW#21): In ESU, category 3
ODFW Willamette Spring Gene Conservation Group

South Santiam Spring-Run Chinook Salmon (SSNT-KS)

Spring-run chinook salmon are native to the South Santiam River. Egg collection activities began in 1923, when a weir was placed across the river near the town of Foster (Wallis 1961), well below the natural holding and spawning areas (Mattson 1948). Escapement to the South Santiam River was estimated to be 1,300 in 1947 (Mattson 1948). Wallis (1961) estimated that, due to poor husbandry practices, releases from the South Santiam Hatchery did not significantly contribute to escapements (the hatchery may have mined returning naturally produced adults each year.)

In 1976, Foster Dam (RKm 77) blocked access to nearly all historical spring-run chinook salmon spawning areas (Middle Santiam River, Quartzville Creek, and South Santiam River [Mattson 1948]). The South Santiam Hatchery currently collects broodstock from a trap near the base of Foster Dam. With the loss of nearly all their historical spawning habitat, spring-run chinook salmon in the South Santiam River became dependent on artificial propagation for their sustainability. ODFW (1995) considered that the naturally spawning populations in the South Santiam River were "probably extinct." In 1998, 166 spring-run chinook salmon redds were observed in the South Fork; however, these are most likely the progeny of hatchery-produced spring-run fish (Lindsay et al. 1999). No genetic analyses are available for South Santiam River spring-run chinook salmon. Fall-run chinook salmon are also present in the Santiam River basin, but the spring-run and fall-run chinook salmon generally appear to be spatially and temporally separated on the spawning grounds. There have been several attempts to trap and haul spring-run chinook salmon above Foster Dam; however, the low success rates for juvenile downstream passage may be the limiting factor in this program.

NMFS Rating South Santiam Hatchery Spring Run (ODFW #24): In ESU, category 3
ODFW Willamette Spring Gene Conservation Group

Calapooia River Spring-Run Chinook Salmon (CALA-KS)

A small run of spring chinook salmon historically existed in the Calapooia River. Parkhurst et al. (1950) reported that the run size in 1941 was approximately 200 adults, while Mattson (1948) estimated the run at 30 adults in 1947. Kostow (1995) considered the run in the Calapooia to be extinct, with limited future production potential.

ODFW Willamette Spring Gene Conservation Group

McKenzie River Spring-Run Chinook Salmon (MCKZ-KS)

Spring-run chinook salmon are native to the McKenzie River basin. Historical natural spawning areas included the mainstem McKenzie River, Smith River, Lost Creek, Horse Creek, South Fork, Blue River, and Gate Creek (Mattson 1948, Parkhurst et al. 1950). ODF (1903) surveyed much of the "M'Kenzie" [sic] River to site a hatchery and collection rack. The report states, "It has been generally reported by settlers and those living along the river that salmon can be seen spawning during the months of August and September all along the river, but principally from Leaburg post office up to its source." Currently, the McKenzie River is the only basin above Willamette Falls with any level of sustained natural production. The McKenzie River Hatchery (RKm 52), which began egg-taking operations in 1902, obtained a peak collection of 25.1 million eggs in 1935 (Wallis 1961), from an estimated 7,844 females (@ 3,200 eggs per female). The construction of the Cougar Mountain Dam (RKm 101) in 1963 eliminated 56 km of spawning habitat on the South Fork McKenzie River. The South Fork was generally believed to be the best salmon-producing stream in the McKenzie drainage (USFWS 1948). The Blue River Dam (1968, RKm 88) prevented access to an additional 32 km of spawning habitat.

Genetic analysis of juveniles from the McKenzie River indicated that the naturally produced fish were most closely related to other naturally and hatchery-produced spring-run chinook from the Upper Willamette and Clackamas Rivers (NMFS 1998a, see Appendix B). There is very little apparent straying based on the recoveries of CWT fish released from the McKenzie River Hatchery, with more than 97% of all freshwater recoveries occurring in the McKenzie River basin.

NMFS Rating McKenzie River Hatchery Spring Run (ODFW #23): In ESU, category 3
ODFW Willamette Spring Gene Conservation Group

Middle Fork Willamette River Spring-Run Chinook Salmon (MFWL-KS)

The Middle Fork Willamette River supported historical populations of spring-run chinook salmon. Spawning aggregations were in Fall Creek, Salmon Creek, North Fork Middle Willamette River, mainstem Middle Fork Willamette River, and Salt Creek (Mattson 1948, Parkhurst et al. 1950). Based on records from the Willamette River Hatchery (Dexter Ponds) (1909–present), the largest egg collection, 11,389,000 in 1918 (Wallis 1962), would correspond to 3,559 females (@ 3,200 eggs/female).

The construction of Lookout Point and Dexter Dams (RKm 328) in 1953 eliminated access to almost 345 km of salmon habitat (Cramer et al. 1996). Only the Fall Creek basin remains accessible to anadromous salmonids. Although Parkhurst et al. (1950) estimated the Fall Creek basin could support several thousand salmon, by 1938 the run was already severely depleted: in 1947, it had dwindled to an estimated 60 fish (Mattson 1948). Construction of the Fall Creek Dam (1965) included fish passage facilities, but passage is only possible during high-flow years (Connolly et al. 1992). Kostow (1995) concluded that the native spring-run population was extinct, although some natural production, presumably by hatchery-origin adults may still occur.

