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Status Review of Coho Salmon from Washington, Oregon, and California

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Contents

EXECUTIVE SUMMARY

The Endangered Species Act (ESA) allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. The policy of the National Marine Fisheries Service (NMFS) on this issue for Pacific salmon and steelhead is that a population will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the species as a whole. To be considered an ESU, a population or group of populations must 1) be substantially reproductively isolated from other populations, and 2) contribute substantially to ecological/genetic diversity of the biological species. Once an ESU is identified, a variety of factors related to population abundance are considered in determining whether a listing is warranted.

In October 1993, in response to three petitions seeking protection for coho salmon under the ESA, NMFS initiated a status review of coho salmon in Washington, Oregon, and California, and formed a Biological Review Team (BRT) to conduct the review. This report summarizes biological and environmental information gathered in that process.

Proposed Coho Salmon ESUs

The BRT examined genetic, life history, biogeographic, geologic, and environmental information to identify where ESU boundaries should be located. In particular, physical environment and ocean conditions/upwelling patterns, estuarine and freshwater fish distributions, and coho salmon river entry and spawn timing and marine coded-wire-tag recovery patterns were found to be the most informative for this process. Based on this examination, the BRT identified six coho salmon ESUs in Washington, Oregon, and California. The geographic boundaries of the six proposed ESUs are as follows:

1) Central California coast. The geographic boundaries of this ESU extend from Punta Gorda in northern California south to and including the San Lorenzo River in central California, and include tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system.

2) Southern Oregon/northern California coasts. This ESU includes coho salmon from Cape Blanco in southern Oregon to Punta Gorda in northern California.

3) Oregon coast. This ESU covers coastal drainages along most of the Oregon coast from Cape Blanco to the mouth of the Columbia River.

4) Lower Columbia River/southwest Washington coast. Historically, this ESU probably included coho salmon from all tributaries of the Columbia River below the Klickitat River on the Washington side and below the Deschutes River on the Oregon side (including Willamette River as far upriver as the Willamette Falls), as well as coastal drainages in southwest Washington between the Columbia River and Point Grenville (between the Copalis and Quinault Rivers).

5) Olympic Peninsula. The geographic boundaries of this ESU are entirely within Washington, including coastal drainages from Point Grenville to and including Salt Creek (directly west of the Elwha River).

6) Puget Sound/Strait of Georgia. This ESU includes coho salmon from drainages of Puget Sound and Hood Canal, the eastern Olympic Peninsula (east of Salt Creek), and the Strait of Georgia from the eastern side of Vancouver Island and the British Columbia mainland (north to and including Campbell and Powell Rivers), excluding the upper Fraser River above Hope.

Assessment of Extinction Risk

The ESA (section 3) defines the term “endangered species” as “any species which is in danger of extinction throughout all or a significant portion of its range.” The term “threatened species” is defined as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” According to the ESA, the determination whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In this review, the BRT did not evaluate likely or possible effects of conservation measures and, therefore, did not make recommendations as to whether identified ESUs should be listed as threatened or endangered species; rather, the BRT drew scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue. The resulting conclusions for each ESU follow.

1) Central California coast. There was unanimous agreement among the BRT that natural populations of coho salmon in this ESU are presently in danger of extinction. The chief reasons for this assessment were extremely low current abundance, especially compared to historical abundance, widespread local extinctions, clear downward trends in abundance, extensive habitat degradation and associated decreased carrying capacity, and a long history of artificial propagation with the use of non-native stocks. In addition, recent droughts and current ocean conditions may have further reduced run sizes.

2) Southern Oregon/northern California coasts. There was unanimous agreement among the BRT that coho salmon in this ESU are not in danger of extinction but are likely to become endangered in the foreseeable future if present trends continue. Current run size, the severe decline from historical run size, the frequency of local extinctions, long-term trends that are clearly downward, degraded habitat and associated reduction in carrying capacity, and widespread hatchery production using exotic stocks are all factors that contributed to the assessment. Like the central California ESU, recent droughts and current ocean conditions may have further reduced run sizes.

3) Oregon coast. The BRT concluded that coho salmon in this ESU are not in danger of extinction but are likely to become endangered in the future if present trends continue. The BRT reached this conclusion based on low recent abundance estimates that are 5-10% of

historical abundance estimates, clearly downward long-term trends, recent spawner-to-spawner ratios that are below replacement, extensive habitat degradation, and widespread hatchery production of coho salmon. Drought and current ocean conditions may have also reduced run sizes.

4) Lower Columbia River/southwest Washington coast. Previously, NMFS concluded that it could not identify any remaining natural populations of coho salmon in the lower Columbia River (excluding the Clackamas River) that warranted protection under the ESA. The Clackamas River produces moderate numbers of natural coho salmon. The BRT could not reach a definite conclusion regarding the relationship of Clackamas River late-run coho salmon to the historic lower Columbia River ESU. However, the BRT did conclude that *if* the Clackamas River late-run coho salmon is a native run that represents a remnant of a lower Columbia River ESU, the ESU is not presently in danger of extinction but is likely to become so in the foreseeable future if present conditions continue.

For southwest Washington coho salmon, uncertainty about the ancestry of coho salmon runs given high historical and current levels of artificial production prevented the BRT from reaching a definite conclusion regarding the relationship between coho salmon in that area and the historical lower Columbia River/southwest Washington ESU. If new information becomes available, the relationship and status of the ESU will be reexamined.

5) Olympic Peninsula. While there is continuing cause for concern about habitat destruction and hatchery practices within this ESU, the BRT concluded that there is sufficient native, natural, self-sustaining production of coho salmon that this ESU is not in danger of extinction and is not likely to become endangered in the foreseeable future unless conditions change substantially.

6) Puget Sound/Strait of Georgia. The BRT was concerned that if present trends continue, this ESU is likely to become endangered in the foreseeable future. Although current population abundance is near historical levels and recent trends in overall population abundance have not been downward, there is substantial uncertainty relating to several of the risk factors considered. These risk factors include widespread and intensive artificial propagation, high harvest rates, extensive habitat degradation, a recent dramatic decline in adult size, and unfavorable ocean conditions. Further consideration of this ESU is warranted to attempt to clarify some of these uncertainties.

ACKNOWLEDGMENTS

The status review for west coast coho salmon was conducted by a team of researchers from the National Marine Fisheries Service (NMFS). This biological review team relied on information in the Endangered Species Act Administrative Record for West Coast Coho Salmon, which was developed pursuant to this review and includes comments, data, and reports submitted by the public and by state, tribal, and federal agencies. The authors acknowledge the efforts of all who contributed to this record, especially the Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, California Department of Fish and Game, U.S. Fish and Wildlife Service, and Northwest Indian Fisheries Commission.

The biological review team for this status review included: Peggy Busby, Dr. David Damkaer, Robert Emmett, Dr. Jeffrey Hard, Dr. Orlay Johnson, Dr. Robert Kope (formerly with the Southwest Fisheries Science Center), Dr. Conrad Mahnken, Gene Matthews, George Milner, Dr. Michael Schiewe, David Teel, Dr. Thomas Wainwright, William Waknitz, Dr. Robin Waples, Laurie Weitkamp, Dr. John Williams, and Dr. Gary Winans, all from the Northwest Fisheries Science Center (NWFSC), and Gregory Bryant from the NMFS Southwest Region. Craig Wingert, from the NMFS Southwest Region, and Steven Stone, from the NMFS Northwest Regional Office, also participated in the discussions and provided information on coho salmon life history and abundance.

Jason Griffith and Megan Ferguson, students from the University of Washington, were instrumental in compiling information on coho salmon hatcheries. Don Vandoornik and Dave Kuligowski (NWFSC) collected new genetic data for the status review, and Kathleen Neely (NWFSC) provided most of the graphics for this document and assisted in the completion of this status review in numerous other

INTRODUCTION

Coho salmon (Oncorhynchus kisutch) is a widespread species of Pacific salmon, occurring in most major river basins around the Pacific Rim from central California to Korea and northern Hokkaido, Japan (Laufle et al. 1986). Recently published investigations have reported that a number of local populations of coho salmon in Washington, Oregon, Idaho, and California have become extinct, and that the abundance of many others is depressed (e.g., Brown and Moyle 1991, Nehlsen et al. 1991, Frissell 1993, Wilderness Society 1993). These declines have led several conservation groups to petition the National Marine Fisheries Service (NMFS) to list populations of coho salmon as threatened or endangered "species" under the U.S. Endangered Species Act (ESA, technical terms and abbreviations such as "ESA" are defined in the glossary, Appendix A). Under the ESA, the term "species" is defined rather broadly to include subspecies and "distinct population segments" of vertebrates (such as salmon) as well as taxonomic species.

The first petition to NMFS for coho salmon requested ESA protection for populations in the lower Columbia River, excluding the Willamette River and its tributaries (Oregon Trout et al. 1990). Following a status review, NMFS concluded that as a result of substantial and long-term stock transfers, habitat degradation, and overfishing, they were unable to identify any indigenous populations of coho salmon in the lower Columbia River that warranted protection under the ESA (Johnson et al. 1991, NMFS 1991a).

In March 1993, NMFS was petitioned by the Santa Cruz County Planning Department to list coho salmon in Scott and Waddell Creeks, California as a threatened or endangered species (SCCPD 1993). Before a status review was completed for this petition, NMFS received two additional petitions for ESA listing of coho salmon. Oregon Trout, the Portland Audubon Society, and the Siskiyou Regional Education Project asked NMFS for ESA protection for 40 coho salmon populations in Oregon (Oregon Trout et al. 1993). In response to these petitions, NMFS announced a coastwide review of coho salmon from California, Oregon, and Washington in a Federal Register Notice (58 FR 57770; 27 October 1993) (NMFS 1993). However, a week before this broader status review was announced, NMFS received a petition from the Pacific Rivers Council and 22 co-signers for ESA listing of coho salmon throughout their range in Washington, Oregon, Idaho, and California (Pacific Rivers Council et al. 1993). This petition thus included all populations covered by the previous three petitions.

In 1994, NMFS announced its determination that coho salmon from Scott and Waddell Creeks do not by themselves constitute an ESA "species," and therefore a listing was not warranted (Bryant 1994, NMFS 1994).

Scope and Intent of the Present Document

This document considers environmental and biological information for coho salmon populations in Washington, Oregon, and California (Fig. 1) and British Columbia. These

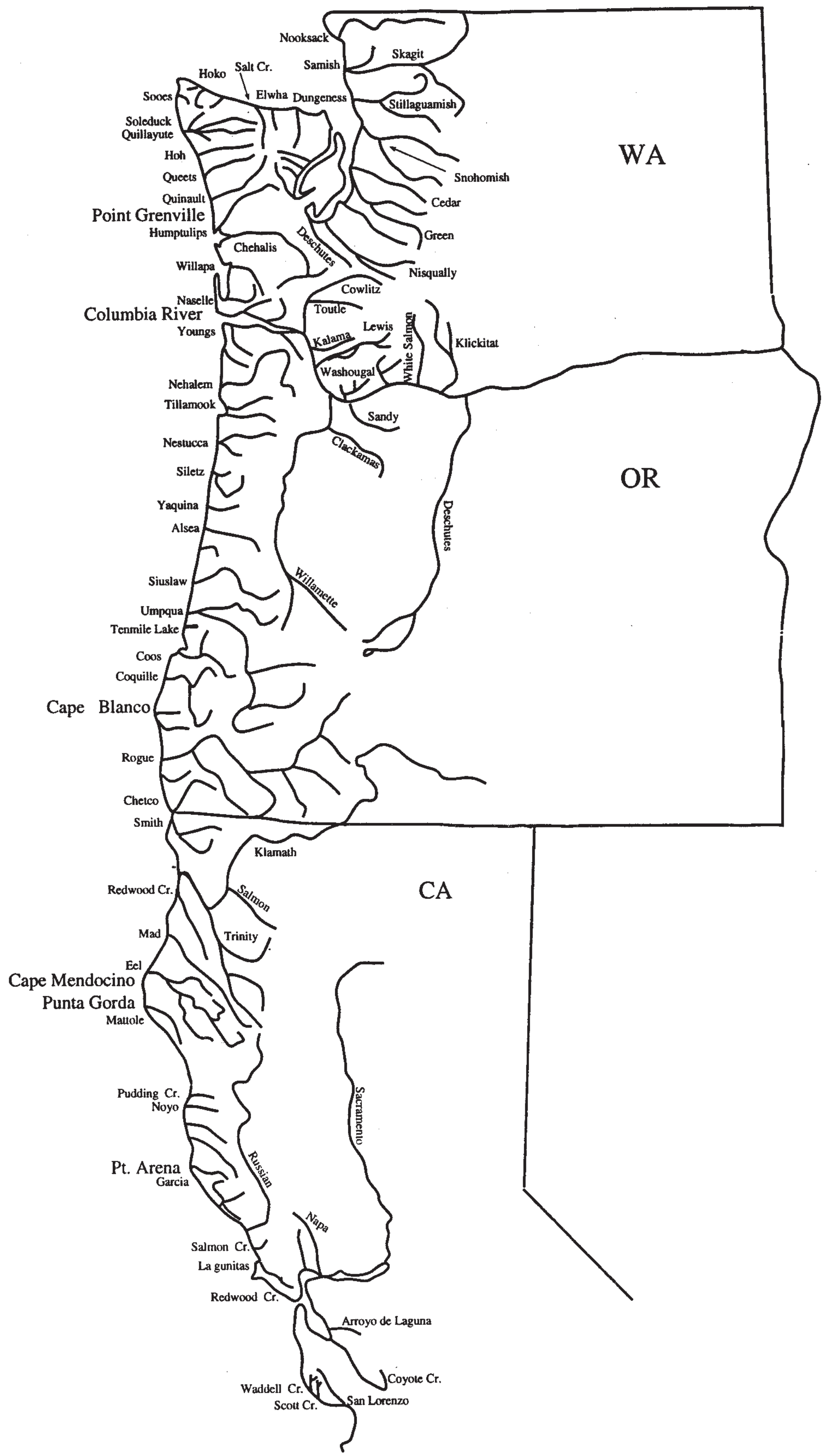

Figure 1. Map showing major rivers and other key geographic locations discussed in this status review.

populations will be collectively referred to in this document as west coast coho salmon. The scope of this document thus encompasses both the Oregon Trout et al. (1993) and the Pacific Rivers Council et al. (1993) petitions. In addition, we determine the boundaries of the "distinct population segment" that includes coho salmon from Scott and Waddell Creeks.

Because the ESA stipulates that listing determinations should be made on the basis of the best scientific information available, NMFS formed a team of scientists with diverse backgrounds in salmon biology to conduct this status review[1]. This Biological Review Team (BRT) discussed and evaluated scientific information contained in an extensive public record developed for west coast coho salmon. This document represents the findings and conclusions of the BRT on the status of west coast coho salmon under the ESA.

Key Questions in ESA Evaluations

An ESA status review involves answering two key questions: 1) Is the entity in question a "species" as defined by the ESA? and 2) If so, is the "species" in danger of extinction or likely to become so (the "extinction risk" question)? These two questions are addressed in separate sections in the text that follows.

The "Species" Question

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. However, the ESA provides no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity has led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991b). A more detailed discussion of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991a). The NMFS policy stipulates that a salmon population (or group of populations) will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component of the evolutionary legacy of the species.

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[1] The Biological Review Team for west coast coho salmon included: Peggy Busby, Dr. David Damkaer, Robert Emmett, Dr. Jeffrey Hard, Dr. Orlay Johnson, Dr. Conrad Mahnken, Gene Matthews, George Milner, Dr. Michael Schiewe, David Teel, Dr. Thomas Wainwright, William Waknitz, Dr. Robin Waples, Laurie Weitkamp, Dr. John Williams, and Dr. Gary Winans, all from the Northwest Fisheries Science Center. Gregory Bryant and Craig Wingert from the Southwest Regional Office, Dr. Robert Kope from the Southwest Fisheries Science Center, and Steven Stone from the NMFS Northwest Regional Office also participated in the discussions and provided information on coho salmon life history and abundance.

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

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

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

Artificial propagation—NMFS policy (Hard et al. 1992, NMFS 1993) stipulates that in determining 1) whether a population is distinct for purposes of the ESA, and 2) whether an ESA species is threatened or endangered, attention should focus on “natural” fish, which are defined as the progeny of naturally spawning fish (Waples 1991a). This approach directs attention to fish that spend their entire life cycle in natural habitat and is consistent with the mandate of the ESA to conserve threatened and endangered species in their native ecosystems. Implicit in this approach is the recognition that fish hatcheries are not a substitute for natural ecosystems.

Nevertheless, artificial propagation is important to consider in ESA evaluations of anadromous Pacific salmonids for several reasons. First, although natural fish are the focus of ESU determinations, possible effects of artificial propagation on natural populations must also be evaluated. For example, stock transfers might change the genetic or life history characteristics of a natural population in such a way that the population might seem either less or more distinctive than it was historically. Artificial propagation can also alter life history characteristics such as smolt age and migration and spawn timing. Second, artificial propagation poses a number of risks to natural populations that may affect their risk of extinction or endangerment. These risks are discussed below in “The ‘Extinction Risk’

Question" section. Finally, if any natural populations are listed under the ESA, then it will be necessary to determine the ESA status of all associated hatchery populations. This latter determination would be made following a proposed listing and is not considered further in this document.

The "Extinction Risk" Question

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

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

Summary of Information Presented by the Petitioners

This section briefly summarizes information presented by the petitioners (Oregon Trout et al. 1993, Pacific Rivers Council et al. 1993) to support their arguments that coho salmon in Washington, Oregon, Idaho, and California qualify as a threatened or endangered species under the ESA. We discuss this information and related issues in the following sections, and we evaluate the status of west coast coho salmon in the conclusions of the Assessment of Extinction Risk section.

Distinct Population Segments

The two petitioners differed in the approach they suggested NMFS use for listing coho salmon under the ESA. Oregon Trout et al. (1993) identified 40 coho salmon populations in Oregon that they believed comprised five “distinct population segments” from the following geographic areas: 1) south of Cape Blanco, 2) the Coquille and Coos Rivers, 3) the Umpqua River, 4) all coastal drainages north of the Umpqua River, and 5) the lower Columbia River, including the Clackamas River. Based primarily on evidence from a genetic analysis of mitochondrial DNA from coho salmon from Oregon (Currens and Farnsworth 1993), Oregon Trout et al. (1993) argued that these population groups qualified as ESUs under NMFS policy and recommended that each be listed as a separate “species” under the ESA.

In contrast, Pacific Rivers Council et al. (1993) did not focus on identifying distinct population segments or ESUs of coho salmon. Rather, they argued that a listing of all populations in California, Oregon, Washington, and Idaho[2] was warranted because this region “comprises an ecologically, evolutionarily, economically, and culturally significant portion of the range of the species” (Pacific Rivers Council et al. 1993, p. 4). Under this scenario, west coast coho salmon could be listed as a single species, rather than as multiple ESUs.

In this review, we have focussed on identifying ESUs of coho salmon that can be considered for listing under the ESA. This approach has been taken for several reasons. First, it is consistent with NMFS policy and with the approach that has been taken with other ESA status reviews for Pacific salmon. Second, identifying ESUs provides biological information for the species on a scale corresponding to the smallest units that can be listed under the ESA. Finally, this approach would not preclude a broader listing under the ESA if it were determined that the biological species is threatened in all or a significant portion of its range. In fact, such an evaluation could most easily be made by considering the status of each of the species’ distinct population segments, or ESUs.

Population Abundance

Pacific Rivers Council et al. (1993) and Oregon Trout et al. (1993) presented qualitative and quantitative information indicating that current abundance of west coast coho salmon populations have declined to small fractions of their historic levels and continuing declines and local extinctions are widespread within this range. Nehlsen et al. (1991) identified 35 stocks of coho salmon that are at short-term risk of extinction in Washington, Oregon, Idaho, and California and 15 stocks that are extinct in California, southern Oregon, and the Columbia River. Frissell (1993) estimated that coho salmon are extinct in the eastern half of their range in the lower 48 states and imperiled throughout the southern two-thirds of this range. The petitioners also referred to a report (Wilderness Society 1993) that estimated that coho salmon are extinct in 56% of their historic range, endangered in 13%, threatened in

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[2]Although Pacific Rivers Council et al. (1993) also included populations from Idaho in their petition, all native populations of coho salmon from Idaho are believed to be extinct.

20%, of special concern in 5%, and not known to be extinct, declining, depressed, or facing imminent threat in only 6.5% of their historic range.

The petitioners also provided region-specific estimates of current vs. historical population levels. For California coho salmon, Pacific Rivers Council et al. (1993) reported that Brown and Moyle (1991) estimated that naturally spawned adult coho salmon (regardless of origin) returning to California streams were less than 1% of their abundance at mid-century, and indigenous, wild coho salmon populations in California did not exceed 100 to 1,300 individuals. They further state that Brown and Moyle (1991) found that 46% of California streams, which historically supported coho salmon populations, and for which recent data were available, no longer supported runs.

Oregon Trout et al. (1993) argued that wild coho salmon spawner abundance along the Oregon coast declined between 1965 and 1975 and has fluctuated at low levels since then. According to Oregon Trout et al. (1993), escapement goals and maximum sustained-yield escapement levels have not been reached since 1986 and 1971, respectively. Pacific Rivers Council et al. (1993) used historical catch estimates (Lichatowich 1989) to calculate that the potential production of wild coho salmon in coastal Oregon rivers in the 1980s had decreased 86% from the turn of the century. Pacific Rivers Council et al. (1993) also cited Lichatowich and Nicholas' (in press) estimate that current production, including hatchery fish, in many coastal basins is less than 10% of historic levels. The petitioners expressed concern that the "standard" survey methods used to estimate Oregon coast coho salmon abundance overestimated population sizes (Oregon Trout et al. 1993, Pacific Rivers Council et al. 1993).

Discussion of Columbia River populations by Oregon Trout et al. (1993) was restricted to coho salmon from the Clackamas River. They suggested that this population should be listed as a separate "species" under the ESA because it is genetically distinct from other Columbia River populations and has undergone continuing declines in abundance. In contrast, Pacific Rivers Council et al. (1993) did not emphasize any particular stocks of Columbia River coho salmon. They cited several reports (Nehlsen et al. 1991, Chilcote et al. 1992[3], WDF et al. 1993) that show that coho salmon above Bonneville Dam are largely extinct, and the majority of populations below the Dam are endangered, depressed, or out of compliance with ODFW's wild fish policy.

Pacific Rivers Council et al. (1993) presented several estimates of current vs. historical coho salmon abundance in Washington rivers outside of the Columbia River Basin. They reported substantial declines (40-50%) in coho salmon populations in Puget Sound (Bledsoe et al. 1989), the Chehalis River Basin (Hiss and Knudsen 1992), and in the Queets and Quinault Rivers on the Olympic Peninsula (Houston 1983) between the earlier part of this century and the period from the 1970s to the present.

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[3]Pacific Rivers Council et al. (1993, p. 11) cite this document as ODFW 1992.

Causes of Decline for Coho Salmon

The petitioners identified many of the same factors discussed above, including habitat destruction, overfishing, artificial propagation, and poor ocean conditions, as the causes of decline for coho salmon. Both petitioners argued that the primary cause for decline has been habitat destruction (Oregon Trout et al. 1993, Pacific Rivers Council et al. 1993). Oregon Trout et al. (1993) also identified overutilization of the species for commercial and recreational purposes as an equally important factor for Oregon coho salmon, while the Pacific Rivers Council et al. (1993) identified deteriorating ocean conditions as a major cause for the general decline of west coast coho salmon. Both petitioners cited adverse effects of artificial propagation as an aggravating factor. Pacific Rivers Council et al. (1993) also identified intraspecific hybridization and interspecific hybridization with chinook salmon as an additional concern.

INFORMATION RELATING TO THE SPECIES QUESTION

In this section, we summarize environmental and biological information that is relevant to determining the nature and extent of ESUs for west coast coho salmon. This information was used to indicate possible ESU boundary locations, as a systematic means of dealing with the large area concerned, multitudes of coho salmon populations, and high variability in environmental conditions and biological characteristics. This process involved determining where significant changes in environmental and biological parameters occurred, and then identifying locations or zones where attributes changed in common. Areas where many attributes exhibited significant changes were identified as possible boundary locations for ESUs. Final ESU boundaries were determined by the BRT on the basis of the team’s professional opinion of the value or weight that these attribute changes merited with respect the reproductive isolation and ecological/genetic diversity of west coast coho salmon.

Environmental Features

Environmental information was used to indicate where ESU boundaries might occur. We identified areas where the physical environment appeared to change based on environmental characteristics (i.e., river flow patterns, ocean conditions, water temperatures, climate, etc.), and on the distributions of other organisms. Areas with different habitat types may have different selective pressures, and may lead to local adaptations within specific areas. The distributions of organisms sympatric with coho salmon were considered because these distributions may reflect environmental, ecological, or historical processes that may also affect coho salmon.

Physical features of the freshwater environment

The following discussion includes climate data from the U.S. Department of Commerce (1968) and Farley (1979), calculations of river flow patterns using U.S. Geological

Survey (USGS) data from Hydrosphere Data Products, Inc. (1993), and information from Forstall (1969). Riverflow data are presented in Figures 2-6 and Appendix Table B-1, water temperature data are presented in Figures 7-8 and Appendix Table B-2, and average annual precipitation is presented in Figure 9. Because coho salmon typically spawn and rear in small tributaries, run timing and spawning timing are particularly sensitive to patterns in river flow. In this respect, river flow patterns help define the temporal availability of, and access to, rearing and spawning habitat.

California and southern Oregon—California rivers having coho salmon, from Redwood Creek (in Humboldt County) southward, drain the 500-1,000 m-high Coast Range, an area underlain by easily eroded sedimentary rocks of the Franciscan Formation (California State Lands Commission 1993). To the north, the Rogue and Klamath River Basins cut through the Coast Range to drain the Cascade Mountains as well. Maximum elevations in this area are typically 1,000-2,000 m. Rivers from the Rogue River south to the Mattole River exhibit peak flow in late January or early February, while rivers farther south have peak flows in late February (Fig. 2). Duration of peak flows in rivers south of the Mattole are much shorter than in those farther north (Fig. 3), although both areas experience relatively low flows during the summer and early fall (Fig. 4). Annual precipitation levels are also much higher along the west side of the Coast Range in northern California and southern Oregon (160-200 cm) than they are farther south (60-160 cm) or in the dry interior along the east slope of the Coast Range (60-160 cm) (Fig. 9). Central California has a relatively short rainy season compared to regions farther north. Annual winter snowfall at higher elevations is also lower south of the Mattole River, averaging 60 cm or less, compared to 60-250 cm in the Klamath Mountains Province. Maximum summer stream temperatures (18-26ºC) (Fig. 7) and average summer maximum and winter minimum air temperatures (around 21ºC and 4ºC, respectively) are similar along the California coast north of the San Lorenzo River through southern Oregon. However, winter stream temperatures in coastal river basins in central California (between Cape Mendocino and Monterey Bay) are generally warmer (8-12ºC) than they are in northern California/southern Oregon (3-8ºC) (Fig. 8, Appendix Table B-2). Finally, average annual sunshine along the coast in central California is higher than it is anywhere farther north, averaging 2,200-2,800 hours per year (h yr-1), while northern California/southern Oregon receives 2,000-2,200 h yr-1 of sunshine.

Oregon coast—North of Cape Blanco, all coastal Oregon rivers, with the exception of the Umpqua River, drain only the west side of the Coast Range. The Oregon Coast Range is relatively low, with peaks at 500-1,000-m elevations, in contrast to most Cascade peaks which are 1,000-2,000-m high. Seasonal river flows in this region follow a fairly consistent pattern, with a single peak in December or January (Figs. 2, 5) and relatively low flow (Fig. 4) in summer and fall. The Oregon coast receives high rainfall (120-240 cm yr-1) compared to areas east of the Coast Range (60-120 cm yr-1) or farther south (60-200 cm yr-1), but receives less rainfall than the extremely wet Olympic Peninsula farther north (>240 cm yr-1) (Fig. 9). Both air and stream (Figs. 7-8) temperatures are fairly consistent along the Oregon coast, with little latitudinal change. Minimum average winter air and stream temperatures are typically around 4ºC and 4-8ºC, respectively, while maximum average summer air and stream temperatures are typically around 21ºC and 15-21ºC, respectively. Because of the relatively low elevation, snowfall in the Coast Range is low, averaging 30-60 cm annually, while the

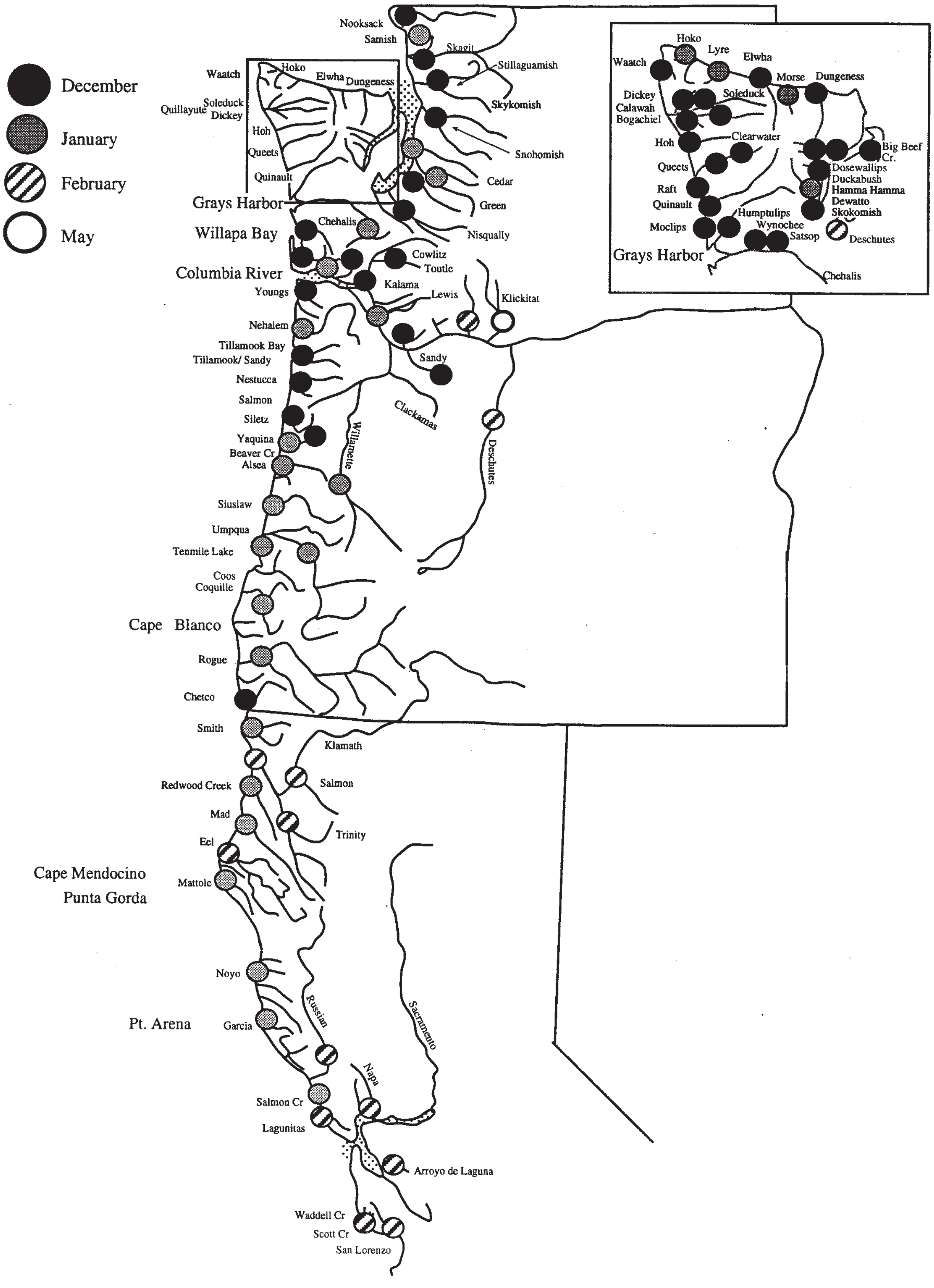

Figure 2. Timing of annual peak flow (by month) for selected rivers in Washington, Oregon, and California. If two peaks in flow occur, the indicated timing represents the timing of the first peak. Based on USGS streamflow data presented in Appendix Table B-1 (Hydrosphere Data Products, Inc. 1993).

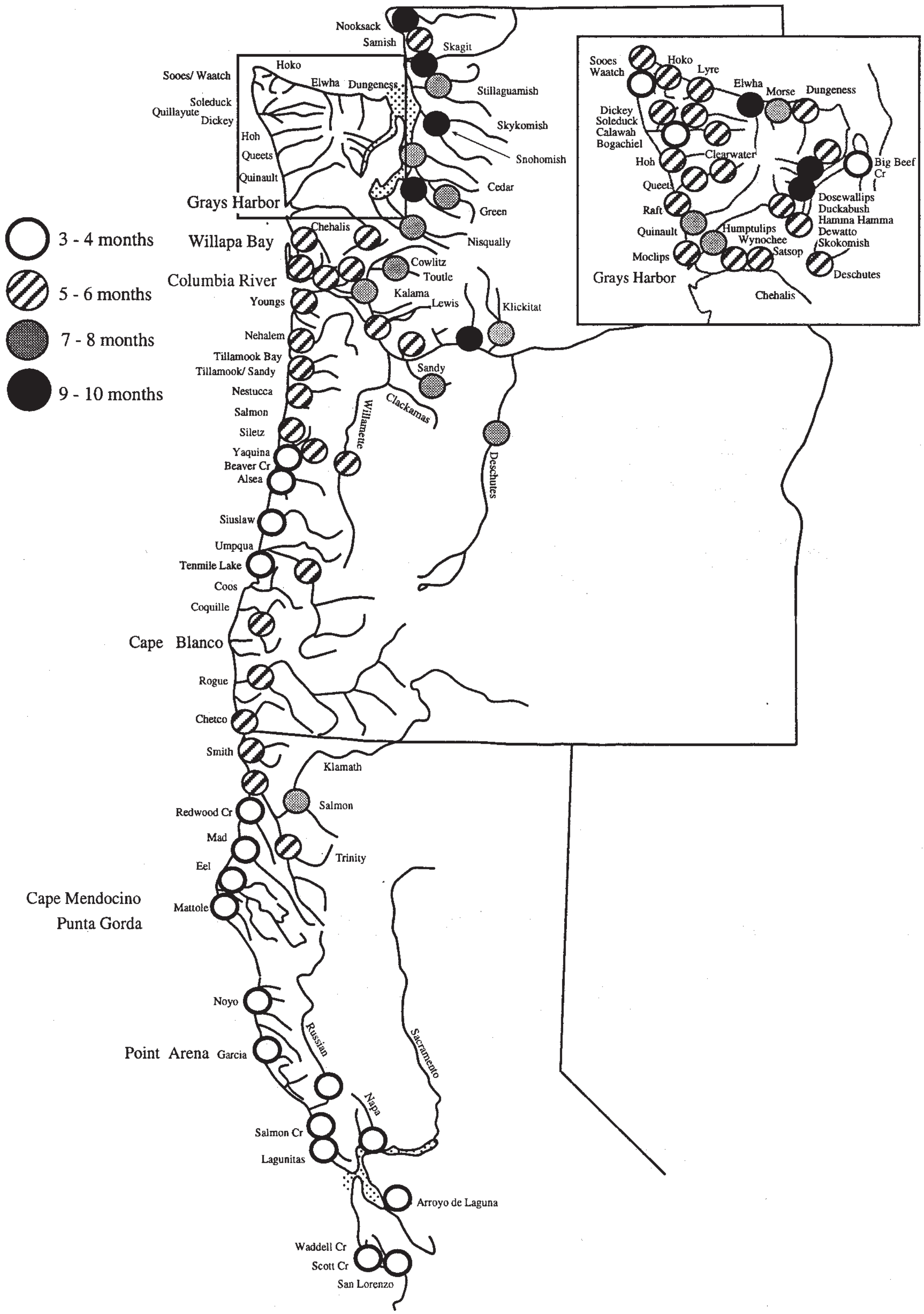

Figure 3. Duration of high flows (number of months when flow is equal to or exceeds 50% of peak monthly flow) for selected rivers in Washington, Oregon, and California. Based on USGS streamflow data presented in Appendix Table B-1 (Hydrosphere Data Products, Inc. 1993).

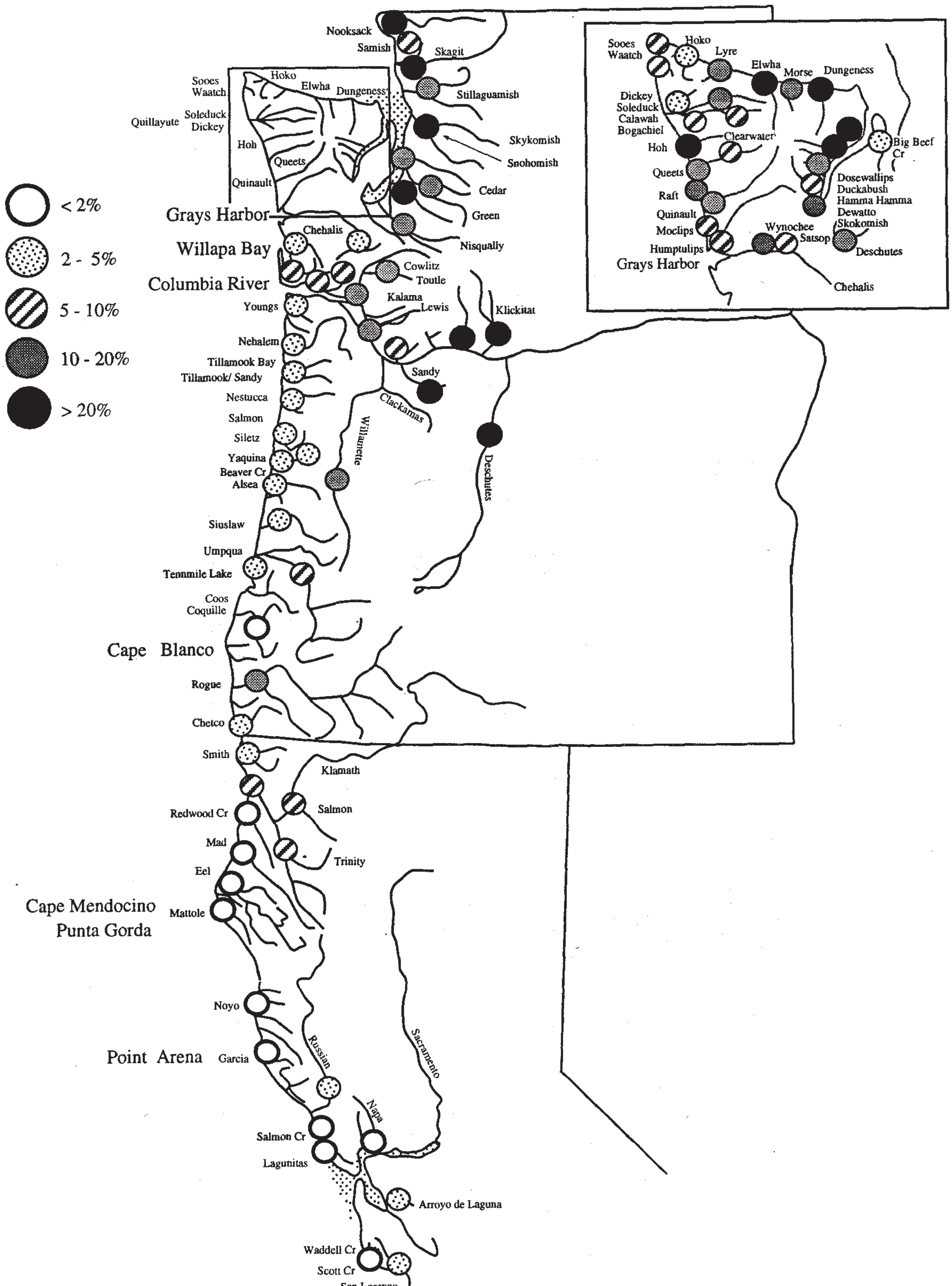

Figure 4. Annual minimum monthly flow expressed as a percentage of annual maximum monthly flow for selected rivers in Washington, Oregon, and California. Based on USGS streamflow data presented in Appendix Table B-1 (Hydrosphere Data Products, Inc. 1993).