Studies of juvenile emigration from the Middle Fork Willamette River in 1941 indicated that downstream migration occurred more or less continuously from March through autumn (Craig and Townsend 1946). Genetic analysis of naturally produced juveniles from the Dexter Ponds trap indicated that the fish were most closely related to other naturally and hatchery-produced spring-run chinook from the Upper Willamette and Clackamas Rivers (NMFS 1998a).

NMFS Rating Willamette Hatchery Spring Run (ODFW #22): In ESU, category 3
ODFW Willamette Spring Gene Conservation Group

Steelhead

Steelhead (Lower Columbia River)

Western Cascade Slope Tributaries

Rivers in the western Cascade slope region are larger than those in the coastal region. With headwaters high in the Cascade Mountains, many rivers are over 100 km long, with basins covering 1,000 km^2 or more. Snowmelt and groundwater sources are substantial, and maintain good year-round flows and cool water temperatures. River flows peak in December or January and sustain at least 50% of peak for six months or more. The lower reaches of these rivers are relatively low gradient, but high-gradient sections are common in the middle and upper reaches.

This region extends from the Cowlitz River (RKm 106.2) to the Washougal River (RKm 194.9) on the Washington State side of the Columbia River and from the Willamette River (RKm 162.5) to the Sandy River (RKm 193.6) on the Oregon side. Several major populations appear to have existed in this region, based on historical population abundance estimates and watershed size.

In general, little life-history information is available to distinguish steelhead populations, other than winter and summer run times. Historical references to steelhead rarely made any distinction between summer and winter runs. The majority of steelhead are believed to have emigrated to saltwater as 2-year-old fish and returned to spawn as 4-year-old adults (i.e., having spent two years in the ocean). The ability of steelhead to ascend waterfalls and cascades has given them a wide distribution in many basins that are not readily accessible to other anadromous salmonids. There is a considerable genetics database for Lower Columbia River steelhead; however, a number of the naturally spawning and hatchery populations were strongly influenced by transfers of fish from Puget Sound hatcheries (Puget Sound ESU), the Big Creek Hatchery (Southwest Washington ESU), and the Skamania Hatchery (Phelps et al. 1995).

Cowlitz River Basin

Summer and winter steelhead are present in the Cowlitz River basin; however, only winter steelhead are believed to be native. The Cowlitz River contains two stocks of winter steelhead: an early-returning winter run that spawns in December and January, and a late-returning winter run that spawns in April and May (Howell et al. 1985). The early-returning winter run is a hybrid of native Cowlitz River winter steelhead and Puget Sound Chambers Creek Hatchery stock, while the late-returning winter steelhead are reported to be representative of native fish (Busby et al. 1996). Genetic analysis substantiates the origins of these run times. Summer steelhead in the Cowlitz River are derived from hatchery introductions of Skamania Hatchery summer steelhead. Furthermore, the Cowlitz River late-return winter steelhead are one of the most distinct in this ESU (Phelps et al. 1997). Both the early-returning winter steelhead and summer steelhead stocks are not considered part of the ESU (NMFS 1998a),

Historically, there were runs of over 20,000 winter steelhead in the Cowlitz River (Hymer et al. 1992). The construction of Mossyrock and Mayfield Dams eliminated approximately 50% of the historical spawning habitat. Additionally, the eruption of Mount St. Helens dramatically altered habitat in the Toutle River basin. Naturally spawning populations exist in the lower mainstem Cowlitz, Coweeman, and Toutle River basins.

Analysis of allozyme variation indicates that there are significant differences between late-run, native winter steelhead in the mainstem Cowlitz, Green (North Fork Toutle), and South Fork Toutle Rivers (Phelps et al. 1997, see Appendix B). The mainstem Cowlitz River population may represent the homogenized genetic resources of all winter-run populations from the upper and lower Cowlitz, Cispus, and Tilton basins. Furthermore, samples from the Green River (Cowlitz River basin) clustered with hatchery samples known to be strongly influenced by introductions of Chambers Creek (Puget Sound) winter-run steelhead, and may not be representative of the historical population.

Cispus River Winter Steelhead (CISP-SW), Tilton River Winter Steelhead (TILT-SW), Upper Cowlitz River Winter Steelhead (UCWL-SW)

Winter steelhead were historically found throughout the Cowlitz River basin. Construction of Mayfield Dam in 1968 eliminated access to spawning habitat in the Tilton, Cispus, and upper Cowlitz Rivers. Until 1981, returning steelhead were passed above the dam and into the Tilton River to enhance a sport fishery. Natural production by these fish was limited, and downstream passage facilities for naturally produced juveniles were inadequate. Reintroduction of adults (from the late-winter steelhead returning to the hatchery) above the dam into the three basins began again in 1994, with juveniles produced in the upper Cowlitz and Cispus Rivers being collected at the Cowlitz Falls Dam, and juveniles produced in the Tilton River being passed at Mayfield Dam.

With the construction of Mayfield Dam, many adults returning to the Cispus, Tilton, and upper Cowlitz Rivers were taken into the Cowlitz Trout Hatchery to establish the late-winter steelhead broodstock. The hatchery probably also collected adults returning to the lower Cowlitz winter steelhead DIP (LCWL-SW) into the broodstock. Two other nonnative steelhead broodstocks are also reared at the Cowlitz Trout Hatchery: the early-returning winter steelhead stock (derived from Puget Sound and southwestern Washington sources) and the summer steelhead broodstock (derived from the Skamania Hatchery broodstock). Although some hybridization between these three stocks may have occurred, genetic analysis indicates that the late-winter steelhead stock is distinct from the other stocks.

NMFS Rating Chambers Creek/Lower Columbia River Mix (Early Winter Steelhead): Out of ESU
NMFS Rating Cowlitz Late-Winter Steelhead: In ESU
NMFS Rating Skamania Summer Steelhead: Out of ESU
SASSI Cowlitz Winter Steelhead: Mixed origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Lower Cowlitz River Winter Steelhead (LCWL-SW)

Winter steelhead are native to the lower Cowlitz River and its tributaries. However, habitat degradation and changes in water quality due to Mayfield Dam have severely limited natural production. Wade (2000a) reported that 92% of the adults spawning in the lower Cowlitz River were of hatchery origin. The Cowlitz Trout Hatchery late-winter steelhead stock is an amalgamation of fish from populations that existed above and below Mayfield Dam. Two other nonnative steelhead broodstocks are also reared at the Cowlitz Trout Hatchery: the early-returning winter steelhead stock (derived from Puget Sound and southwestern Washington sources) and the summer steelhead broodstock (derived from the Skamania Hatchery broodstock). Although some hybridization between these three stocks may have occurred, genetic analysis indicates that the late-winter steelhead stock is distinct from the other stocks.

NMFS Rating Chambers Creek/Lower Columbia River Mix (Early-Winter Steelhead): Out of ESU
NMFS Rating Cowlitz Late-Winter Steelhead: In ESU
NMFS Rating Skamania Summer Steelhead: Out of ESU
SASSI Cowlitz Winter Steelhead: Mixed origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

North Fork Toutle River (Green River) Winter Steelhead (NTOU-SW)

Winter steelhead are native to the North Fork Toutle River basin, but the eruption of Mount St. Helens in 1980 dramatically degraded spawning and rearing habitat in the North Fork Toutle River basin. Before the eruption, winter steelhead from the Cowlitz River (main stem), Elochoman River, and Chambers Creek Hatchery (Puget Sound) were released into the Toutle River basin. After the eruption, the steelhead population declined dramatically and founder effects may have substantially influenced population structure. In 1988, returning adults were collected and spawned as part of a supplementation program to recover winter-run steelhead in the North Fork Toutle River. Currently, the North Fork is managed for natural production, and the contribution of hatchery fish to spawner escapement is thought to be near 0% in the North Fork and 17% in the Green River (Wade 2000a). Genetic analysis of samples from the Green River (Toutle River basin) clustered with hatchery samples that were known to be strongly influenced by introductions of Chambers Creek (Puget Sound) winter-run steelhead, and may not be representative of the historical population.

SASSI Mainstem/North Fork Toutle Winter Steelhead: Native origin, wild production
SASSI Green (Toutle) Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

South Fork Toutle River Winter Steelhead (STOU-SW)

Winter steelhead are native to the South Fork Toutle River basin. The eruption of Mount St. Helens did not affect habitat in the South Fork to the same extent it did in the North Fork. Introductions of nonnative hatchery winter steelhead into the South Fork Toutle River have been limited. The South Fork Toutle River is managed for natural production, and hatchery strays are reported to comprise 17% of the natural spawning escapement (Wade 2000a). Genetic analysis of winter steelhead from the South Fork Toutle River indicates a strong association with other native steelhead populations in the Lower Columbia River (Phelps et al. 1997).

SASSI South Fork Toutle Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Coweeman River Winter Steelhead (COWE-SW)

Winter steelhead are native to the Coweeman River basin. This population is considered native by WDFW (WDF et al. 1993), despite the release of large numbers of out-of-basin winter steelhead released from the Coweeman Ponds (Myers et al. 1998). Wade (2000a) estimated that only 27% of the natural spawners were of hatchery origin.

SASSI Coweeman Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Kalama River Summer Steelhead (KALA-SS)

Summer steelhead are native to the Kalama River basin. Summer steelhead are found throughout the basin as far as the falls at RKm 56. Historically, they may have been the only salmonids able to ascend Kalama Falls (RKm 16). Modifications to Kalama Falls allowed winter steelhead to access the upper portion of the Kalama River and may have resulted in some hybridization between the two run types. Substantial numbers of nonnative summer steelhead have been released into the Kalama River basin, primarily from the Skamania Hatchery (out of ESU). Hatchery fish comprise 67% of escapement (Wade 2000b). In spite of the large proportion of hatchery-produced summer steelhead in the basin, native summer steelhead are genetically distinct from the Skamania summer steelhead that are released in the basin. Differences in spawning time and overall fitness between the two stocks may have reduced the extent of introgression.

NMFS Rating Skamania Summer Steelhead: Out of ESU
SASSI Kalama River Summer Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Kalama River Winter Steelhead (KALA-SW)

Winter steelhead are native to the Kalama River basin, but historically they may not have been able to migrate beyond Kalama Falls (RKm 16). Side-channel and tributary habitat is limited in the Kalama River basin, and the historical population may not have been very large. There have been a number of hatchery introductions from outside the basin (primarily Elochoman and Chambers Creek stocks). Approximately 31% of naturally spawning winter steelhead are of hatchery origin (Wade 2000b). Genetic analysis indicates that the existing native population is very distinct from the Lower Columbia River/Puget Sound hatchery stock mix.