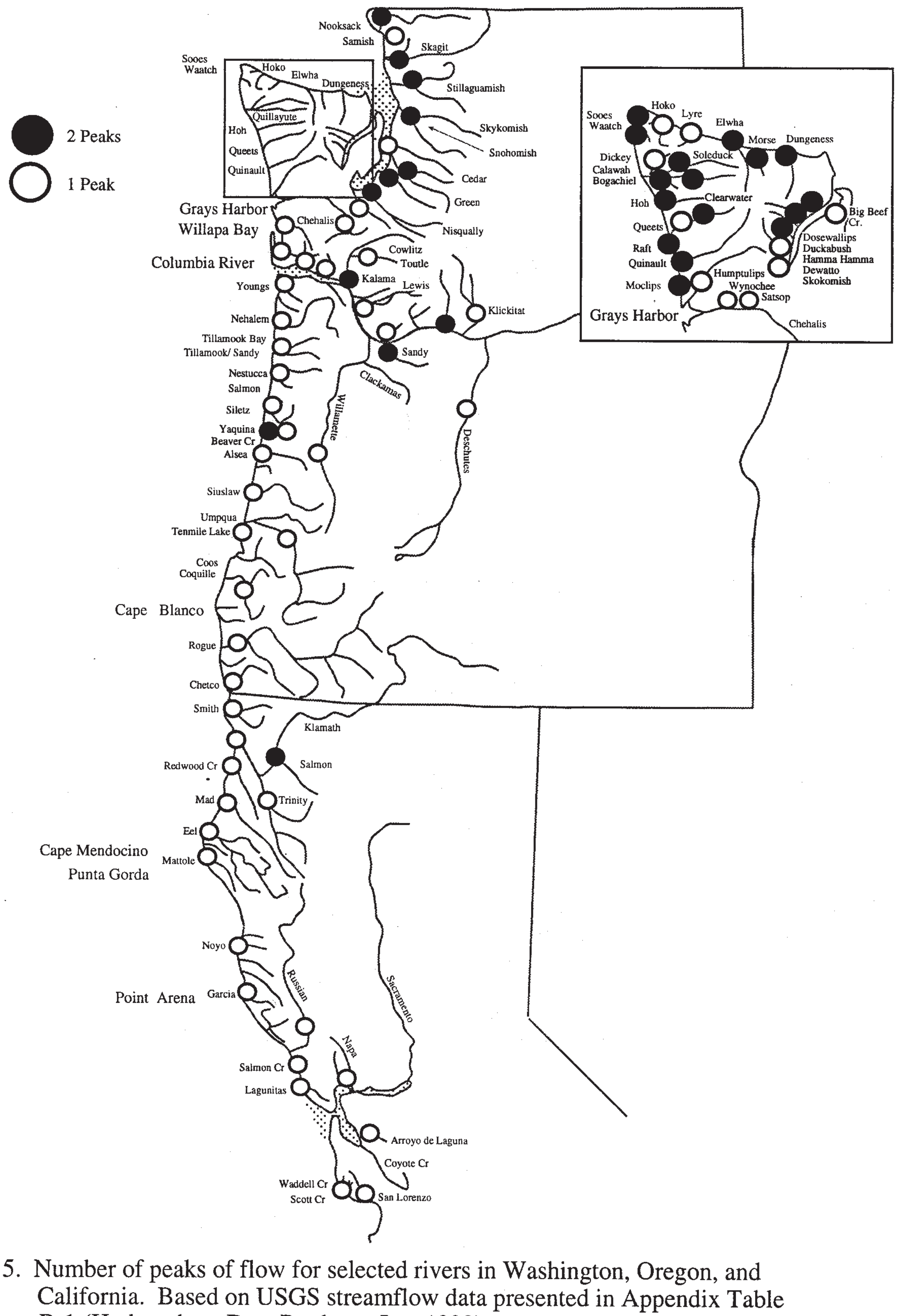

Figure 5. Number of peaks of flow for selected rivers in Washington, Oregon, and California. Based on USGS streamflow data presented in Appendix Table B-1 (Hydrosphere Data Products, Inc. 1993).

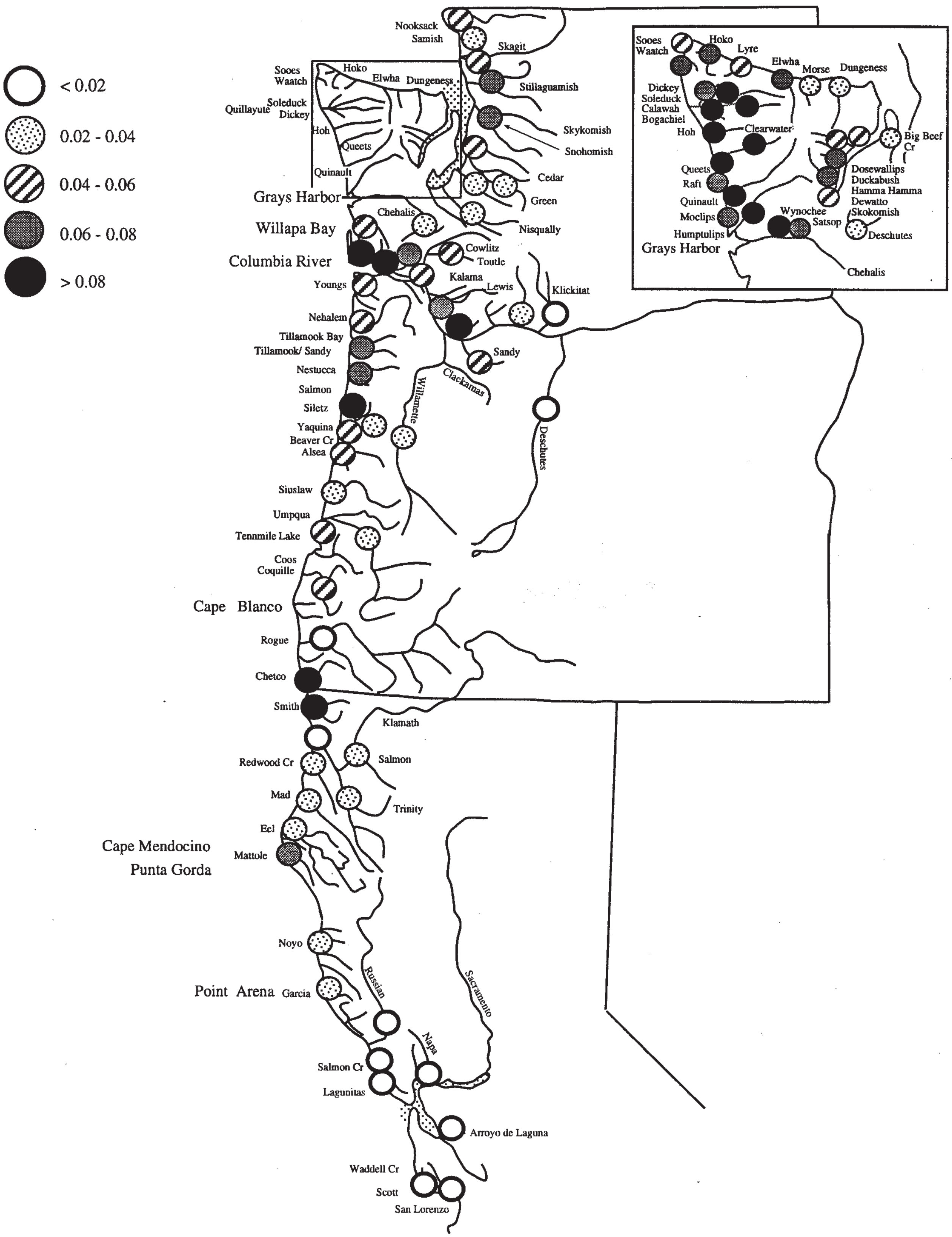

Figure 6. Average annual flow per area (m^3s^{-1} km^{-2}) for selected rivers in Washington, Oregon, and California. Values were calculated as the average annual flow for each gauging station divided by the reported gauged area. Based on USGS streamflow data presented in Appendix Table B-1 (Hydrosphere Data Products, Inc. 1993).

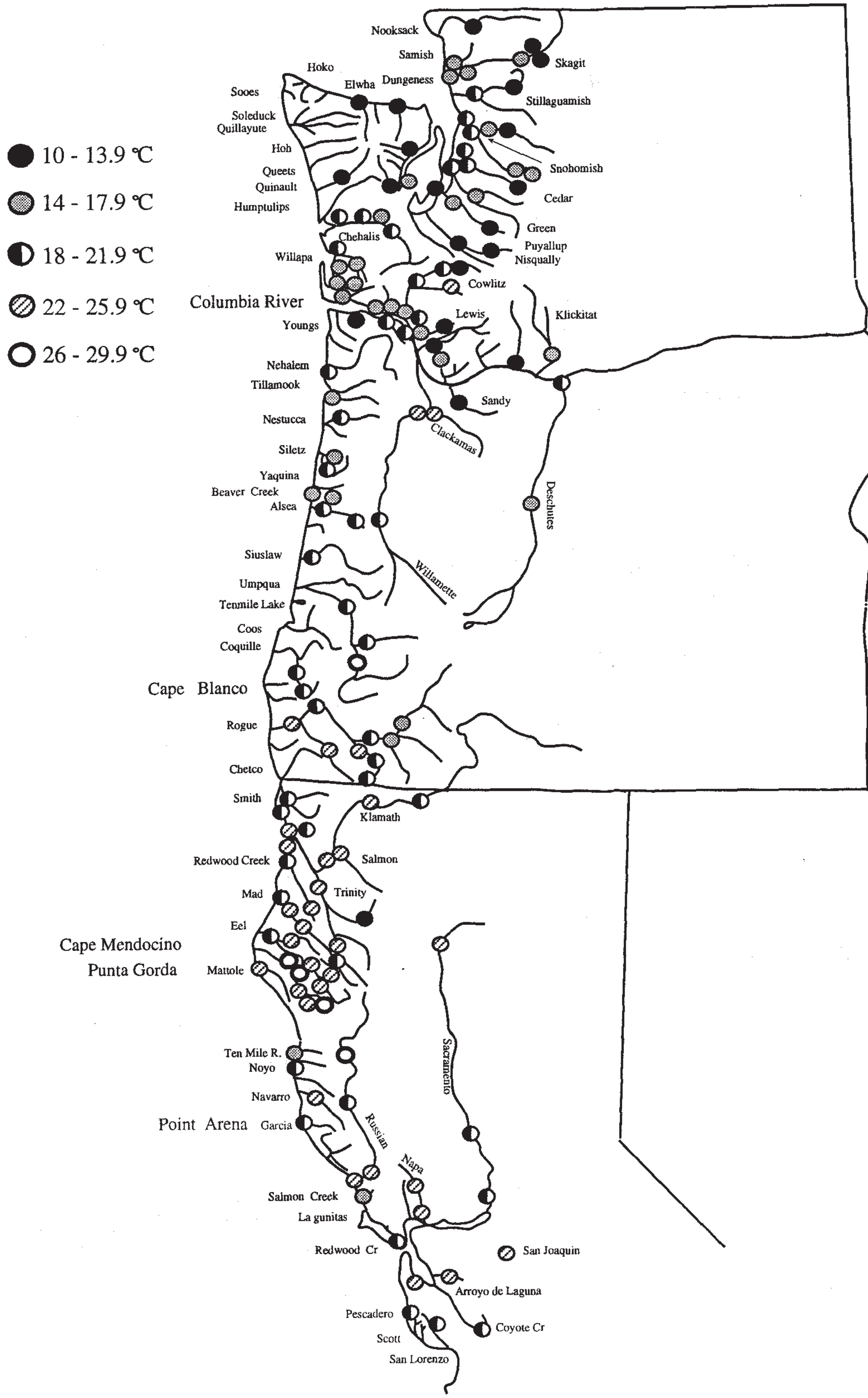

Figure 7. Annual maximum monthly stream temperatures (°C) for selected river basins in Washington, Oregon, and California. Maximum water temperatures primarily occured in July, occasionally in August. Based on USGS streamflow data presented in Appendix Table B-2 (Hydrosphere Data Products, Inc. 1993).

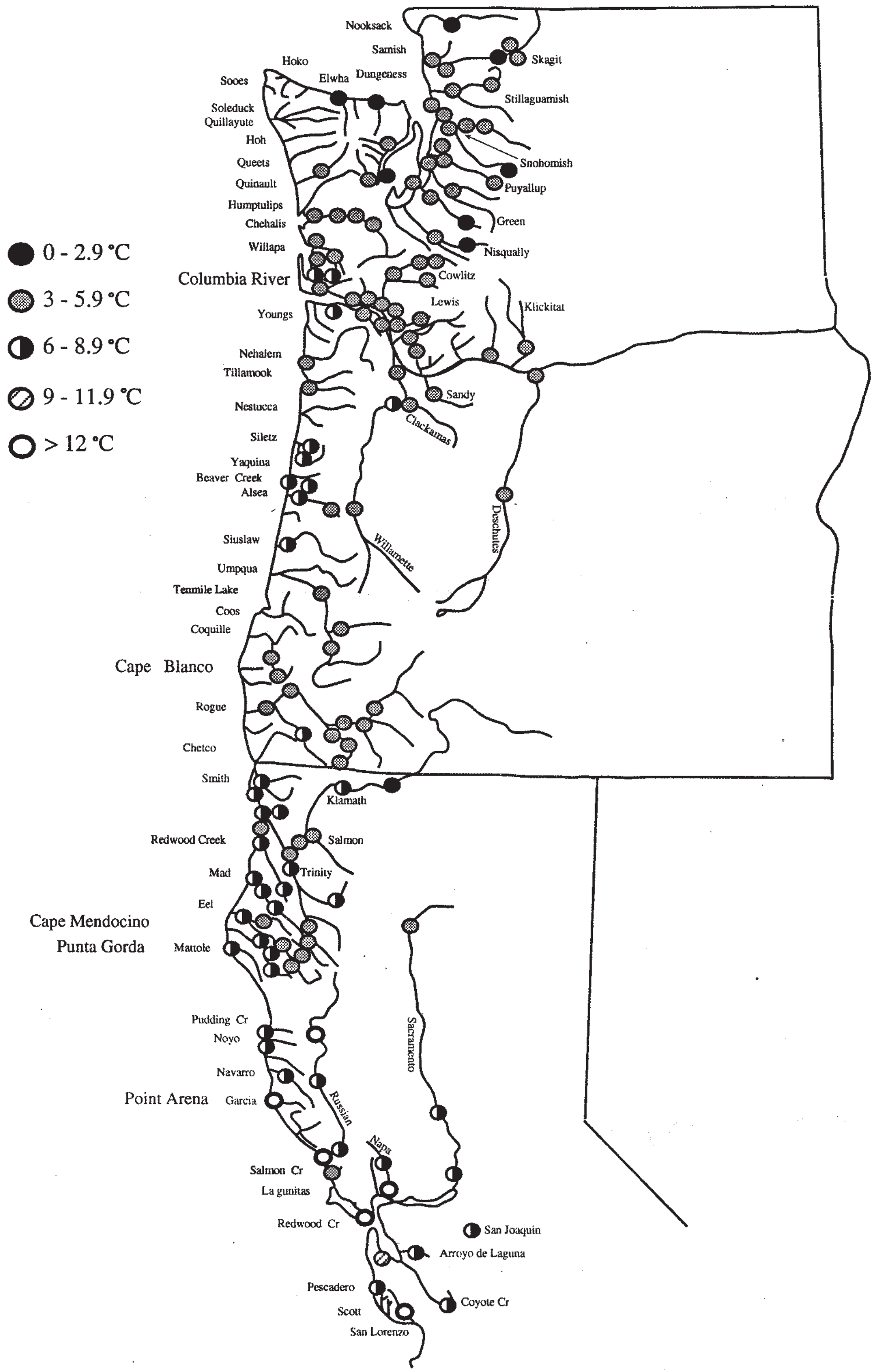

Figure 8. Annual minimum monthly stream temperatures (°C) for selected river basins in Washington, Oregon, and California. Minimum water temperatures primarily occured in January, occasionally in February. Based on USGS streamflow data presented in Appendix Table B-2 (Hydrosphere Data Products, Inc. 1993).

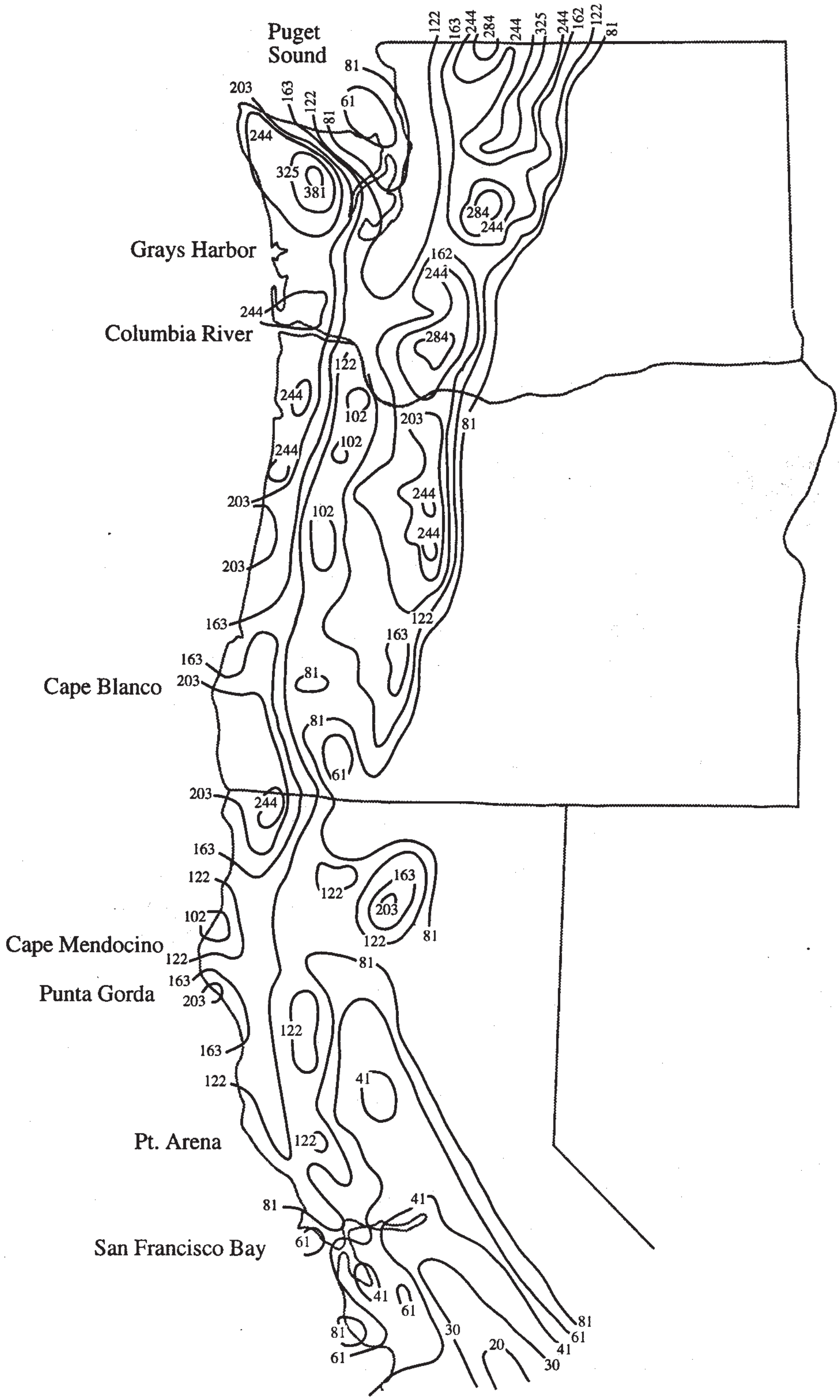

Figure 9. Average annual precipitation (cm) for selected areas of Washington, Oregon, and California. (U.S. Dep. Commerce 1968).

higher Cascade Mountains receive 250-760 cm annually. On average, the Oregon coast receives more sunshine (1,800-2,200 h yr^{-1}) than the wetter Olympic Peninsula (<1,800 h yr^{-1}), but less than northern California and southern Oregon (2,000-2,200 h yr^{-1}).

Columbia River Basin—Rivers draining into the Columbia River have their headwaters in increasingly drier areas moving from west to east, as the Columbia River cuts through the 500-1,000-m-high Coast Range/Willapa Hills and the 1,000-2,000-m-high Cascade Mountains farther inland. Flow patterns for rivers draining into the lower Columbia River are similar to those of coastal rivers immediately north and south of the Columbia River, with a single peak in December or January (Figs. 2 and 5) and relatively low flows (Fig. 4) in summer and fall. Columbia River tributaries draining the Cascade Mountains have proportionally higher flows (Fig. 4) in late summer and early fall than rivers on the Oregon coast, reflecting the greater contribution of snowmelt to these systems.

Precipitation levels in the Willamette Valley in Oregon (100-120 cm yr^{-1}) are much lower than those on the coast (120-240 cm yr^{-1}) or the Cascades (120-280 cm yr^{-1}) (Fig. 9). Water and air temperatures also reflect the more extreme climate east of the Coast Range. Maximum water temperatures in rivers draining into the Columbia River are slightly warmer (13-23ºC) and minimum temperatures are slightly cooler (3-6ºC) than those along the coast (Figs. 7-8, Appendix Table B-2). Similarly, maximum air (around 27ºC) and minimum air (around -1ºC) temperatures during the summer and winter are warmer and cooler, respectively, than along the coast. The Willamette Valley receives 2,000-2,200 h yr^{-1} sunshine, while the lower Columbia River receives less than 2,000 h yr^{-1}.

Southwest Washington—Rivers in southwest Washington drain the Willapa Hills, an area characterized by relatively low elevations (500-1,000 m), with moderate amounts of rain (200-240 cm yr-1) (Fig. 9). These rivers flow either south into the lower Columbia River or west into the Pacific Ocean through Willapa Bay and Grays Harbor. However, many characteristics of rivers draining the Willapa Hills, such as water temperature (Figs. 7-8), a single peak in flow in December or January (Figs. 2, 5), and relatively low flows (Fig. 4), which occur during late summer and early fall, are similar regardless of the direction they drain.

The Chehalis River is the largest river flowing into Grays Harbor; it drains the south slope of the Olympic Mountains and a small area of the Cascade Mountains, in addition to the Willapa Hills. Although the Chehalis River is much larger and drains additional areas, it shares many of the characteristics of other southwest Washington rivers. Most striking is the similarity between the Columbia River estuary, Willapa Bay, and Grays Harbor; all three are characterized by extensive intertidal mud and sandflats and are very different from estuaries to the north or south.

Part of this similarity results from the shared geology of the area; the Chehalis River Basin was the northern-most area that remained ice free during the most recent glaciation (McPhail and Lindsay 1986), and the Chehalis and Columbia Rivers periodically had much higher flows during that time period, which greatly enlarged their respective valleys (Alt and Hyndman 1984, Allen et al. 1986). The Columbia River estuary, Willapa Bay, and Grays

Harbor were all inundated as ocean levels rose following the last ice age. Material carried by the Columbia River has slowly been filling the lower Columbia River and has been transported northward along the coast to form Long Beach, which in turn has formed Willapa Bay. In addition, this material has created extensive sand beaches and dunes north and south of Grays Harbor (Alt and Hyndman 1984, Allen et al. 1986, Landry et al. 1989).

Olympic Peninsula—The Olympic Peninsula is much wetter (160-380 cm precipitation yr^{-1}) than southwest Washington or areas farther east (Fig. 9) and receives considerable snowfall (over 150 cm yr^{-1}) at higher elevations. This high precipitation results at least partially from the relatively high elevation of the Olympic Mountains (1,000-2,000 m) compared to the Willapa Hills or the Oregon Coast Range (both approximately 500-1,000 m high). Olympic Peninsula rivers derive much of their water from snowmelt that causes a second flow peak each year (Fig. 5). These rivers have relatively high flows even in summer (Fig. 4) and have the highest annual flows, given their drainage areas, of any of the areas discussed here (Fig. 6). Maximum and minimum air and water temperatures (Figs. 7-8) are cooler in the Olympic Peninsula than along the Oregon coast, reflecting both latitudinal effects and elevation. Annual maximum and minimum water temperatures are 10-14ºC and 2-4ºC, respectively, while annual maximum and minimum air temperatures are <21ºC and around 2ºC, respectively. Annual sunshine along the Olympic Peninsula coast is the lowest of anywhere in the continental United States, averaging less than 1,800 hours per year.

Coastal British Columbia—The very wet climate of the Olympic Peninsula continues north along the west coast of Vancouver Island and along the British Columbia mainland north of Vancouver Island. Limited hydrographic data (Farley 1979) indicate that river flow patterns in this area are similar to those on the Olympic Peninsula, with relatively high flows throughout the year. There is a general decrease in summer air temperatures with increasing north latitude—the Olympic coast is 3-5ºC warmer than the southwest coast of Vancouver Island, which is 3-5ºC warmer than the northwest coast and the mainland north of Vancouver Island.

Inland Waters—Precipitation rapidly decreases east of the Olympic Peninsula because of the rainshadow caused by the Olympic and Vancouver Island Mountains to the north, and Willapa Hills and Oregon Coast Range to the south. This rainshadow continues from the Willamette Valley through lowland Puget Sound, up the lowlands bordering the Strait of Georgia, to the south end of Queen Charlotte Strait. It receives less than 120 cm rain yr^{-1}, with some areas receiving as little as 50 cm yr^{-1} (Fig. 9). Mountains on either side of this rainshadow receive high precipitation (up to 280 cm yr^{-1}) (Fig. 9) and have an annual snowfall of 500-1,020 cm yr^{-1}.

Because of snowmelt in their headwaters, rivers along the eastern Strait of Juan de Fuca, Puget Sound, and Hood Canal share many features with Olympic Peninsula rivers. All have relatively high flows in summer and two peaks of high flow, although the levels of flow relative to the basin area are not as large (Figs. 4-6). Limited data from British Columbia indicate similar river flow patterns (Farley 1979).

There appears to be a summer temperature cline within the greater rainshadow region: average maximum air temperatures in the Willamette Valley (around 27ºC) are a few degrees higher than those in Puget Sound and Hood Canal (20-24ºC), which in turn are slightly higher than in the Strait of Georgia (16-20ºC) or areas inside Vancouver Island farther north (14-16ºC). In contrast, winter air temperatures are more uniform and average 0-5ºC throughout the area. Stream temperatures in the area are fairly cold, with a maximum of 12-20ºC in summer and 0-4ºC in winter (Figs. 7-8). The greater Puget Sound area receives 2,000-2,200 h yr^{-1} of sunshine.

Vegetation

Dominant vegetation types are a valuable indicator of relative precipitation, temperature, soil type, solar radiation, and altitude because of the specific requirements of different forest communities. Consequently, changes of vegetation types indicate changes in the physical environment, which may affect freshwater salmon habitat. The following discussion of vegetation was compiled from studies by Viereck and Little (1972), Franklin and Dyrness (1973), Barbour and Major (1977), Farley (1979), and Whitney (1985).

Sitka spruce zone—Coastal regions in Oregon, Washington, and British Columbia are forested with a Sitka spruce-dominated floral community: Sitka spruce, western hemlock, western red cedar, red alder, and Douglas fir are major species. This vegetation type is restricted to coastal regions and river valleys; only over coastal plains does it extend farther than a few kilometers inland, and it reaches elevations above 150 m only in areas immediately adjacent to the ocean. This vegetation type is typified by a uniformly wet and mild climate. Sitka spruce forests could be considered a variant of western-hemlock forests of higher elevations and inland areas, but they are distinguished by frequent summer fogs and proximity to the ocean (Franklin and Dyrness 1973).

Along the coast, Sitka spruce forests grade into redwood forests in southern Oregon and northern California and into western hemlock-dominated forests along the Strait of Juan de Fuca to the north. Sitka spruce forests also extend up the Columbia River to approximately the Clatskanie River (River Kilometer (RKm) 80), beyond which point the vegetation increasingly reflects the drier climate east of the Coast Range. The Columbia River passes through western hemlock forests in the Coast Range and Cascade Mountains, Oregon white oak forests in the Willamette Valley, and areas dominated by ponderosa pine or sagebrush in the arid interior east of the Cascade Mountains.

Redwood zone—Beginning in the Chetco River basin in southern Oregon, Sitka spruce and western hemlock are replaced by redwood forests, slightly inland and in river bottoms along the coast. This forest type forms the dominant coastal vegetation south to Monterey at elevations between 30 and 800 m. From the redwood zone along the coast, vegetation on the moist western slopes changes to Douglas fir/hardwood forests at lower elevations, followed by Shasta red fir and white fir, and finally mountain hemlock at higher elevations.

Vegetation in the upper basins of the Rogue and northern California rivers is adapted to a more arid climate than that of basins closer to the coast and, consequently, is distinct from upper-basin vegetation types either north or south. These vegetation types include forests dominated by Oregon oak, mixed evergreen, Klamath montane, coastal montane, blue oak-digger pine, and chapparal. South of the Mattole River, upper basins are not as arid, and the vegetation shows greater similarity to the coastal type—primarily redwoods with patches of mixed evergreens and mixed hardwoods, and coastal prairie-scrub around the San Francisco Bay area.

Western hemlock zone—Along the Washington and Oregon coasts, the western hemlock-dominated floral community replaces Sitka spruce at elevations above 150 m, and in the Puget Sound/Strait of Georgia area forms the dominant vegetation from sea level to 700-1,000 m. This zone includes western hemlock, Douglas fir, red alder, and western red cedar as major floral species. The transition point between Sitka spruce and western hemlock along the Strait of Juan de Fuca appears to be approximately the Elwha River on the U.S. side and Sooke Inlet on the Canadian side. South of the Columbia River, the western hemlock zone extends southward along the Coast Range to the Klamath Mountains and southward along the Cascade Mountains to the Umpqua River.

Forests in the Puget Sound area are often considered a special type of western hemlock forest. Because of Puget Sound’s lower precipitation and glacial soils, drought-tolerant western white, lodgepole, and occasionally ponderosa pines are major species, whereas they are considered minor species elsewhere in the western hemlock zone.

Alpine and subalpine zones—The headwaters of rivers draining higher mountains, such as the Olympic and Cascade Mountains, and the British Columbia and Oregon Coast Ranges, begin in alpine meadows and subalpine parklands, before they change to western hemlock-dominated forests below 700-1,000 m. The higher, alpine regions are typified by a mosaic of meadows and tree patches with extended and deep snow cover. The subalpine zone is dominated by mountain hemlock and subalpine fir and is wetter and colder than areas at lower elevations but has less extended snow cover than higher alpine areas.

Analyses of vegetation types—In his factor analysis of western U.S. floras, based on the distribution of over 9,000 plant species, McLaughlin (1989) defined three floristic areas within the range of coho salmon: the Vancouverian, Sierra Nevada, and California areas. The Vancouverian area includes the Sitka spruce zone described above, the western hemlock zone excluding the central and southern Oregon Cascade Mountains, and the redwood zone from its northern boundary to approximately Cape Mendocino. The California floristic area is comprised of the redwood zone south of Cape Mendocino and the lower elevation portions of the Sacramento/San Joaquin Valley, while the Sierra Nevada area is defined by the central and south Oregon Cascade Mountains, the interior Klamath Mountain Province, and the Sierra Nevada Mountains. In a similar analysis based solely on Pacific coast beach vegetation, Breckon and Barbour (1974) identified a “temperate” eco-floristic zone, which extended from 54ºN to 36º30’N. This zone was subdivided into northern North Coastal Zone and a southern Mediterranean Zone with the boundary at 43º30’N, approximately the Coos River, about 70 km north of Cape Blanco.

Upwelling

Ocean upwelling (the movement of cold, nutrient-rich subsurface water to the surface) along the coasts of British Columbia, Washington, and Oregon is primarily wind driven (Bakun 1973, 1975). Consequently, upwelling in the area is both seasonal and episodic, because winds that cause upwelling are more frequent in the spring and summer but do not occur uniformly even at those times (Smith 1983, Landry et al. 1989). Wind-driven upwelling also occurs within the Strait of Georgia, where it is similarly limited both spatially and temporally (Thompson 1981). One exception to this pattern has been observed off the southwest corner of Vancouver Island, where consistent and strong upwelling appears to occur throughout the year (Denman et al. 1981). Upwelling in this area is thought to be caused by current-driven as well as wind-driven events, leading to relative temporal and spatial stability.

South of Cape Blanco, (43º30’N), upwelling is much more consistent, less seasonal, and is stronger on average than in areas farther north (Bakun 1973, 1975). This strong upwelling area extends into central and southern California, beyond the southern distribution of coho salmon.

Zoogeography

Patterns of marine and freshwater species’ distributions, like vegetation types, indicate changes in the physical environment which they share with coho salmon. These environmental differences may affect salmon habitat and provide different selective pressures in different areas to which salmon must adapt.

Marine fishes—There are two distinct faunal boundaries for marine fishes within the range considered in this status review: Point Conception (34º30’N) and the northern tip of Vancouver Island (approximately 50ºN) (Allen and Smith 1988). Marine fishes north of 50ºN are primarily coldwater, subarctic species; those between 50ºN and 34º30’N are primarily temperate species; and those south of 34º30’N are primarily subtropical. Although not a distinct faunal boundary, Cape Mendocino represents the southern limit beyond which the presence of many northern species markedly declines (Horn and Allen 1978).

Marine invertebrates—The distribution of marine invertebrates shows transition points between major faunal communities similar to those for marine fishes (Hall 1964, Valentine 1966, Hayden and Dolan 1976, Brusca and Wallerstein 1979). Invertebrate faunal boundaries along the west coast of North America occur at approximately Dixon Entrance (directly west of Prince Rupert), Strait of Juan de Fuca, and Point Conception, with minor boundaries at Cape Mendocino and Monterey Bay (Hall 1964, Valentine 1966). The primary cause of this zonation is attributed to temperature (Hayden and Dolan 1976), but other abiotic (Valentine 1966) and biotic (Brusca and Wallerstein 1979) factors may also influence invertebrate distribution patterns.

Freshwater fishes—Freshwater fishes in south/central British Columbia, Washington, and most of coastal Oregon are of Columbia River origin (McPhail and Lindsey 1986, Minckley et al. 1986). Variations in the makeup of freshwater fish communities in these areas reflect the varied dispersal patterns of fishes between river basins. The Stikine River in northern British Columbia is the point at which freshwater fishes from the north displace the Columbia River fish fauna (McPhail and Lindsay 1986). Similarly, the Sixes River in southern Oregon marks the southern extent of the Columbia River freshwater fish fauna (Minckley et al. 1986). Freshwater fishes in the Klamath-Rogue ichthyofaunal region, which includes the Klamath and Rogue Rivers, differ from the Columbia River-dominated assemblages to the north and the Sacramento/San Joaquin River-dominated faunas to the south (Moyle 1976, Minckley et al. 1986). Freshwater fishes in north/central California between Redwood Creek and the San Lorenzo River are derived from the Sacramento-San Joaquin River system. However, many of the smaller basins have no exclusively freshwater species, but only those that can move readily through salt water (Moyle 1976). From the San Lorenzo River southward, freshwater fishes belong to the Pajaro-Salinas type (Moyle 1976). This faunal type is derived from the Sacramento-San Joaquin River system, but it has been isolated for some time, which has allowed for significant divergence from species of that system.

Estuarine fishes—Estuarine fishes also show regional differences based on presence or absence of species and can be roughly divided into five groups in Washington, Oregon, and north/central California (Monaco et al. 1992). Two groups were identified in Washington: one restricted to Puget Sound and Hood Canal, and a second consisting of Grays Harbor, Willapa Bay, and the Columbia River estuary. Two large groups with considerable geographic overlap extend from Willapa Bay in Washington to the Eel River estuary in California. The differentiation between these latter two groups appeared to be related to the size of the respective estuaries. A final group extends from Tomales Bay to Morro Bay in California.

Amphibians—Although most amphibians are not restricted to aquatic habitats and therefore have little direct habitat overlap with coho salmon, many amphibian species have very restricted distributions, suggesting preferences for specific habitat types and environmental conditions. Because of this sensitivity, patterns of amphibian distributions may serve as indicators of subtle differences in environmental conditions.

The distributions of many amphibians appear to begin and end at several common geographical areas within the range of west coast coho salmon. For example, the Strait of Georgia and Vancouver Island are the northern extent of many amphibian distributions including tailed and red-legged frogs, and Pacific giant, western long-toed, western red-backed, Oregon, and brown salamanders (Cook 1984). Southern Oregon, in the vicinity of Cape Blanco, is both the northern (southern long-toed, Del Norte’s, and California salamanders), and the southern (western red-backed salamander) extent of some amphibian distributions (Stebbins 1966, Leonard et al. 1993), as is Cape Mendocino (northern endpoint of the southern red-legged frog, red-bellied newt, and the arboreal salamander, and southern endpoint of the northern red-legged frog and Del Norte’s salamander distributions) (Stebbins 1966). In addition, several amphibians are restricted to the Olympic Peninsula (Olympic torrent and Van Dyke’s salamanders), while other species occur in most areas in western Washington and Oregon except in the Olympic Peninsula (Pacific giant and Dunn’s salamanders) (Leonard et al. 1993).

Other Ecological Factors

The U.S. Environmental Protection Agency has developed a system of ecoregions, based on the patterns of a combination of factors such as land use, climate, topography, potential natural vegetation, and soils (Omernik and Gallant 1986, Omernik 1987). Under this system, the range of coho salmon in Washington, Oregon, and California covers seven ecoregions, although only three border on salt water: the “coast range” ecoregion extends from the Strait of Juan de Fuca to Monterey Bay, from the ocean to approximately the crest of the coastal mountains; the “southern and central California plains and hills” ecoregion extends from the Sacramento/San Joaquin basin through the coast range ecoregion to the coast around San Francisco Bay; and the “Puget lowland” ecoregion begins at approximately the Dungeness River on the eastern end of the Strait of Juan de Fuca and extends through Puget Sound to the Canadian border. The remaining four ecoregions cover the upper basins of coastal rivers and were defined as the “Willamette Valley,” “Cascades,” “Sierra Nevada,” and “eastern Cascades slopes and foothills” ecoregions. There has generally been good correspondence between Omernik’s ecoregions and the distribution of freshwater fish assemblages (Hughes et al. 1987, Lyons 1989).

The Washington and Oregon portion of the “coast range” ecoregion has since been subdivided (Thiele et al. 1992), primarily on the basis of elevation and geology. One interesting subregion, however, is the “California coast range extension” subregion, which begins at Cape Blanco and extends south into California, replacing “coastal lowlands” and “mid-coastal sedimentary” subregions to the north.

Coho Salmon Life History

Several types of biological evidence were considered in evaluating the contribution of west coast coho salmon to ecological/genetic diversity of the biological species under the ESA. Life history traits examined for naturally spawning coho salmon populations included smolt size and outmigration timing, age and size at spawning, river entry timing, spawn timing, fecundity, and ocean migration patterns based on marine code-wire-tag (CWT) recoveries. The primary objective of this examination was to determine regional patterns in these traits that might indicate stock groupings, and to identify geographic areas where patterns change. Because these traits are believed to have both genetic and environmental bases, similarities among populations could indicate either shared genetic heritage or similar responses to shared environmental conditions.

Compilation and comparison of life history trait information on a regional scale is confounded by several factors. First is the high spatial and temporal variability of these traits, which is presumably in large part a reflection of high environmental variability. Fish examined in different years or from different locations or habitats within a basin may display different life history characteristics, making it difficult to estimate values that characterize historic or basinwide populations. This variability creates considerable “noise,” which may be as large as differences between geographically distant populations, and may mask subtle regional patterns. High interannual variability also means that results of studies may be sensitive to the time period over which they were conducted. For example, measurements of many life history traits for Oregon coho salmon during the 1983 El Niño were very different than those in the years preceding and succeeding that event (Johnson 1988).

A second factor which has confounded data compilation is lack of information on life history traits, especially the lack of long-term data sets, from most naturally spawning populations. Very little information on any life history trait is available for many central California populations, and the available information on some life history traits of naturally spawning populations in the better-studied areas (southern British Columbia and Washington) is also lacking or limited. There appear to be population or regional differences in some traits, such as spawner size, relative fecundity, body morphology, and egg size, in coho salmon (Beacham 1982, Hjort and Schreck 1982, Taylor and McPhail 1985, Swain and Holtby 1989, Fleming and Gross 1990, Murray et al. 1990) and other salmon species (Riddell and Leggett 1981, Beacham and Murray 1987, Jonsson and L'Abée-Lund 1993), but not enough information is available on these traits to examine coastwide patterns.

A third confounding complication is that anthropogenic activities such as land-use practices (Hartman et al. 1984, Holtby 1987) and artificial propagation (Steward and Bjornn 1990, Flagg et al. 1995) may alter life history traits. To help limit this bias, life history trait comparisons in this status review have focused on naturally spawning populations. However, because of the widespread practice of off-station plants of hatchery fry and smolts, many studies of naturally spawning populations may have included first- or second-generation hatchery fish. Life history trait information from hatchery populations was used only when insufficient information from naturally spawning populations was available, as in the case of ocean migration patterns. In this case, comparisons of ocean migration patterns in paired natural and hatchery populations were made to confirm that patterns exhibited by hatchery populations could serve as a surrogate for those of naturally spawning populations. As with environmental variability, the effects of anthropogenic activities may confuse the determination of average life history traits yet are difficult to factor out.

Because of these potential sources of variability, we felt that statistical analyses of life history traits would not be particularly informative. Instead, data were collected from as many sources as possible from each system to give some indication of the "average" results, and older data sets were especially sought to indicate coho salmon population traits prior to the proliferation of hatchery programs which produced fish with relatively high survival rates.

Age

From central British Columbia south, the vast majority of coho salmon adults are 3-year-olds, having spent approximately 18 months in fresh water and 18 months in salt water (Gilbert 1912, Pritchard 1940, Marr 1943, Briggs 1953, Shapovalov and Taft 1954, Foerster 1955, Milne 1957, Salo and Bayliff 1958, Loeffel and Wendler 1968, Wright 1970). The primary exception to this pattern are "jacks," sexually mature males that return to freshwater to spawn after only 5-7 months in the ocean. However, in southeast and central Alaska, the majority of coho salmon adults are 4-year-olds, having spent an additional year in fresh water before going to sea (Godfrey et al. 1975, Crone and Bond 1976). The Keogh River at the north end of Vancouver Island produces relatively low (8-11% of total outmigrating smolts) but consistent numbers of 4-year-old adults (Irvine and Ward 1989), suggesting that the transition zone between predominantly 3-year-old and 4-year-old adults occurs somewhere between central British Columbia and southeast Alaska.

Trends in Jacks—Drucker (1972) suggested that there is a latitudinal cline in the proportion of jacks in a coho salmon population, with populations in California having more jacks and those in British Columbia having almost none. Although the production of jacks is a heritable trait in coho salmon (Iwamoto et al. 1984), it is also strongly influenced by environmental factors (Shapovalov and Taft 1954, Silverstein and Hershberger 1992). The proportion of jacks in a given coho salmon population appears to be highly variable and may range from less than 6% to over 43% over 9-35 years of monitoring (Shapovalov and Taft 1954, Fraser et al. 1983, Cramer and Cramer 1994).

Some systems have also shown long-term changes in the proportion of jacks produced. The Tenmile Lakes system (Oregon) historically produced large numbers of jacks (Morgan and Henry 1959) but no longer does (Ursitti 1989), presumably because of altered freshwater predation pressures (Reimers et al. 1993). Because of this high level of variability in the relative production of jacks in a population, the proportion of jacks appeared to be a poor indicator of regional patterns and was not pursued further.

Fecundity

Because larger females have higher fecundity than smaller females, any comparison of fecundity between populations is confounded by differences in female size (Rounsefell 1957). Consequently, comparisons of fecundity should be adjusted for size (Beacham 1982), which requires measurements of both size and fecundity from the same individuals. Available information that provides these measurements for naturally spawning coho salmon populations was insufficient to adequately evaluate patterns of relative fecundity in west coast coho salmon.

However, two analyses of fecundity of coho salmon provide some insight. Beacham (1982) found differences in relative fecundity between coho salmon populations in California, Washington, British Columbia, and Alaska that he attributed to river size, but only weak increases in fecundity with increasing north latitude. In contrast, Fleming and Gross (1990) found significant increases in fecundity with increasing north latitude. The fact that separate researchers reached different conclusions about fecundity over approximately the same area suggests that the observed relationships are strongly influenced by both the data used and temporal and spatial variability in fecundity. This degree of variability may interfere with the ability to detect differences between areas. Other researchers have reported that fecundity can be effectively used to differentiate other salmon populations (Gard et al. 1987), while fecundity of Clupeidae showed strong latitudinal trends in eastern North America (Jessop 1993).

Smolt Size and Outmigration Timing

There does not appear to be any clear, regional pattern for either smolt outmigration timing (Fig. 10, Appendix Table C-1) or smolt size (Fig. 11, Appendix Table C-2) in west coast coho salmon. Regardless of the area of origin, peak outmigration timing generally occurs in May, with some runs earlier or later, and with most smolts measuring 90-115 mm fork length. Smolts from southwest Washington and the Klamath River Basin (northern California) tend to be relatively large, but this is possibly due to influences of off-station hatchery plants. Large smolts observed in Tenmile Lakes were thought to have resulted from a productive lake-rearing environment (McGie 1970).

Smolt outmigration timing and smolt size appear to respond to small-scale habitat variability. Smolts residing in ponds or lakes often have different outmigration timing and are a different size than smolts residing in streams within the same basin (Swales et al. 1988, Irvine and Ward 1989, Rodgers et al. 1993, Nielsen 1994). Both smolt outmigration timing and size exhibit considerable interannual variation; mean smolt sizes from a single system can vary by over 15 mm between years (Blankenship et al. 1983; Fraser et al. 1983; Lenzi 1983, 1985, 1987), while peak outmigration timing can vary by several weeks to a month (Shapovalov and Taft 1954; Salo and Bayliff 1958; Blankenship and Tivel 1980; Seiler et al. 1981, 1984; Blankenship et al. 1983; Fraser et al. 1983; Lenzi 1983, 1985, 1987).

Because of their responses to small-scale habitat variability, smolt size and outmigration timing have also been shown to be affected by anthropogenic activities, including habitat degradation (Moring and Lantz 1975, Scrivener and Andersen 1984, Holtby and Scrivener 1989), habitat restoration (Johnson et al. 1993, Rodgers et al. 1993), and flow control (Fraser et al. 1983). These factors thoroughly complicate the assessment of any regional pattern that may exist for either trait, since these activities have occurred throughout the range of coho salmon. Sampling design may also influence reported smolt sizes and outmigration timing.

Despite these confounding problems, it appears that regional patterns for some aspects of smolt outmigration do exist. Spence (1994 App.[4]) conducted a detailed evaluation of coho salmon smolt outmigration timing and the factors that appear to influence it. Using only long-term data sets to minimize interannual variability, he found that the duration and between-year variation of smolt outmigration timing exhibited distinctive patterns between areas. These areas were identified as the Columbia River and south, Puget Sound/Strait of Georgia, and central/north British Columbia and Alaska. Spence concluded that these patterns were likely driven by differences in the predictability of nearshore ocean conditions.

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[4]Citations followed by “App.” are given in Appendix C.

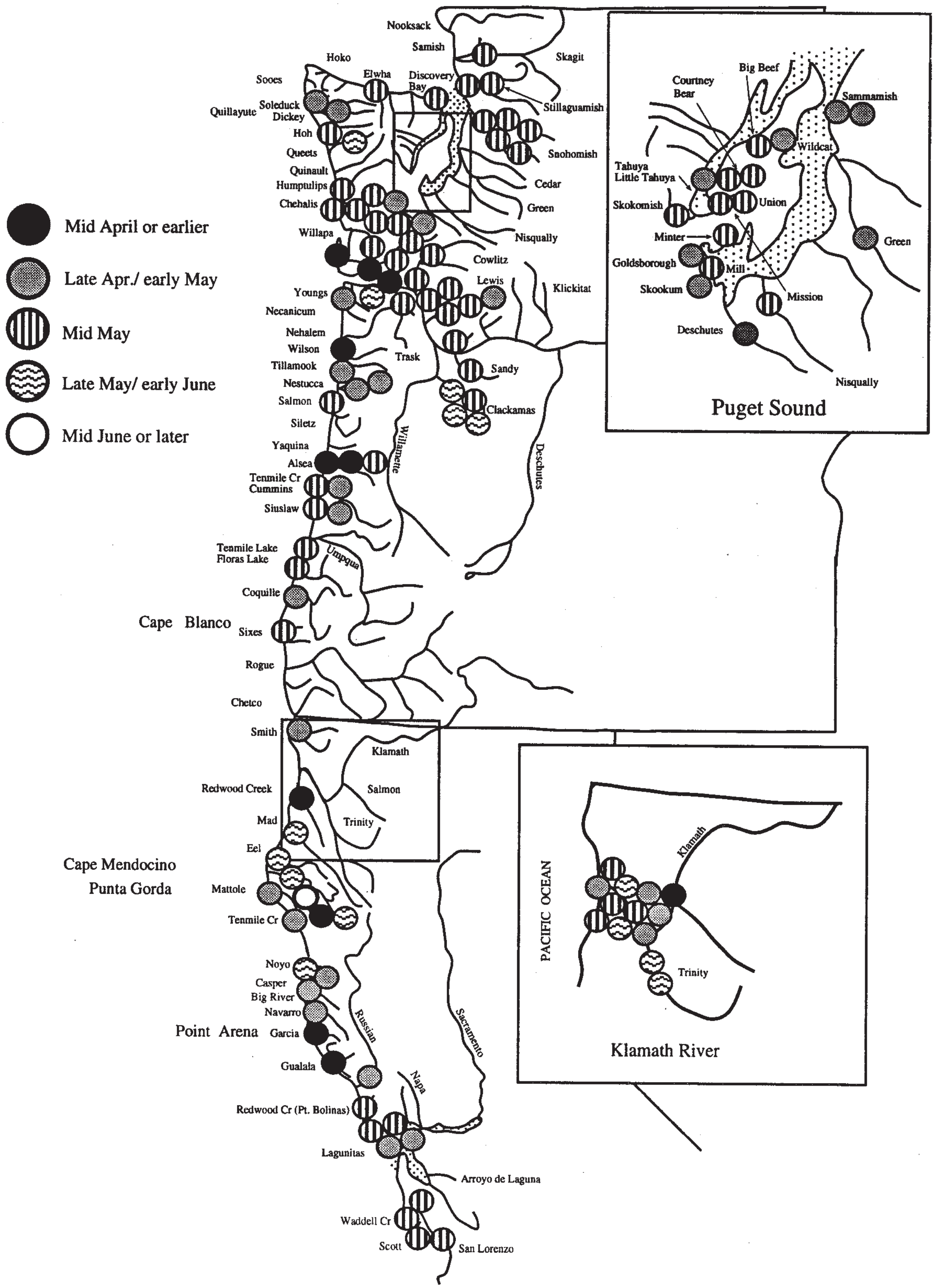

Figure 10. Peak smolt outmigration timing of coho salmon from selected river basins in Washington, Oregon, and California. Multiple studies from the same system reporting different values are each given a separate circle. Data from Appendix Table C-1.

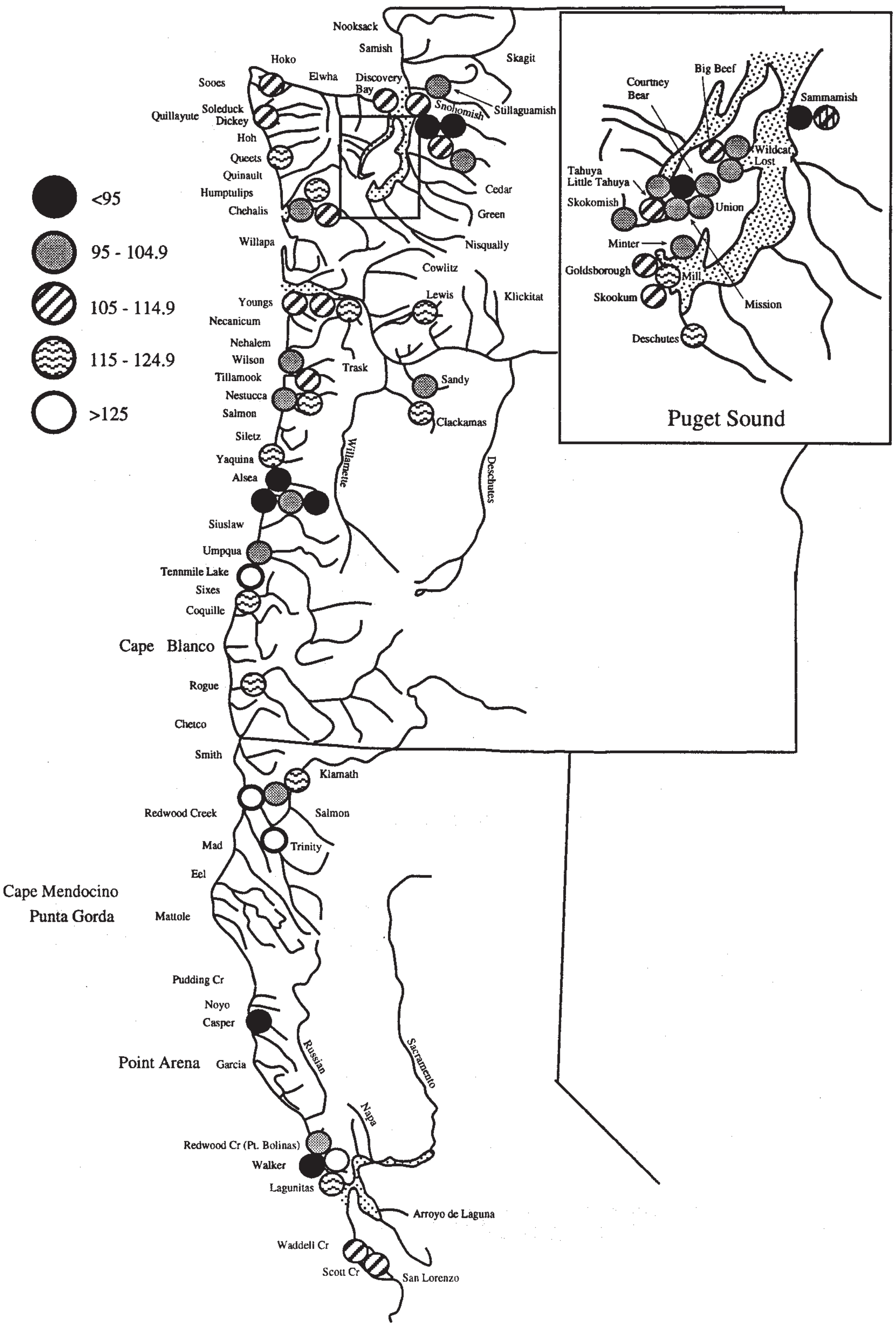

Figure 11. Mean smolt size (mm fork length) for selected river basins in Washington, Oregon, and California. Multiple studies from the same system reporting different values are each given a separate circle. Data from Appendix Table C-2.

Adult Run Timing

In general, river entry[5] and spawn timing[6] showed considerable spatial and temporal variability. Despite this high variability, some regional patterns were observed. Most west coast coho salmon enter rivers in October (Fig. 12, Appendix Table C-3) and spawn from November to December and occasionally into January (Fig. 13, Appendix Table C-4). However, coho salmon from central California enter rivers much later, in late December or January, and spawn immediately afterwards, probably in response to late peak river flows of limited duration. Consequently, central California fish spend little time between river entry and spawning, while northern stocks may spend 1 or 2 months in fresh water before spawning (Flint and Zillges 1980, Fraser et al. 1983). Stocks from British Columbia, Washington, and the Columbia River often have very early (entering rivers in July or August) or late (spawning into March) runs in addition to “normally” timed runs.

Coho salmon river entry timing is influenced by many factors; one of the most important appears to be river flow (Shapovalov and Taft 1954, Salo and Bayliff 1958, Sumner 1953, Eames et al. 1981, Lister et al. 1981). Coho salmon wait for freshets before entering rivers, so a delay in fall rains delays river entry and, potentially, spawn timing as well. Delays in river entry of over a month are not unusual (Salo and Bayliff 1958, Eames et al. 1981). Many small California systems have sandbars which block their mouths for most of the year except during winter. In these systems, coho salmon and other salmon species are unable to enter the rivers until sufficiently strong freshets break the sandbars (Sandercock 1991).

There is also considerable temporal variability in river entry and spawn timing, especially in large river systems. For example, the Skagit (northern Washington), Chehalis (southwest Washington), Columbia, and Klamath Rivers have coho salmon which enter freshwater over a broad period from August until December (WDF 1951, Leidy and Leidy 1984, WDF et al. 1993, J. Polos 1994 App.). In general, earlier migrating fish spawn farther upstream within a basin than later migrating fish, which enter rivers in a more advanced state of sexual maturity (Sandercock 1991).

On a smaller scale, Lister et al. (1981) found that spawn timing of coho salmon in tributaries of the Cowichan River (British Columbia) was strongly correlated to tributary water temperature: coho salmon spawning in warmer tributaries spawned later than those spawning in colder tributaries. All these factors make determinations and comparisons of “average” or “peak” river entry and spawn timing difficult because of the high spatial and temporal variability exhibited within basins.

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[5]River entry was taken from reports which specifically listed it, or was based on the timing of peak in-river catches of coho salmon.

[6]Spawn timing was compiled from reports listing spawn timing, or based on an average of the dates when peaks in spawning occurred, as reported in spawning ground surveys.

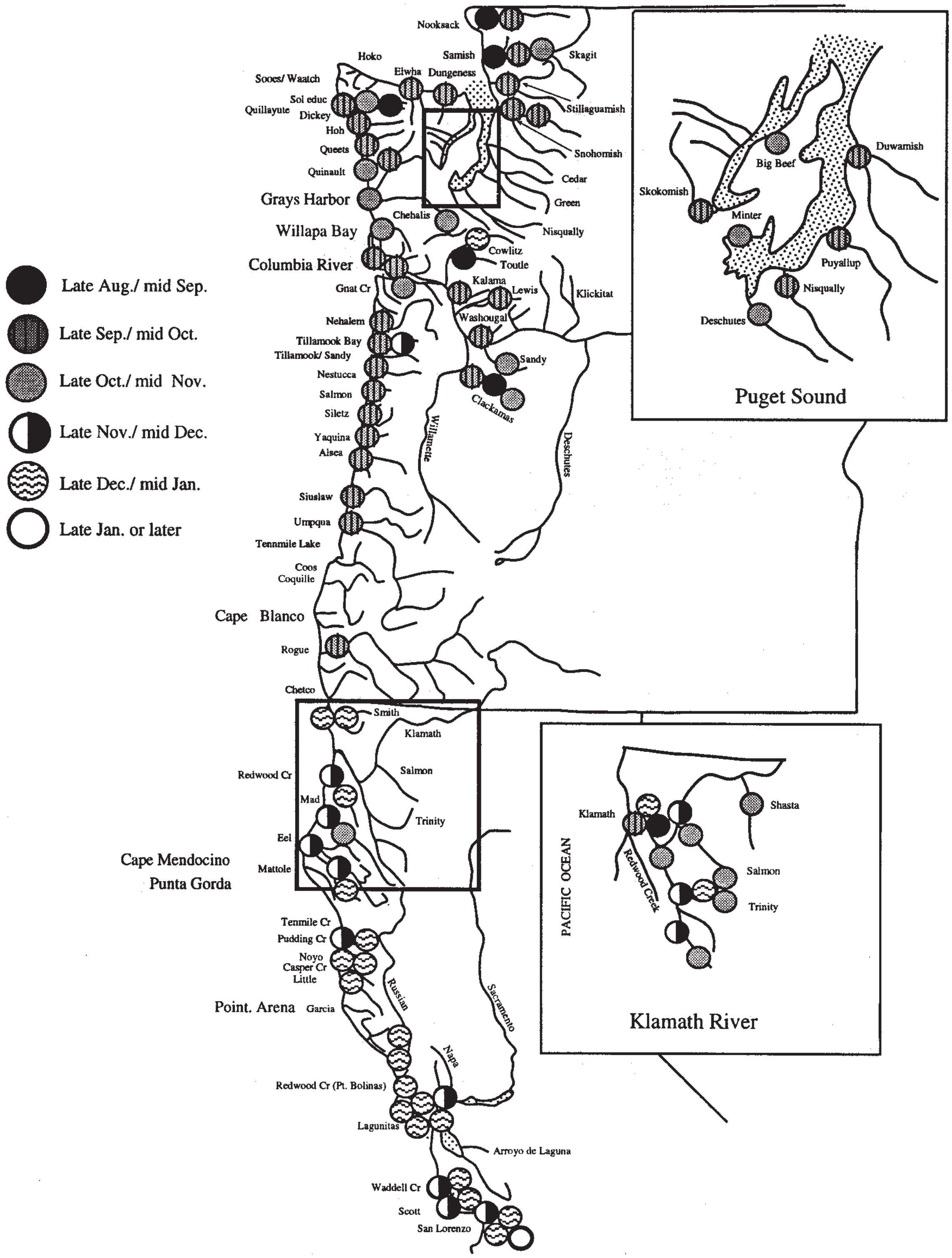


Figure 12. Peak river entry timing of coho salmon in selected river basins in Washington, Oregon, and California. Multiple studies from the same system reporting different values are each given a separate circle. Data from Appendix Table C-3.

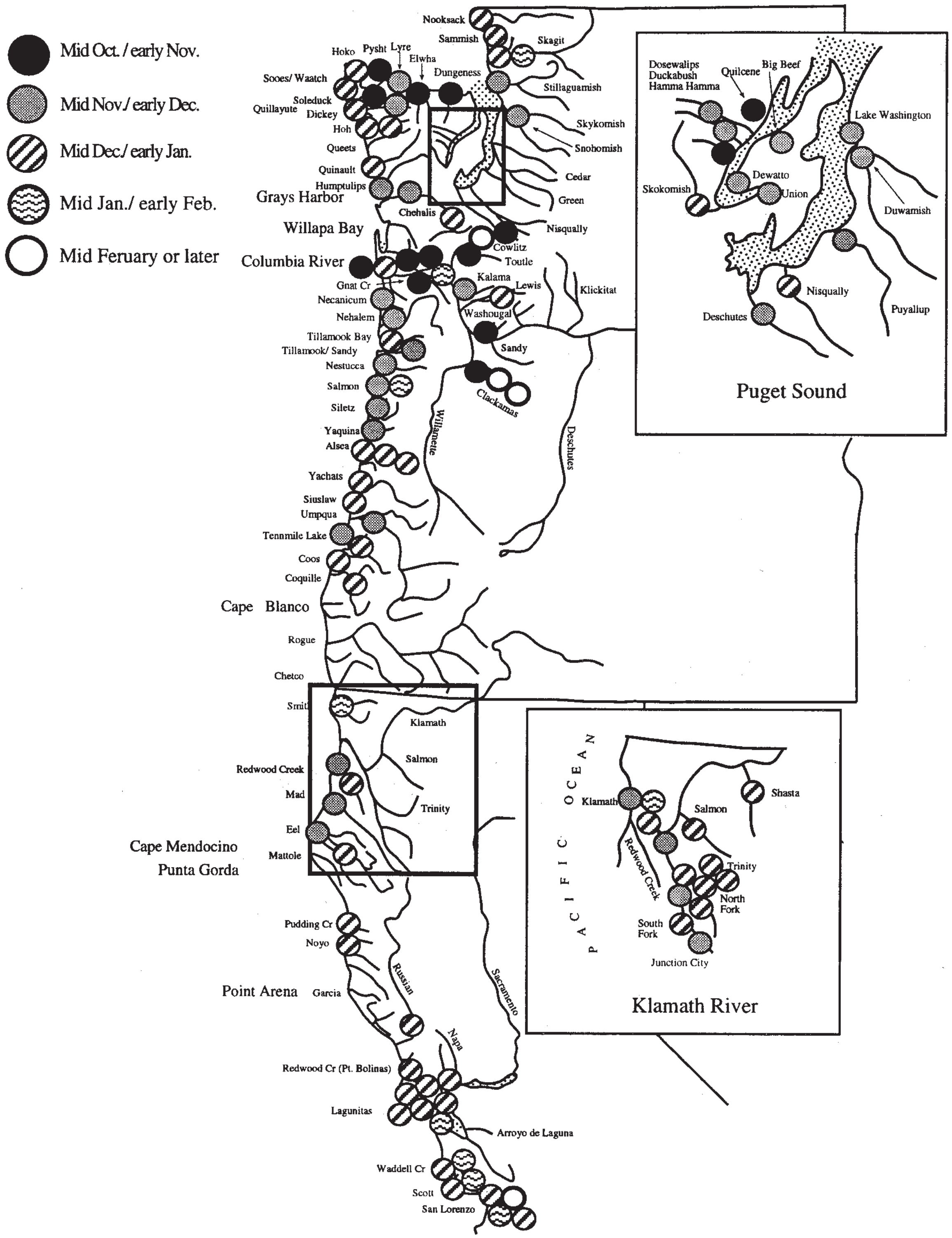


Figure 13. Reported peak spawn timing from selected river basins in Washington, Oregon, and California. Multiple studies from the same system reporting different values are each given a separate circle. Data from Appendix Table C-4.

Compared to “normal” run times, river entry of some coho salmon stocks are exceptionally early or late; these stocks are often referred to as summer or winter runs, respectively (Godfrey 1965), and are thought to have evolved in response to particular flow conditions (Sandercock 1991). The relationship between populations with unusually timed runs and normally timed runs within the same basin is not well understood. For example, in some cases, such as the Soleduck (Washington coast) and Clackamas (Willamette River) Rivers, differently-timed, sympatric runs are thought to be largely reproductively isolated from each other (Houston 1983, Cramer and Cramer 1994), while in the Grays Harbor Basin, there is believed to be reproductive overlap (WDF et al. 1993). Exceptionally timed runs are found in numerous geographic areas. However, because there is no evidence to suggest that all runs of a certain type are closely related, we considered differently-timed runs to be a component of overall life history diversity within each area.

Spawner Size

Regional variation—Like the other life history traits discussed above, adult spawner size[7] in naturally spawning populations shows considerable spatial and temporal variability which may obscure regional patterns of variation. Except for the tendency of some populations of Puget Sound/Strait of Georgia coho salmon to be slightly smaller, there did not appear to be obvious patterns for adult spawner size (Fig. 14, Appendix Table C-5). Similarly, Sandercock (1991) observed no obvious patterns of spawner size across the range of the species.

Variability in spawner size results from numerous factors and occurs both over the course of a run and between years (Chapman 1940, Salo and Bayliff 1958, Shapovalov and Taft 1954, Fraser et al. 1983). Spawner size is affected by migration patterns (Allen 1959), genetic heritage (Hershberger et al. 1990), and conditions experienced during the last year of growth (van den Berghe and Gross 1989), especially during anomalous ocean events such as El Niños (Johnson 1988). In addition, runs that enter freshwater later tend to have larger spawners than those entering earlier (Sandercock 1991), and coho salmon that spawn in mainstem areas may be larger than those spawning in tributaries (Lister et al. 1981).

Decrease in spawner size—One factor which has thoroughly confounded comparisons of spawner size is that coho salmon, throughout their range, are declining in size over time, and the rates of decrease are population- or area-specific (Ricker 1981, Bigler and Helle 1994). Decreases in size for other salmon species have also been observed (Ricker 1981, Healey 1986, Ishida et al. 1993, Bigler and Helle 1994).

Table 1 shows statistics of size regressed on time for coho salmon collected from various fisheries or locations in British Columbia, Washington, Oregon and California. Although the data sets used for these regressions include measurements made on both hatchery

[7]The data presented come from measurements of naturally spawning coho salmon and fish landed in in-river fisheries. This latter source of data is included because of the scarcity of direct data for naturally spawning populations.

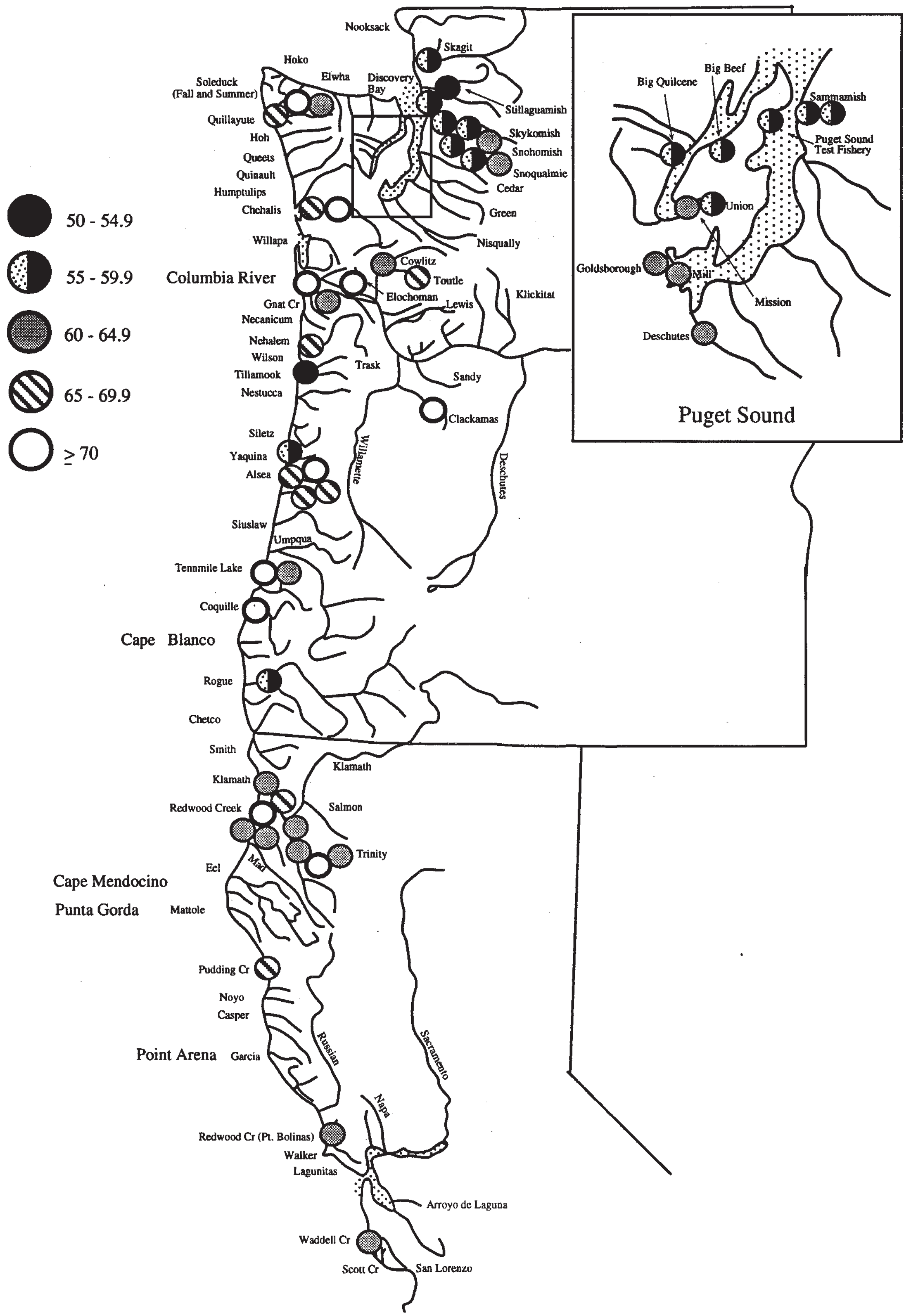


Figure 14. Mean spawner sizes (cm fork length) from selected river basins in Washington, Oregon, and California. Multiple studies from the same system reporting different values are each given a separate circle. Data from Appendix Table C-5.

Table 1. Results of regression analysis of coho salmon size (fork length (cm) or total weight (kg)) over time for selected populations and fisheries in British Columbia, Washington (WA), Oregon (OR), and California. Slopes which are statistically significant at $P < 0.05$ are indicated in bold.

System/Fishery	Measurement source	Measurement	Years covered	r^2	Slope	P value	Data source(s)
Big Qualicum (Vancouver Is.)	spawners	length	59-72	0.144	-3.57	0.181	a
WA total commercial catch	all	weight	35-91	0.669	-0.03	**0.000**	b
All WA commercial troll	troll	weight	54-92	0.718	-0.04	**0.000**	c
Apple Cove Point test fishery	purse seine	length	85-94	0.299	-0.53	0.102	d
Apple Cove Point test fishery	purse seine	weight	85-94	0.468	-0.10	**0.029**	d
All Puget Sound	net	weight	68-91	0.587	-0.06	**0.000**	b
Big Beef Creek (Hood Canal)	spawmer	length	78-91	0.081	-0.43	0.325	e
Nooksack	in river	weight	77-93	0.299	0.03	**0.023**	f
Skagit	in river	weight	78-93	0.581	-0.06	**0.001**	f
Stillaguamish	in river	weight	80-93	0.082	-0.02	0.320	f
Duwamish/Green	in river	weight	72-93	0.567	-0.09	**0.000**	f
Puyallup	in river	weight	72-93	0.714	-0.09	**0.000**	f
Nisqually	in river	weight	72-93	0.663	-0.08	**0.000**	f
Deschutes River	spawners[a]	length	78-92	0.514	-0.96	**0.003**	e
Skokomish	in river	weight	79-90	0.207	-0.04	0.138	f
Dungeness	in river	weight	75-83	0.170	-0.06	0.271	f
Elwha	in river	weight	77-93	0.471	-0.08	**0.002**	f
Sooes/Waatch	in river	weight	72-93	0.095	-0.02	0.163	f
Quillayute	in river	weight	72-93	0.560	-0.05	**0.000**	f
Hoh	in river	weight	72-93	0.258	-0.03	**0.016**	f
Queets	in river	weight	77-93	0.280	-0.03	**0.011**	f
Quinault	in river	weight	77-93	0.432	-0.03	**0.001**	f
Chehalis	in river	weight	77-93	0.021	0.01	0.584	f
Bingham Creek (Chehalis R.)	spawners[a]	length	83-91	0.300	-0.74	0.127	e
Columbia total catch	in river	weight	54-92	0.400	-0.03	**0.000**	g
Columbia	in river	length	76-93	0.079	-1.29	0.258	h
All Oregon troll	troll	weight	52-90	0.150	-0.03	**0.015**	i
Oregon troll, August	troll	weight	52-90	0.117	-0.04	**0.033**	i
Nehalem	spawners	length	78-92	0.053	-1.95	0.408	j
Alsea	spawners	length	78-92	0.050	-1.73	0.422	j
Coquille	spawners	length	78-92	0.012	1.38	0.695	j
Rogue	spawners	length	76-86	0.007	-1.50	0.794	k
All CA troll	troll	weight	52-90	0.323	-0.05	**0.000**	h
CA troll, September	troll	weight	52-90	0.258	-0.05	**0.001**	h
Klamath estuary test fishery	beach seine	length	81-91	0.056	0.28	0.509	l

[a]Males and females combined.

Sources: a: Fraser et al. 1983; b: WDF 1981, Hoines 1994; c: Wright 1970, WDF 1981, Hoines 1994; d: Anderson and Milward 1992, S. Boessow 1994 App.; e: Seiler et al. 1981, C. Knudsen 1995 App.; f: WDFW 1994a; g: ODFW and WDF 1993; h: S. King 1994 App.; i: PFMC 1993b; j: S. Jacobs 1994a App.; k: ODFW 1989; l: Adair et al. 1982-1985, Tuss et al. 1989, Kisanuki et al. 1991, Rueth et al. 1992.

and naturally spawning fish, they provide the most reasonable proxies for specific information on size of naturally spawning coho salmon, which are largely unavailable. In most cases, the slope of the relationship was negative, although not always statistically different than zero ($P < 0.05$) (Table 1). Differences in the rate of decline in adult size among areas, such as those indicated by the varied regression slopes in Table 1, make regional patterns in adult size difficult to interpret. In addition, long-term data sets on size of all commercially-caught and troll-caught coho salmon in Washington State indicated declines in size that began in the mid-1950s (Fig. 15) (Wright 1970, WDF 1981, Hoines 1994). This suggests that declines in adult size in other areas, such as Puget Sound, may have begun earlier than the available data sets indicate. However, no other evidence exists that indicates earlier declines in size.

The size of coho salmon adults in Puget Sound/Strait of Georgia is declining at a much faster rate than in other areas (Table 1). Coho salmon caught in in-river fisheries in Puget Sound decreased in weight by about 50% between 1972 and 1993, from average weights of approximately 4 kg to about 2 kg (Fig. 16). Whether the size of naturally spawning coho salmon in Puget Sound is also declining is largely unknown. Coho salmon weight in the Skagit River, a river managed for natural production (WDF et al. 1993), declined from about 3.5 kg in 1978 to about 2.5 kg in 1992 (Fig. 16), showing a clear, statistically significant downward trend (Table 1).

Big Beef Creek (Hood Canal) and Deschutes River (south Puget Sound) populations are the only naturally spawning Puget Sound coho salmon populations for which there are long-term (14-15 years) size data. These data show that average spawner length decreased between 1978 and 1991/92 from about 64 and 60 cm fork length (FL) for Deschutes River and Big Beef Creek populations, respectively, to approximately 53 cm FL for both populations (Fig. 17) (Seiler et al. 1981, Knudsen 1995 App.). The Deschutes River regression of length over time was statistically significant ($P < 0.05$), while that for Big Beef Creek was not (Table 1).

Because measurements from Big Beef Creek and Deschutes River were taken for length and those from the Skagit River were taken for weight, the two analyses are not directly comparable. To compare declines in size between these naturally spawning populations (Big Beef Creek, Deschutes and Skagit Rivers), length data were converted to weight data using the length-weight equation described by Holtby and Healey (1986). This equation was calculated from coho salmon returning to Rosewall Creek on Vancouver Island and was used to estimate weight ($\log_{10}$weight (g) = 3.3183 ([$\log_{10}$fork length (mm)]-5.843).

The regression of estimated weight over time for Deschutes River coho salmon was statistically significant ($P = 0.003$), and the regression statistics (slope = -0.07, $r^2 = 0.510$) were quite similar to those from the Skagit River ($P = 0.001$, slope = -0.06, $r^2 = 0.581$) (Table 1). In contrast, estimated weight regressed over time for Big Beef Creek fish was not statistically significant ($P = 0.315$, slope = -0.02, $r^2 = 0.084$), and it exhibited about one-third of the rate of decline in size as either Deschutes or Skagit River coho salmon. This comparison suggests that rates of decrease in size over time of Skagit and Deschutes River coho salmon are roughly comparable, and they exceed the rate of decline of the naturally spawning population at Big

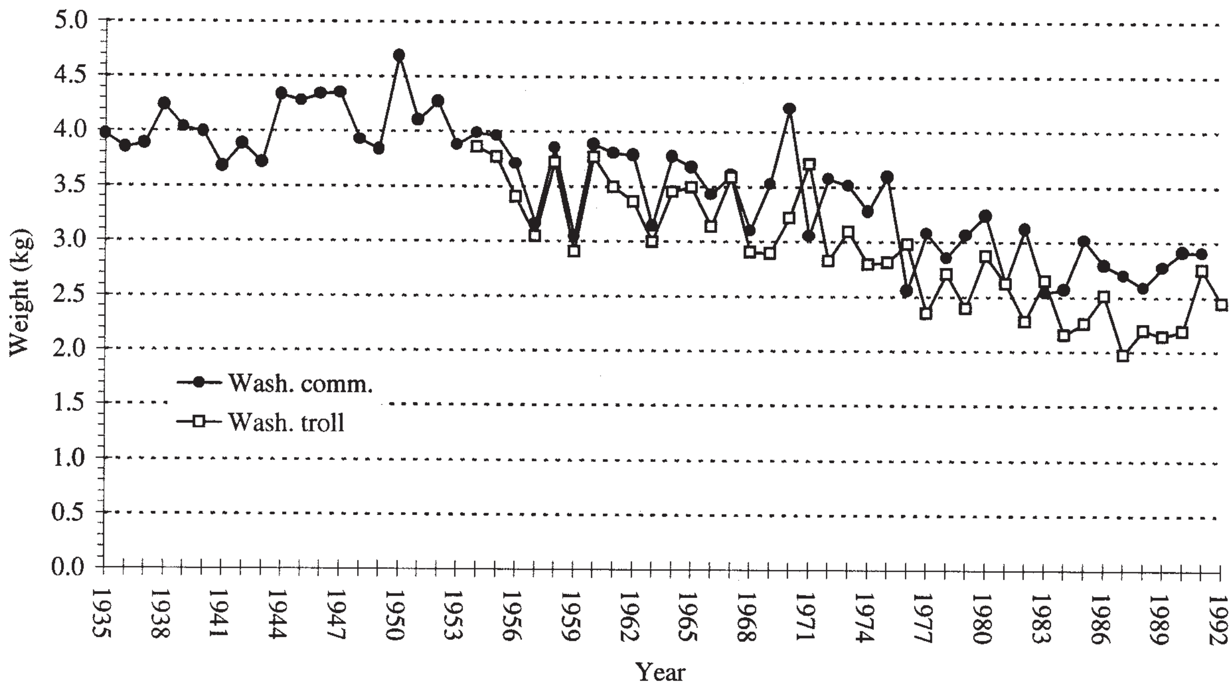
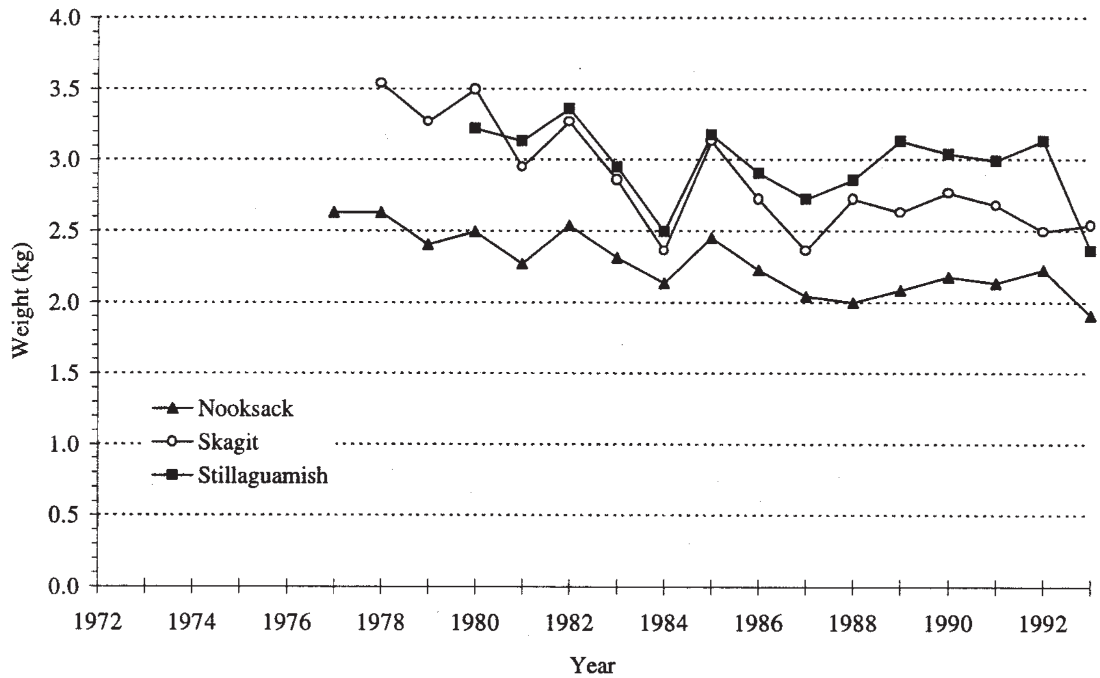


Figure 15. Changes in the average annual weight (kg) of coho salmon caught in all Washington commercial fisheries and Washington troll fisheries, 1935-92. Data from Wright 1970, WDF 1981, and Hoines 1994.



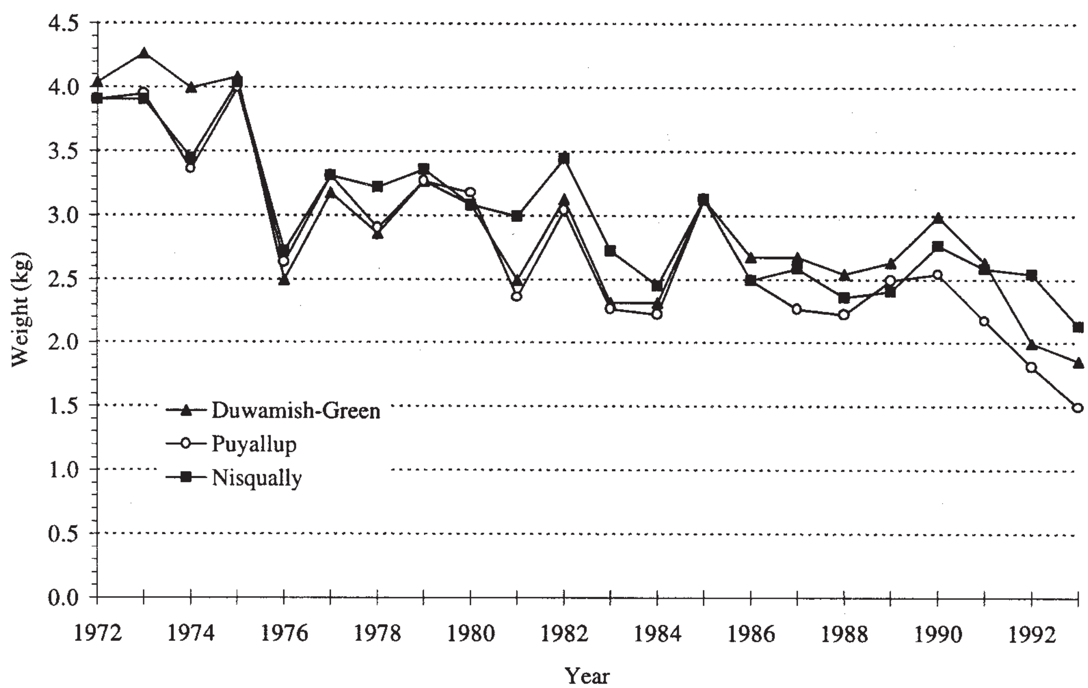


Figure 16. Changes in coho salmon size over time from selected Puget Sound rivers, 1972-93. Size data are average annual weight (kg) per fish caught in in-river fisheries (WDFW 1994a).