NMFS Rating Lower Columbia River/Chambers Creek Steelhead: Out of ESU
SASSI Kalama River Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

North Fork Lewis River Summer Steelhead (NLEW-SS)

Summer steelhead are native to the North Fork Lewis River. The construction of three mainstem dams—Merwin Dam (RKm 31), Yale Dam (RKm 55), and Swift Dam (RKm 77)—eliminated access to over 80% of historical spawning and rearing habitat. Despite attempts to maintain naturally spawning steelhead through a trap-and-haul program over Merwin Dam following its construction in 1931, the summer steelhead population dwindled (Parkhurst et al. 1950). Currently, some spawning takes place below the dams and possibly in a tributary, Cedar Creek, but naturally produced adults account for only 7% of total escapement in the North Fork Lewis River (Wade 2000b). Hatchery releases of nonnative summer steelhead, primarily from the Skamania Hatchery, have been common in the North Fork since 1979. Genetic analysis of

North Fork Lewis River summer steelhead is not available, but given the limited amount of spawning habitat currently accessible it is unlikely that an independent self-sustaining population could exist.

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
SASSI North Fork Lewis River Summer Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

North Fork Lewis River Winter Steelhead (NLEW-SW)

Winter steelhead are native to the North Fork Lewis River, but construction of three mainstem dams—Merwin (RKm 31), Yale (RKm 55), and Swift (RKm 77)— eliminated access to over 80% of the historical spawning and rearing habitat. Despite attempts to maintain naturally spawning steelhead through a trap-and-haul program over Merwin Dam following its construction in 1931, the winter steelhead population dwindled (Parkhurst et al. 1950). Currently, some spawning takes place below the dams and in tributaries, Cedar and Fossil Creeks, but naturally produced adults accounted for only 6% of North Fork Lewis River total escapement in 1990 (Wade 2000b). Hatchery releases of nonnative winter steelhead, a mixture of Chambers Creek Hatchery (Puget Sound), Beaver Creek Hatchery (southwest Washington), and other hatchery populations have been common in the North Fork. Genetic analyses of North Fork Lewis River winter steelhead suggest a strong similarity to nonnative hatchery populations, rather than populations known to be endemic to the region (Phelps et al. 1997, Myers et al. 2002).

NMFS Rating LCR/Puget Sound Mix Hatchery Winter Steelhead: Out of ESU
SASSI North Fork Lewis River Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

East Fork Lewis River Summer Steelhead (ELEW-SS)

Summer steelhead are native to the East Fork Lewis River. In contrast to the North Fork Lewis River, accessible habitat for summer steelhead may have increased from historical levels with the “notching” of Sunset Falls (RKm 52.6) in 1982. Wade (2000b) reported that 12% of summer steelhead now spawn above Sunset Falls. Summer steelhead, primarily from the Skamania Hatchery, have been planted into the East Fork Lewis River since 1964 (WDF et al. 1993). However, genetic analysis indicates that East Fork summer steelhead are most similar to other endemic populations in this region, especially East Fork winter steelhead (Phelps et al. 1997, Myers et al. 2002). The level of genetic differentiation between hatchery and naturally produced summer steelhead is surprising given that 71% of escapement consists of hatchery fish (Wade 2000b). Phelps et al. (1997) suggest that temporal differences in spawn timing may contribute to reproductive isolation between these two groups.

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
SASSI East Fork Lewis River Summer Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

East Fork Lewis River Winter Steelhead (ELEW-SW)

Winter steelhead are native to the East Fork Lewis River. Introductions of nonnative winter steelhead have occurred in the basin since 1954, and 100,000 fish are still planted throughout the Lewis River basin to enhance sport fisheries. Despite this level of intervention, naturally produced winter steelhead are distinct from hatchery populations and most similar to other endemic populations from this region. Hatchery fish contribute 51% of the total escapement to the East Fork Lewis River, and it is possible that differences in spawn timing provide some level of reproduction isolation (Phelps et al. 1997). WDF et al. (1993) estimate little contribution by hatchery fish to the naturally produced winter steelhead population.

NMFS Rating Lower Columbia River/Puget Sound Mix Hatchery Winter Steelhead: Out of ESU
SASSI East Fork Lewis River Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Salmon Creek Winter Steelhead (SALM-SW)

Winter steelhead are native to Salmon Creek and nearby tributaries to the Columbia River. The basin is highly urbanized, and it is not known to what degree the naturally reproducing population is self-sustaining. Hatchery introductions began in this area in 1954 and are still common, and a large proportion of adults observed are likely hatchery strays. No genetic sampling has been undertaken in this area. The escapement goal for this area is 400 adults, although there have been no recent spawner surveys.

NMFS Rating LCR/Puget Sound Mix Hatchery Winter Steelhead: Out of ESU
SASSI Salmon Creek Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Clackamas River Winter Steelhead (CLCK-SW)

Winter steelhead are native to the Clackamas River basin. Although summer steelhead are present and naturally spawning in this system, they originated from releases of Skamania Hatchery summer steelhead stock (Murtagh et al. 1992, Chilcote 1997). Genetic analysis of winter-run steelhead from the Clackamas River suggest a close relationship to Skamania Hatchery summer steelhead; however, there is some suggestion that the juvenile sample analyzed contained a mixture of winter and summer steelhead (A. Marshall[1]).

In the early 1960s over 2,000 wild winter steelhead were returning to the upper Clackamas River (Murtagh et al. 1992). Recent returns to the Clackamas River (enumerated at North Fork Dam) indicate that 278 of the 530 (52%) winter steelhead were of wild or native origin. Additionally, Chilcote (1997) estimated that competition between summer and winter steelhead significantly reduced the productivity of winter steelhead.

Upstream migration was limited or blocked with the construction of the Cazadero Dam (later called the Faraday Diversion Dam, RKm 45) in 1904 and the River Mill Dam (RKm 37) in

[1] A. Marshall, WDFW, 600 Capitol Way N., Olympia, WA 98501-1091, pers. comm., November 2001.