Beef Creek. Whether other naturally spawning Puget Sound populations are declining in size at similar rates remains to be determined.

The average size of coho salmon caught in the 1994 Washington Department of Fish and Wildlife (WDFW) Apple Cove Point test fishery (2.2 kg, 55.6 cm FL) was larger than in the previous 2-3 years (1.4-2.1 kg, 47.9-52.5 cm FL in 1991-93) (Fig. 18) (Anderson and Milward 1992, S. Boessow 1994 App.). Two possible explanations for this increase are the near-absence of ocean harvest in 1994 and the low abundance of coho salmon, which led to the fishing restriction. Many salmon harvest methods are size-selective for larger fish (Ricker 1981, Healey 1986), and 1994 was the first year on record when almost all ocean harvest for coho salmon was halted (PFMC 1993a). The 1994 fishing restriction was implemented because the year class was expected to be extremely weak; however, this may have allowed fish that did survive to attain greater size since adult size is often inversely correlated with year class strength (Ishida et al. 1993).

Even including the 1994 data, the sizes of fish caught in the test fishery still show a decline over the period, and the decline in weight is statistically significant (Table 1). Whether continued relaxation of ocean fishing pressure and weak year classes would allow Puget Sound coho salmon to return to their previous size is not known. In any case, 1994 sizes are still smaller than those observed in 1985, and considerably smaller than the 3.6 kg reported for Puget Sound-caught coho salmon during 1915-26 (WDFG 1928).

It is not clear whether the dramatic size reductions observed in Puget Sound/Strait of Georgia coho salmon are due to harvest practices, effects of fish culture, declining ocean productivity, density-dependent effects in the marine and freshwater environments attributable to large numbers of hatchery releases, or a combination of these factors. Similarly, it is not known whether there have been permanent genetic changes related to size changes in these populations. Regardless of its cause or genetic basis, reduced adult size in itself poses a number of serious risks to natural populations of coho salmon, and could be a sign of other factors placing the population at risk.

Declines in adult size can have direct implications for individual reproductive success and population viability. As is the case in other salmon species, coho salmon fecundity is a nonlinear function of size (Fleming and Gross 1989), such that a small reduction in size can lead to a substantial reduction in fecundity. For example, using the length-fecundity relationship given by Shapovalov and Taft (1954, Fecundity = 0.01153 (FL (cm)$^{2.9403}$), a 17% decrease in spawner size (from 60 to 50 cm FL) results in a 42% reduction in fecundity (from 1,950 to 1,141 eggs). Knudsen (1995 App.) estimated that as female sizes decreased between 1960 and 1992 at four Washington state hatcheries (Skykomish, Simpson, George Adams, and Puyallup), coho salmon fecundity decreased by one-third to one-half.

Smaller coho salmon females also dig fewer and shallower redds than do larger females (van den Berghe and Gross 1984). This subjects the redds of smaller individuals to greater risk of destruction by superimposition of redds of larger individuals or by scouring from floods. Flooding frequency has increased throughout much of Puget Sound because of habitat degradation (Booth 1991), further decreasing the survival potential of redds created by small

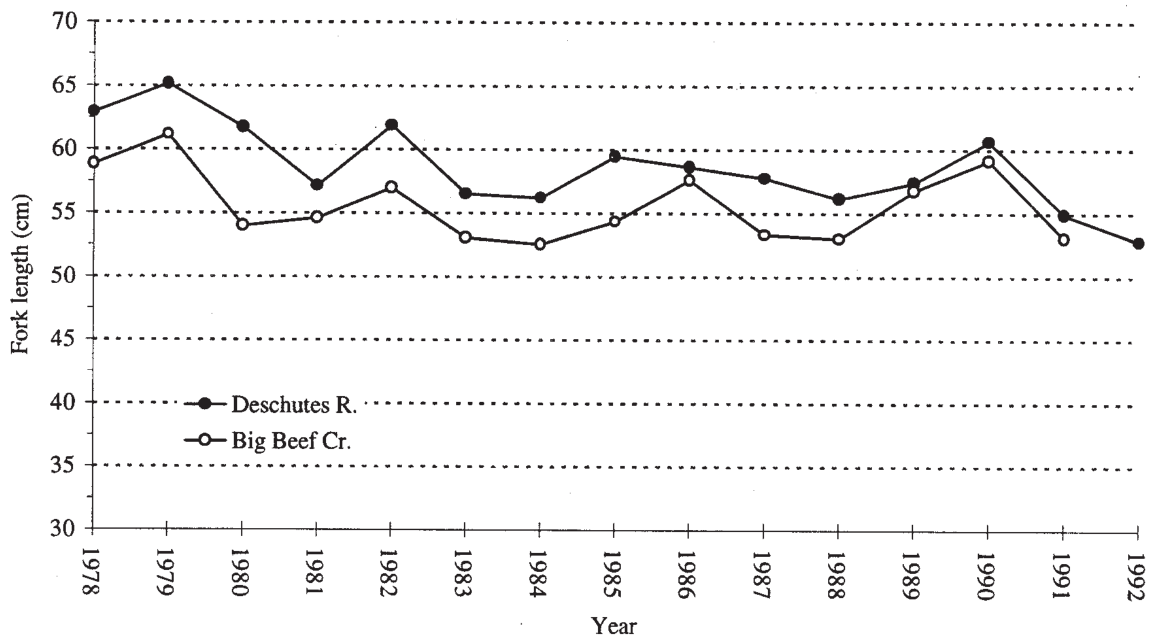


Figure 17. Average annual length (cm fork length) of naturally-spawning coho salmon from Big Beef Creek and Deschutes River (south Puget Sound), 1978-92. Data from Seiler et al. 1981, C. Knudsen 1995 App.

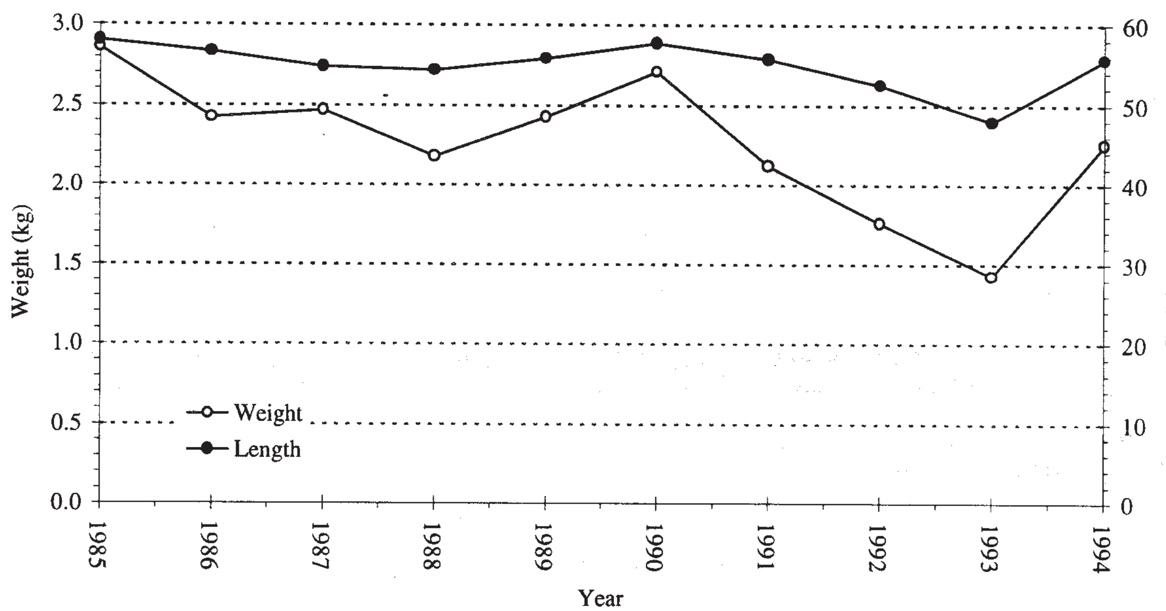


Figure 18. Average annual weight (kg) and length (cm fork length) of coho salmon caught in the Apple Tree Cove test fishery, 1985-94. (Anderson and Milward 1992, S. Boessow 1994 App.)

females. Smaller coho salmon may also be unable to consume prey items available to larger individuals, or may be more susceptible to some forms of predation (Holtby et al. 1990). There also appears to be some size advantage for anadromous fishes making long or strenuous migrations (Bernatchez and Dodson 1987, L'Abée-Lund 1991). All these factors suggest that smaller adults may be less able to reach spawning grounds and successfully spawn than larger adults, and this can directly affect population survival rates.

Ocean Migration

Coded-wire tag studies—Ocean distribution of coho salmon, inferred from marine recoveries of coded-wire-tagged fish, showed distinctive differences between regions. Coded-wire tags (CWTs) are primarily recovered in salt or fresh water as the salmon return to their natal streams after overwintering in the ocean. Consequently, CWT recovery patterns only indicate ocean migration patterns during the last few months of a 11/2-year long migration. Although patterns of movement during earlier stages of ocean migration have been studied (e.g., Loeffel and Forster 1970, French et al. 1975, Hartt 1980, Miller et al. 1983, Hartt and Dell 1986, Pearcy and Fisher 1988), the studies are insufficiently broad in scope to adequately compare early migration patterns for coho salmon released from different areas. However, the extremely large number of CWTs released and recovered for coho salmon provides a detailed picture of the later stages of ocean migration.

Ocean distribution patterns based on CWT marine recovery patterns were determined from CWT recovery data for 66 North American hatcheries (Appendix Table C-6) from the Pacific States Marine Fisheries Commission's (PSMFC 1994) Regional Mark Information System. Marine (as defined in the database) CWT recoveries of adults and jacks were expanded for sampling but not for unmarked fish and were summed over all years for each hatchery by state or province of landing. These tag recoveries represent 1,892,270 coho salmon released between 1972 and 1991 and recovered between 1973 and 1992. Recoveries were made during an average of 10 years for each facility, with an average of 28,671 tags recovered per facility; only Warm Springs had less than 1,000 total recoveries, while six facilities had over 100,000 total recoveries (Appendix Table C-6).

The patterns of recoveries showed marked differences between areas, with extremely limited "transition zones" between areas (Fig. 19). Eight general CWT recovery patterns were identified, which can be grouped by releases from the following areas: 1) northern California and the Oregon coast south of Cape Blanco, 2) the Oregon coast north of Cape Blanco, 3) Columbia River, 4) Washington coast, 5) Puget Sound, Hood Canal, and Strait of Juan de Fuca, 6) southern British Columbia, 7) northern British Columbia, and 8) Alaska. Patterns observed in each of these areas are discussed below.

1) Northern California and Oregon south of Cape Blanco. Coho salmon released from the southernmost facilities (those south of Cape Blanco) had the most southerly recovery patterns: these fish were recovered primarily in California (65-92%), with some recoveries in Oregon (7-34%) and almost none (<1%) in Washington or British Columbia (Fig. 19). The recovery pattern of coho salmon released from the southernmost hatchery, Warm Springs (Russian River), had a much higher proportion of California recoveries (92%) than the other

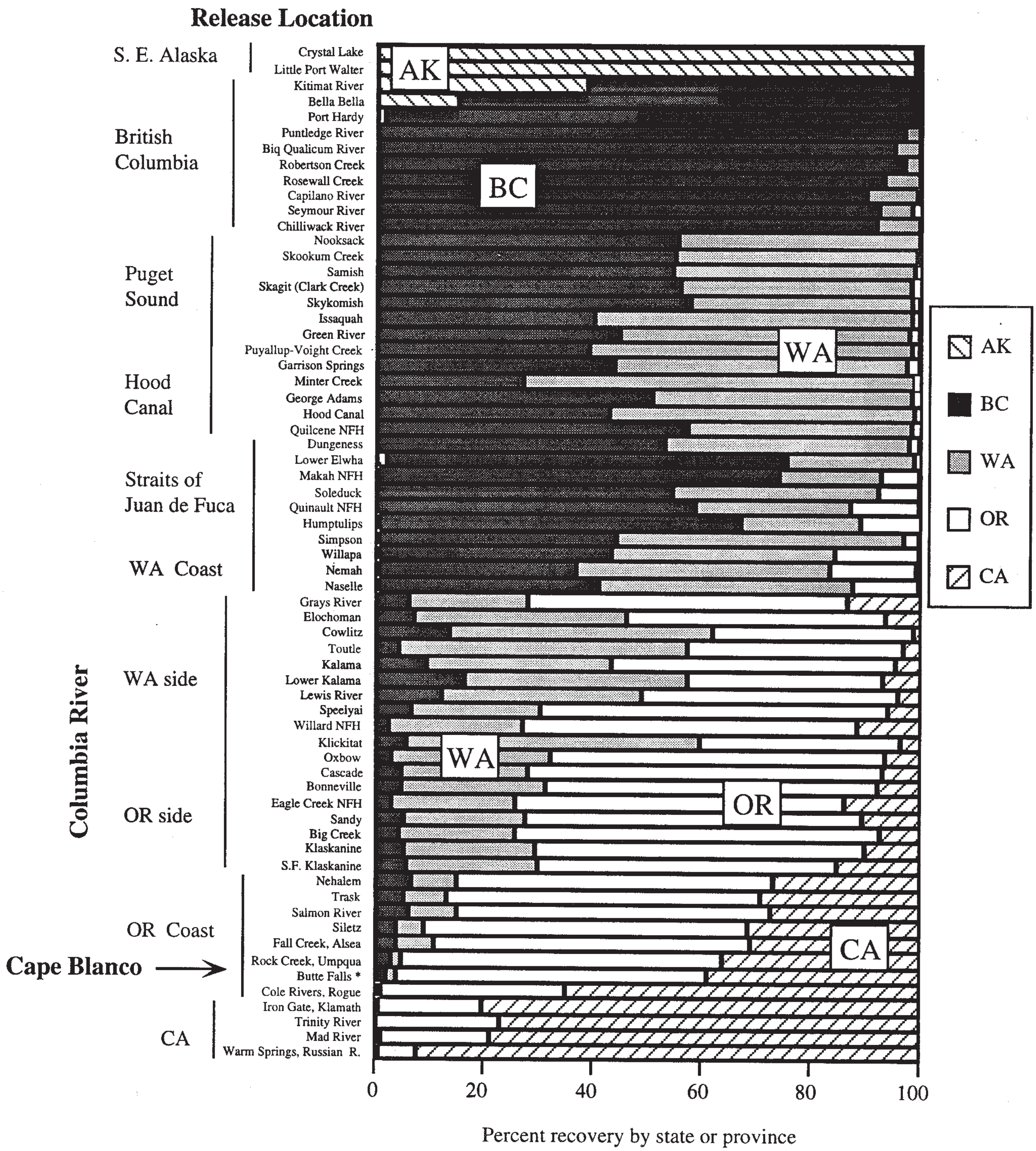


Figure 19. Marine recoveries by state or province of coded-wire-tagged coho salmon released from selected hatcheries in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA). *Butte Falls Hatchery is located on the Rogue River but rears Umpqua River coho salmon and releases them into the Umpqua River. (PSMFC 1994).

California and southern Oregon facilities. Whether this represents a unique recovery pattern, or results from the southerly location of the hatchery, is not known. No hatcheries in central California release or recover sufficient numbers of coho salmon tags to be used for comparison.

2) Oregon coast north of Cape Blanco. Tagged coho salmon from Oregon coast hatcheries north of Cape Blanco have a more northern distribution than those released farther south. The majority of Oregon coast coho salmon are recovered in Oregon (57-60%), followed by California (27-39%), Washington (2-9%), British Columbia (2-6%), and Alaska (<1%) (Fig. 19). The Butte Falls Hatchery is located on the Rogue River (south of Cape Blanco) but rears Umpqua River fish and releases them into the Umpqua River. The recovery pattern of these fish is most similar to the Oregon coast pattern, rather than nearby Cole Rivers Hatchery, indicating that ocean distribution is more heavily influenced by stock history and release location than it is by rearing location.

3) Columbia River. Coho salmon released from Columbia River hatcheries are recovered primarily in Oregon (36-67%) and Washington (22-54%), with lower but consistent recoveries from British Columbia (2-16%) and California (1-15%) (Fig. 19). Compared to Oregon coast coho salmon, Columbia River fish are recovered less frequently in California and more frequently in Washington. Although they share the same general recovery pattern, coho salmon from Washington-side Columbia River hatcheries are caught more frequently in Washington and British Columbia and less frequently in Oregon than those from Oregon-side hatcheries. This is presumably the result of a successful program aimed at increasing the Washington catch of Washington-produced Columbia River coho salmon (Hopley undated).

4) Washington coast. Coho salmon released from these coastal hatcheries are recovered primarily in British Columbia (37-74%) and Washington (18-53%), with few recoveries from Oregon (3-16%) and almost none (<1%) from California or Alaska (Fig. 19). Compared to Columbia River fish, Washington coastal hatchery coho salmon have much higher recovery rates from British Columbia and much lower recovery rates from Oregon and California. The Makah National Fish Hatchery produces coho salmon with exceptionally high recoveries in British Columbia. As this facility is closest to Canadian waters, its fish may be more susceptible to Canadian fisheries than other coastal stocks. Tagged coho salmon from the Simpson Hatchery (Chehalis River) have very low Oregon recoveries and relatively high Washington recoveries, perhaps reflecting high terminal marine fisheries.

5) Puget Sound, Hood Canal and Strait of Juan de Fuca. Coho salmon released from Puget Sound, Hood Canal, and Strait of Juan de Fuca hatcheries have approximately equal marine recoveries from Washington (23-72%) and British Columbia (27-74%), with few recoveries from Oregon (0-3%), and essentially none from Alaska or California (Fig. 19). Recovery patterns from this group are similar to those of fish released from the Washington coast, except that the Oregon catch is much smaller and the Washington catch tends to be higher. Lower Elwha River Hatchery fish have a recovery pattern which is intermediate between that of fish from hatcheries to the east and west; their high British Columbia recoveries are similar to recoveries of fish from the Makah National Fish Hatchery. These fish are seldom recovered in Oregon, however, which is the pattern typical of coho salmon from Puget Sound/Hood Canal and other Strait of Juan de Fuca hatcheries.

The proportion of Washington recoveries for coho salmon released from Puget Sound hatcheries generally increases from north to south, presumably because fish returning to south Puget Sound facilities spend more time in Washington waters. Removing Puget Sound recoveries from Washington recoveries to correct for marine fisheries that other populations are not subjected to, results in this group having recovery patterns intermediate between those from the Washington coast and British Columbia (Fig. 20). The "corrected" marine recoveries are highest in British Columbia (65-86%), followed by recoveries in Washington waters outside of Puget Sound (14-32%), with few recoveries in Oregon and California (<3% combined) (J. DeLong 1994 App.).

6) Southern British Columbia. Coho salmon released from Vancouver Island and south mainland British Columbia facilities are recovered primarily from British Columbia (90-99%) and Washington (0-9%), with few recoveries from Alaska (0-1%), Oregon (<1%), or California (0%) (Fig. 19).

7) Northern British Columbia. Marine CWT recovery patterns for fish released from British Columbian facilities north of Vancouver Island are intermediate between those from Alaska and Vancouver Island/south British Columbia mainland, with the majority of recoveries from British Columbia (61-85%), and the remainder from Alaska.

8) Alaska. Tagged coho salmon released from Alaskan facilities were overwhelmingly recovered in Alaskan waters (>98%), with the remainder captured in British Columbia (Fig. 19).

The methodology used in this analysis did not address several sources of variability that may have altered the observed patterns. For example, experimental release groups may have had unique migration patterns compared to nonexperimental production releases from the same facility, and observed migration patterns were probably also affected by differences in the number of tags released and recovered each year, and by interannual variation in migration patterns. However, addressing these factors was beyond the scope of our status review. Because the observed differences in recovery patterns between areas were large and often represented presence or absence of recoveries by state or province rather than differences of a few percentage points, manipulations to correct for sources of variability would be expected to clarify, rather than cloud, recovery patterns. For example, Puget Sound coho salmon are not recovered in California, and no amount of data manipulation is likely to change that fact.

Although there appear to be differences in CWT recovery patterns between hatchery populations from the eight areas, it is reasonable to ask whether hatchery migratory patterns are similar to those of nearby naturally spawning populations and can therefore be used as a surrogate for naturally spawning populations. In order to address this uncertainty, CWT recovery patterns of the few naturally spawning populations that have been tagged were compared to those of nearby hatchery populations. In most cases, recovery patterns of the two

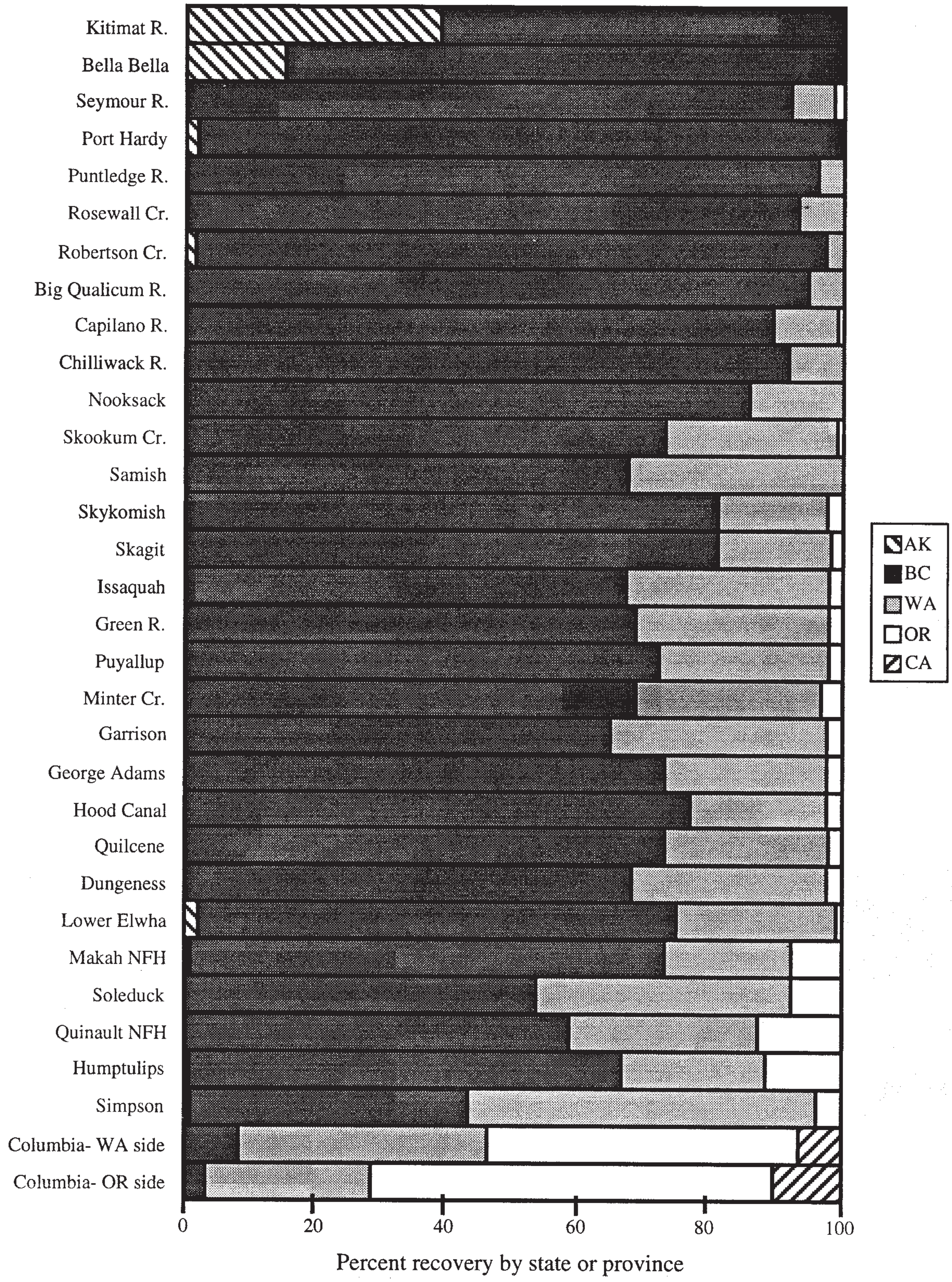


Figure 20. Marine recoveries by state or province of coded-wire-tagged coho salmon released from Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR) and California (CA) hatcheries. Washington recoveries from Puget Sound and Hood Canal hatcheries have been "corrected" by removing Puget Sound recoveries from the total Washington recoveries, an area not frequented by coho salmon from other areas. (PSMFC 1994).

groups were quite similar to each other (Fig. 21) and to the regional pattern (Garrison and Carmichael 1982, Garrison 1985, Cramer and Cramer 1994, Lestelle and Weller 1994, PSMFC 1994). The two populations (from the Hoko and Skokomish Rivers) which were less similar to nearby hatcheries are purposely avoided by terminal fisheries targeting the hatchery runs (WDF et al. 1992).

Other methods—An assessment of differences in ocean migration patterns independent of CWT recovery patterns was also made by considering changes in adult size from different areas during anomalous years. Interannual variation in adult size is largely caused by variation in growth rates during the last year in the ocean (van den Berghe and Gross 1989). Assuming that variation in ocean productivity is area-specific, differences in ocean migration patterns could cause differences in growth rates and therefore in adult size, in addition to other factors which may also influence adult size. Distinctive differences in adult size between areas were apparent during anomalous years. For example, adult coho salmon from the Columbia River and Oregon coast north of Cape Blanco experienced a dramatic decrease in size in 1983 during the strong El Niño (Johnson 1988), and underwent smaller decreases in size in 1989 and 1992 (Fig. 22) (S. Jacobs 1994a App., S. King 1994 App., S. Markey 1994 App.). Coho salmon from other areas did not exhibit the marked size decrease in 1983 but showed decreases during other years (Figs. 22-23). For example, Rogue River fish declined in size in 1979 and 1982 (ODFW 1989), Washington coast fish size declined slightly in 1976, 1989 and 1992 (WDFW 1994a), and Puget Sound coho salmon size declined in 1976, 1984, and 1993 (WDFW 1994a).

These patterns suggest that the ocean environment experienced by these groups were different, at least during the anomalous years; this difference would occur if ocean migration patterns were also different. The CWT recovery patterns (Fig. 19, Appendix Table C-6) generally agree with groupings based on observed patterns in adult size: Rogue River (Cole Rivers Hatchery) fish are predominately recovered in California; both Oregon coast and Columbia River coho salmon have high recovery rates from Oregon, and low rates from Washington and British Columbia; and Washington coast and Puget Sound/Hood Canal coho salmon have high recovery rates from Washington and British Columbia, and low recovery rates from Oregon. Although the true causes of unusually small adult sizes from some areas and not others is not known, it is likely that ocean migration patterns are a factor.

Ocean migration patterns and genetic heritage—This discussion assumes that differences in migratory patterns between areas, as inferred from CWT recovery patterns or changes in adult size, reflect differences in the genetic heritage of those groups. Several lines of evidence support the notion that ocean migration patterns have some genetic basis. For example, CWT recovery patterns of local and transplanted coho salmon released from the same general area are often different. Oregon Aqua Foods (Yaquina Bay) and Anadromous Inc. (Coos Bay) began coho salmon production using primarily Puget Sound stocks (Wagoner et al. 1990, Borgenson et al. 1991). The CWT recovery patterns from these fish are much more northerly than those of other Oregon coast stocks (Table 2) (PSMFC 1994), despite the high Oregon recoveries, presumably from terminal fisheries, which target these two stocks. Similarly, Alsea and Klaskanine coho salmon were released from California hatcheries (Jensen 1971). Klaskanine recovery patterns were much more northerly than patterns of local stocks,

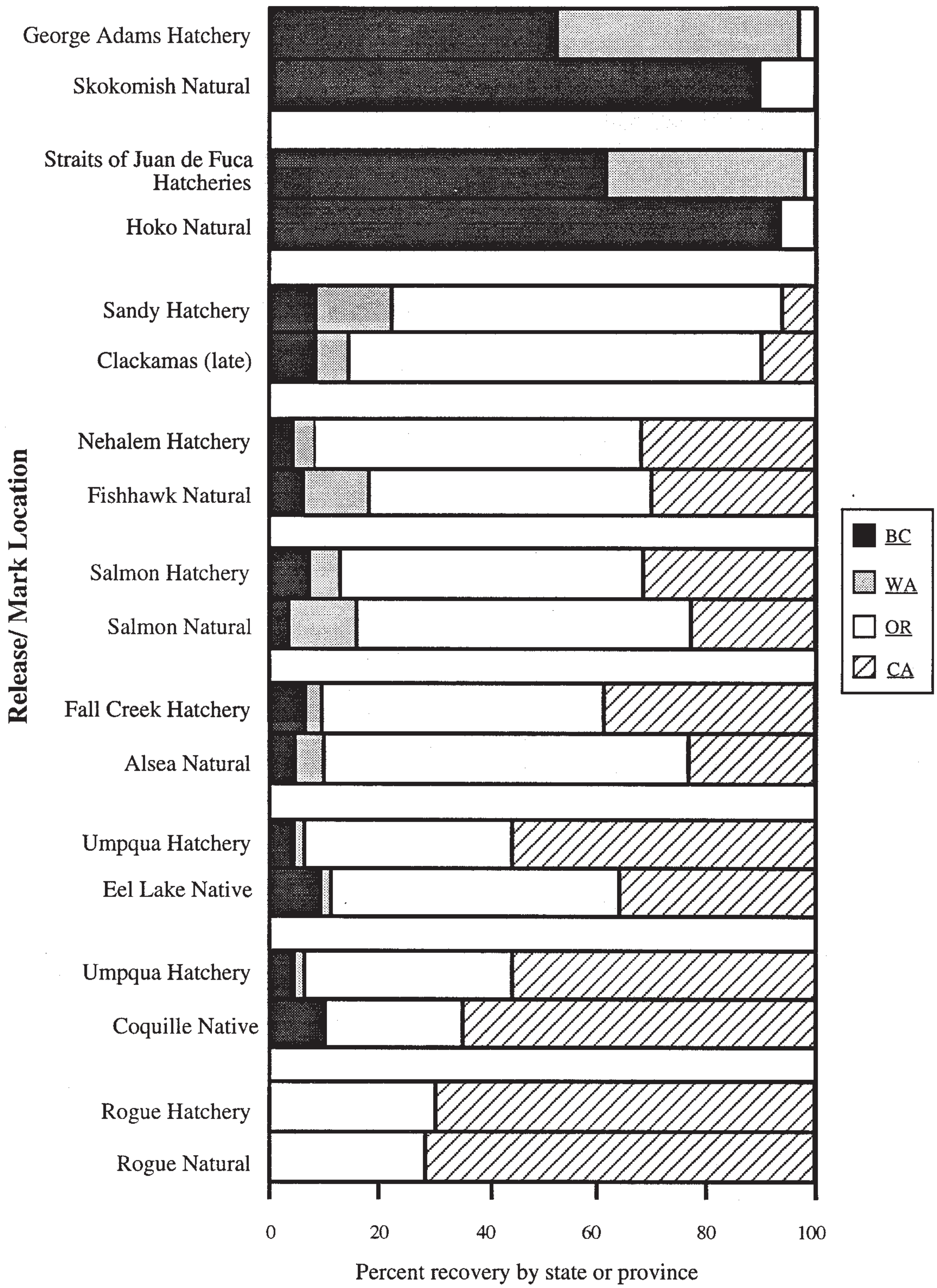
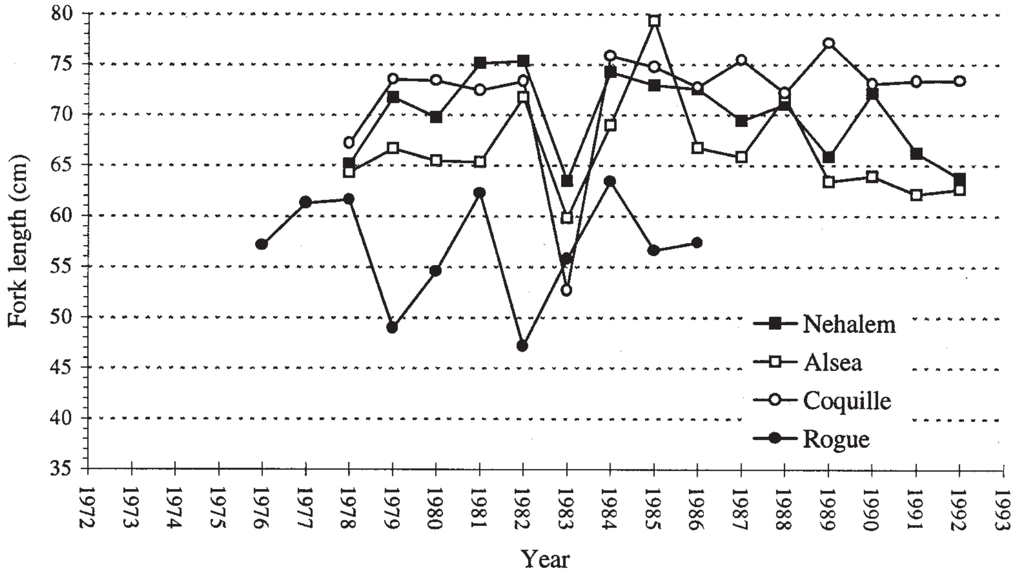


Figure 21. Comparison of marine coded-wire-tag recovery patterns from naturally spawning populations, and adjacent hatchery populations in British Columbia (BC), Washington (WA), Oregon (OR), and California (CA). (Garrison and Carmichael 1982, Garrison 1985, Lestelle and Weller 1994, Cramer and Cramer 1994, PSMFC 1994).



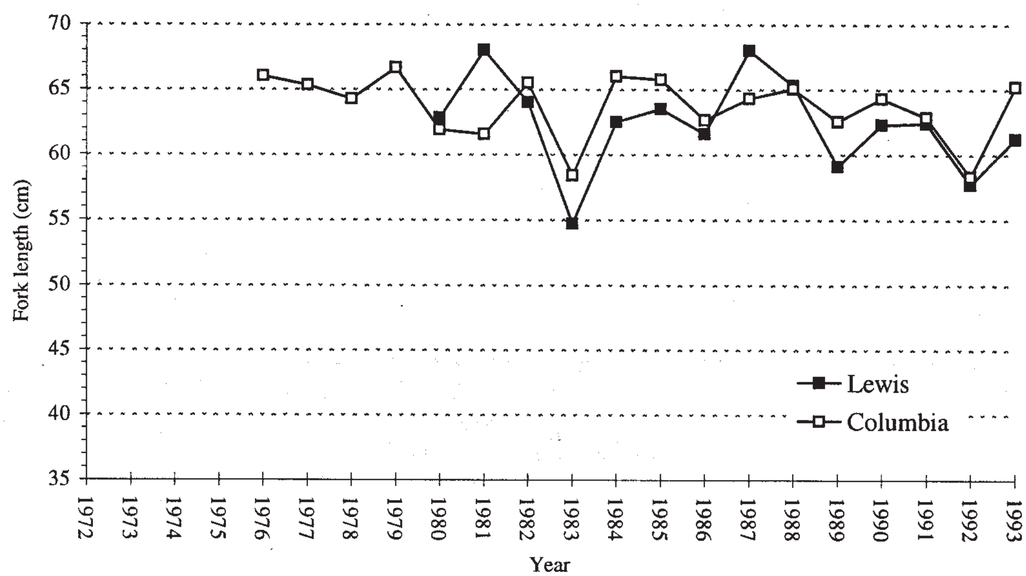


Figure 22. Patterns of adult size (fork length (cm)) over time from selected Oregon coast (top) and Columbia River (bottom) coho salmon populations. Data from ODFW 1991, S. Jacobs 1994b App., S. King 1994 App., and S. Markey 1994 App.

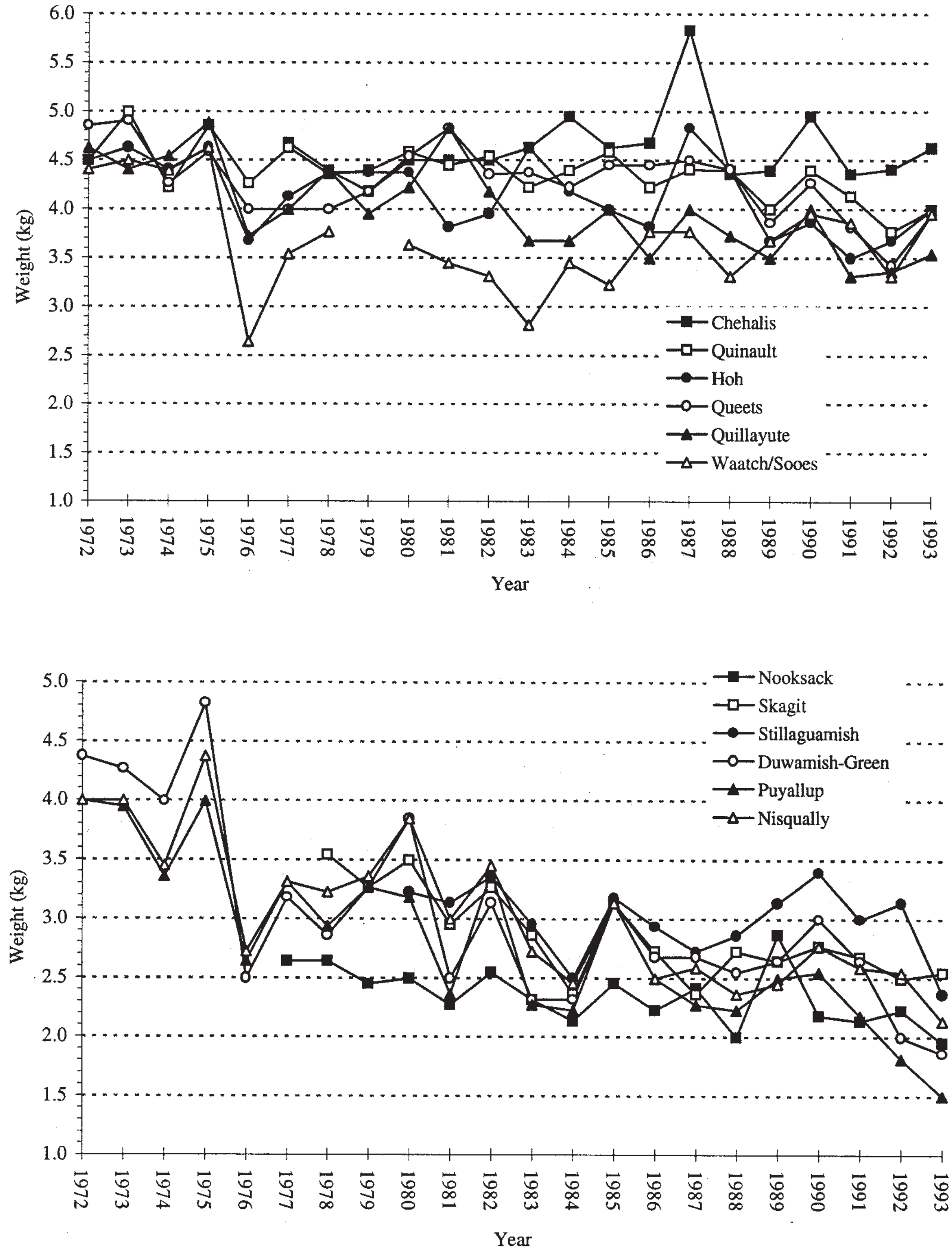


Figure 23. Patterns of adult size (weight (kg)) over time from selected Washington coast (top) and Puget Sound (bottom) coho salmon populations. Fish were caught in river. Data from WDFW 1994a.

Table 2. Comparison of ocean recovery patterns of marked local and exotic coho salmon stocks released from the same general areas (PSMFC 1994 and Jensen 1971).

Local/ exotic	Stock	Release location	Years	Recovery (%) by state/province[a] BC	WA	OR	CA
Exotic	Puget Sound	Anadromous Inc., Coos Bay	75, 77-87	16	9	71	5
Exotic	Puget Sound	Oregon Aqua Foods, Yaquina Bay	74-89	13	12	69	5
Local	Oregon coast	Oregon coast north of Cape Blanco	73-89	2-6	2-9	57-60	27-39
Exotic	Klaskanine R.	Mad River	57, 61			42[b]	59
Local	Pudding Cr.	Pudding Creek[c]	57, 61			3[b]	98
Local	Mad River	Mad River Hatchery	75, 78-79, 84-86	0	1	20	79
Exotic	Alsea River	Noyo River	61-62			9[b]	91
Local	Pudding Cr.	Pudding Creek[c]	61-62			11[b]	90

[a]Percentages may not add to 100% because of rounding.
[b]Includes marine recoveries from both Washington and Oregon.
[c]Pudding Creek is approximately 165 km south of the mouth of the Mad River and 3 km north of the mouth of the Noyo River.

although Alsea patterns were not (Table 2). The WDFW has also based much of its Columbia River coho salmon production on migration patterns of different stocks (Hopley undated). The agency has concentrated production on Type N (north-turning) stocks because they are caught more frequently by Washington fishers than Type S (south-turning) stocks. Other studies using different salmon species have indicated that ocean migration patterns are a heritable characteristic (Nicholas and Hankin 1988).