1912. Ladders provided steelhead access to the upper watershed until 1917, when the ladder washed out (Murtagh et al. 1992). Passage was not restored until 1939.

A number of hatchery programs release steelhead into the Clackamas River basin: Skamania Hatchery summer steelhead, Clackamas Hatchery winter steelhead (#20) derived from Big Creek Hatchery stock (southwest Washington ESU), Eagle Creek Nation Fish Hatchery Stock (Big Creek derivative), Clackamas Hatchery winter steelhead (#122) derived from late-returning native spawners. It has been determined that only the Clackamas Hatchery stock (#122) is part of the Lower Columbia River ESU. The Big Creek Hatchery stock of winter steelhead return to the Clackamas River earlier (October to early March) than the native winter steelhead (February to June) (Murtagh et al. 1992). Furthermore, the peak spawning period for Big Creek–derived fish is January to early March, compared with May and June for native Clackamas River winter steelhead.

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
NMFS Rating ODFW Big Creek Hatchery (#13): Out of ESU
NMFS Rating Skamania Hatchery Winter Steelhead (#19): Out of ESU
NMFS Rating ODFW Clackamas Hatchery Winter Steelhead (#20): Out of ESU
NMFS Rating ODFW Clackamas Hatchery Late-Winter Steelhead (#121): In ESU
ODFW Lower Columbia Conservation Group

Sandy River Winter Steelhead (SAND-SW)

Winter and summer steelhead are present in the Sandy River basin, although only winter steelhead are thought to be native (Kostow 1995). Historically, winter steelhead escapement may have been in excess of 20,000 fish (Mattson 1955). Loss of spawning habitat in the Bull Run and Little Sandy River basins, in combination with the effects of dams on the mainstem Sandy River, reduced the run to 4,400 in 1954. More recently, the estimated wild escapement of hatchery fish over Marmot Dam (RKm 43) was 851 in 1997, although distinguishing between wild and hatchery-derived winter steelhead was very difficult (Chilcote 1997).

Winter steelhead have been propagated in the Sandy River basin since 1901 (Wallis 1963). Initially, returning adults were intercepted for use as broodstock. Beginning in 1960, Big Creek winter steelhead were introduced into the Sandy River (Wallis 1963). Hatchery fish constituted nearly 40% of the winter steelhead passing over Marmot Dam in 1997 (Chilcote 1997). ODFW predicted that changes in the release strategy for winter steelhead should limit the proportion of hatchery winter steelhead at Marmot Dam to 10% or less (Chilcote 1997). Releases of summer steelhead (Skamania Hatchery stock) began in 1976, and spawning escapement to the Sandy River currently averages 2,000 fish (Chilcote 1997), although there are plans to terminate the summer steelhead program in the Sandy River basin. Additionally, there are plans to remove several dams on the Bull Run, which may provide additional spawning and rearing habitat to a basin that once produced 5,000 adults (Mattson 1955).

There are no genetic analyses available for Sandy River winter steelhead. Differences in spawning time between Big Creek early winter steelhead and native late-winter steelhead may have minimized hybridization between the two groups. Prior to 1999, when hatchery fish were excluded from migrating above Marmot Dam, hatchery fish often contributed more than 50% of the spawning escapement above Marmot Dam.

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
NMFS Rating Big Creek Hatchery Winter Steelhead (#13/15): Out of ESU
ODFW Lower Columbia Conservation Group

Washougal River Summer Steelhead (WASH-SS)

Summer steelhead are native to the Washougal River basin. Two sets of falls, Salmon Falls (RKm 28) and Dougan Falls (RKm 34), present migration barriers to returning adult steelhead during low-water periods (Parkhurst et al. 1950, Hymer et al. 1992). In July 1935, a survey counted 539 summer steelhead in resting holes below Salmon Falls (Parkhurst et al. 1950). WDF (1951) provided no escapement estimates, but did estimate that the Washougal River basin contributed 55,000 kg to the fishery (prior to construction of the Skamania Hatchery).

The summer and winter steelhead stocks currently released from the Skamania Hatchery are not considered part of the ESU due to the inclusion of out-of-ESU stocks into the hatchery program (NMFS 1998a). The Skamania Hatchery is located on the West Fork Washougal River. Wade (2000c) reports that hatchery fish comprise 87% of spawners in the West Fork, but only 1% in the mainstem Washougal River. Genetic analysis indicates that the naturally spawning summer steelhead are genetically distinct from the Skamania Hatchery summer steelhead, and similar to endemic steelhead from the Wind River.

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
SASSI Washougal River Summer Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Washougal River Winter Steelhead (WASH-SW)

Summer steelhead are native to the Washougal River basin. Two sets of falls, Salmon Falls (RKm 28) and Dougan Falls (RKm 34), present a barrier to returning adult steelhead during low-water periods (Parkhurst et al. 1950, Hymer et al. 1992). Winter steelhead are distributed in the mainstem Washougal, the Little Washougal, and various tributaries within the Washougal subbasin. Generally, Dougan Falls (RM 21.6) is considered the upstream extent of winter steelhead distribution in the mainstem Washougal River. The SASSI spawner escapement goal was 841 wild winter steelhead for the mainstem Washougal River. Timing of adult migration most likely occurs from January through May, with peak movement in March (WDF et al. 1993).

The summer and winter steelhead stocks currently released from the Skamania Hatchery are not considered part of the ESU due to the inclusion of out-of-ESU stocks into the hatchery program (NMFS 1998b). The Skamania Hatchery is located on the West Fork Washougal River. Approximately 110,000 hatchery winter steelhead smolts are released annually in the Washougal River (Wade 2000c). These smolts are Skamania Hatchery–origin steelhead, reared primarily at the Skamania Hatchery on the Washougal River, but also at the Vancouver and Beaver Creek facilities. Interbreeding between hatchery and wild steelhead is thought to be very low because of run-timing (WDF et al. 1993).

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
NMFS Rating Skamania Hatchery Winter Steelhead: Out of ESU
SASSI Washougal River Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Lower Gorge Tributaries Winter Steelhead (LGRG-SW)

Impassable waterfalls limit accessible habitat to less than a half mile on most small creeks in this region. Larger rivers contain falls or cascades in their lower reaches, which may present migrational barriers during all or most of the year. Furthermore this region marks a transition between the high-rainfall areas of the Cascades and the drier areas to the east. Spawning steelhead were observed in several small creeks that line the Columbia Gorge during surveys conducted during the 1930s and 1940s. None of these streams provides sufficient habitat for large spawning aggregations of fish, and it is unlikely that there were any independent populations.

Relatively little information is available on the winter steelhead that occupy tributaries in the lower Columbia Gorge region. This area includes Hamilton Creek, which contains a SASSI stock identified by WDFW. Numerous natural and artificial barriers in the lower parts of most tributaries limit spawning and rearing habitat in this area. There have been a number of hatchery introductions from the Skamania and Beaver Creek (southwest Washington ESU) hatcheries, although the current contribution of hatchery fish to escapement is thought to be less than 5% (Wade 2000).

SASSI Hamilton Creek and Other Tributaries Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Wind River Summer Steelhead (WIND-SS)

Summer and winter steelhead are native to the Wind River basin. Shipherd Falls (RKm 3) presented a migratory barrier to chinook salmon, but not to steelhead (Hymer et al. 1992), although winter steelhead passage over the falls may have been intermittent at best. Additionally, a lumber-mill dam at RKm 22.5 on the mainstem Wind River blocked upstream passage until 1947. In 1956, Shipherd Falls was laddered and additional modifications were made to a number of other falls and cascades to provide greater access throughout the watershed. SASSI (WDF et al. 1993) originally identified three distinct stocks of summer steelhead in the Wind River basin; however, after recent revisions to the stock inventory, Wind River summer steelhead are considered to be one stock.

Steelhead escapement in 1951 was estimated at 2,000 fish (WDF 1951). Both summer (Skamania Hatchery stock) and winter (Chambers Creek/Lower Columbia stock mixture) steelhead have been released in the Wind River watershed. Busby et al. (1996) reported that summer steelhead escapement to the Wind River averaged 600 fish, half of which were of hatchery origin. Genetic analysis of samples from the Wind River and two of its primary tributaries: Trout Creek and Panther Creek, indicates very different relationships among fish at the sample sites. Trout Creek samples were taken above a fish trap that excludes hatchery fish. The Trout Creek fish were most similar to steelhead from the Washougal River. On the other hand, samples from the mainstem Wind River and Panther Creek were similar to other samples that have been influenced by Skamania Hatchery introductions.

Overall, hatchery-produced adults account for 53% of the spawning escapement, although differences in spawning time may reduce the potential for interbreeding. Sport fishery regulations requiring the release of naturally produced steelhead have been in effect since 1981.

NMFS Rating Skamania Hatchery Summer Steelhead: Out of ESU
SASSI Wind River Summer Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Wind River Winter Steelhead (Part of Upper Gorge Tributaries DIP)

Winter steelhead are native to the Wind River basin. Shipherd Falls (RKm 3) presented a migratory barrier to chinook salmon but not to steelhead (Hymer et al. 1992), although winter steelhead passage over the falls may have been intermittent at best. Additionally, a lumber-mill dam at RKm 22.5 on the mainstem Wind River blocked upstream passage until 1947. In 1956, Shipherd Falls was laddered, and additional modifications were made to a number of other falls and cascades to provide greater access throughout the watershed.

Very little is known about winter steelhead in the Wind River. Given the limited historical passage for winter steelhead over Shipherd Falls, this population was considered to be part of the upper gorge tributaries winter steelhead DIP. With the laddering of Shipherd Falls and the expansion of accessible habit, it may be possible to manage winter steelhead in this basin as a distinct population. Chambers Creek/Lower Columbia River winter steelhead have been released in the Wind River watershed, but direct introductions were terminated in the 1960s. Genetic analysis of winter steelhead from the Wind River has not been undertaken. The population is not monitored, although run-size estimates are less than 100 fish (Wade 2000d). Direct hatchery effects are thought to be minimal, given the absence of recent winter steelhead introductions. The effects of summer steelhead releases and straying winter steelhead from other hatchery programs into the Wind River are unknown.

SASSI Wind River Winter Steelhead: Native origin, wild production
WDFW GDU (3) Lower Columbia River Steelhead

Upper Gorge Tributaries Winter Steelhead (UGRG-SW)

Impassable waterfalls limit accessible habitat to less than a half mile on most small creeks in the upper Columbia Gorge. The upper gorge tributary DIP, extends from the historical location of the Bonneville Rapids to the eastern boundary of the ESU (Wind and Hood Rivers). Larger rivers contain falls or cascades in their lower reaches, which may present migrational barriers during all or most of the year. Furthermore, this region marks a transition between the high-rainfall areas of the western Cascades and the drier areas to the east. During surveys conducted in the 1930s and 1940s, spawning steelhead were observed in several small creeks that line the Columbia Gorge. None of these streams provides sufficient habitat for large spawning aggregations of fish, and it is unlikely that there were any independent populations.