In conclusion, it appears that at least some portion of ocean migration patterns are genetically based. Given the similarity of recovery patterns for hatchery and nearby naturally spawning populations, hatchery and naturally spawning coho salmon from the eight different regions have distinctive ocean migration patterns, suggesting similar genetic heritages.

Disease

Disease resistance is listed as one of several phenotypic traits to consider when determining the ecological/genetic importance of salmon populations under the ESA (Waples 1991b, p. 14). Using this guideline, the resistance to *Ceratomyxa shasta* of most Columbia River coho salmon was one of many factors contributing to the conclusion that lower Columbia River coho salmon were a historical ESU (Johnson et al. 1991). It was recently suggested that coho salmon from the Nehalem River, Oregon, qualify as their own ESU because they are the only Oregon coast stock which is resistant to *C. shasta* (Cramer 1994). Aside from the fact that numerous factors in concert are used to determine ESU boundaries, several key questions remain to be adequately answered concerning resistance to, and the historical distribution of, *C. shasta* in the Nehalem River.

At present, there is considerable confusion surrounding the historical resistance of populations to *C. shasta*, likelihood of *C. shasta* resistance detection, and the rate at which populations may acquire resistance (Zinn et al. 1977). The documented distribution of *C. shasta* within the Pacific Northwest has been expanding since its discovery in 1948 (Hoffmaster et al. 1988, Bartholomew et al. 1989). Whether this increase reflects a true spread of the disease or improved detection methods remains unclear (Bartholomew et al. 1989). However, it appears that the abundance of *C. shasta*, at least in the Columbia River Basin, really is increasing (Ratliff 1983), and may be spreading to other areas. Accordingly, the historical presence and abundance of *C. shasta* within other river basins, such as the Nehalem, is unknown.

Conflicting reports about *C. shasta* resistance of several coho salmon populations, such as those of the Alsea River (Schafer 1968, Udey et al. 1975, Zinn et al. 1977) and Columbia River (Conrad and Decew 1966, Hemmingsen et al. 1986), have also confused the interpretation of *C. shasta* resistance. *Ceratomyxa shasta*-resistance has also been identified in populations which are not thought to have been exposed to the parasite, and not all populations that are expected to be resistant because of exposure are in fact resistant (Zinn et al. 1977). In addition, there is also some concern that commonly used methods of detecting infection in fish are inadequate (Yasutake et al. 1986, Bartholomew et al. 1992), while methods of detecting the parasite in open waters are hampered by parasite concentrations which have high spatial and temporal variability (Sanders et al. 1970, Hoffmaster et al. 1988). These factors make it difficult to interpret resistance to C. shasta in terms of ESU determinations.

Clackamas River Late-Run Coho Salmon

One population that warrants specific discussion because of its complex history is late-run Clackamas River coho salmon. The Clackamas River, a tributary of the Willamette River, was excluded from the petition for lower Columbia River coho salmon considered by NMFS in 1991 (Johnson et al. 1991), but it is within the area under consideration for this status review. Cramer and Cramer (1994) suggested that this population is the last remaining viable wild coho salmon population in the Columbia River Basin. This section briefly reviews information relevant to coho salmon from the Clackamas River; unless noted, the following information comes from Cramer and Cramer (1994).

The Clackamas River historically had runs of coho salmon and other anadromous species. However, the river also has a long history of obstructions to fish passage by dams. Cazadero Dam (1905, River Kilometer (RKm) 47) and River Mill Dam (1911, RKm 38) were the first large dams to completely block river flow. Both dams were equipped with fish passage facilities, which were often blocked for egg taking. In 1917, the fish ladder at Cazadero Dam washed out, and for 22 years, until the fish ladder was finally restored in 1939, coho salmon were unable to access the upper Clackamas River.

Subsequently, the upper river was repopulated by natural immigration and, possibly, unrecorded releases. Because of the relatively low success of hatcheries at producing adult coho salmon at that time (Hopley undated, Lichatowich and Nicholas in press), the immigrants were most likely natural coho salmon from either the Clackamas River below RKm 47, the Willamette River, or elsewhere in the lower Columbia River. In 1958, North Fork Dam was built at RKm 50. This dam was built with an extensive fish passage facility that has allowed enumeration of salmon entering and leaving the upper Clackamas River.

The history of coho salmon production and runs in the Clackamas River is also complex. Delph Creek Hatchery, located on Eagle Creek (Clackamas River) first raised coho salmon between 1945 and 1948, using Stubbe Creek (a Clackamas River mainstem tributary) as the source population. After the closure of Delph Creek Hatchery in 1954, the Eagle Creek Hatchery began operation in 1956. Initially, Eagle Creek Hatchery used two stocks of coho salmon: an early-run stock transplanted from the Sandy and Toutle Rivers, and a late-run stock which was present at the site and was possibly the progeny of Delph Creek Hatchery stocks. Eagle Creek Hatchery managers recognized that the two stocks had different run timings—the earlier Sandy/Toutle stock spawning peak occurred in November, and the later "natural" stock peak occurred in January—and made attempts to avoid spawning the two stocks together. However, the criteria by which the two groups were differentiated is not known, so it is possible that some mixing of the two stocks occurred. In 1967, production of the late-run stock at the Eagle Creek Hatchery was terminated, confining coho salmon production to the early-run Sandy/Toutle-derived stock.

At present, the distribution of coho salmon passing the North Fork Dam is bimodal (Fig. 24), with a peak of early-run fish passing the dam in September, and a late-run peak passing the dam in January/February. Early and late-run populations also spawn in different areas of the basin, with the earlier fish spawning higher in the basin than later fish. It has been suggested that differences in run timing between the early and late populations, in addition to spatially-segregated spawning areas, have kept the two populations reproductively isolated. However, the early and late runs are much earlier and later, respectively, than they formerly were.

Beginning with the first North Fork Dam counts until about 1980, the distribution of coho salmon over the dam was unimodal, with a single peak in late November/early December, which presumably included both early and late runs (Fig. 24). Cramer and Cramer (1994) argued that intensive fishing pressure during the middle of this peak, targeted on Cowlitz River coho salmon, caused the changes in run timing. According to this hypothesis, this severe harvest pressure selected against the intermediate run timing and forced the two tails of the Clackamas River run to diverge, thus producing the current bimodal distribution of unusually early- and unusually late-running coho salmon.

Since the run timing over the North Fork Dam of early- and late-run Clackamas coho salmon overlapped extensively prior to about 1980, the spawn timings of the two populations may have also overlapped. Spawning areas currently available to late-run coho salmon are thought to be limited by the cold water temperatures they encounter because of their late run timing. Prior to the shift to even later run timings, late-run coho salmon may have been able to use more of the upper basin, potentially overlapping areas used by early-run fish. Although early- and late-run Clackamas coho salmon currently appear to be reproductively isolated spatially and temporally, they may have been less so previously, and this would have allowed mixing of the two populations either naturally in the river or in the Eagle Creek Hatchery, where both populations were maintained between 1956 and 1967.

Cramer and Cramer (1994) suggested that late-run Clackamas coho salmon are distinctive from other lower Columbia River coho salmon because of their late run timing, ocean migration pattern, large adult size, high fecundity, and small egg size. Current timing of late-run Clackamas River coho salmon is extreme, with spawning occurring from February to March. However, the historical timing of late-run Clackamas coho salmon is thought to have occurred in December or January, closer to other native, lower Columbia River coho salmon populations. The ocean distribution of late-run Clackamas coho salmon, as inferred from marine CWT recoveries, includes fewer Washington recoveries than other Oregon-side, lower Columbia River early-run hatchery populations but is otherwise similar to these (Fig. 25), and other Columbia River populations, as discussed earlier (Fig. 19).

Adult late-run Clackamas coho salmon are large compared to other lower Columbia River and west coast coho salmon (Fig. 14, Appendix Table C-5). However, this is not surprising because they reside longer in the ocean than other coho salmon, especially during the late summer and early fall when growth is rapid (Allen 1959). Other late run coho salmon, such as those from the Satsop River (Chehalis River Basin), are also large (WDF 1966).

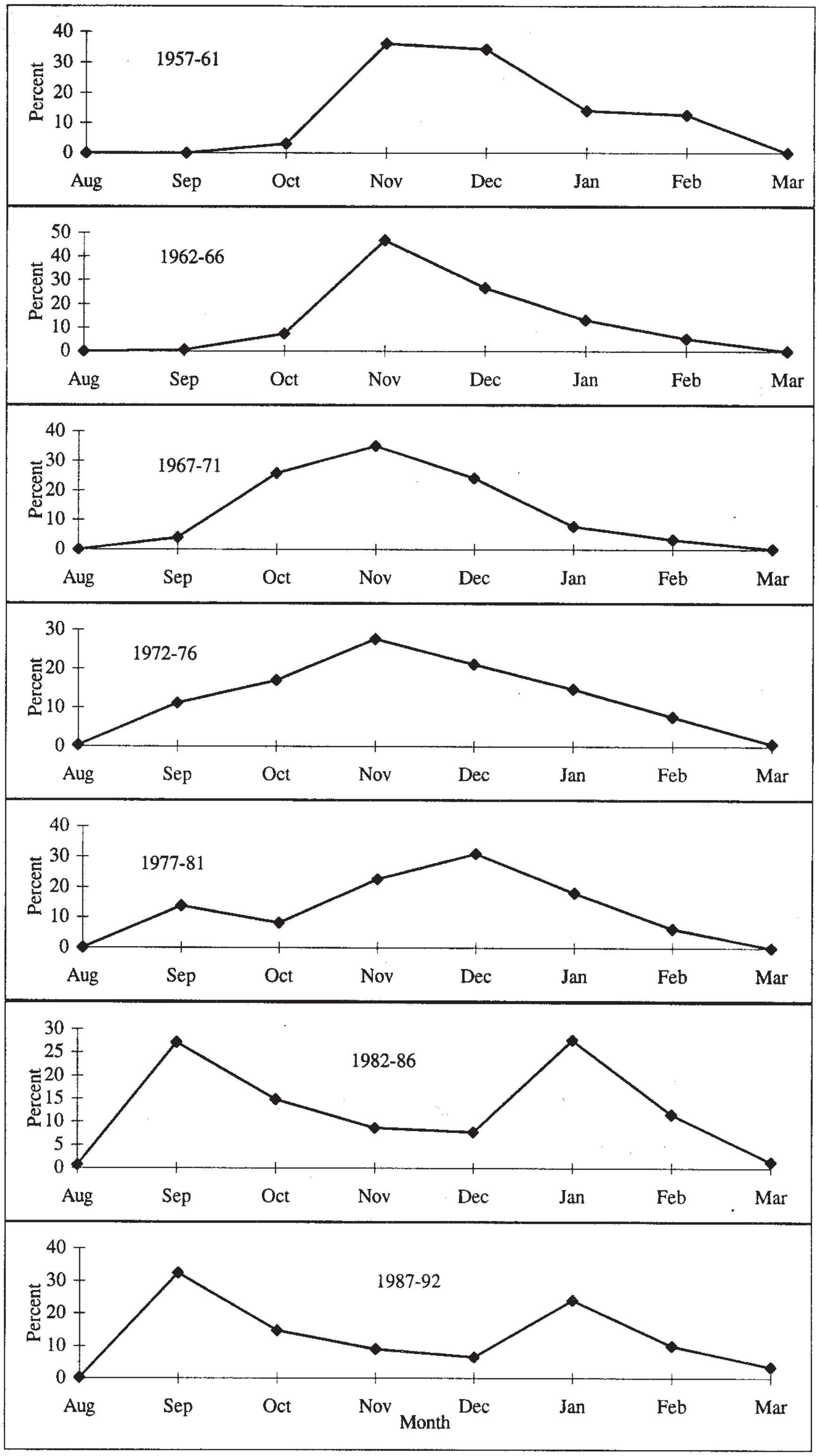


Figure 24. Percent of the total run of coho salmon passing over the North Fork Dam (Clackamas River) each month, grouped by five-year periods, 1957-92. Since about 1980, the passage of coho salmon over the dam has changed from a unimodal distribution, centered around November/ December, to a bimodal distribution with peaks in September and January. (Cramer and Cramer 1994.)

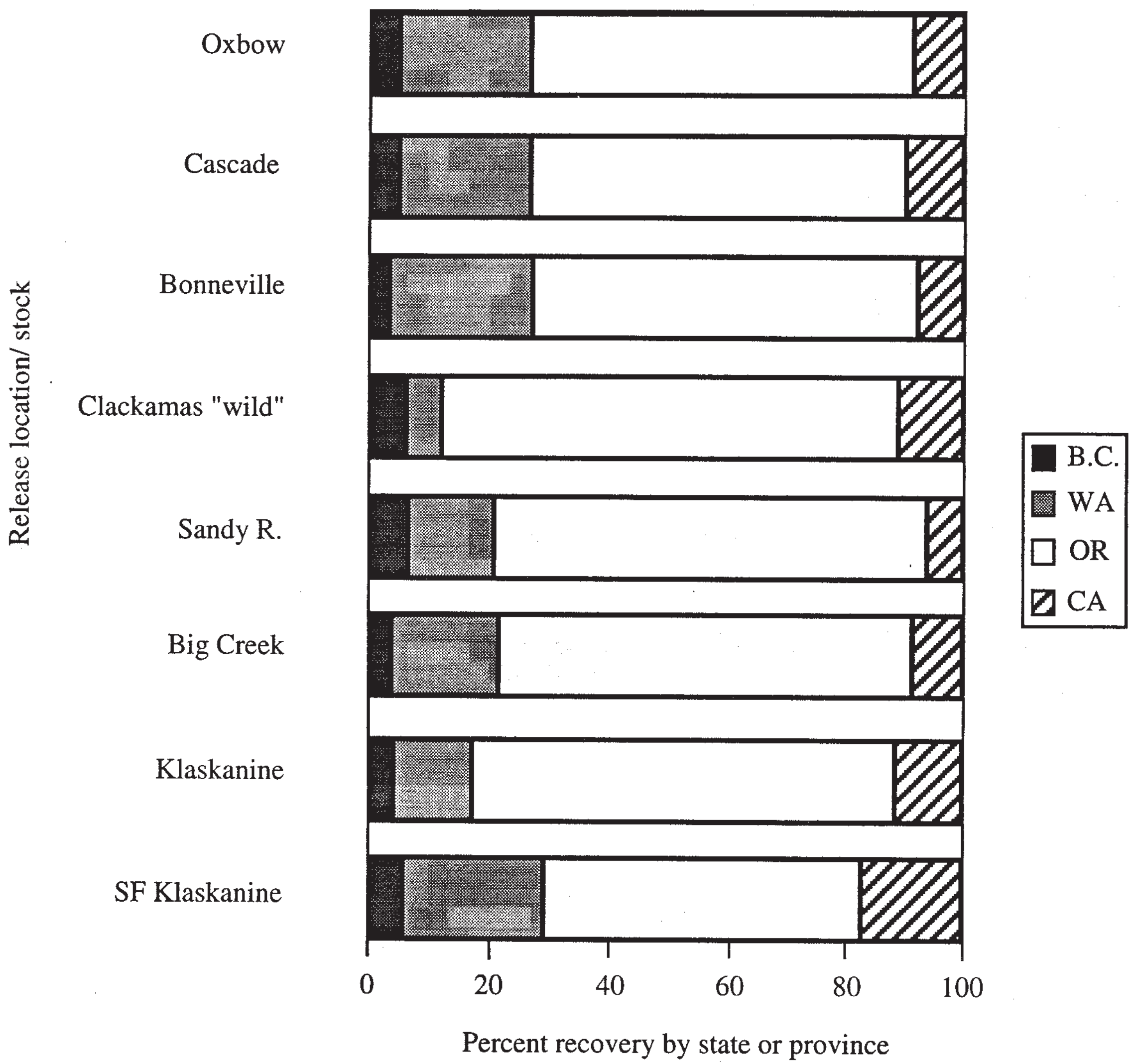


Figure 25. Marine CWT recoveries by state or province for late-run Clackamas River and Oregon-side Columbia River coho salmon hatchery populations, 1988-90. Bars indicate the percentage of all marine recoveries of tagged fish recovered from British Columbia (BC), Washington (WA), Oregon (OR), and California (CA) marine waters. (Cramer and Cramer 1994, PSMFC 1994.)

Based on a limited comparison with two Columbia River hatchery stocks, Cramer and Cramer (1994) suggested that Clackamas River coho salmon have high fecundity and small egg size. However, compared to other west coast coho salmon, late-run Clackamas coho salmon do not have exceptionally high fecundity given their body size (Fig. 26) (Crone and Bond 1976, Beacham 1982, Cramer and Cramer 1994), nor is their egg size, expressed as egg weight, unusually small (Fig. 27) (Fleming and Gross 1989, Cramer and Cramer 1994). If anything, the hatchery populations used by Cramer and Cramer (1994) for comparison purposes were unusual, having large egg size and relatively low fecundity given their size. Although Clackamas River coho salmon do have a late run timing and are large, neither of these traits are unusual within the Columbia River Basin, nor was their fecundity or egg size exceptional. Consequently, we found no characteristics which would clearly distinguish late-run Clackamas River coho salmon from other Columbia River stocks.

Genetics

Previous Genetic Studies

Since 1982, a variety of genetic studies have found evidence for population structure in coho salmon using allozymes, transferrin, or DNA characters. However, these studies were limited to specific geographical regions and did not examine patterns of genetic relationships on a broader basis. In addition, several other factors may have limited the conclusions that could be drawn from these studies.

First, allozyme studies published prior to 1988 included less than half of the 10 most polymorphic loci recently identified for coho salmon (Milner 1993). These previous studies generally reported a lack of genetic variation and relatively low levels of population subdivision. Second, many of these studies were also limited by small sample sizes. The use of small sample sizes may be a particular problem for coho salmon because of the large number of loci which are variable at low levels (Reisenbichler and Phelps 1987, Bartley et al. 1992).

Finally, several of the studies (Hjort and Schreck 1982, Olin 1984, Solazzi 1986, Bartley et al. 1992) used data for the highly variable transferrin locus. Suzumoto et al. (1977) and Winter et al. (1980) reported differential resistance to bacterial kidney disease among transferrin genotypes. Also, Pratschner (1978) showed differential mortality from vibriosis, cold-water disease, and furunculosis between transferrin genotypes. Because transferrin polymorphisms may be maintained by a selective mechanism and may reflect adaptive properties of different genotypes rather than ancestral relationships, data for this locus are difficult to interpret in terms of population structure.

Bartley et al. (1992) examined the population structure of coho salmon from 27 California populations using 22 variable allozyme loci and the transferrin locus. They reported low levels of variability and little evidence of geographic pattern to the observed genetic variability. However, Bartley et al. (1992) did find significant allele frequency differences among all samples as well as within six regional groupings. They pointed out that the “genetic

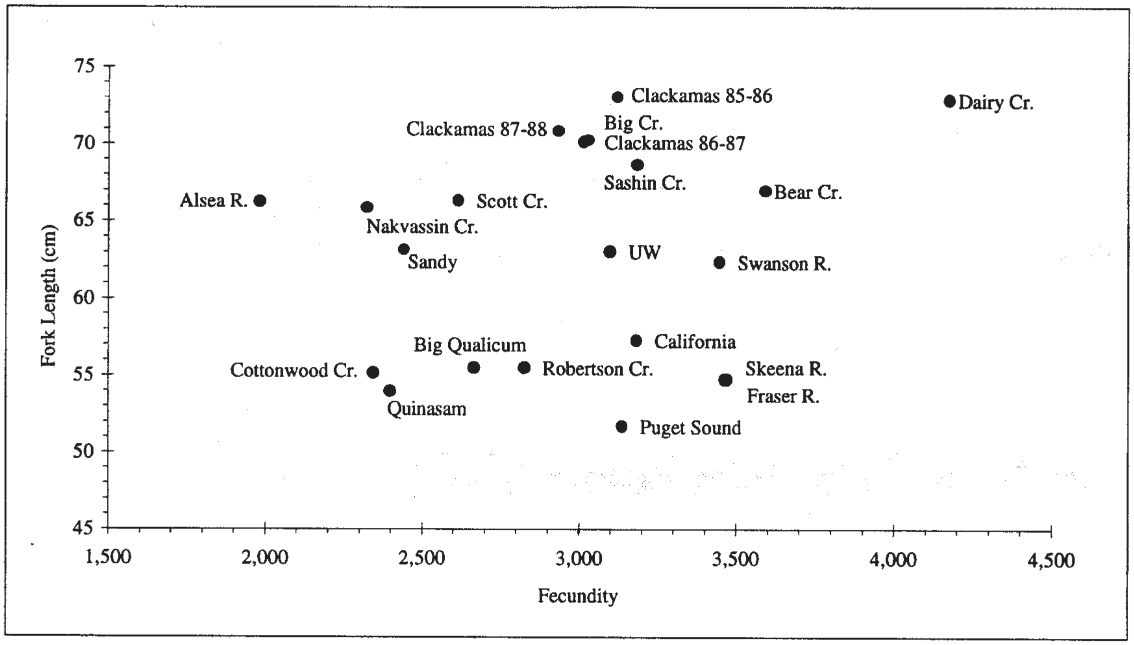


Figure 26. A comparison of fecundity and female size (cm fork length) for late-run Clackamas River coho salmon with other coho salmon populations in British Columbia, Washington, Oregon, and California. (Crone and Bond 1976, Beacham 1982, Cramer and Cramer 1994.)

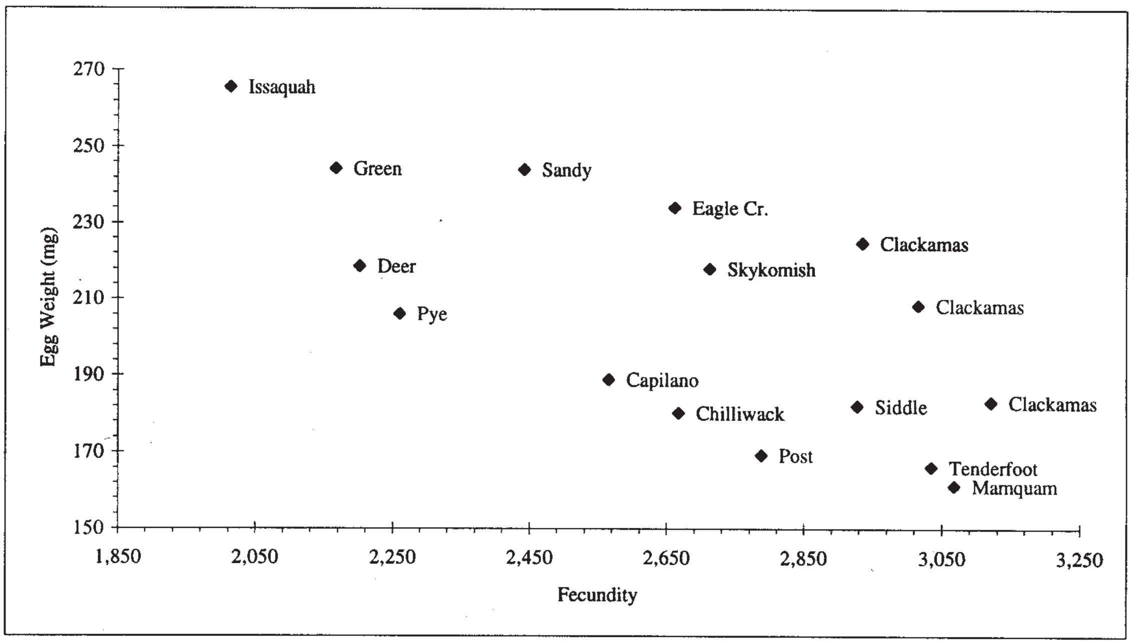


Figure 27. A comparison of egg size (mg) and fecundity for late-run Clackamas River coho salmon with other coho salmon populations in British Columbia, Washington, and Oregon. (Fleming and Gross 1989, Cramer and Cramer 1994.)

analyses could be greatly improved by increasing the samples sizes," which averaged only 34 fish per sample.

In a study based on 30 variable allozyme loci in addition to transferrin, Olin (1984) found a generally low level of genetic variability in 23 samples from the Oregon coast. He identified four major genetic groupings: 1) the Nehalem River south to the Coos River (just north of Cape Arago); 2) the Nehalem River south to the Alsea River; 3) the Siuslaw River south to Morton Creek (just north of Cape Blanco); and 4) the Rogue and Klamath Rivers. The last group was the most southerly and the most genetically distinctive. Geographic coverage of groups 1 and 2 overlapped and also were the most genetically similar.

Solazzi (1986) examined a dendrogram provided by researchers from the University of California at Davis. This dendrogram was based on some of the data from the allozyme and transferrin studies reported by Olin (1984) and Bartley et al. (1992) and included hatchery and wild samples from the Columbia River (n = 8), the Oregon coast (n = 28), and the California coast (n = 16). The dendrogram featured three major clusters: 1) Oregon coast north of the Rogue River; 2) Columbia, Rogue, and Klamath Rivers, plus two samples from small rivers north of Cape Mendocino; and 3) California samples from south of Cape Mendocino. Eight samples, including three from the Oregon coast and five from California, were outliers and only loosely associated with the major clusters.

Hjort and Schreck (1982) examined population structure using an agglomerative method based on frequencies for one allozyme locus (GPI-B2*) and transferrin, as well as life history and morphological characters. Over half (23) of their samples were from the Oregon coast, with others representing the Washington coast (1), Hood Canal (1), the Columbia River (7), and California (3). Their cluster analysis identified three major groupings: 1) hatchery populations from the north coast of Oregon; 2) Columbia River populations, as well as samples from the Rogue and Klamath Rivers; and 3) coastal Oregon populations. The Oregon coastal group consisted of subclusters of hatchery samples from the south coast, natural samples from the mid coast, and natural samples from the north coast. Three hatchery samples (Quinault from the Washington coast, Quilcene from Hood Canal, and Mad River from the California coast) were outliers in the analysis, being distinct from the three major groups and also from each other.

Reisenbichler and Phelps (1987) used 21 variable allozyme loci and found little geographic structure among seven samples of coho salmon from the northwestern coast of Washington.

Wehrhahn and Powell (1987) surveyed 16 gene loci of low variability for 95 populations from southern British Columbia and reported significant differences between allele frequencies from the lower coastal mainland of British Columbia and those of Oregon reported by Olin (1984). They also reported significant differences between upper Fraser River and lower coastal mainland fish. However, Wehrhahn and Powell (1987) concluded that, based on the distribution of rare alleles, "there are no absolute barriers to dispersal and to gene flow in the area we sampled" (p. 825).

Two recent reports have studied variation in coho salmon at the DNA level. Currens and Farnsworth (1993) studied mitochondrial DNA variation in 18 Oregon populations. Their analysis identified three major groups: 1) north and central coastal Oregon; 2) the Columbia River, and 3) south coastal Oregon (Rogue and Coquille Rivers), together with two Columbia River populations (the Clatskanie and Clackamas Rivers). Forbes et al. (1993) examined nuclear DNA variation for two growth hormone genes in seven samples from Columbia River and Oregon coastal populations. They reported highly significant differences between Columbia River and Oregon coastal coho salmon but only "marginal differences among stocks within these regions."

New Data

NMFS geneticists have collected allozyme data over a 10-year period from over 100 coho salmon samples as part of Genetic Stock Identification (GSI) studies (Milner 1993), a previous ESA status review (Johnson et al. 1991), and for this status review. Sample locations ranged from California to Alaska, with a primary focus on Oregon, Washington, and southern British Columbia (Table 3, Fig. 28). Electrophoretic procedures described by Aebersold et al. (1987) were used to examine up to 87 loci coding for 39 enzymes (Milner 1993). The following 53 loci were variable and used to examine population structure (locus nomenclature follows Shaklee et al. 1990): *sAAT-1,2*; sAAT-3*; sAAT-4*; ADA-1*; ADA-2*; mAH-2*; sAH*; ALAT*; CK-A1*; CK-A2*; CK-C1*; CK-C2*; EST-1*; FBALD-3*; FBALD-4*; FH*; bGALA*; GAPDH-2*; GAPDH-3*; GAPDH-4*; bGLUA*; GPI-A*; GPI-B1*; GPI-B2*; GR*; HAGH*; mIDHP-1*; mIDHP-2*; sIDHP-1*; sIDHP-2*; LDH-A1*; LDH-A*2; LDH-B1*; LDH-B2*; LDH-C*; aMAN*; sMDH-A1,2*; sMDH-B1,2*;MPI*; PEPA*; PEPB-1*; PEPC*; PEPD-2*; PEPLT*; PGDH*; PGK-1*; PGK-2*; PGM-1*; PGM-2*; PNP-1*; sSOD-1*; TPI-1*; TPI-3*.*

Regional patterns of allele frequency—Plots of allele frequencies at selected gene loci illustrate the regional differences seen in the allozyme data set (Fig. 29). For example, samples from Puget Sound northward are characterized by lower frequencies of the 100 allele of *EST-1** than those from other regions. Columbia River samples are characterized by relatively high frequencies of the 100 allele at *PGM-1** and *EST-1**. Samples from Alaska have an unusually low frequency for the 100 allele of *PEPA**. Additional regional patterns of allele frequency can be seen in the scatterplots.

Genetic distance—Genetic distances (D) computed for 53 loci between each pair of samples were used to construct the dendrogram shown in Figure 30. We examined both Cavalli-Sforza and Edwards' (1967) chord distance and Nei's (1978) unbiased genetic distance, but only the former is shown. Nei's distance metric includes a correction for sampling error, which can be important if sample sizes are small or if they vary among collections. However, in the present data set the bias correction led to a number of negative D values, which made it difficult to depict genetic relationships on a dendrogram.

Seven major clusters were identified that were largely distinct geographically (Figure 30). Clusters I (separated from other clusters at a D value of 0.088) and II (D = 0.086) are the

Table 3. Samples of coho salmon used in NMFS allozyme analysis. Map codes correspond to those in Figure 28. N is the number of fish in each sample. All fish are juveniles unless otherwise indicated.

Area	Map code	Name	Source	Brood year	N
California	1	Trinity	Trinity Hatchery	1982	98
So. Oregon Coast	2	Rogue	Illinois River, Greyback Creek	1992	40
	3	Rogue	Illinois River, Silver Creek	1991	29
	4	Rogue	Cole Rivers Hatchery, stock #52	1992	80
	5	Elk	North Fork Elk and Elk Rivers	1992	32
Oregon Coast	6	Sixes	Crystal and Edson Creeks	1992	44
	7	New	Bether and Morton Creeks	1992	62
	8	Coquille	Butte Falls Hatchery, stock #44	1992	80
	9	Coos	Cole Rivers Hatchery, stock #37	1992	80
	10	Coos	Millicoma River and Marlow Creek	1992	22
	11	Coos	South Fork Coos River, Tioga Creek	1992	29
	12	Eel	Butte Falls Hatchery, stock #63	1992	80
	13	Tenmile	Big Creek, Noble Creek, and Tenmile Lake	1991	56
	14	Umpqua	Rock Creek Hatchery, stock #55	1992	80
	15	Umpqua	North Umpqua River, Williams Creek	1992	40
	16	Umpqua	Butte Falls Hatchery, stock #18	1992	80
	17	Smith	Smith River, Halfway Creek	1992	40
	18	Tahkenitch	Fall Creek Hatchery, stock #113	1992	80
	19	Alsea	Fall Creek Hatchery, stock #31	1992	80
	20	Alsea	Fall Creek Hatchery, stock #43	1992	80
	21	Beaver	Beaver Creek	1992	62
	22	Siletz	Forth of July, Sunshine, and Buck Creeks	1991	50
	23	Siletz	Salmon River Hatchery, stock #33	1992	80
	24	Salmon	Salmon River Hatchery, stock #36	1992	80
	25	Salmon	Salmon River Hatchery	1982	96
	26	Trask	Trask River Hatchery, stock #34	1992	80
	27	Trask	Trask River Hatchery	1991	120
	28	Nehalem	Nehalem River Hatchery, stock #32	1992	80
	29	Nehalem	Nehalem River Hatchery, Fishhawk stock	1982	110
	30	Nehalem	Nehalem Hatchery, Fishhawk stock	1990	80
Columbia River	31	Lewis and Clark	Lewis and Clark River	1992	30
	32	Grays	Grays River Hatchery	1989	40
	33	Grays[a]	Grays River Hatchery	1989	40
	34	Grays	Grays River Hatchery	1982	100
	35	Big Creek[b]	Big Creek Hatchery	1989	80
	36	Clatskanie	Carcus Creek	1989	50
	37	Cowlitz	Cowlitz Late	1990	100
	38	Cowlitz	Cowlitz Early	1989	80
	39	Cowlitz	Cowlitz Late	1989	80
	40	Scappoose	Siercks, Raymond, and Milton Creeks	1989	44
	41	Lewis[a]	Lewis River Hatchery Late	1989	80
	42	Lewis	Lewis River Hatchery Early	1989	80

Table 3. Continued.

Area	Map code	Name	Source	Brood year	N
Columbia River (continued)	43	Clackamas	North Fork Clackamas River	1990	90
	44	Clackamas[a]	Clackamas and North Fork Clackamas Rivers	1989	60
	45	Eagle	Eagle Creek Hatchery	1990	100
	46	Eagle[a]	Eagle Creek Hatchery	1989	80
	47	Sandy[a]	Sandy River Hatchery	1989	80
	48	Sandy	Still Creek	1989	62
	49	Sandy	Sandy River Hatchery	1990	100
	50	Hardy[b]	Hardy Creek	1989	50
	51	Bonneville[b]	Bonneville Hatchery	1989	80
	52	Willard	Willard Hatchery	1989	80
Southwest Washington Coast	53	Naselle	Naselle River Hatchery	1990	100
	54	Nemah	Nemah River Hatchery	1990	100
	55	Willapa	Willapa River Hatchery	1990	100
	56	Chehalis[c]	Simpson Hatchery	1989	40
	57	Chehalis	Satsop River, Bingham Creek and Simpson River Hatchery[c]	1982, 1988	140
	58	Humptulips[d]	Humptulips River Hatchery	1988	40
Olympic Peninsula	59	Queets	Clearwater River	1982	95
	60	Quillayute	Bogachiel River	1985	80
	61	Soleduck	Bear Creek	1982	95
	62	Hoko	Hoko River	1985	80
Puget Sound	63	Hood Canal	Hood Canal Hatchery, Baker stock	1992	80
	64	Big Beef	Big Beef Creek	1982	80
	65	Green	Green River Hatchery	1982	100
	66	Green	Green River Hatchery	1992	80
	67	Snohomish	Pilchuck River, Little Pilchuck Creek	1985	80
	68	Snohomish	Snoqualmie River, Harris Creek	1985	120
	69	Snohomish	Skykomish River	1982	80
	70	Stillaguamish	Church Creek	1985	80
	71	Stillaguamish	North Fork Stillaguamish River, Fortson Creek	1985	80
	72	Stillaguamish	North Fork Stillaguamish River, McGovern Creek	1985	40
	73	Stillaguamish	South Fork Stillaguamish River, Tiger Creek	1985	80
	74	Skagit	Upper Skagit River	1991	127
	75	Skagit	Carpenter Creek	1991	139
	76	Skagit	West Fork Nookachamps Creek	1991	120
	77	Skagit	West Fork Nookachamps Creek	1985	100
	78	Skagit	Baker River	1991	183
	79	Skagit[c]	Baker River	1989	120
	80	Skagit	Upper Sauk River	1991	200
	81	Skagit	Suiattle River, All Creek	1985	80
	82	Skagit	Suiattle River, All Creek	1991	120
	83	Skagit[c]	Skagit River Hatchery, Baker stock	1989	120
	84	Skagit[c]	Skagit River Hatchery, Clark stock	1989	120

Table 3. Continued.

Area	Map code	Name	Source	Brood year	N
Puget Sound (continued)	85	Skagit	Skagit River Hatchery, Clark stock	1991	120
	86	Skagit	Upper Cascade River	1991	224
	87	Skagit	Skagit River Hatchery, Baker stock	1991	120
	88	Nooksack[d]	Nooksack River Hatchery	1982	80
British Columbia	89	Chilliwack	Chilliwack River Hatchery	1982	100
	90	Coldwater	Spius River Hatchery	1985	80
	91	Coldwater	Spius River Hatchery	1986	80
	92	Cowichan	Cowichan River Hatchery	1982	80
	93	Big Qualicum[a]	Big Qualicum Hatchery	1989	80
	94	Big Qualicum	Big Qualicum Hatchery	1982	80
	95	Robertson	Robertson Creek Hatchery	1982	100
	96	Capilano	Capilano Hatchery	1989	80
	97	Squamish[c, d]	Squamish River Hatchery	1985	80
Alaska	98	Cabin	Cabin Creek	1990	80
	99	Karta	Karta River	1990	76
	100	Campbell	Campbell Creek	1990	80
	101	Goodnews	Goodnews River	1990	80

[a]Sample is missing data for EST1*. Missing data were filled with allele frequency from other year.
[b]Sample is missing data for EST1*. Missing data were filled with allele frequency of area mean.
[c]Sample is from adult coho salmon.
[d]Sample is missing data for PNP1*. Missing data were filled with allele frequency of area mean.

Figure 28. Location of 97 samples used in the NMFS allozyme analysis of coho salmon from the Pacific Northwest. Samples from Alaska (98-101) are not shown. Numbers correspond to map codes in Table 3.

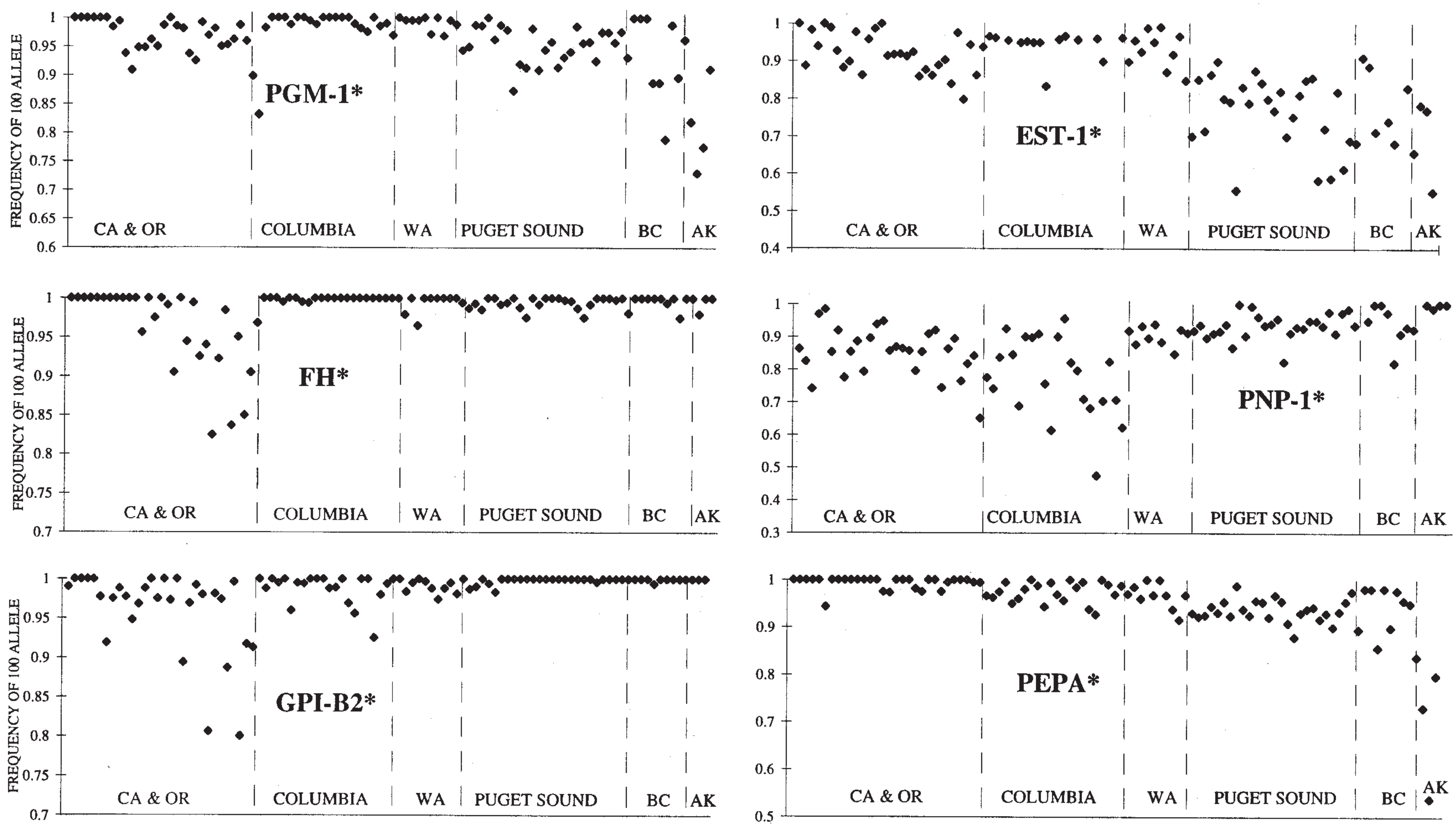


Figure 29. Allele frequencies at 6 gene loci for 101 samples of coho salmon from California (CA), Oregon (OR), Washington (WA), British Columbia (BC), and Alaska (AK). Samples are arranged from south to north in the same order listed in Table 3.

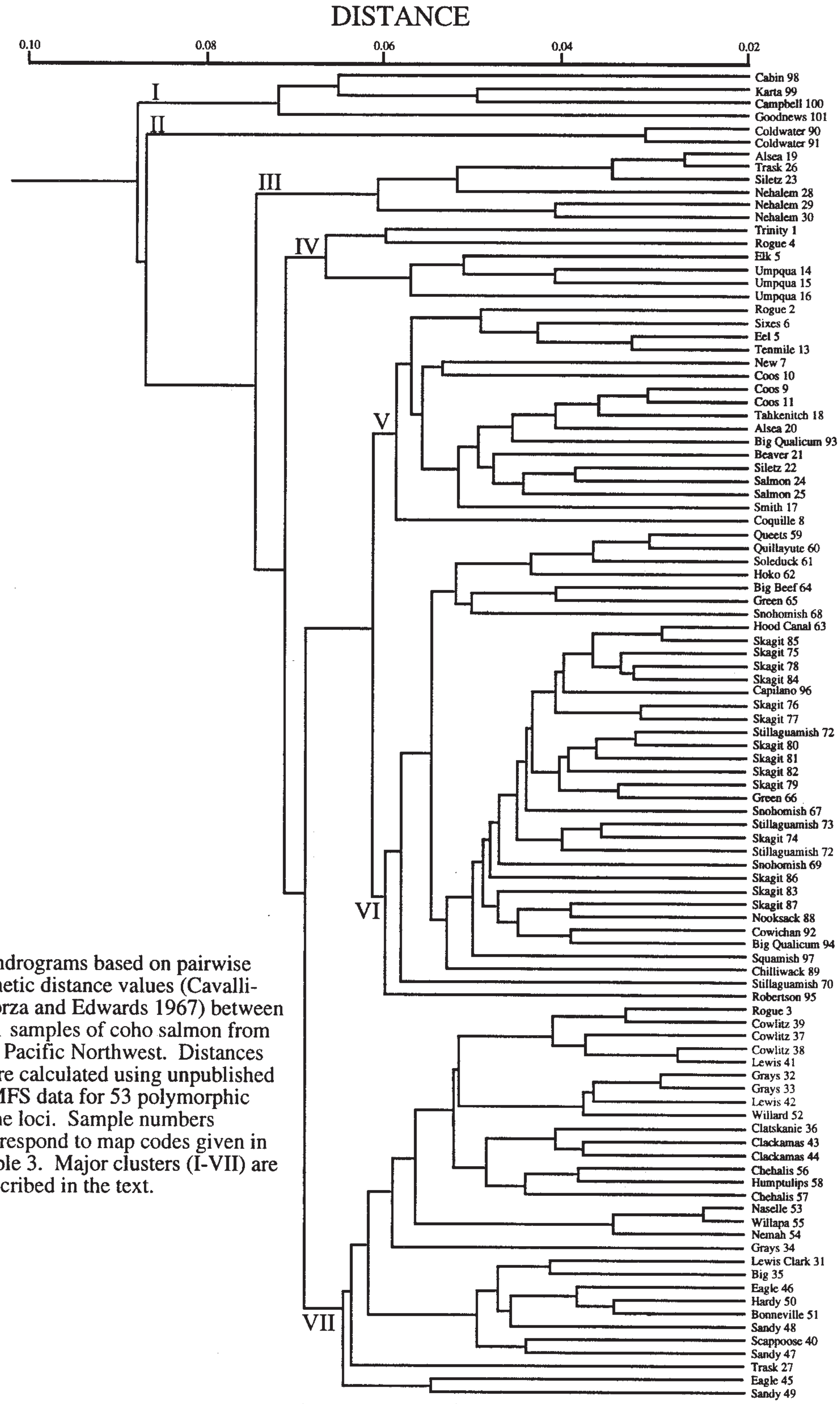


Figure 30. Dendrograms based on pairwise genetic distance values (Cavalli-Sforza and Edwards 1967) between 101 samples of coho salmon from the Pacific Northwest. Distances were calculated using unpublished NMFS data for 53 polymorphic gene loci. Sample numbers correspond to map codes given in Table 3. Major clusters (I-VII) are described in the text.

most distinct major clusters and consist of the four samples from Alaska and the two samples from the mid-Fraser River, respectively. These samples are not discussed further in this report.

Clusters III, IV, and V contain Oregon coastal populations. Cluster III is comprised of hatchery populations from northern Oregon (Alsea, Trask, Siletz, and Nehalem) and is the most distinctive cluster (D = 0.074) except for those from the Fraser River and Alaska. Cluster IV (D = 0.071) includes a sample from the Rogue River (Cole Rivers Hatchery) as well as natural and hatchery samples from the Elk and Umpqua Rivers. The Elk and Umpqua Rivers samples constitute a tight subcluster that is more distantly linked to the Rogue River sample. Somewhat less distantly linked are other samples from the Rogue River and the Trinity Hatchery in northern California. Cluster V (D = 0.062) contains wild and hatchery populations ranging from the Rogue River (Illinois River, Greyback Creek) in the south through the Salmon River in the north.

Cluster VI (D = 0.062) includes all of the Puget Sound and British Columbia samples (except the two Fraser River samples noted above and one of two samples from Big Qualicum Hatchery). All of the British Columbia samples except that for Robertson Creek (on the west Coast of Vancouver Island) are from streams draining into the Strait of Georgia. Four samples from the Strait of Juan de Fuca and the northern coast of Washington (Queets, Quillayute, Soleduck, and Hoko Rivers) form a subgroup within the larger Puget Sound/Strait of Georgia group.

Cluster VII (D = 0.068) includes all of the samples from the lower Columbia River, as well as those from the southwestern Washington coast. This cluster also includes a sample from the Rogue River Basin (Illinois River, Silver Creek) and one from Trask Hatchery. Within this cluster are several subclusters and three branches with only one or two members. Two subclusters comprise most of the lower Columbia River samples: one consisting primarily of samples from Washington and the other consisting primarily of samples from Oregon. Another subcluster contains three samples from Willapa Bay. A final subcluster contains a group of samples from the Clackamas and Clatskanie Rivers, together with a group that includes samples from the Humptulips and Simpson hatcheries from southwestern Washington.

Principal component analysis—A principal components analysis was used to provide another way of interpreting the pattern of genetic relationships among samples. We focused on data for the following 29 loci, in which the common allele had a frequency of less than 0.95 in at least one sample: *sAAT-3**, *sAAT-4**, *ADA-1**, *mAH-2**, *sAH**, *CK-A2**, *EST-1**, *FBALD-4**, *FH**, *bGALA**, *GAPDH-2**, *GAPDH-3**, *bGLUA**, *GPI-A**, *GPI-B2**, *sIDHP-1**, *sIDHP-2**, *LDH-B1**, *MPI**, *PEPA**, *PEPC**, *PEPD-2**, *PEPLT**, *PGK-1**, *PGM-1**, *PGM-2**, *PNP-1**, *sSOD-1**, *TPI-3**. Eigenvectors were extracted from a matrix of correlations computed from allele frequencies. The NTSYS-pc computer program was used for the principal component analysis (Exeter Software 1993).

A scatterplot of principal component scores for principal components PC1 and PC2 is provided in Figure 31. These two components together describe about 22% of the total variance among samples, so considerable information is contained in other principal

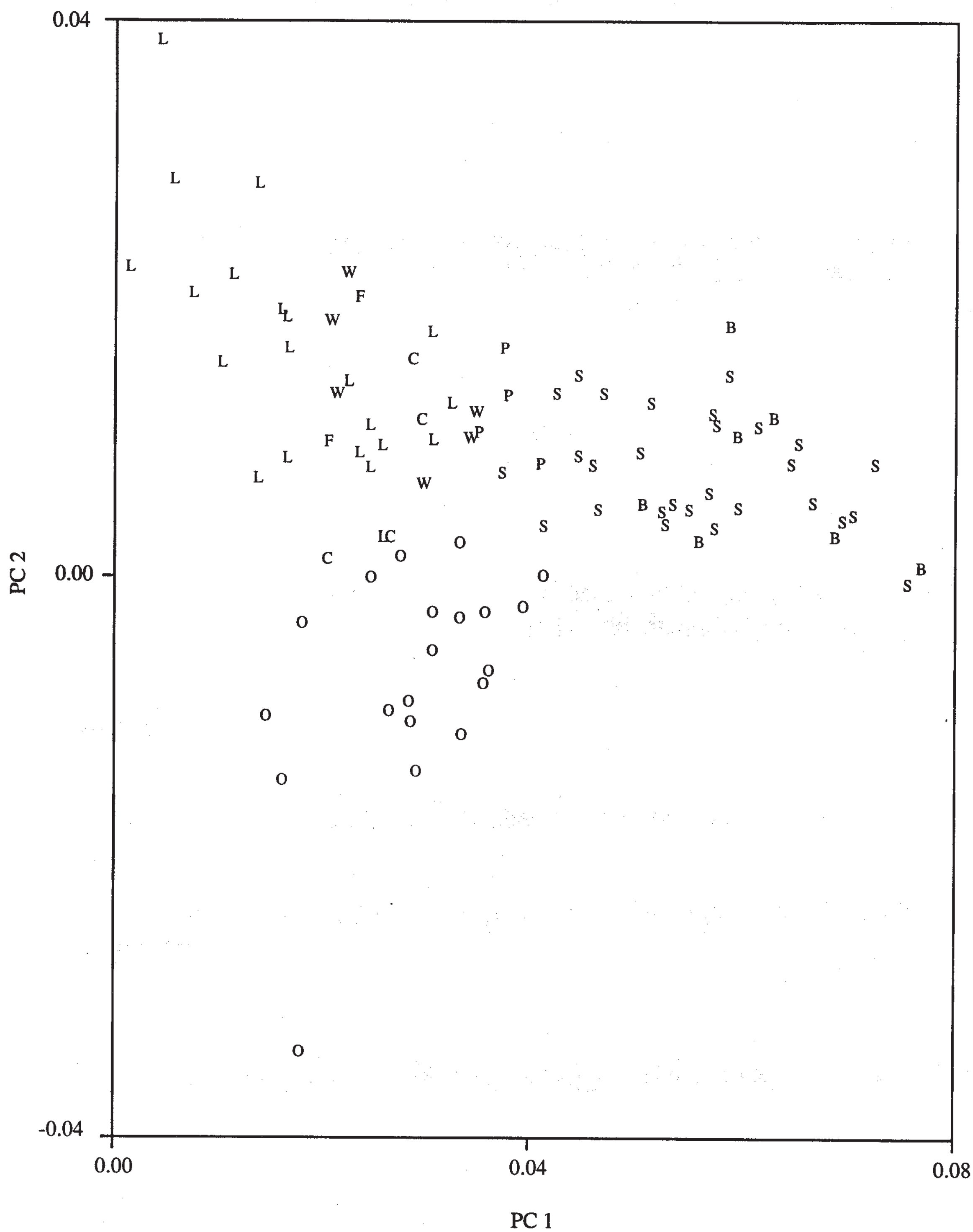


Figure 31. Scatterplot of scores for the first two principal components (PC1 and PC2) from an analysis of genetic data for 29 of the most variable gene loci from 101 samples of coho salmon from the Pacific Northwest. Letters correspond to major geographic areas: south of Cape Blanco (C), Oregon coast (O), lower Columbia River (L), southwest Washington coast (W), Olympic Peninsula (P), Puget Sound (S), mid-Fraser River (F), and remainder of British Columbia (B). Samples from Alaska are beyond the scale of the plot.

components not shown in the figure. Several geographic clusters are identifiable here. For example, samples from Alaska are the most divergent and are well separated with PC1 scores greater than 0.09 (off the scale and therefore not shown in Figure 31). Samples from British Columbia and Puget Sound are characterized by high PC1 scores and moderate PC2 scores. Samples from the Oregon coast north of Cape Blanco have moderate to low scores for PC1 and low scores for PC2.

Two samples from the lower Columbia River and three samples from south of Cape Blanco are also located in the Oregon coast portion of the scatterplot. Samples from the lower Columbia River have low PC1 scores and high PC2 scores. Three of the samples from the southwest Washington coast, two samples from south of Cape Blanco, and the two samples from the mid-Fraser River are also located in the Columbia River portion of the scatterplot. The mid-Fraser samples, however, are well separated from all other samples by PC4. The remaining three samples from the southwest Washington coast and the three samples from the Olympic Peninsula have moderate scores from both PC1 and PC2 and are near the convergence of the Puget Sound/British Columbia and lower Columbia River clusters.

California and southern Oregon data set—Because our new data set included only a single sample from California, we examined the genetic relationships of California and southern Oregon coho salmon populations by combining data for NMFS samples from this area with data from Olin (1984) and Bartley et al. (1992). The geographic coverage of samples in this analysis can be seen in Figure 32 and Table 4; these include the 5 most southern NMFS samples, 20 samples from Bartley et al. (1992), and the Iron Gate Hatchery sample from Olin (1984). Samples with 25 or fewer fish were excluded from the analysis.

Ideally, inferences about genetic relationships based on genetic distances should be based on a set of gene loci common to all pairwise comparisons of populations. Even after exclusion of the smallest samples, however, few loci were scored in all samples in the combined dataset. Therefore, to allow an analysis using a minimally-representative set of loci, we computed genetic distances (Cavalli-Sforza and Edwards 1967) for each pair of populations using the maximum number of loci common to both samples. The following 13 polymorphic loci were considered in this analysis: *sAAT-1, 2*; sAH; GPI-A*; IDDH-1*; LDH-B1*; LDH-B2*; sMDH-B1,2*; MPI*; PEPA*; PEPC*; PEPD-2*; PGDH*; PGM-1**. Each of these loci had a common allele frequency of 0.95 or less in at least one sample and was scored in at least 50% of the samples.

In the dendrogram resulting from this analysis (Fig. 33), two major geographic clusters are apparent and are separated by a relatively large genetic distance (D = 0.126). The northern (and primarily large-river) group includes 11 samples from the Elk River (near Cape Blanco) to the Eel River (just north of Cape Mendocino). The southern (and primarily small-river) group includes nine samples spanning a geographic range from Fort Bragg to Tomales Bay (Lagunitas Creek), in addition to three samples from north of Cape Mendocino. The single sample from south of Tomales Bay (Scott Creek) and two additional samples from south of Punta Gorda (Cottoneva and Pudding Creeks) are outliers to both of the major groups. Considerable genetic diversity among populations is apparent within both groups.

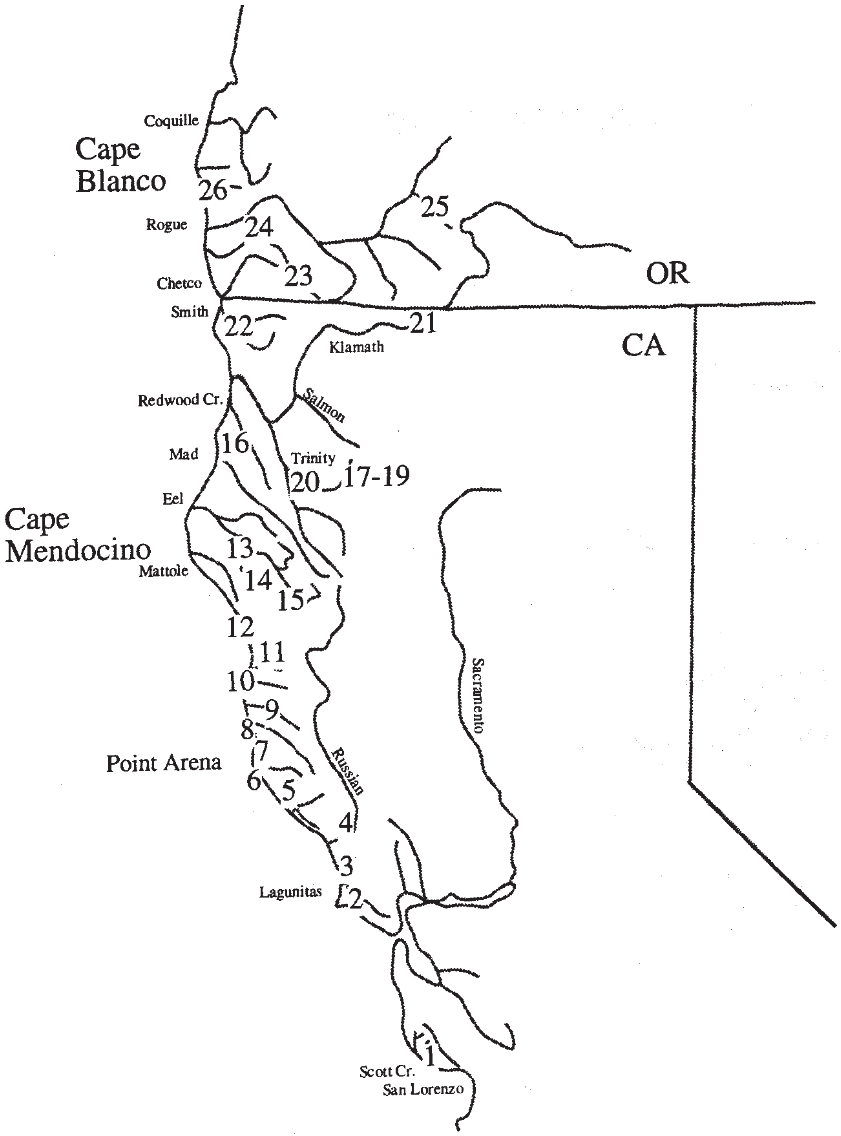


Figure 32. Locations of 26 samples used in allozyme analysis of coho salmon from southern Oregon and California. Numbers correspond to map codes in Table 4.

Table 4. Samples used in allozyme analysis of coho salmon from southern Oregon and California. Map codes correspond to those in Figure 32. N is the number of fish in each sample.

Map code	Sample	Source[a]	N
1	Scott Creek	1	39
2	Lagunitas Creek	1	32
3	Tanner Creek, Salmon Creek	1	62
4	Russian River, Willow Creek	1	38
5	Navarro River, Flynn Creek, John Smith Creek	1	61
6	Albion River	1	30
7	Little River	1	51
8	Russian Gulch	1	31
9	Caspar Creek	1	82
10	Hare Creek	1	28
11	Pudding Creek	1	47
12	Cottoneva Creek	1	28
13	South Fork Eel River, Huckleberry Creek	1	104
14	South Fork Eel River, Butler Creek	1	60
15	South Fork Eel River, Redwood Creek	1	58
16	Elk River (Humboldt Bay)	1	30
17	Trinity River, Trinity Hatchery	1	172
18	Trinity River, Trinity Hatchery	1	36
19	Trinity River, Trinity Hatchery	2	98
20	Trinity River, Deadwood Creek	1	26
21	Klamath River, Iron Gate Hatchery	3	92
22	Smith River, West Branch Mill Creek	1	30
23	Rogue River, Illinois River, Greyback Creek	2	40
24	Rogue River, Illinois River, Silver Creek	2	29
25	Rogue River, Cole Rivers Hatchery	2	80
26	Elk and North Fork Elk Rivers	2	32

[a]1 = Bartley et al. 1992; 2 = Samples collected by NMFS for this status review; 3 = Olin 1984

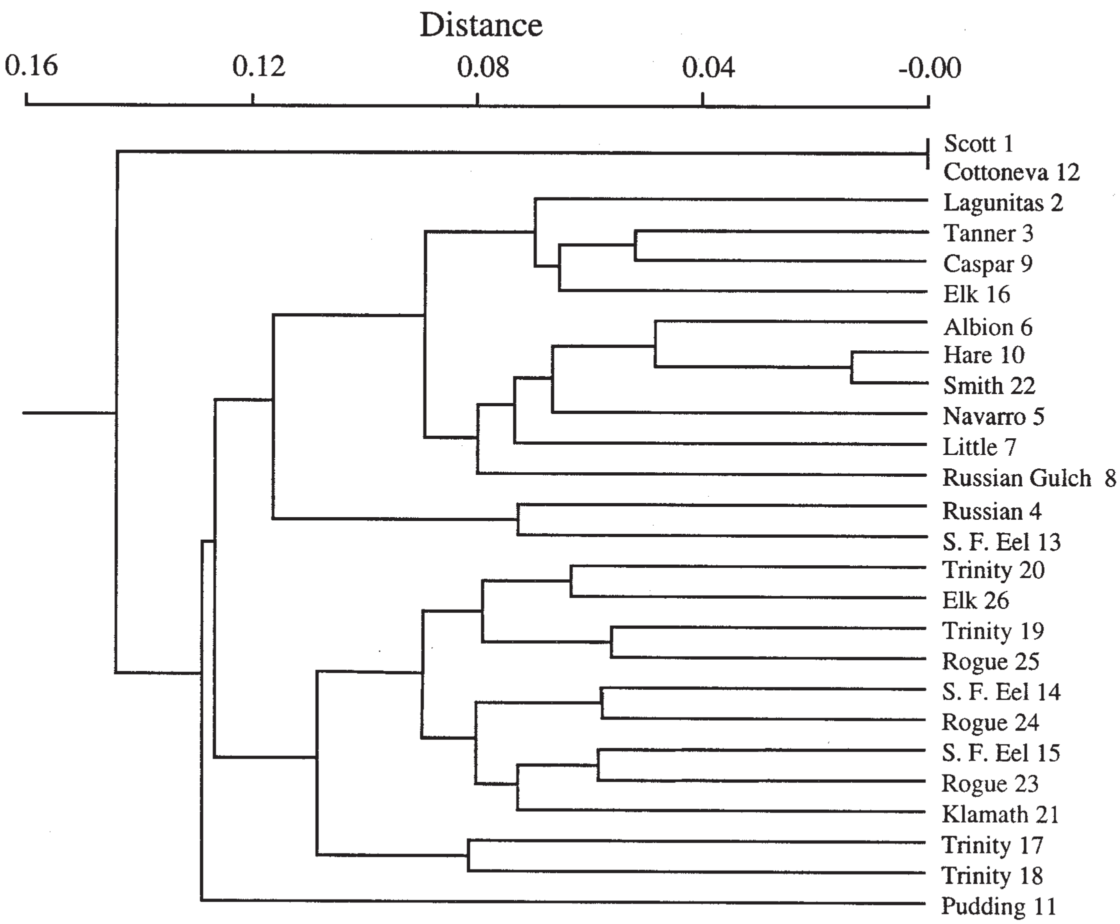


Figure 33. Dendrogram based on pairwise genetic distance values (Cavalli-Sforza and Edwards 1967) between 26 samples of coho salmon from southern Oregon and California. Distances were calculated using data for 13 polymorphic gene loci. Sample numbers correspond to map codes shown in Table 4. Data sources include Olin (1984), Bartley et al. (1992), and samples collected by NMFS for this status review.

Discussion and Conclusions on ESU Determinations

In this section, we summarize evidence developed in the status review that is relevant to the two criteria that must be met for a population(s) to be considered an ESU and, hence, a species under the ESA: reproductive isolation and contribution to ecological/genetic diversity.

Reproductive Isolation

Coho salmon are generally believed to have strong tendencies to home to their natal stream (Donaldson and Allen 1958, Quinn and Tolson 1986, Sandercock 1991, Labelle 1992). Fish that do stray are most commonly found in streams near their natal stream (Shapovalov and Taft 1954, Jacobs 1988b, Labelle 1992). Because a low level of natural straying is expected to occur, some exchange of fish between adjacent rivers (within-ESU exchanges) probably occurs. The ESUs defined below are relatively large and identify regions among which we believe gene flow to be limited.

Genetic data (from studies of protein electrophoresis and DNA) provide further evidence for the reproductive isolation criterion. Genetic information presented in this status review indicate that there are several locations where genetic discontinuity/transition occurs. These locations are approximately: Punta Gorda, California; Cape Blanco, Oregon; the north Oregon coast/Columbia River; the area between the Chehalis and Queets Rivers; and areas between Puget Sound/Strait of Georgia and the upper Fraser River and Alaska. These genetic discontinuities or transition zones indicate a restriction of gene flow across these areas, suggesting a reasonable degree of reproductive isolation from each other.

There is also evidence for genetic heterogeneity within many of the areas defined by these boundary locations, such as the greater Olympic Peninsula/Puget Sound/Strait of Georgia area, and Oregon coast north of Cape Blanco. This heterogeneity suggests fairly high reproductive isolation of individual populations or groups of populations. In the case of the greater Olympic Peninsula/Puget Sound/Strait of Georgia area, Olympic Peninsula fish are both geographically and genetically distinct, indicating they form a major subgroup within the larger unit. In contrast, Oregon coast fish lack clear geographic patterns to the genetic structuring that would allow us to identify major subgroups within this area.

Ecological/Genetic Diversity

The physical environments to which west coast coho salmon are adapted, and the life history traits and genetic characteristics exhibited by these fish indicate a substantial degree of ecological and genetic diversity. Physical environments in the six ESUs summarized below are unique within the range of the species, and are expected to exert distinctive selection pressures. These environments range from the relatively dry climate in central California with strong and consistent upwelling offshore, to the extremely wet Olympic Peninsula with its snow-fed rivers.

Between these extremes, the environments in the other ESUs present their own particular challenges: Oregon coastal rivers receive considerable rain but little snowmelt and flow into an unpredictable ocean environment; fish inhabiting Columbia River tributaries must navigate one of the largest rivers along the West Coast of North America; and coho salmon in the Puget Sound/Strait of Georgia inhabit glacially-fed rivers which flow into a productive and stable marine environment. Ocean migration patterns, as inferred from marine CWT recovery patterns, are also distinctive in each of the six ESUs. The distinctiveness of these patterns indicates the unique adaptations made by the six groups of fish to their environments.

Conclusions

Based on information discussed above and summarized below, the BRT identified six ESUs for west coast coho salmon populations (Fig. 34). The proposed ESUs are briefly described and characterized below.

1) Central California coast—The geographic boundaries of this ESU extend from Punta Gorda in northern California south to the San Lorenzo River in central California, and include tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system. These boundaries encompass coho salmon populations from the present southern extreme range of the species. This area is characterized by very erosive soils, and redwood forest is the dominant vegetation for these coastal drainages. Precipitation is much lower and less prolonged here than in areas to the north, and elevated stream temperatures (>20ºC) are common in the summer. Freshwater fishes in this area are derived from the Sacramento River fauna. Coastal upwelling in this region is strong and consistent, resulting in a relatively productive nearshore marine environment.

Both run and spawn timing of coho salmon in this region are very late (both peaking in January), with little time spent in freshwater between river entry and spawning. This compressed adult freshwater residency appears to coincide with the single, brief peak of river flow characteristic of this area. Coho salmon released from the Warm Springs Hatchery on the Russian River have a much more southern distribution than fish released north of the ESU. Whether this pattern reflects a unique migration pattern for the ESU as a whole or just the southerly location of the hatchery is not known. However, genetic data indicate that most samples from this region differ substantially from coho salmon north of Punta Gorda.

The northern boundary of this ESU, Punta Gorda, was selected primarily because of the clear shift in terrestrial and marine environments that occurs in the vicinity of Punta Gorda and Cape Mendocino. The freshwater environment of the Mattole River, which enters the Pacific Ocean between these two points, is more similar to rivers north of Cape Mendocino, and coho salmon populations from the Mattole River are likewise more similar to populations farther north. However, there is scant information on coho salmon from the numerous small basins between Punta Gorda and the Ten Mile River, some 90 km to the south, which might indicate their greater similarity to populations to the north or south.

Available information indicates that the San Lorenzo River currently is the southernmost population of coho salmon, and this is the southern geographic boundary for the proposed ESU. However, it should be recognized that any coho salmon found spawning south

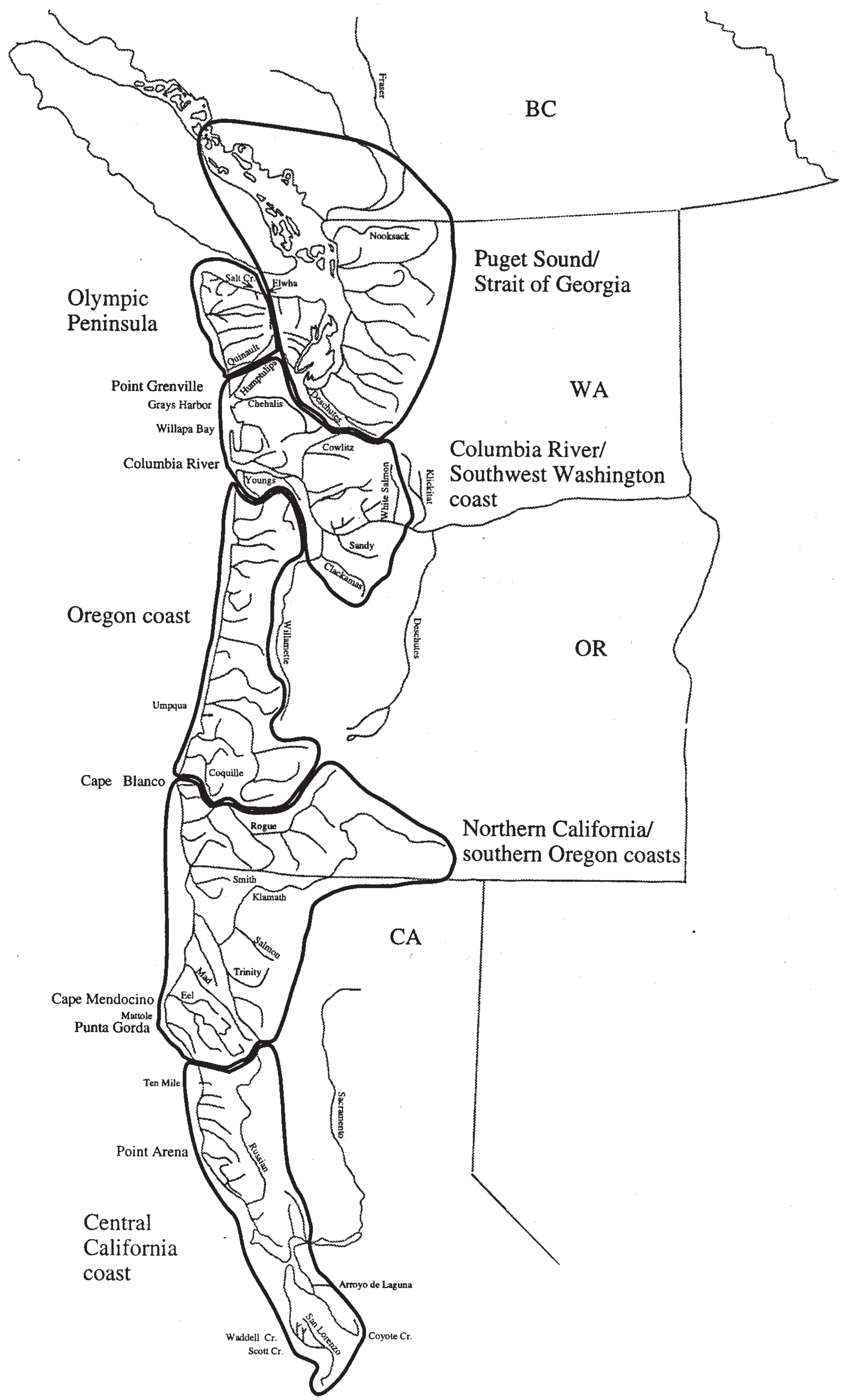


Figure 34. Proposed west coast coho salmon evolutionarily significant units.

of the San Lorenzo River that have not resulted from stock transfers should also be considered part of this ESU.

2) Southern Oregon/northern California coasts—This ESU includes coho salmon from Cape Blanco in southern Oregon to Punta Gorda in northern California. Geologically, this region includes the Klamath Mountains Geologic Province, which has soils that are not as erosive as those of the Franciscan Formation to the south. Dominant vegetation along the coast is redwood forest, while some interior basins are much drier than surrounding areas and are characterized by many endemic plant species. Elevated stream temperatures are a factor in some areas, but not to the extent that they are in areas south of Punta Gorda.

Rivers in this ESU are relatively long compared to those to the south. With the exception of major river basins such as the Rogue and Klamath, most streams in this region have short duration of peak flows and relatively low flows given both peak flow levels and basin sizes, compared to rivers farther north. Freshwater fishes include elements of the Sacramento River fauna as well as from the Klamath-Rogue ichthyofaunal region. Strong and consistent coastal upwelling begins around Cape Blanco and continues south into central California, resulting in a relatively productive nearshore marine environment. In contrast to coho salmon from north of Cape Blanco, which are most frequently captured off the Oregon coast, coho salmon from this region are captured primarily in California waters.

Genetic data indicate that most samples from this region differ substantially from coho salmon from south of Punta Gorda. In general, populations from southern Oregon also differ from coastal Oregon populations north of Cape Blanco. However, some samples from the Rogue River show an unexplained genetic affinity to samples from outside the region, including some from the Columbia River. In addition, a sample from the Elk River (just south of Cape Blanco) clustered with samples from the Umpqua River.

The southern boundary of this ESU is farther south than the boundary designated for the Klamath Mountains Province steelhead ESU, which includes the Klamath River but not drainages to the south (Busby et al. 1994). Both the steelhead and coho salmon ESUs share the northern boundary of Cape Blanco. Although the Klamath River (inclusive) serves as the southern boundary for the Klamath Mountains Geological Province and for freshwater fish faunas, major changes in ocean currents and environmental characteristics, as well as the southern limit of the steelhead half-pounder life history strategy, occur at Cape Mendocino/ Punta Gorda.

Consequently, the southern limit of the steelhead ESU was based primarily on strong genetic discontinuity between Klamath River steelhead and steelhead populations to the south (Busby et al. 1994). In contrast, Punta Gorda serves as the southern boundary of the southern Oregon/northern California coho salmon ESU because of the strong environmental transition at Punta Gorda, and because genetic data indicate Punta Gorda, rather than the Klamath River, as an approximate transition area for coho salmon.

3) Oregon coast—This ESU covers much of the Oregon coast, from Cape Blanco to the mouth of the Columbia River, an area with considerable physical diversity ranging from extensive sand dunes to rocky outcrops. With the exception of the Umpqua River, which extends through the Coast Range to drain the Cascade Mountains, rivers in this ESU have their headwaters in the Coast Range. These rivers have a single peak of flow in December or January and relatively low flow in late summer. Upwelling north of Cape Blanco is much less consistent and weaker than in areas south of Cape Blanco. Sitka spruce is the dominant coastal vegetation and extends to Alaska. Precipitation in coastal Oregon is higher than in southern Oregon/northern California but lower than on the Olympic Peninsula. Oregon coast coho salmon are caught primarily in Oregon marine waters and have a slightly earlier adult run timing than populations farther south.

Genetic data indicate that Oregon coast coho salmon north of Cape Blanco form a discrete group, although there is evidence of differentiation within this area. However, because there is no clear geographic pattern to the differentiation, the area is considered to be a single ESU with relatively high heterogeneity.

4) Lower Columbia River/southwest Washington coast—The BRT concluded that historically, there was probably an ESU that included coho salmon from all tributaries of the Columbia River below the Klickitat River on the Washington side and below the Deschutes River on the Oregon side (including the Willamette River as far as the Willamette Falls), as well as coastal drainages in southwest Washington between the Columbia River and Point Grenville (between the Copalis and Quinault Rivers). The Columbia River estuary, Willapa Bay, and Grays Harbor all have extensive intertidal mud and sandflats and similar estuarine fish faunas, and they differ substantially from estuaries to the north and south. This similarity results from the shared geology of the area and the transportation of Columbia River sediments northward along the Washington coast.

Rivers draining into the Columbia River have their headwaters in increasingly drier areas moving from west to east. Columbia River tributaries that drain the Cascade Mountains have proportionally higher flows in late summer and early fall than rivers on the Oregon coast. Coded-wire-tag (CWT) data indicate a distinctive oceanic distribution pattern for Columbia River coho salmon, with a higher percentage of recoveries from Washington compared to recovery patterns for Oregon coastal stocks and a much lower percentage of recoveries from British Columbia compared to recovery patterns for Washington coastal populations, including populations from the southwest Washington coast. Genetic data indicate that Columbia River coho salmon are distinct from coastal Oregon populations but similar to populations from several coastal streams in southwest Washington.

The question of where the southwest Washington coast (areas draining Willapa Bay and Grays Harbor) should be placed with respect to coho salmon ESUs prompted considerable debate within the BRT: Should it be part of the lower Columbia River ESU, the Olympic Peninsula ESU, or its own ESU? The southwest Washington coast has many traits in common with the lower Columbia River: the hydrology, topography, and climate of river basins in the two areas are similar; Grays Harbor, Willapa Bay and the Columbia River estuary are physically and biologically similar; and coho salmon from southwest Washington are genetically most similar to Columbia River fish. However, the southwest Washington coast also shares traits with the Olympic Peninsula: tributaries draining the north side of the

Chehalis River Basin share the same hydrology, topography, and climate as Olympic Peninsula rivers, and marine CWT recovery patterns of coho salmon released from southwest Washington coast hatcheries are more similar to those released from Olympic Peninsula facilities than to releases from the Columbia River.

The southwest Washington coast also has distinctive features—it forms the transition zone between the moderately wet Oregon coast and the extremely wet Olympic Peninsula, and although its rivers share many characteristics with lower Columbia River tributaries, they drain directly into the Pacific Ocean. Why the CWT recovery patterns of coho salmon from southwest Washington do not follow the genetic patterns remains to be determined. It was concluded that because of the similarity of southwest Washington coast and the lower Columbia River, and the genetic similarity of coho salmon from the two areas, southwest Washington coast should be part of the lower Columbia River ESU.

Once it was decided that coho salmon from the southwest Washington coast and the lower Columbia River form a single ESU, the location of its border with the Olympic Peninsula had to be identified. This also prompted debate within the BRT because of the broad transition zone between southwest Washington and the Olympic Peninsula. In particular, tributaries draining the northern part of the Chehalis River Basin are typical of Olympic Peninsula basins with respect to hydrology, topography, and climate, while in most other respects the Chehalis River Basin is physically and biologically similar to other southwest Washington coast basins. In addition, river basins between the Chehalis and Quinault Rivers (Humptulips, Copalis, and Moclips Rivers) drain low-elevation coastal areas and have flow characteristics typical of rivers farther south. Although some Chehalis River tributaries share traits with Olympic Peninsula rivers, BRT members ultimately decided that the region between Point Grenville and Grays Harbor was most similar to southwest Washington, so the northern boundary of the lower Columbia River/southwest Washington coast ESU was placed at Point Grenville.

In the status review for lower Columbia River coho salmon (excluding the Clackamas River), NMFS concluded that, historically, at least one ESU of coho salmon probably occurred in the lower Columbia River Basin, but that the agency was unable to identify any remaining natural populations that warranted protection under the ESA (Johnson et al. 1991, NMFS 1991a). This status review has not uncovered substantial new information on coho salmon populations considered by that earlier status review. However, the BRT considered further information regarding coho salmon in the Clackamas River and along the southwest Washington coast. Evidence of extensive hatchery production and outplanting and high harvest rates led the BRT to conclude that, similar to the lower Columbia River, we cannot at this time identify any remaining natural populations of coho salmon along the Washington coast south of Point Grenville that warrant protection under the ESA.

Evidence regarding the history of hatchery influence on late-run Clackamas River coho salmon is not as clear, and the BRT could not reach a definite conclusion as to whether these fish represent the historical lower Columbia River/southwest Washington ESU.

5) Olympic Peninsula—The geographic boundaries of this ESU are entirely within Washington, including coastal drainages from Point Grenville to Salt Creek. This region is characterized by high levels of precipitation and streams with cold water, high average flows, and a relatively long duration of peak flows, including a second peak later in the year resulting from snow melt. In contrast to inland areas, such as Puget Sound, where western hemlock is the dominant forest cover, vegetation in this region is dominated by the Sitka spruce. Coho salmon from the Olympic Peninsula ESU have a more northerly ocean distribution than populations from the Columbia River or coastal regions in Oregon, and they are more commonly captured in Canadian waters than are coho salmon from the Puget Sound region. Genetic data show that coho salmon from this region are distinct from populations to the south and somewhat differentiated from populations in the Puget Sound area.

Like the southern boundary of this ESU discussed earlier, the eastern boundary of the Olympic Peninsula ESU also overlays an extended transition zone between the extremely wet Olympic Peninsula and the much drier Puget Sound/Strait of Georgia. The transition point between the wet Olympic Peninsula and the rainshadow farther east is thought to occur east of the Elwha River. However, the Elwha River is physically more similar to the Dungeness River than it is to basins farther west; the Elwha and Dungeness Rivers are both relatively long and begin in alpine areas of the Olympic Mountains, while rivers west of the Elwha River are much shorter, draining the low ridge that separates the Soleduck River from the Strait of Juan de Fuca.

Coded-wire-tag recovery patterns of coho salmon released from the Elwha River are also typical of those from stocks to the east. However, Dungeness River coho salmon have been extensively planted in the Elwha River, and the effect of these plants on Elwha River CWT recovery patterns is unknown. Although the climate of the Elwha River Basin may be considered more similar to that of the Olympic Peninsula than to areas farther east, we felt the Elwha River's physical similarity to the Dungeness River and the similarity of CWT recovery patterns from the two basins provided sufficient evidence to keep the two rivers in the same ESU. Therefore, the boundary between the Olympic Peninsula and Puget Sound/Strait of Georgia ESUs was placed at Salt Creek, the basin immediately west of the Elwha River.

The west coast of Vancouver Island in British Columbia shares many of the physical and environmental features of the Olympic Peninsula ESU. However, we have little biological information for coho salmon from this area. The Strait of Juan de Fuca is potentially a strong isolating mechanism, and although comparable data are not available for coho salmon, genetic data for chinook salmon show that populations from the west coast of Vancouver Island differ genetically from those on the northern Washington coast. Therefore, until more complete information becomes available, we concluded that the geographic boundaries of this ESU do not extend across the Strait of Juan de Fuca.