There is little information on naturally spawning aggregations in this area. It is likely that the large numbers of summer and winter steelhead released from hatcheries in this area contribute to natural reproduction.

WDFW GDU (3) Lower Columbia River Steelhead

Hood River Summer Steelhead (HOOD-SS)

Summer steelhead are native to the Hood River basin (Kostow 1995). The combined escapement for both winter and summer steelhead (excluding known hatchery fish) averaged around 1,000 fish during the 1950s and 1960s (Howell et al. 1985). Summer steelhead alone are able to ascend Punchbowl Falls and access the West Fork Hood River, while winter steelhead are the dominant run in the Middle and East Forks (Kostow et al. 2000). Native summer steelhead escapement was 181 in 1997 and may have been as low as 80 in 1998 (Chilcote 1997). A local summer steelhead broodstock (ODFW #50) was established in 1998, using unmarked returning summer steelhead. Skamania Hatchery–derived summer steelhead (ODFW #24) were released in the basin for a number of years, and it is possible that unmarked (naturally produced) Skamania summer steelhead were incorporated into the broodstock (Kostow et al. 2000). From 1993 to 1998, unmarked summer steelhead accounted for only 16.1% of the summer steelhead passed over Powerdale Dam. Beginning in 1997, however, releases in the upper basin were terminated, and marked summer steelhead are prevented from migrating past Powerdale Dam (RKm 6.4). There is no genetic analysis available for Hood River summer steelhead.

NMFS Rating ODFW Summer Steelhead (Skamania Hatchery) (#24): Out of ESU
NMFS Rating ODFW Summer Steelhead (#50): Undetermined
ODFW GCG Lower Columbia

Hood River Winter Steelhead (HOOD-SW)

Winter steelhead are native to the Hood River basin (Kostow 1995). The combined escapement for both winter and summer steelhead (excluding known hatchery fish) averaged around 1,000 fish during the 1950s and 1960s (Howell et al. 1985). Winter steelhead are not found in the West Fork of the Hood River, but are the predominant run in the East and Middle Forks. Punchbowl Falls (RKm 0.6) prevents winter-run fish from ascending into the West Fork (Olsen et al. 1992).

Hatchery winter steelhead (ODFW Big Creek Hatchery #13) have been released into the Hood River basin since 1962, but the program was terminated following the development of a local winter steelhead broodstock (ODFW #50) in 1991. The winter steelhead #50 broodstock was established using unmarked returning steelhead, and it is possible that some naturally produced Big Creek–origin fish were incorporated (as well as unmarked fish from other basins or hatcheries). Genetically, Hood River and Big Creek winter steelhead are quite distinct (Kostow et al. 2000).

NMFS Rating ODFW Winter Steelhead (#50): Undetermined
ODFW GCG Lower Columbia

Upper Willamette River

Native steelhead in the Upper Willamette River ESU are known as late-run winter steelhead. The same flow conditions at Willamette Falls (RKm 37) that only allowed access for spring-run chinook salmon also provided an isolating mechanism for this run time. Howell et al. (1985), however, reported that peak passage time at Willamette Falls for "wild" winter steelhead is in April. Redd counts for late-run winter steelhead in the Willamette River basin are conducted in May (Howell et al. 1985). ODFW currently uses February 15 to discriminate native and nonnative Big Creek winter steelhead at Willamette Falls (Kostow 1995). It is generally agreed that steelhead did not historically emigrate farther upstream than the Calapooia River (Fulton 1970). Since the Willamette Falls were laddered in the 1950s, hatchery stocks of summer and early-run winter steelhead have also been introduced into the Upper Willamette River. Native steelhead are distributed in a few, relatively small, natural populations. In 1982, it was estimated that 15% of the late-run winter steelhead ascending Willamette Falls were of hatchery origin (Howell et al. 1985). Counts of native late-run winter steelhead past Willamette Falls had a 5-year geometric mean abundance of just over 3,000 fish through 1997 (ODFW 1998).

The predominant tributaries to the Willamette River that historically supported steelhead include the Molalla (RKm 58), Calapooia (RKm 192), and Santiam (RKm 174)—all drain the Cascades to the east (Mattson 1948, Nicholas 1995). The status of rainbow trout and steelhead populations in basins that drain the Coast Range is the subject of considerable debate.

Molalla River Winter Steelhead (MOLA-SW)

The Molalla River currently contains three distinct runs of steelhead: native late-run winter steelhead, introduced early-run winter steelhead (from Lower Columbia River populations), and introduced Skamania summer-run steelhead (Chilcote 1997). Releases of the early-run steelhead into the Molalla were discontinued in 1997 (Chilcote 1997), although some natural production of early-run winter steelhead may still be present.

Genetic analyses indicate a close genetic affinity between winter steelhead populations in the Santiam, Molalla (North Fork), and Calapooia Rivers. Steelhead descended from summer-run (Skamania) and early-run winter (Big Creek) hatchery populations are distinct from the native steelhead.