6) Puget Sound/Strait of Georgia—This ESU includes coho salmon from drainages of Puget Sound and Hood Canal, the eastern Olympic Peninsula (east of Salt Creek), and the Strait of Georgia from the eastern side of Vancouver Island (north to and including Campbell River) and the British Columbia mainland (north to and including Powell River), excluding the upper Fraser River above Hope. This region is drier than the rainforest area of the western Olympic Peninsula and the west side of Vancouver Island and is dominated by western hemlock forests. Streams are similar to those of the Olympic Peninsula, being characterized by cold water, high average flows, a relatively long duration of peak flows, and a second snow-melt peak, although flow levels per basin area are much lower than in the Olympic Peninsula. Genetic and CWT data both show substantial differences between coho salmon from this region and those from the Columbia River and more southern coasts, and more modest differences between coho salmon from this region and populations from the Olympic Peninsula. Coho salmon samples from Puget Sound and the Strait of Georgia form a coherent genetic cluster. The few samples we have examined from Alaska and the upper Fraser River showed substantial genetic differences from all Washington, Oregon, and California populations.

Drainages entering the Strait of Georgia from both sides share many of the physical and environmental features that characterize the Puget Sound area. From the Queen Charlotte Strait north, the prevalence of coho salmon smolting at age 2 (rather than age 1) begins to increase. At about this point, the British Columbia mainland assumes more of the physical and environmental characteristics of the outer coast of Vancouver Island. However, genetic and life history data for populations between the Strait of Georgia and Queen Charlotte Strait are insufficient to indicate relationships between coho salmon in this area and those to the north and south. Therefore, we concluded that until further information is available, the geographic boundaries of this ESU extend into Canada to include drainages from both sides of the Strait of Georgia as far as the north end of the strait.

Additional Comments

Historically, coho salmon have been reported to occur in U.S. waters outside of the geographic areas covered by proposed ESUs, and a brief discussion of this topic is necessary.

It is generally believed that at least some coho salmon populations may have existed in the Sacramento River Basin prior to 1880 (Brown et al. 1994, Bryant 1994). After that time, placer mining, dams, diversions, and other perturbations caused extreme habitat degradation throughout the basin, and any coho salmon there became extinct (Brown and Moyle 1991). In recent decades, attempts have been made to reintroduce coho salmon to the basin, but these attempts have not been successful. Intermittent reports of small numbers of coho salmon in the Sacramento River are generally attributed to strays or to remnants of these stocking programs. We found no evidence that coho salmon eligible for ESA consideration presently occur in the Sacramento River.

Although several tributaries in the upper Columbia River Basin, including the Snake River, once supported coho salmon runs, we are not aware of any native coho salmon production in the upper basin at the present time. Consequently, although the petitioners included Idaho coho salmon in the petition, there are no coho salmon in Idaho which would qualify for listing under ESA. Columbia River stock summary reports (Columbia River Coordinated Information System (CIS) 1992) identify no coho salmon of native origin in this region except in the Hood and Deschutes Rivers in Oregon. According to Nehlsen et al.

(1991), all coho salmon above Bonneville Dam are extinct except those spawning in the Hood River. Both the Hood and Deschutes Rivers have had extensive outplanting of hatchery coho salmon, and no recent natural production estimates are available.

Artificial Propagation

The effects of artificial propagation can be relevant to ESA listing determinations, as discussed in the "Introduction." In this section, we present information on the magnitude and patterns of artificial propagation of west coast coho salmon. The importance of this information to risk assessments for each ESU will be discussed in the subsequent section.

Patterns of Artificial Propagation and Stock Transfers

Artificial propagation of coho salmon and stock transfers, both between production facilities and out-of-basin, off-station plants, have been and continue to be common within the petitioned range. The nature and magnitude of these transfers varies by ESUs, as discussed below. However, the true impact of these transfers and plants remain unclear for two reasons.

First, because there have been transfers and planting of fish which were unrecorded, the best compilation of hatchery data will remain incomplete. Second, there has generally been little evaluation of the success of hatchery plants and stocks, especially prior to the widespread application of CWTs. Accordingly, although there are fairly good records of which fish were released, there are almost no comprehensive reports of which fish came back. In addition, the pedigrees of many stocks, or individual year classes of stocks, change over time as additional stocks are deliberately or unintentionally added to them, further complicating the compilation of hatchery records. Despite these complications and limitations, however, comparing the relative magnitude, pattern, and frequency of stock transfers and plants remains the best approximation of the potential for hatchery impacts to west coast coho salmon ESUs.

The following compilations of coho salmon hatchery production information are not complete, but are sufficiently thorough to indicate trends in the magnitude, frequency, and types of stock transfers between ESUs. Table 5 presents the average annual release of coho salmon from selected production facilities in 1987-91, summarized by ESU. Figures 35-37 display coho salmon stocks used by selected hatcheries or production facilities within the geographic range of the six ESUs, while Figures 38-40 present out-of-basin stocks planted in selected river basins in ESUs in Oregon and Washington.

The actual data for out-of-basin plants in Oregon and Washington are presented in Appendix Tables E-1, E-2. Out-of-basin plants for California were not compiled because most coho salmon released from California Department of Fish and Game (CDFG) hatcheries occur within basin, and planting records for private production facilities are incomplete. Figure 41 indicates stocks used at selected saltwater-release facilities in California, Oregon and Washington.

Table 5. Average annual releases of coho salmon juveniles (fry and smolts) by evolutionarily significant unit (ESU) from selected production facilities in California, Oregon, Washington, and British Columbia, during release years 1987-91. Releases from facilities for which only one year of data were available were not used. Releases from earlier time periods were used when information from 1987-91 was not available. Production facilities followed by an asterisk (*) are no longer in operation.

Facility	5-Year Average (1987-91)	Source
	Central California coast ESU	
Monterey Bay Salmon and Trout	25,764	Streig 1993
Silver King*	95,074[a]	Streig 1991
Noyo Eggtake Station	107,918	Poe 1988; Grass 1990-92b
Warm Springs	123,157	Gunter 1988b, 1990a-91; Cartwright 1992
Total	351,913	
	Southern Oregon/northern California coasts ESU	
Cochran Ponds (Humboldt Fish Action Council)	35,931[b]	Hull et al. 1989
Mad River	372,863	Barngrover 1988, 1990a-91, Gallagher 1992
Prairie Cr.*	89,009[c]	NRC 1995
Trinity	496,813	Bedell 1990a-91b
Iron Gate	147,272	Hiser 1990-92
Cole Rivers	271,492	R. Beamesderfer 1994 App.
Total	1,413,380	
	Oregon coast ESU	
Butte Falls[d]	379,353	R. Beamesderfer 1994 App.
Bandon	396,521	R. Beamesderfer 1994 App.
Oregon Aqua Foods* and Anadromous, Inc.*, Coos Bay	2,173,625[e]	Wagoner et al. 1990
Rock Cr. (Umpqua)	328,573	R. Beamesderfer 1994 App.
Fall Cr.	1,360,284	R. Beamesderfer 1994 App.
Oregon Aqua Foods*, Yaquina Bay	4,840,000[f]	Borgerson et al. 1991
Salmon River	1,305,576	R. Beamesderfer 1994 App.
Cedar Cr. (Nestucca)	42,680	R. Beamesderfer 1994 App.
Trask	1,087,587	R. Beamesderfer 1994 App.
Nehalem	786,164	R. Beamesderfer 1994 App.
Total	12,700,363	
	Lower Columbia River/southwest Washington coast ESU	
Klaskanine	1,146,128	R. Beamesderfer 1994 App.
Clatsop Economic Development Committee	1,097,210[g]	S. Allen 1994 App.
Big Creek	675,593	R. Beamesderfer 1994 App.
Eagle Cr. NFH	1,859,477	S. Allen 1994 App.
Sandy	1,049,055	R. Beamesderfer 1994 App.
Bonneville	2,481,746	R. Beamesderfer 1994 App.
Cascade	1,417,881	R. Beamesderfer 1994 App.
Oxbow/Wahkeena Pond	1,184,569	R. Beamesderfer 1994 App.
Klickitat	1,532,498[g]	S. Allen 1994 App.
Willard	3,269,220[g]	S. Allen 1994 App.
Washougal	3,885,612[g]	S. Allen 1994 App.

Table 5. Continued.

Facility	5-Year Average (1987-91)	Source
Lower Columbia River/southwest Washington coast ESU, continued		
Speelyai	1,356,904[g]	S. Allen 1994 App.
Lewis	6,180,000[g]	S. Allen 1994 App.
Kalama Falls	990,000[g]	S. Allen 1994 App.
Lower Kalama	831,605[g]	S. Allen 1994 App.
Toutle	478,090[g]	S. Allen 1994 App.
Cowlitz	7,956,089[g]	S. Allen 1994 App.
Elokomin	2,013,032[g]	S. Allen 1994 App.
Grays River	744,655[g]	S. Allen 1994 App.
Sea Resources	125,500[g]	S. Allen 1994 App.
Naselle	3,028,580	NRC 1995
Nemah	1,148,940	NRC 1995
Willapa	1,140,865	NRC 1995
Willapa Bay Gillnetters	529,167[h]	NRC 1995
Westport Pens	154,615[i]	NRC 1995
Aberdeen Net Pens	103,574[j]	WDFW 1994b
Ocean Shores Pens*	100,000[k]	WDFW 1994b
Pacific Trollers (Grays Harbor)	454,931	NRC 1995
Simpson	4,411,488	NRC 1995
Humptulips	3,667,491	NRC 1995
Total	55,214,270	
Olympic Peninsula ESU		
Quinault NFH	1,167,595	NRC 1995
Quinault Lake Tribal Pens	1,207,296	NRC 1995
Soleduck	1,714,747	NRC 1995
Makah NFH	684,405	NRC 1995
Total	4,774,043	
Puget Sound/Strait of Georgia ESU		
Lower Elwha	743,395	NRC 1995
Dungeness	704,751	NRC 1995
Port Gamble Pens	373,567	WDFW 1994b
Quilcene Bay Pens	200,482	WDFW 1994b
Quilcene NFH	1,155,107	NRC 1995
Hood Canal	131,400	NRC 1995
George Adams	932,160	NRC 1995
Squaxin Coop	1,049,758	NRC 1995
S. Sound Pens	1,402,783	NRC 1995
Garrison Springs	883,986	NRC 1995
Fox Island Pens	270,789	WDFW 1994b
Minter Cr.	3,723,359	NRC 1995
Kalama Cr.	823,793	NRC 1995
Puyallup	2,083,898	NRC 1995
Green River	1,316,681	NRC 1995
Crisp Cr. (Green R. satellite)	1,957,936	NRC 1995

Table 5. Continued

Facility	5-Year Average (1987-91)	Source
	Puget Sound/Strait of Georgia ESU, continued	
Elliott Bay Pens	137,312	WDFW 1994b
Suquamish Pens (Agate Pass)	412,826	WDFW 1994b
Grovers Cr.	190,914	NRC 1995
Issaquah	2,205,195	NRC 1995
Univ. Washington	49,434	NRC 1995
Skykomish	1,270,302	NRC 1995
Tulalip	820,224	NRC 1995
S. Whidbey Salmon	105,833	NRC 1995
Baker	110,670	C. Feldman 1994 App.
Skagit	308,622	NRC 1995
Swinomish Channel	980,055	NRC 1995
Lummi Sea Ponds	801,277[i]	NRC 1995
Skookum Cr.	1,628,901	NRC 1995
Nooksack	2,497,740	NRC 1995
British Columbia inside[l] production facilities	13,918,384[e]	Cross et al. 1991
Total	43,191,534	
Total for all areas	117,645,503	

[a]Average from 4 years of data: 1984-88.
[b]Average from 2 years of data: 1987-88.
[c]Average from 4 years of data: 1987-88, 1990-91.
[d]Butte Falls Hatchery, although located within the southern Oregon/northern California coast ESU, is considered to be part of the Oregon coast ESU because it rears Umpqua River coho salmon and releases them into the Umpqua River.
[e]Average from 5 years of data: 1985-89.
[f]Average from 5 years of data: 1986-90.
[g]Smolt releases only.
[h]Average from 3 years of data: 1987, 1990-91.
[i]Average from 4 years of data: 1988-91.
[j]Average from 3 years of data: 1989-91.
[k]Average from 2 years of data: 1990-91.
[l]"Inside" production area includes the following: Johnstone Strait, Georgia Strait--Vancouver Island, Strait of Georgia--mainland, and Lower Fraser.

ESU	HATCHERY	CCC		S. Oregon/N. Calif. coasts								Oregon coast											LCR/ SWC				PS/SG			Other			
		Warm Springs	Noyo R.	Eel R.	Humboldt State	Humboldt Ponds	Mad River	Prairie Cr.	Trinity	Iron Gate	Cole Rivers	Coquille	Coos R.	Tenmile Lakes	Umpqua	Alsea/Fall Cr.	Siletz	Salmon R.	Nestucca	Trask	Nehalem	Necanicum	Klaskanine	Big Cr.	Cascade	Sandy	Skagit	Green R.	Minter Cr.	Crystal Lake	Mt Shasta	Silverado	Unspec. other(s)
CCC	Warm Springs (Russian R.)	X	X				X	X		X															X								
CCC	Noyo Egg Taking Sta.	X	X				X																							X	X	X	
S. Oreg./n. Calif. c.	Humboldt Cochran Ponds		X			X	X			X										X													
S. Oreg./n. Calif. c.	Humboldt State		X		X		X		X	X										X													
S. Oreg./n. Calif. c.	Mad R.	X	X		X		X	X	X	X						X				X			X			X	X	X	X			X	
S. Oreg./n. Calif. c.	Prairie Cr. (Redwood Cr.)						X	X	X	X										X			X										X
S. Oreg./n. Calif. c.	Trinity		X	X					X							X									X						X		
S. Oreg./n. Calif. c.	Iron Gate (Klamath R.)								X	X													X		X								X
S. Oreg./n. Calif. c.	Cole Rivers (Rogue R.)										X		X	X	X																		
Oregon coast	Butte Falls											X	X	X	X	X	X		X														
Oregon coast	Bandon (Coquille R.)											X		X	X	X			X														
Oregon coast	Coos R.											X	X	X		X						X	X										
Oregon coast	Alsea/Fall Cr.												X	X	X	X	X		X	X	X		X	X									
Oregon coast	Siletz													X		X	X	X		X	X												
Oregon coast	Salmon R.															X	X	X		X													
Oregon coast	Cedar Cr. (Nestucca)																		X	X	X												
Oregon coast	Trask													X					X	X	X												
Oregon coast	Nehalem												X	X			X		X	X	X		X			X							

Figure 35. Coho salmon stocks used by selected production facilities within the geographic range of the central California coast (CCC), southern Oregon/ northern California coasts, and Oregon coast evolutionarily significant units (ESUs). The production facilites are listed on the left from south (top) to north (bottom), and the stocks are listed across the top, from south (left) to north (right), with an "X" indicating stocks used. Thick lines delineate the ESUs. ESU abbreviations are LCR/SWC: lower Columbia River/southwest Washington coast; and PS/SG: Puget Sound/Strait of Georgia. Stocks listed under "other" came from rearing/distribution centers which do not directly release fish; the origin of these stocks are not known. (Murray 1959, 1961, 1962a-b, 1964-68; Wallis 1961a-b, 1963a, d, e; Riley 1967a-68, 1970; Bedell 1970a-b, 1972a-b, 1974-76, 1978-80, 1982-84, 1987a-b, 1990-91b; Marshall 1970; Arnold 1972a-b, 1974-75, 1977a-c; Will 1973a-c, 1975-76, 1978-79; Hiser 1979, 1982-83, 1985a-b, 1987a-b, 1990-93; Snyder and Sanders 1979; Ducey 1980, 1982a-c; Sanders 1980, 1982-83b; Estey 1982-84, 1986; Grass 1982, 1990-92b; ODFW 1982; Barngrover 1983, 1986-92; Poe 1984, 1988; Milligan 1986-87, Gunter 1988a-b, 1990a-91; Cartwright 1992; Ramsden 1993; R. Berry 1994 App.; NRC 1995)

STOCKS USED

ESU	HATCHERY	Lower Columbia River/southwest Washington coast																						Oregon coast							Puget S./Str. Georgia							OP
		Klaskanine	Big Cr.	Eagle Cr.	Sandy R.	Bonneville	Cascade	Oxbow	Klickitat	Washougal	Lewis R.	Kalama Falls	Lower Kalama	Toutle R.	Cowlitz	Elokomin	Grays R.	Humptullips	Satsop	Simpson	Willapa	Nemah	Naselle	Coos R.	Tenmile Lakes	Alsea/Fall Cr.	Yaquina	Siletz	Nestucca	Trask	Puyallup	Samish	Green R	Minter Cr.	Hood Canal	Puget sound unspec.	Dungeness	Soleduck
Lower Columbia River/southwest Washington	Klaskanine	X	X		X	X	X				X														X	X		X	X	X								
	Big Cr.	X	X			X									X																							
	Eagle Cr.	X	X		X		X					X																										
	Sandy R.		X		X	X																																
	Bonneville	X	X	X	X	X	X	X			X			X										X	X	X	X			X								
	Cascade		X	X	X	X	X	X							X																							
	Oxbow		X	X	X	X	X	X							X										X													
	Klickitat		X						X	X	X	X		X	X	X																						
	Washougal		X							X				X	X																		X					
	Lewis		X								X			X	X																							
	Kalama Falls	X								X		X	X	X	X																							
	Low. Kalama	X								X	X	X	X	X	X		X																					
	Toutle									X		X		X	X																		X					
	Cowlitz													X	X																							
	Elokomin	X	X								X			X	X	X	X														X		X					
	Grays River	X								X				X	X		X																					
	Humptullips																	X	X	X	X	X	X									X	X			X	X	X
	Simpson																	X	X	X		X	X									X	X	X	X	X	X	X
	Willapa														X			X	X		X	X											X			X	X	X
	Nemah																		X		X	X	X										X			X	X	
	Naselle														X			X	X		X	X	X										X				X	X

Figure 36. Coho salmon stocks used by selected production facilities within the geographic range of the lower Columbia River/southwest Washington coast evolutionarily significant unit (ESU). The production facilites are listed on the left from south (top) to north (bottom), and the stocks are listed across the top, with an "X" indicating stocks used. Thick lines delineate the ESUs. ESU abbreviation is OP: Olympic Peninsula. (U.S. Dep. Interior 1959; Wallis 1961c, 1963b, c, 1964a-b, 1966; ODFW 1982, 1993a; Fuss et al. 1993; WDFW 1994c; R. Berry 1994 App.; H. Fuss 1994 App.; NRC 1995.)

STOCKS USED

ESU	HATCHERY	Olympic Pen.				Puget Sound/Strait of Georgia															L. Columbia R./SW Wash. coast								
		Soleduck	Hoh	Queets	Quinault	Elwha	Dungeness	Quilcene	Hood Canal	Geo. Adams	Garrison Spr.	Minter Cr.	Puyallup	Green R.	Issaquah	Skykomish	Skagit R.	Samish	Nooksack	Capilano (BC)	Moclips	Satsop	Simpson	Willapa	Cowlitz	Toutle	Eagle Cr.	Bonneville	Washougal
O P	Quinault NFH	X		X	X			X	X	X				X			X				X		X	X	X				
	Quinault Lake	X		X	X			X		X				X		X							X	X	X	X			
	Soleduck	X	X	X			X			X															X				X
	Makah				X			X																					
Puget Sound/Strait of Georgia	Dungeness	X				X	X			X		X	X	X			X			X						X			
	Quilcene				X		X	X	X	X						X											X		
	Hood Canal	X					X	X	X	X		X	X	X		X	X	X	X	X									
	Geo. Adams	X							X	X		X	X	X			X			X									
	Garrison Springs								X	X	X	X	X			X	X	X	X										
	Minter Cr.						X	X		X		X	X	X	X	X	X		X										
	Puyallup									X	X	X	X	X			X												X
	Green R.									X		X	X	X	X	X	X	X	X			X	X			X			
	Issaquah											X	X	X	X	X	X	X								X			
	Skykomish														X	X													
	Skagit R.													X		X	X	X	X										
	Samish													X		X	X	X	X										
	Nooksack													X			X	X	X	X									

Figure 37. Coho salmon stocks used by selected coho salmon production facilities within the geographic range of the Olympic Peninsula and Puget Sound/Strait of Georgia evolutionarily significant units (ESUs). The production facilites are listed on the left from south (top) to north (bottom), and the stocks are listed across the top from south (left) to north (right), with an "X" indicating stocks used. Thick lines delineate the ESUs. ESU abbreviation is OP: Olympic Peninsula. (Houston 1983; USFWS 1985; Kenworthy 1986a-b; Zajac 1988-1992; Fuss et al. 1993; D. Dailey 1994 App.; J. Harp 1994 App.; H. Fuss 1994 App.; WDFW 1994c; R. Wunderlich 1994 App.; NRC 1995.)

STOCKS RELEASED

ESU	RIVER	SO/NCC		Oregon coast														LCR/SWC					
		Cole Rivers	Elk R.	Floras Cr./New R	Coquille	Coos	Tenmile Lake	Umpqua	Tahkenitch	Siltcoos	Alsea	Siletz	Salmon	Nestucca	Trask	Nehalem	Necanicum	Klaskanine	Big Creek	Sandy	Bonneville	Cascade	Carson
SO/NCC	Chetco					X																	
	Rogue					X					X												
Oregon coast	New		X		X	X					X				X						X	X	
	Umpqua	X				X					X	X				X							
	Siuslaw			X		X		X		X	X	X			X								X
	Coquille	X				X					X	X											
	Coos		X		X		X				X	X			X		X	X			X	X	
	Yachats											X											
	Alsea											X			X	X							
	Yaquina								X		X	X				X		X					
	Siletz										X		X		X	X							
	Salmon										X	X			X	X							
	Nestucca										X	X			X	X					X		
	Tillamook													X	X	X		X			X		
	Trask										X	X		X						X	X		
	Wilson										X			X	X	X		X			X		
	Kilchis														X	X		X	X		X		
	Miami														X	X		X	X				
	Nehalem										X				X			X	X		X		
	Necanicum											X			X	X		X					

Figure 38. Out-of-basin coho salmon stocks released as juveniles and adults into selected river basin in the southern Oregon/northern California coasts (SO/NCC) (Oregon portion only) and Oregon coast evolutionarily significant units (ESUs). River basins are listed on the left from south (top) to north (bottom), and the stocks are listed across the top from south (left) to north (right), with an "X" indicating stocks used. Thick lines delineate the ESUs. ESU abbreviation is LCR/SWC: Lower Columbia River/southwest Washington coast. (Wallis 1961a-b, 1963a, d-e; Willis 1979; ODFW 1993a.)

STOCKS RELEASED

ESU	RIVER	OC		Lower Columbia River/southwest Washington coast																				Olympic Pen.				Puget Sound/Strait Georgia							
		Siletz	Trask	Klaskanine	Big Creek	Clackamas	Sandy	Eagle Cr.	Bonneville	Cascade	Oxbow	Washougal	Lewis R.	Kalama Falls	Toutle/Type S	Cowlitz/Type N	Nemah	Naselle	Willapa	Satsop Springs	Simpson	Wishkah	Humptulips	Quinault	Queets	Quillayute	Sooes/Makah	Dungeness	Skokomish	Hood Canal	Quilcene	Geo. Adams	Green River	Skagit	Samish
Lower Columbia River/southwest Washington coast	Lewis and Clark			X			X		X																										
	Youngs			X	X	X	X		X					X		X																			
	Klaskanine	X	X		X	X	X	X	X							X																			
	Big Cr.								X																										
	Gnat Cr.				X																														
	Claskanie				X		X		X							X																			
	Clackamas		X		X		X		X	X	X					X																			
	Sandy								X																										
	Big White Salmon														X	X																			
	Wind												X		X	X																			
	Washougal				X			X					X		X	X																	X		
	Lewis			X	X			X				X		X	X	X																			
	Kalama			X								X	X		X	X																			
	Cowlitz			X	X								X	X																			X		
	Elochoman			X	X			X				X	X		X	X																	X		
	Grays			X	X							X	X		X	X																	X		
	Naselle														X	X	X		X	X	X		X			X		X					X		
	Willapa															X	X	X		X	X		X			X		X					X		
	North																X	X	X		X							X					X		
	Chehalis														X		X	X	X			X	X	X		X	X	X	X	X		X	X	X	X
	Humptulips																X	X	X	X	X	X				X							X		
	Copalis																		X		X		X	X		X									
	Moclips																		X					X	X	X					X				

Figure 39. Out-of-basin coho salmon stocks released in selected rivers in the lower Columbia River/southwest Washington coast evolutionarily significant unit (ESU). River basins are listed on the left from south (top) to north (bottom), and the stocks are listed across the top from south (left) to north (right), with an "X" indicating stocks used. Thick lines delineate the ESUs. ESU abbreviation is OC: Oregon coast. (Wallis 1961c, 1963b-c, 1964a-b, 1966; ODFW 1991; ODFW 1993a; J. Harp 1994 App.; WDFW 1994c).

STOCKS RELEASED

ESU	RIVER	L. Columbia R./SW Wash. coast										Olympic Pen.					Puget Sound/Strait of Georgia													
		Eagle Cr.	Bonneville	Cascade	Washougal	Kalama Falls	Cowlitz/Type N	Toutle	Willapa	Simpson	Humptulips	Quinault	Queets	Hoh	Quillayute	Sooes/Makah	Elwha	Dungeness	Hood Canal	Quilcene	Geo. Adams	Puyallup	Minter Cr.	Green River	Univ. Wash.	Issaquah	Skykomish	Skagit	Samish	Nooksack
Olympic Peninsula	Quinault						X			X	X		X		X						X									
	Queets								X			X			X															
	Hoh								X			X			X			X						X				X		
	Quillayute	X					X			X				X				X		X	X			X				X		
	Sooes											X			X			X		X	X									
	Waatch											X				X				X	X									
	Sekiu														X		X	X			X									
	Hoko														X		X	X			X			X						
	Pysht														X		X	X			X			X				X		
Puget Sound/Strait of Georgia	Elwha									X					X			X						X						
	Dungeness							X									X				X	X		X				X		
	Big Beef Cr.																			X	X		X	X			X			
	Big Quilcene	X																	X		X									
	Dosewallips																	X	X	X	X		X	X					X	
	Duckabush																	X	X	X	X	X	X	X			X		X	
	Hamma Hamma																	X	X	X	X		X	X					X	
	Skokomish														X			X	X	X		X	X	X			X	X	X	
	Deschutes									X					X						X	X	X	X			X			
	Minter Creek		X					X												X	X			X			X	X		X
	Nisqually					X															X	X	X	X		X	X	X		
	Puyallup				X																X		X	X		X	X	X		
	Green River		X					X		X												X	X			X	X			X
	Sammamish							X													X	X	X	X			X	X	X	
	Snohomish														X								X	X	X	X		X	X	
	Stillaguamish																							X		X	X	X	X	
	Skagit																				X	X	X	X			X		X	X
	Samish																							X			X	X		X
	Nooksack			X		X									X									X			X	X	X	

Figure 40. Out-of-basin coho salmon stocks released in selected rivers in the Olympic Peninsula and Puget Sound/Strait of Georgia evolutionarily significant units (ESUs). River basins are listed on the left from south (top) to north (bottom), and the stocks are listed across the top from south (left) to north (right), with an "X" indicating stocks used. Thick lines delineate the ESUs. (D. Dailey 1994 App.; T. Kane and P. Wampler 1994 App.; WDFW 1994c).

ESU/STOCKS RELEASED

		CCC	SO/NCC		Oregon coast				LCR/SWC					OP	Puget Sound/Strait of Georgia											
ESU	SALTWATER RELEASE FACILITY	Noyo	Klamath R.	Rogue R	Rock Cr.	Fall Cr/Alsea	Siletz	Trask	Bonneville	Cowlitz	Type S/Toutle	Simpson	Humptulips	Soleduck	Dungeness	Geo. Adams	Minter Cr.	Puyallup	Green R.	Issaquah	Univ. Wash.	Skykomish	Skagit	Samish	Capilano (BC)
CCC	SilverKing, Davenport Landing, CA	X	X			X			X	X	X										X				
Oreg. cst.	Anadromous Inc. & OAF, Coos Bay			X		X												X	X			X	X		
	Oregon Aqua Foods (OAF), Yaquina Bay				X	X	X	X								X		X	X		X	X	X	X	
LCR/SWC	Ocean Shores											X													
	Aberdeen Netpens											X	X												
	Westport Pens											X	X	X											
Puget Sound/Strait of Georgia	Port Gamble														X	X									
	Quilcene Bay														X										
	Squaxin													X		X	X	X	X	X		X	X		
	South Sound																X		X	X		X	X		
	Poncin Cove															X						X			
	Fox Island																X			X		X	X		
	Commencement Bay																					X	X		
	Des Moines																					X	X		
	Little Clam Bay																		X	X		X	X		
	Suquamish															X	X					X			
	Seattle Aquarium																X					X	X		X
	Elliot Bay																X		X			X	X		
	Edmonds																				X	X	X		
	South Whidbey																						X		
	Oak Harbor																					X	X	X	

Figure 41. Coho salmon stocks used by selected saltwater release facilities within the geographic range of the central California coast (CCC), lower Columbia River/southwest Washington coast (LCR/SWC), and Puget Sound/Strait of Georgia evolutionarily significant units (ESUs). Production facilities are listed on the left from south (top) to north (bottom) and the stocks are listed along the top from south (left) to north (right), with an "X" indicating stocks used. Thick lines delineate the ESUs. ESU abbreviations are SO/NCC: southern Oregon/northern California coasts; OP: Olympic Peninsula. (Wagoner et al. 1990, Borgerson et al. 1991, Bryant 1994, WDFW 1994c, NRC 1995.)

Unless specified, these tables and figures were compiled from the following sources: Murray 1959, 1961-62b, 1964-68; U.S. Dep. Interior 1959; Wallis 1961a-c, 1963a-64b, 1966; Riley 1967a-68, 1970; Bedell 1970a-b, 1972a-b, 1974-76, 1978-80, 1982-84, 1987a-b, 1990a-91b; Marshall 1970; Arnold 1972a-b, 1974-75, 1977a-c; Will 1973a-c, 1975-76, 1978a-79; Hiser 1979, 1982a-83, 1985a-b, 1987a-b, 1990-93; Snyder and Sanders 1979; Willis 1979; Ducey 1980, 1982a-83; Sanders 1980, 1982a-83b; Estey 1982a-84, 1986; Grass 1982, 1990-92c; ODFW 1982, 1993a; Barngrover 1983, 1986-88, 1990a-92; Houston 1983; Poe 1984, 1988; USFWS 1985; Kenworthy 1986a-b; Milligan 1986-87; Gunter 1988a-b, 1990a-91; Zajac 1988-92; Cross et al. 1991; Cartwright 1992; Fuss et al. 1993; Ramsden 1993; S. Allen 1994 App.; R. Beamesderfer 1994 App.; R. Berry 1994 App.; Bryant 1994; D. Dailey 1994 App.; H. Fuss 1994 App.; J. Harp 1994 App.; WDFW 1994c; and Natural Resources Consultants (NRC) 1995.

Central California coast ESU—Compared to areas farther north, the few hatcheries located in the central California ESU are relatively small, with approximately 350,000 coho salmon released annually between 1987 and 1991. The largest production facilities each release about 100,000 coho salmon each year (Table 5). There has been considerable movement of coho salmon between hatcheries or egg-taking stations in central and northern California, with the fish eventually outplanted in either area. These transfers primarily involved California hatchery stocks and may have also included Oregon and Washington stocks that were not identified as such.

Southern Oregon/northern California coasts ESU—Hatchery production of coho salmon in the southern Oregon/northern California coasts ESU[8] is greater than in the central California coast ESU, but considerably less than in more northerly ESUs. Large hatcheries within this ESU (e.g., Mad, Trinity) have released 400,000-600,000 coho salmon annually in recent years, with total annual production at approximately 1.4 million coho salmon between 1987 and 1991 (Table 5). Aside from considerable movement of coho salmon between hatcheries or egg-taking stations in central and northern California, northern California hatcheries have also received fairly large transplants of coho salmon from hatcheries in areas outside the ESU, including the Oregon coast, lower Columbia River/southwest Washington coast, and Puget Sound/Strait of Georgia (Fig. 35). In contrast, Cole Rivers Hatchery (Rogue River), appears to have relied almost exclusively on native stocks (Fig. 35). The frequency and magnitude of out-of-basin plants in the southern Oregon/northern California coasts ESU appears to be relatively low (Fig. 38), although records are incomplete.

Oregon coast ESU—Each large public hatchery along the Oregon coast (Trask, Salmon, Fall Creek) has released just over 1 million coho salmon annually between 1987 and 1991. In recent years, private production facilities released between 2.2 and 4.8 million coho salmon annually (Wagoner et al. 1990, Borgerson et al. 1991), for total annual production in

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[8]The Butte Falls Hatchery is located on the Rogue River (in the southern Oregon/northern California coasts ESU) but raises Umpqua River coho salmon and releases them into the Umpqua River (in the Oregon coast ESU). Because of the fish used and release location, we consider this hatchery under the Oregon coast ESU.

the Oregon coast ESU of about 12.7 million coho salmon (Table 5). Most transfers of coho salmon between public hatcheries used stocks from within the area, most commonly from Tenmile Lake and Trask (Fig. 35). Some transfers into these hatcheries have occurred from the lower Columbia River/southwest Washington coast, but these were relatively infrequent and minor. In contrast, private Oregon coast hatcheries began coho salmon production using Puget Sound stocks, which were later mixed with Oregon coastal stocks (Fig. 41) (Wagoner et al. 1990, Borgerson et al. 1991). These private facilities are presently not in operation. Most outplants of coho salmon into Oregon coastal rivers have used Oregon coastal stocks, with outplants of stocks from outside the Oregon coast being relatively small and infrequent (Fig. 38, Appendix Tables E-1, E-2). Plants of sexually mature adults were common within this ESU in the late 1960s and early 1970s, and they used stocks from within and outside of the Oregon coast (Appendix Table E-2). Recipient basins of stock transfers along the Oregon coast, either to hatcheries or off-station plants, are generally those closest to the source stock.

Lower Columbia River/southwest Washington coast ESU—Hatchery production of coho salmon in the lower Columbia River/southwest Washington coast ESU far exceeds that of any other area with respect to the number of hatcheries and quantities of fish produced; total annual production was just over 55 million fish between 1987 and 1991 (Table 5). Many hatcheries within this ESU released 1-3 million smolts annually, with the two largest hatcheries, Cowlitz and Lewis, releasing an average of 6-7 million smolts annually (Table 5). Coho salmon production from Washington-side Columbia River hatcheries (29.4 million smolts per year) provides about 53% of the total annual production, with the remainder split between Oregon-side Columbia River (10.9 million smolts) and southwest Washington coast (14.7 million fish) facilities.

Extensive stock transfers have occurred within the lower Columbia River/southwest Washington coast ESU. Most transfers of coho salmon have used stocks from within the ESU, although transfers from outside the ESU have also occurred, including those from the Oregon coast, Olympic Peninsula, and Puget Sound/Strait of Georgia ESUs (Fig. 36). Outplanting records show a similar pattern to transfers between hatcheries, with extensive use of within-ESU stocks, in addition to less frequent use of stocks from the same three ESUs (Fig. 39). Most movement of coho salmon, either as hatchery transfers or off-station releases, has occurred within each of the three areas of this ESU (Oregon-side Columbia River, Washington-side Columbia River, and southwest Washington coast), with little movement of fish among the three areas. The Clackamas River has also been extensively outplanted with early-running Columbia River stocks and was outplanted with coho salmon from the Oregon coast in 1967 (Cramer and Cramer 1994).

Olympic Peninsula ESU—Coho salmon production facilities in the Olympic Peninsula ESU each produce 1-2 million coho salmon annually, with a total annual release of 4.8 million coho salmon between 1987 and 1991 (Table 5). Natural production in the ESU is relatively high, due in large part to nearly pristine habitat within the Olympic National Park. Hatcheries within this ESU have relied on native stocks, with contributions of stocks from the lower Columbia River/southwest Washington and Puget Sound/Strait of Georgia (Fig. 37). Olympic Peninsula drainages are primarily outplanted with Olympic Peninsula stocks; however, some outplants of fish from adjacent ESUs have also occurred (Fig. 40).

Puget Sound/Strait of Georgia ESU—Hatchery production in the Puget Sound/Strait of Georgia ESU is extensive, with 43 million coho salmon released annually in 1987-91 (Table 5). Many of the larger Washington hatcheries (Minter Creek, Puyallup, Crisp Creek, Issaquah, and Nooksack) each recently released 2-4 million coho salmon annually, while the larger net-pen facilities (South Sound Net Pens and Squaxin Coop) released a total of over 2 million coho salmon annually (Table 5). Net-pen operations, unlike hatcheries, generally do not attempt to attract or recover returning adults. Most coho salmon released from Puget Sound net-pen facilities are of local origin and produced at local hatcheries, with Skykomish and Skagit River stocks most commonly used. About one-third of the artificial production in this ESU occurs in British Columbia. In addition to extensive hatchery production in the ESU, there is also considerable natural production.

Stock transfers and outplants within the Washington portion of the Puget Sound/Strait of Georgia ESU have been extensive. Most stocks involved have been derived from within the geographic boundaries of the ESU, but stocks from the lower Columbia River/southwest Washington and Olympic Peninsula have also been used (Figs. 37, 40-41). The stocks which are most commonly transferred between Washington hatcheries in the area include Skagit, Skykomish, Green River, and Dungeness, while the most commonly planted out-of-basin stocks include Samish, Skagit, Skykomish, Green River, Minter Creek, Puyallup, and George Adams. In British Columbia, stock transfers have also occurred (Aro 1979), although many hatcheries there have relied primarily on native stocks. In some areas of British Columbia, virtually all production releases are marked (Hilborn and Winton 1993), and there is an emphasis on using wild broodstock (Miller 1990).

Run Timing

A common phenomenon in hatchery populations is advancement and compression of run timing, and these changes can affect future generations of naturally spawning fish. Fry of early-spawning adults generally hatch earlier, grow faster, and can displace fry of later-spawning natural fish. Conversely, early spawning coho salmon redds are more prone to destruction from early fall floods. Consequently, early-spawning individuals may be unable to establish permanent, self-sustaining populations but may nevertheless adversely affect existing natural populations (Nickelson et al. 1986). A recent study found that over a period of 13 years, spawn timing of coho salmon at five Washington hatcheries decreased from 10 to 3 weeks, causing the period of return to hatcheries to decrease by half (Fig. 42) (Flagg et al. 1995).

Juvenile Outplants

Another common hatchery practice with coho salmon is release of “excess” hatchery juveniles into natural habitat as fry or parr (Flagg et al. 1995). Outplanting large numbers of large hatchery juveniles into streams already occupied by naturally produced juveniles may place the resident fish at a competitive disadvantage and force them into marginal habitats with low survival potential (Chapman 1962, Solazzi et al. 1990). The overstocked hatchery fish may also have low survival potential under these conditions and fail to return as adults in adequate numbers. This practice may cause streams planted with presmolts to remain below

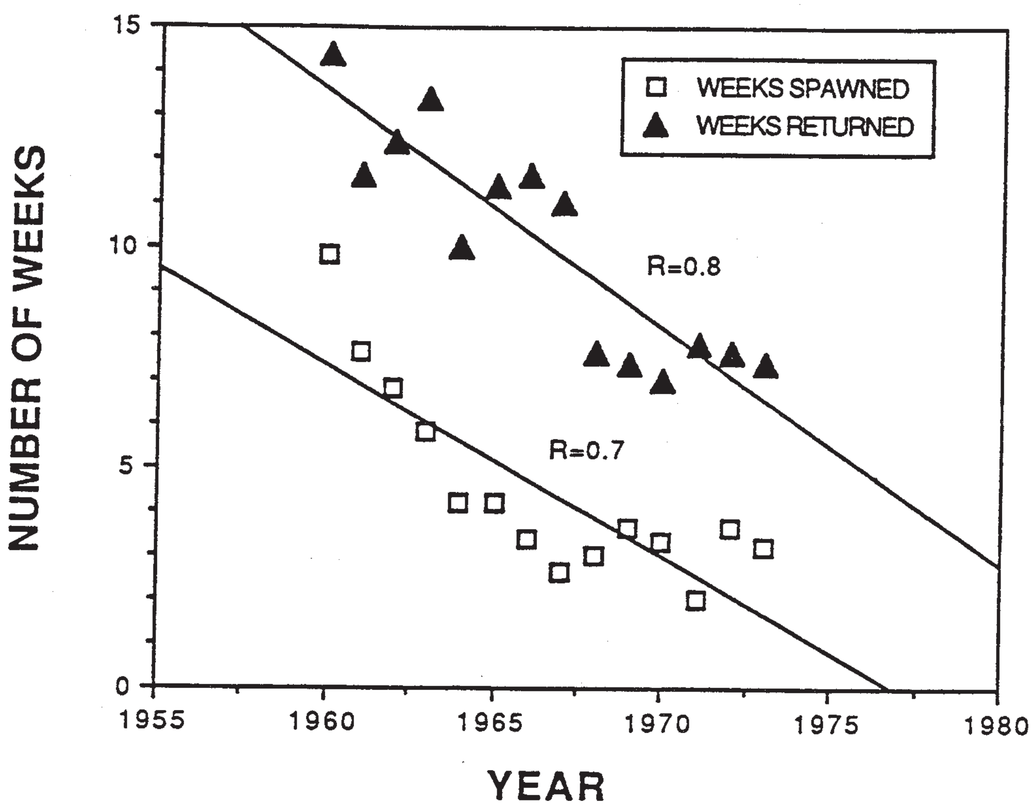

Figure 42. Changes over a 25-year period in the duration of return and spawning timing for coho salmon from five Washington hatcheries. (Reproduced from Flagg et al. 1995).

juvenile carrying capacity (Nickelson et al. 1986). Stocking of over 10 million presmolts annually into small streams of Columbia River tributaries has occurred (ODFW 1991, WDF 1991), far exceeding expected carrying capacity.

ASSESSMENT OF EXTINCTION RISK

Background

As outlined in the "Introduction" above, NMFS considers a variety of information in evaluating the level of risk facing an ESU. Aspects of several of these risk considerations are common to all coho salmon ESUs. These are discussed in general below; more specific discussion of factors for each of the ESUs under consideration here can be found in the following sections. Because we have not taken future effects of conservation measures into acount (see "Introduction"), we have drawn scientific conclusions about the risk of extinction faced by identified ESUs under the assumption that present conditions will continue. Future effects of conservation measures will be taken into account by the NMFS Northwest and Southwest Regional Offices in making listing recommendations.