NMFS Rating ODFW Summer Steelhead (#24): Out of ESU
ODFW Willamette River Conservation Group

North Santiam River Winter Steelhead (NSNT-SW)

Native late-winter and introduced Skamania summer-run steelhead are both present in the North Santiam River (Chilcote 1997). Surveys done in 1940 estimated that the run of steelhead was at least 2,000 fish (Parkhurst et al. 1950). Parkhurst et al. (1950) also reported that larger runs of steelhead existed in the Breitenbush, Little North Santiam, and Marion Fork Rivers. Native steelhead were artificially propagated at the North Santiam Hatchery beginning in 1930, when a record 2,860,500 eggs (686 females @ 4,170 eggs/female) were taken (Wallis 1963). The release of hatchery-propagated steelhead (late-winter run) in the North Santiam was discontinued in 1998 (NMFS 1999a). Through 1994, average escapement to the North Santiam averaged 1,800 fish of mixed hatchery and natural origin (Busby et al. 1996).

Genetic analysis indicates a close genetic affinity between late-run winter steelhead populations in the Santiam, Molalla, and Calapooia Rivers. Steelhead descended from summer-run (Skamania) and early-run winter (Big Creek) hatchery populations are distinct from the native steelhead.

ODFW Willamette River Conservation Group

South Santiam River Winter Steelhead (SSNT-SW)

Native late-winter and introduced Skamania summer-run steelhead are both present in the South Santiam River. Hatchery releases have not occurred in this basin since 1989, and the proportion of hatchery-reared fish that currently spawn naturally in the South Santiam River is believed to be less than 5% (Chilcote 1997). Hatchery operations began in 1926, and in 1940 a record 3,335,000 eggs were taken (800 females @ 4,170 eggs/female); however, it should be noted that river conditions at that time did not allow the weir to be set in place until after a portion of the steelhead run had already passed (Wallis 1961).

ODFW considers the late-run winter steelhead in the South Santiam River to be one population; however, the abundance trends for populations above and below Foster Dam are very different. The number of redds below Foster Dam remained relatively stable (albeit at a low level), while the redd count above Foster Dam declined dramatically in recent years. Live counts of fish passing Foster Dam (1993–1997) averaged 240 fish, regardless of their origin (ODFW 1998).

Genetic analysis indicates a close genetic affinity between winter steelhead populations in the Santiam, Molalla, and Calapooia Rivers. Steelhead descended from summer-run (Skamania) and early-run winter (Big Creek) hatchery populations are distinct from the native steelhead.

NMFS Rating ODFW Summer Steelhead (#24): Out of ESU
ODFW Willamette River Conservation Group

Calapooia River Winter Steelhead (CALA-SW)

Late-run winter steelhead are native to the Calapooia River. Parkhurst et al. (1950) reported that steelhead ascended the Calapooia as far as 87 km upstream, although the Finley Mill Dam (RKm 42) may have not been passable during low-flow periods. There is no hatchery program on the Calapooia River. Chilcote (1997) estimated that the percentage of hatchery fish (strays from other Upper Willamette River releases) is less than 5%. This population has declined to very low levels since the late 1980s. In 1993, spawner density estimates for the Calapooia River were at a record low 1.8 spawners per mile (Chilcote 1997). The average escapement of late-run winter steelhead to the Calapooia River (1993–1997) was 61 fish (ODFW 1998). Genetic analysis indicated a close affinity between winter-run steelhead in the Calapooia and native late-run winter steelhead in the Santiam and Molalla basins.

ODFW Willamette River Conservation Group

Westside Tributaries Winter Steelhead (WEST-WS), Tualatin, Yamhill, Rickreall, and Luckiamute Rivers

Naturally spawning winter steelhead are currently found in several westside tributaries of the Willamette River; however, there is some debate about the origin of these fish. Surveys in 1940 reported anecdotal information that steelhead spawned in Gales Creek, a tributary to the Tualatin River (Parkhurst et al. 1950). Numerous introductions of early-run winter steelhead (Big Creek stock) and late-run (North Santiam stock) winter steelhead have been made into the Tualatin River, however it is unclear whether the existing fish represent native or introduced lineages. Parkhurst et al. (1950) did not report the presence of any salmon or steelhead in the Yamhill, Rickreall, Luckiamute, and Marys Rivers (although their surveys were conducted during summer, when adult steelhead would not be present). Interestingly, Parkhurst et al. (1950) did report on the condition of a number of fish ladders at in-river structures in these tributaries, which suggests that anadromous fish may have been present at some point in time. Hatchery records indicate that large numbers of early-run winter steelhead were stocked into the Luckiamute and Yamhill Rivers. ODFW suggests that, based on spawn timing, late-run winter steelhead may have recently colonized the Yamhill River (NMFS 1999a). Recent genetic analysis of presumptive steelhead from the westside tributaries indicated that fish from the Yamhill River and Rickreall Creek were most genetically similar to steelhead populations from the Lower Columbia River basin (suggesting the influence of Big Creek winter steelhead or Skamania summer steelhead (NMFS 1999a). The sample from the Luckiamute River had no clear affinity with any other steelhead population, and may be descended from resident rainbow trout.

McKenzie and Middle Fork Rivers

Steelhead are not native to these basins; however, a number of naturally spawning “populations” of late-winter and summer-run steelhead are currently found upstream of the Calapooia River. These fish are descendants of introductions from hatcheries within and outside of the ESU. Additionally, resident rainbow trout in the McKenzie and Middle Fork Rivers do not genetically resemble steelhead populations in the Willamette River basin (neither summer, nor early- or late-run winter steelhead) (NMFS 1999a). Genetic analysis indicates little resemblance between these resident rainbow trout and hatchery stocks used by ODFW (NMFS 1999a). It appears that rainbow trout upstream of the Calapooia have remained fairly isolated from other *O. mykiss* populations in the Willamette River and Lower Columbia River basin.