Absolute Numbers

The absolute number of individuals in a population is important in assessing two aspects of extinction risk. For small populations that are stable or increasing, population size can be an indicator of whether the population can sustain itself into the future in the face of environmental fluctuations and small-population stochasticity; this aspect is related to the concept of minimum viable populations (MVP) (Gilpin and Soulé 1986, Thompson 1991). For a declining population, present abundance is an indicator of the expected time until the population reaches critically low numbers; this aspect is related to the concept of "driven extinction" (Caughley 1994).

In addition to total numbers, the spatial and temporal distribution of adults is important in assessing risk to an ESU. Spatial distribution is important both at the scale of river basins within an ESU and at the scale of spawning areas within basins ("metapopulation" structure). Temporal distribution is important both among years, as an indicator of the relative health of different brood-year lineages, and within seasons, as an indicator of the relative abundance of different life history types or runs.

Traditionally, assessment of salmon populations has focused on the number of harvestable or reproductive adults, and these measures comprise most of the data available for Pacific salmon. In assessing the future status of a population, the number of reproductive adults is the most important measure of abundance, and we focus here on measures of the number of adults escaping to spawn in natural habitat. However, total run size (spawning escapement + harvest) is also of interest because it indicates potential spawning in the absence of harvest. Data on other life history stages (e.g., freshwater smolt production) can be used as a supplemental indicator of abundance.

Because the ESA (and NMFS policy) mandates a biological review that focuses on viability of natural populations, we attempted to distinguish natural fish from hatchery produced fish. All statistics are based on data that indicate total numbers or density of adults that spawn in natural habitat ("naturally spawning fish"). The total of all naturally spawning fish ("total escapement") is divided into two components (Fig. 43): "Hatchery produced" fish are reared as juveniles in a hatchery but return as adults to spawn naturally; "Natural" fish are progeny of naturally spawning fish.

Historical Abundance and Carrying Capacity

The relationship of current abundance and habitat capacity to that which existed historically is an important consideration in evaluating risk for several reasons. Knowledge of historical population conditions provides a perspective of the conditions under which present stocks evolved. Historical abundance also provides the basis for establishing long-term population trends. Comparison of present and past habitat capacity can also indicate long-term population trends and problems of population fragmentation.

Although the relationship of present abundance to present carrying capacity is important for understanding the health of populations, the fact that a population is near its current capacity does not in itself mean that it is healthy. If a population is near capacity, there will be limits to the effectiveness of short-term management actions to increase its abundance, and competition and other interactions between hatchery and natural fish may be important considerations because hatchery supplementation will further increase population density in a limited habitat.

Quantitative assessments of habitat are quite rare, although rough estimates of carrying capacity are frequently made for setting management goals. From the evidence available, it is clear that natural production of coho salmon is now substantially below historical levels for all ESUs considered here, although this decline has been offset by hatchery production in many areas. Although we have not attempted analysis of the proportion of total habitat lost due to blockages, we found significant blockages of freshwater habitat in every ESU. Freshwater and estuarine habitats are also degraded throughout the entire region considered, although the severity of degradation varies among ESUs.

Trends in Abundance

Short- and long-term trends in abundance are a primary indicator of risk in salmonid populations. Trends may be calculated from a variety of quantitative data, including dam or weir counts, stream surveys, and catch data. These data sources and methods are discussed in more detail below, under "Approach." When data series are lacking, general trends may be inferred by comparing historical and recent abundance estimates, or by considering trends in habitat quantity or condition.

The role of artificial propagation (in the form of hatcheries) for Pacific salmon requires careful consideration in ESA evaluations. Artificial propagation has implications both for evaluating production trends and in evaluating genetic integrity of populations. Waples

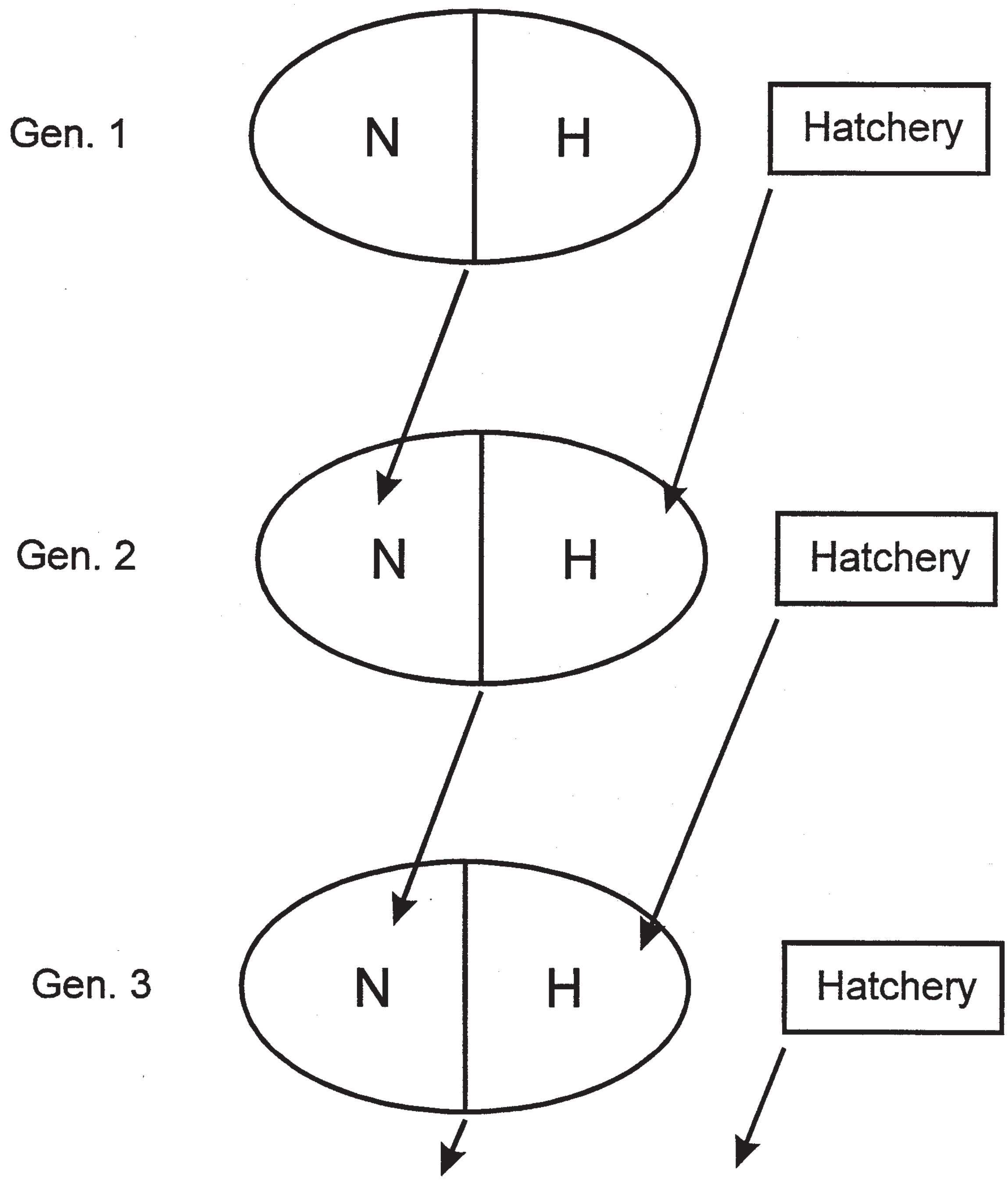

Figure 43. Schematic diagram of mixing of naturally and hatchery produced fish in natural habitat. Ovals represent the total spawning in natural habitat in successive generations (Gen.1-3). This total is composed of naturally produced (N) and hatchery produced (H) offspring of individuals in the previous generation.

(1991a, b) and Hard et al. (1992) discussed the role of artificial propagation in ESU determination and emphasized the need to focus on natural production in the threatened or endangered status determination. Because of the ESA's emphasis on ecosystem conservation, this analysis focuses on naturally reproducing salmon. A fundamental question in ESA risk assessments is whether natural production is sufficient to maintain the population without the constant infusion of artificially produced fish. A full answer to this question is difficult without extensive studies of relative production and interactions between hatchery and natural fish.

One method of evaluating this issue involves calculating the natural cohort replacement ratio, defined as the number of naturally spawning adults naturally produced in one generation divided by the number of naturally spawning adults (regardless of parentage) in the previous generation. Data for coho salmon are rarely sufficient for this calculation, and we have not attempted to estimate this ratio in this report. However, the ratio can be approximated from the average population trend if the degree of hatchery contribution to natural spawning can be estimated (Busby et al. 1994 appendix B). Where such estimates were available, the presence of hatchery fish among natural spawners was taken into consideration in evaluating the sustainability of natural production for individual populations.

Coastwide trends in coho abundance provide another method of evaluating relative production, though from a larger perspective. Coastwide abundance must be approximated from commercial and sport harvest data, which is tracked closely by government agencies. Commercial landings of coho salmon in Washington, Oregon, and California from 1882 to 1982 have been estimated by Shepard et al. (1985). These estimates show relatively constant landings since 1895, ranging mainly between 1.0 and 2.5 million fish, with a low of 390,000 fish (1920) and a high of 4.1 million fish (1971). Comparable recent estimates are not available, but ocean commercial troll and sport landings have been summarized from 1971 to 1994 by PFMC (1995). These data show a recent harvest decline from 4.3 million fish in 1971 to 290,000 fish in 1993, and less than 500 fish in 1994 (Fig. 44). However, this decline largely reflects reductions in allowable harvest, which were imposed in response to perceived declines in production.

Factors Causing Variability

Variations in the freshwater and marine environments are thought to be a primary factor driving fluctuations in salmonid run size and escapement (Pearcy 1992, Beamish and Bouillon 1993, Lawson 1993). Recent changes in ocean condition are discussed below. Habitat degradation and harvest have probably made stocks less resilient to poor climate conditions, but these effects are not easily quantifiable.

Threats to Genetic Integrity

In addition to being a factor in evaluating natural replacement rates, artificial propagation can substantially affect the genetic integrity of natural salmon populations in several ways. First, stock transfers that result in interbreeding of hatchery and natural fish can lead to loss of fitness in local populations and loss of diversity among populations. The latter

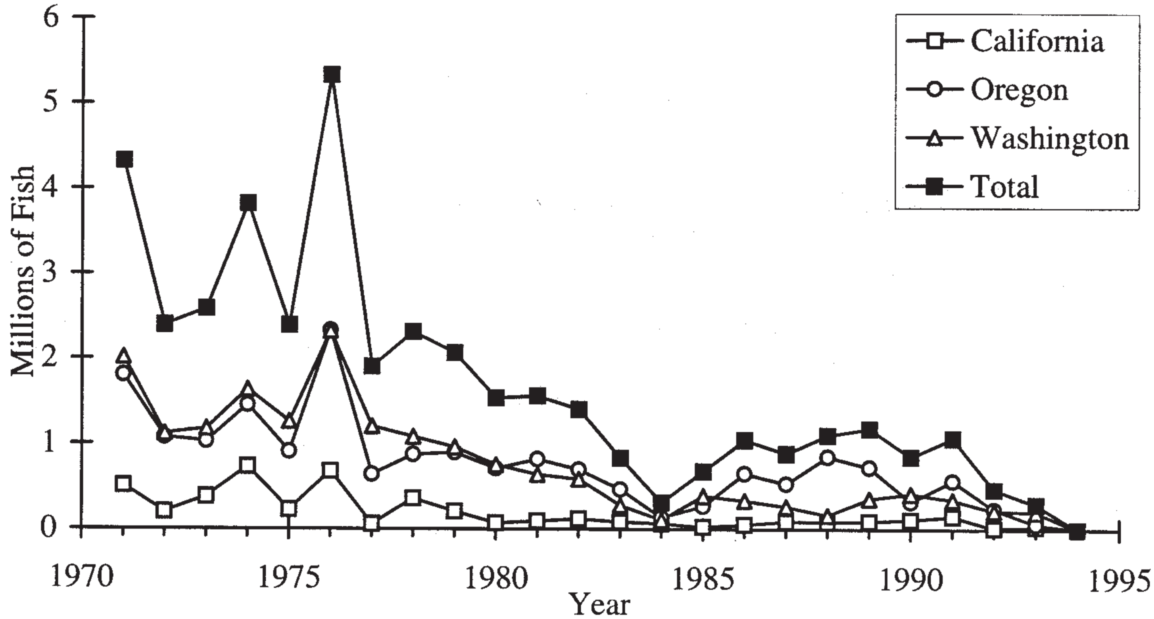

Figure 44. Coho salmon landings for Washington, Oregon, and California ocean troll and sport fisheries. Data from PFMC (1995).

is important to maintaining long-term viability of an ESU because genetic diversity among salmon populations helps to buffer overall productivity against periodic or unpredictable changes in the environment (Riggs 1990, Fagen and Smoker 1989). Ricker (1972) and Taylor (1991) summarized some of the evidence for local adaptations in Pacific salmon that may be at risk from stock transfers.

Second, because a successful salmon hatchery dramatically changes the mortality profile of a population, some level of genetic change relative to the wild population is inevitable, even in hatcheries that use local broodstock (Waples 1991b). These changes are unlikely to be beneficial to naturally reproducing fish.

Third, even if naturally spawning hatchery fish leave few or no surviving offspring, they still can have ecological and indirect genetic effects on natural populations. On the spawning grounds, hatchery fish may interfere with natural production by competing with natural fish for territory or mates. If they successfully spawn with natural fish, they may divert production from more productive natural-by-natural crosses. The presence of large numbers of hatchery juveniles or adults may also alter the selective regime faced by natural fish.

For smaller stocks (either natural or hatchery), small-population effects (inbreeding, genetic drift) can also be important concerns for genetic integrity. Inbreeding and genetic drift are well understood at the theoretical level, and researchers have found inbreeding depression in various fish species (reviewed by Allendorf and Ryman 1987). Other studies (e.g., Simon et al. 1986, Withler 1988, Waples and Teel 1990) have shown that hatchery practices commonly used with anadromous Pacific salmonids have the potential to affect genetic integrity. However, we are not aware of empirical evidence for inbreeding depression or loss of genetic variability in any natural or hatchery populations of Pacific salmon or steelhead.

Recent Events

A variety of factors, both natural and human-induced, affect the degree of risk facing salmon populations. Because of time-lags in these effects and variability in populations, recent changes in any of these factors may affect current risk without any apparent change in available population statistics. Thus, consideration of these effects must go beyond examination of recent abundance and trends. Unfortunately, forecasting future effects is rarely straightforward and usually involves qualitative evaluations based on informed professional judgment. A key question regarding the role of recent events is: Given our uncertainty regarding the future, how do we evaluate the risk that a population may not persist?

For example, climate conditions are known to have changed recently in the Pacific Northwest, and Pacific salmon stocks south of British Columbia have been affected by changes in ocean production that occurred during the 1970s (Pearcy 1992, Lawson 1993). Much of the Pacific coast has also been experiencing drought conditions in recent years, which may depress freshwater salmon production. However, at this time we do not know whether these climate conditions represent a long-term change that will continue to affect stocks in the future or whether these changes are short-term environmental fluctuations that can be expected to be reversed in the near future. Possible future effects of recent or proposed conservation measures have not been taken into account in this analysis.

Other Risk Factors

Other risk factors typically considered for salmonid populations include disease prevalence, predation, and changes in life history characteristics such as spawning age or size. We have not found evidence that any of these factors are widespread throughout any coho salmon ESU, except for the documented decline in body size of adult coho salmon previously discussed in the "Coho Salmon Life History."

Approach

In considering the status of ESUs, we evaluated both qualitative and quantitative information. Qualitative evaluations considered recent, published assessments by agencies or conservation groups of the status of coho salmon stocks within the geographic area (Nehlsen et al. 1991, Higgins et al. 1992, Nickelson et al. 1992, WDF et al. 1993). These evaluations are summarized in Table 6. Nehlsen et al. (1991) considered salmon stocks throughout Washington, Idaho, Oregon, and California and enumerated all stocks that they found to be extinct or at risk of extinction. Stocks that do not appear in their summary were either not at risk of extinction or were not classifiable due to insufficient information. They classified stocks as extinct (X), possibly extinct (A+), at high risk of extinction (A), at moderate risk of extinction (B), or of special concern (C).

Nehlsen et al. (1991) considered it likely that stocks at high risk of extinction have reached the threshold for classification as endangered under the ESA. Stocks were placed in this category if they had declined from historic levels and were continuing to decline, or had spawning escapements less than 200 individuals. Stocks were classified as at moderate risk of extinction if they had declined from historic levels but presently appear to be stable at a level above 200 spawners (stocks in this category were considered by Nehlsen et al. (1991) to have reached the threshold for threatened under the ESA). Stocks were classified as of special concern if a relatively minor disturbance could threaten them, insufficient data were available for them, they were influenced by large releases of hatchery fish, or if they possessed some unique character. For coho salmon, Nehlsen et al. (1991) classified 50 stocks as follows: 15 extinct, 2 possibly extinct, 15 high risk, 16 moderate risk, and 2 special concern.

Higgins et al. (1992) used the same classification scheme as Nehlsen et al. (1991) but provided a more detailed review of northern California salmon stocks. Of the 20 stocks Higgins et al. (1992) identified as being at some risk of extinction, 7 were classified as at high risk of extinction, and the remainder were classified as of special concern.

Table 6. Summary of assessments of coho salmon stock status from recent reviews, grouped by evolutionarily significant unit (ESU) or geographic area.

Basin or stock[a]	Nehlsen et al. 1991[b]	Higgins et al. 1992[b]	Nickelson et al. 1992[c]	WDF et al. 1993 Origin[d]	WDF et al. 1993 Prod. type[e]	WDF et al. 1993 Status[f]
Central California coast ESU						
Ten Mile River		C				
Pudding Creek		A				
Noyo River		C				
Big River		C				
Albion River		C				
Navarro River		C				
Garcia River		A				
Gualala River		A				
Russian River		A				
Scott River		A				
Small Southern CA streams	A					
Southern Oregon/northern California coasts ESU						
Elk River	A	D				
Euchre Creek	X	D				
Rogue River	A	D				
Hunter Creek		D				
Pistol River	A	D				
Chetco River	A	D				
Winchuck River	A	D				
Small Northern CA Streams	B					
Klamath River	C					
Trinity River		C				
Wilson Creek		C				
Lower Klamath River		C				
Redwood Creek		C				
Little River		C				
Mad River		A				
Humboldt Bay		C				
Eel River		C				
Bear River		C				
Mattole River		A				
Oregon Coast ESU						
Necanicum River	B		D			
Elk Creek	B		D			
Nehalem River	B		D, SC			
Tillamook Bay	B		D			
Nestucca River	B		D			
Salmon River	B		D			

Table 6. Continued.

Basin or stock[a]	Nehlsen et al. 1991[b]	Higgins et al. 1992[b]	Nickelson et al. 1992[c]	WDF et al. 1993 Origin[d]	WDF et al. 1993 Prod. type[e]	WDF et al. 1993 Status[f]
Oregon Coast ESU (continued)						
Siletz River	B		D			
Yaquina River			D			
Necanicum River	B		D			
Elk Creek	B		D			
Nehalem River	B		D, SC			
Tillamook Bay	B		D			
Nestucca River	B		D			
Salmon River	B		D			
Siletz River	B		D			
Yaquina River			D			
Beaver Creek	B		D			
Alsea River	B		H			
Yachats River	B		D			
Siuslaw River	B		D			
Siltcoos River			H			
Tahkenitch Creek			H			
Umpqua River	B		D, SC			
Tenmile Creek			D			
Coos River	B		H, D			
Coquille River	B		H, D			
Floras Creek (New River)	A		D			
Sixes River	A		D			
Lower Columbia/southwest Washington ESU						
Grays Harbor				M	C	H
Willapa Bay	A			M	C	U
Sandy River	A					
Clackamas River	B					
Lower Columbia Tributaries	A, A+ (Washougal)			M	C	D
Olympic Peninsula ESU						
Coast minor drainages	C (Lake Ozette)			N, M	W, C	U
Quillayute River				N	W, C	H
Hoh River				N	W	H, U
Queets River				N, X	C	H
Quinault River				M	C	H, U
Puget Sound/Strait of Georgia ESU						
N. Puget Sound minor drainages				N, M, U	W	U
Nooksack River	A+			M	C	U
Samish River				M	C	H
Skagit River				N, U	C	D, U

Table 6. Continued.

Basin or stock[a]	Nehlsen et al. 1991[b]	Higgins et al. 1992[b]	Nickelson et al. 1992[c]	WDF et al. 1993 Origin[d]	WDF et al. 1993 Prod. type[e]	WDF et al. 1993 Status[f]
Puget Sound/Strait of Georgia ESU (continued)						
Stillaguamish River				N, M	W	D, U
Snohomish River				M, X	W, C	H, D
Lake Washington				M	W, C	H, D
Duwamish River				M	C	H, D
Puyallup River				M	C	H, D
Nisqually River				M	C	H
S. Puget Sound minor drainages	A (Chambers Cr.)			M, X	W, C	
Hood Canal				M	W, C	H, D
Strait of Juan de Fuca minor drainages	A (Lyre R.)			M	W, C	H, D, C, U
Dungeness River				M	C	D
Elwha River	A			M	C	H
Upper Columbia Basin (not a designated ESU)						
Klickitat River				M	C	D
Hood River	A					
Middle Columbia Tribs.	X					
Tucannon River	X					
Spokane River	X					
Snake River	X					
Methow River	X					
Yakima River	X					
Wenatchee River	X					
Entiat River	X					
Snake River	X					
Grande Ronde River	X					
Walla Walla River	X					
Umatilla River	X					

[a]Tributaries and minor drainages combined. Multiple status designations indicate different status for tributaries or minor drainages within basin.
[b]A+--possibly extinct; A--high risk, B--moderate risk, C--special concern, X--extinct.
[c]H--healthy, SC--special concern, D--depressed.
[d]N--native, M--mixed, X--non-native, U--unknown.
[e]W--wild, C--composite.
[f]H--healthy, D--depressed, C--critical, U--unknown.

Nickelson et al. (1992) rated coastal (excluding Columbia River Basin) Oregon salmon stocks on the basis of their status over the past 20 years, classifying stocks as “depressed” (spawning habitat underseeded, declining trends, or recent escapements below long-term average), “healthy” (spawning habitat fully seeded and stable or increasing trends), or “of special concern” (300 or fewer spawners or a problem with hatchery interbreeding). They classified 55 coho salmon populations in coastal Oregon as follows: 41 depressed, 2 special concern, 6 healthy, and 6 unknown.

WDF et al. (1993) categorized all salmon stocks in Washington on the basis of stock origin (“native,” “non-native,” “mixed,” or “unknown”), production type (“wild,” “composite,” or “unknown”) and status (“healthy,” “depressed,” “critical,” or “unknown”). Status categories were defined as follows: healthy, “experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock”; depressed, “production is below expected levels . . . but above the level where permanent damage to the stock is likely”; and critical, “experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.” Of the 90 coho salmon stocks identified, 37 were classified as healthy, 35 as critical or depressed, and 18 as unknown. Of the 37 healthy stocks, only 4 (all on the Olympic Peninsula) were identified as native and of wild production type.

One of the problems in applying results of these studies to ESA evaluations is that the definition of “stock” or “population” varied considerably in scale among studies, and sometimes among regions within a study. Identified units range in size from large river basins to minor coastal streams and tributaries. A second problem is the definition of categories used to classify stock status. Only Nehlsen et al. (1991) and Higgins et al. (1992) used categories intended to relate to ESA “threatened” or “endangered” status, and they applied their own interpretations of these terms to individual stocks, not to ESUs as defined here.

Nickelson et al. (1992) and WDF et al. (1993) used general terms describing status of stocks that cannot be directly related to the considerations important in ESA evaluations. For example, the WDF et al. (1993) definition of healthy could conceivably include a stock that is at substantial extinction risk due to loss of habitat, hatchery fish interactions, or environmental variation. A third problem is the selection of stocks or populations to include in the review. Nehlsen et al. (1991) and Higgins et al. (1992) did not evaluate (or even identify) stocks not perceived to be at risk, so it is difficult to determine the proportion of stocks they considered to be at risk in any given area.

Quantitative evaluations included comparisons of current and historical abundance of coho salmon. Historical abundance information for these ESUs is largely anecdotal, although harvest records are available for some areas back to the late 1800s from which minimum run sizes can be estimated. Time-series data are available for many populations, but data extent and quality varied among ESUs. We compiled and analyzed this information to provide several summary statistics of natural spawning abundance, including (where available) recent total spawning run size and escapement, percent annual change in total escapement, recent naturally produced spawning run size and escapement, and average percentage of natural spawners that were of hatchery origin.

Although this evaluation used the best data available, it should be recognized that there were a number of limitations to these data, and not all summary statistics were available for all populations. For example, spawner abundance was generally not measured directly; rather, it often had to be estimated from limited survey data. In many cases, there were also limited data to separate hatchery production from natural production.

Quantitative Methods

Information on stock abundance was compiled from a variety of state, federal, and tribal agency records. We believe these records to be complete in terms of long-term adult abundance records for coho salmon in the region covered. Principal data sources were commercial catch, dam or weir counts, and stream surveys. Specific problems are discussed below for each data type.

Data Types

Quantitative assessments were based on historical and recent run-size estimates and time series of freshwater-spawner and juvenile surveys, harvest rate estimates, and counts of adults migrating past dams. We considered this information separately for each ESU. Because of the disparity of data sources and data quality among different ESUs, data sources and analyses are described separately for each ESU.

Dam and weir counts are available in several river basins along the coast. These counts are probably the most accurate estimates available of total spawning run abundance, but they often represent only small portions of the total population in each river basin. As with angler catches, these counts typically represent a combination of hatchery produced and natural fish, and thus cannot be used as a direct index of natural population trends.

Stream surveys for coho salmon spawning abundance have been conducted by various agencies within most of the ESUs considered here. Survey methods and time-spans vary considerably among regions, so it is difficult to assess the general reliability of these surveys as population indices. For most streams where surveys were conducted, they are the best local indication we have of population abundance trends.

Computed Statistics

To represent current run size or escapement, we have computed the geometric mean of the most recent years reported. We tried to use only estimates that reflected the total abundance for an entire river basin or tributary, avoiding reliance on index counts or dam counts that represented only a small portion of the available habitat.

Where adequate data were available, trends in total escapement (or run size if escapement was not available) were calculated for data sets with more than 5 years of data. As an indication of overall trends in coho salmon populations in individual streams, we calculated average (over the available data series) percent annual change in adult spawner indices within each river basin. Trends were calculated as the slope (*a*) of the regression of ln(abundance) against years corresponding to the biological model $N(t) = b \times e^{at}$. Slopes significantly different from zero ($P < 0.05$) were noted. The regressions provided direct estimates of mean instantaneous rates of population change (a); these values were subsequently converted to percent annual change, calculated as $100(e^{a}-1)$. No attempt was made to account for the influence of hatchery produced fish on these estimates, so the estimated trends include any supplementation effect of hatchery fish.

Analyses of Extinction Risk by ESU

1) Central California Coast

Data on this ESU were limited. The PFMC (1994) states that: "Inside harvest of coho is not available for any river system in California. Spawning escapement estimates are available for Klamath River Basin hatcheries, but not for coho spawning in natural areas." Recent population estimates were compiled under contract to NMFS Southwest Region (Brown and Moyle 1991) and have since been published (Brown et al. 1994). Recent status reviews of coho salmon in California by NMFS (Bryant 1994) and the California Department of Fish and Game (CDFG 1994) have expanded on the work of Brown and Moyle (1991) for estimates of abundance and trends in coho populations throughout much of the state.

In compiling estimates of recent spawner abundance, Brown and Moyle (1991) used a "20-fish rule:" If a stream with historic accounts of coho salmon lacked recent data, it was assumed to still support a run of 20 adults; if coho salmon were present in recent stream surveys, they used 20 adults or the most recent run estimate, whichever was larger. While these estimates are crude, in most cases they are the best data available, and they are generally comparable with other estimates (Bryant 1994, CDFG 1994, Maahs and Gilleard 1994). Unless otherwise indicated, the recent abundance data are taken from Brown et al. (1994).

California statewide (including areas outside this ESU) coho salmon spawning escapement apparently ranged between 200,000 and 500,000 adults per year in the 1940s (Brown et al. 1994). By the mid-1960s, statewide spawning escapement was estimated to have fallen to about 100,000 fish per year (CDFG 1965, California Advisory Committee on Salmon and Steelhead Trout 1988), followed by a further decline to about 30,000 fish in the mid-1980s (Wahle and Pearson 1987). From 1987 to 1991, spawning escapement averaged about 31,000, with hatchery populations making up 57% of this total (Brown et al. 1994).

Brown and Moyle (1991, Brown et al. 1994) estimated average coho salmon spawning escapement in the central California coast ESU as 6,160 naturally spawning coho salmon and 332 hatchery spawned coho salmon for the period from 1987 to 1991 (Table 7). Of the naturally spawning coho salmon, 3,880 were from tributaries in which supplementation occurs (Noyo River and coastal streams south of San Francisco). Only 160 fish in the range of this

Table 7. Regional summary of recent (1980s) average coho salmon spawner abundance in California. Numbers are subdivided by the apparent origin of the fish (probably native, mixture of native and naturalized, or hatchery). Based on data from Brown et al. (1994).

Region	Probably native	Native and naturalized	Hatchery	Total
Del Norte County	1,000	1,860	16,265	19,125
Humboldt County	3,480	740	891	5,111
Subtotal North of Punta Gorda*	4,480	2,600	17,156	24,236
Mendocino County	160	4,790	0	4,950
Sonoma County	0	635	332	967
Marin County	0	435	0	435
San Francisco Bay	0	0	0	0
South of S. F. Bay	0	140	0	140
Subtotal South of Punta Gorda	160	6,000	332	6,492
Total Spawners	4,640	8,600	17,488	30,728

*A few minor coastal streams in Humboldt County south of Punta Gorda are included in this subtotal.

ESU (all in Ten Mile River) were identified as “native” fish, lacking a history of supplementation with non-native hatchery stocks. Based on redd counts, the estimated run of coho salmon in Ten Mile River during the 1991-92 spawning season was 14 to 42 fish (Maahs and Gilleard 1994).

Recent data exist for 133 of 186 streams in the region identified by Brown et al. (1994) as having historic records of adult coho salmon. Of these 133 streams, 62 have recent records of occurrence of adult coho salmon and 71 no longer have coho salmon spawning runs (Table 8). (Note that the summaries by county made by Brown et al. (1994) excluded a few streams at the northern boundary of this ESU and included the Sacramento River, which is outside this ESU.) Nehlsen et al. (1991) provided no information on individual coho salmon stocks in this region, but identified stocks in small coastal streams north of San Francisco as at moderate risk of extinction, and those in small coastal streams south of San Francisco as at high risk of extinction. Higgins et al. (1992) considered only drainages from the Russian River north but identified four coho salmon stocks within this ESU as at risk: three of special concern and one (Gualala River) as at high risk of extinction.

2) Southern Oregon/Northern California Coasts

Data are also limited for this ESU. No regular escapement estimates exist for natural spawning in California streams, and information in Oregon is limited to angler catch summaries for all rivers, dam-passage and seine-survey counts in the Rogue River, and observations of coho salmon during chinook salmon spawner surveys.

Most information for the northern California region of this ESU was recently summarized by the California Department of Fish and Game (CDFG 1994). They concluded that “coho salmon in California, including hatchery stocks, could be less than 6 percent of their abundance during the 1940’s, and have experienced at least a 70 percent decline in numbers since the 1960’s” (CDFG 1994, p. 5-6). They also reported that coho salmon populations have been virtually eliminated in many streams, and that adults are observed only every third year in some streams, suggesting that two of three brood cycles may already have been eliminated.

The Klamath River Basin (including the Trinity River) historically supported abundant coho salmon runs. In both systems, runs have been greatly diminished and are now composed largely of hatchery fish, although there may be small wild runs remaining in some tributaries (CDFG 1994). Of 396 streams within this ESU identified as once having coho salmon runs, Brown et al. (1994) were able to find recent survey information on 115 (30%) (Table 8). Of these 115 streams, 73 (64%) still supported coho salmon runs while 42 (36%) did not. The streams identified as presently lacking coho salmon runs were all tributaries of the Klamath and Eel River systems (Brown et al. 1994). The rivers and tributaries in the California area of this ESU were estimated to have average recent runs of 7,080 natural spawners and 17,156 hatchery returns, with 4,480 identified as “native” fish occurring in tributaries having little history of supplementation with non-native fish (Table 8).

Table 8. Regional summary of numbers of California streams with recent presence or absence of coho salmon among those identified as having supported coho salmon populations in the past. Percentages (in parentheses) are based only on those streams for which recent data are available. Based on data from Brown et al. (1994).

Region	Coho present	Coho absent	Total with recent data	No recent data	Total
Del Norte County	24 (55%)	20 (45%)	44	119	163
Humboldt County	49 (69%)	22 (31%)	71	162	233
Subtotal North of Punta Gorda[a]	73 (64%)	42 (36%)	115	281	396
Mendocino County	46 (59%)	32 (41%)	78	25	103
Sonoma County	4 (14%)	24 (86%)	28	25	53
Marin County	7 (100%)	0 (0%)	7	3	10
San Francisco Bay[b]	0 (0%)	7 (100%)	7	0	7
South of S. F. Bay	5 (38%)	8 (62%)	13	0	13
Subtotal South of Punta Gorda	62 (47%)	71 (53%)	133	53	186
Total Streams	135 (54%)	113 (46%)	248	334	582

[a]A few minor coastal streams in Humboldt County south of Punta Gorda are included in this subtotal.
[b]Includes Sacramento River.

In this region of California, Nehlsen et al. (1991) identified coho salmon in the Klamath River as of special concern, and those in small northern streams as at moderate risk of extinction. Higgins et al. (1992) identified 10 coho salmon stocks as of special concern, and 6 as at high risk of extinction.

Data for coastal Oregon south of Cape Blanco include adult passage counts at Gold Ray Dam in the upper Rogue River (Cramer et al. 1985; Kostow 1994 App.), angler catch estimates for all Oregon rivers (ODFW 1992, 1993b), and seine-survey estimates of adult coho salmon run-size in the Rogue River (Satterthwaite 1992). Recently, most production of coho salmon in this region of Oregon has been in the Rogue River Basin. Recent run-size estimates for this basin (1979-91) (Satterthwaite 1992) have ranged from approximately 450 to 19,200 naturally produced adults, and from 200 to 9,400 hatchery produced adults (Fig. 45). Average run sizes for this period were 3,400 natural and 3,300 hatchery fish, with the total run averaging 49% hatchery fish. (The majority of the hatchery component probably returns to Cole Rivers hatchery rather than spawning in the wild; average hatchery rack returns for this period were 2,800.)

Adult passage counts at Gold Ray Dam provide a long-term view of coho salmon abundance in the upper Rogue River. In the 1940s, passage counts averaged approximately 2,000 adults per year (Fig. 46). Numbers declined and fluctuated during the 1950s and early 1960s, then stabilized at an average of fewer than 200 adults during the late 1960s and early 1970s. In the late 1970s, dam counts increased with returning fish produced at Cole Rivers Hatchery.

Angler catch of coho salmon in the Rogue River has fluctuated considerably, ranging from less than 50 (late 1970s) to a peak of about 800 in 1991; average annual catch over the last 10 years has been about 250 fish. Angler catch in other rivers in southern Oregon has been low, representing only a minor fraction of the total south of Cape Blanco. While there have been no directed surveys for coho salmon in this region, the species would be expected to be observed in the annual chinook salmon spawner surveys. Few coho salmon have been observed in these surveys; for example, in 23 years of chinook salmon surveys over 6 segments of the Elk River, the highest count of coho salmon was 20 adults in 1971. In Oregon south of Cape Blanco, Nehlsen et al. (1991) considered all but two coho salmon stocks to be at high risk of extinction; of the remaining two, one (Euchre Creek) was identified as extinct and the other (Hunter Creek) was not mentioned. (The status of coho salmon in Euchre Creek is in some doubt: no surveys have been conducted recently, but Oregon Department of Fish and Wildlife (ODFW) biologists believe there may be a small coho salmon population there.) South of Cape Blanco, all Oregon coho salmon stocks were rated by Nickelson et al. (1992) as depressed.

Combining recent run-size estimates for the California portion of this ESU with the Rogue River estimates provides a rough minimum run-size estimate for the entire ESU of about 10,000 natural fish and 20,000 hatchery fish.

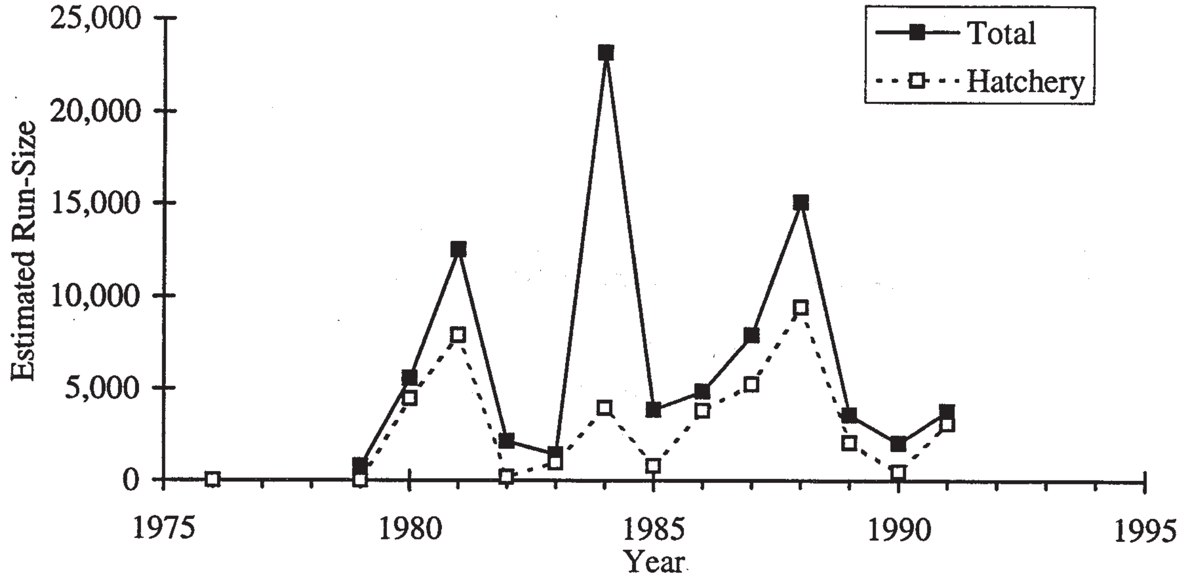

Figure 45. Estimated adult coho salmon run size at Huntley Park, lower Rogue River. Data from Satterthwaite (1992).

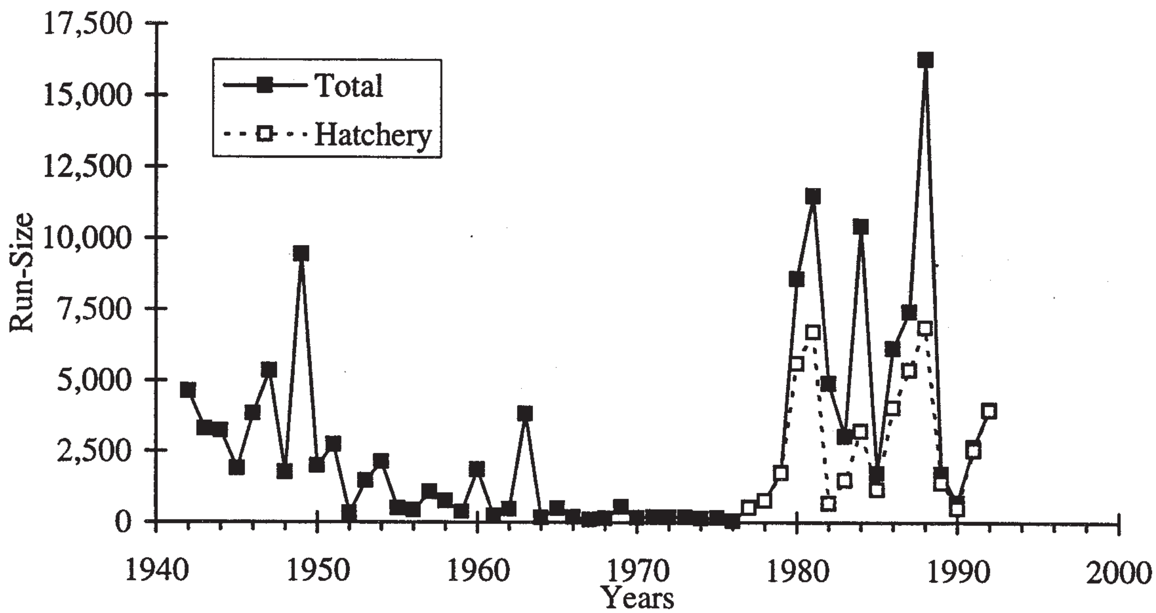

Figure 46. Adult coho salmon counted passing Gold Ray Dam on the upper Rogue River. Data from K. Kostow (1994 App.).

3) Oregon Coast

In this region, we examined the extensive spawner survey records provided by ODFW (Cooney and Jacobs 1994) in conjunction with estimates of ocean harvest rates for coho salmon (PFMC 1993c). Cramer (1994) provided an extensive analysis of these data. There are three related sets of spawner survey data. Beginning in 1950, ODFW conducted annual surveys of peak coho salmon spawning abundance ("peak counts," PC) in standard survey segments of coastal rivers from the Necanicum River to the Coquille River. In 1980, surveys began on a more comprehensive set of river segments: counts were conducted multiple times each season, providing area-under-the-curve (AUC) estimates of total spawning over the season, and a better representation of local population abundance than the PC estimates.

In 1990, a study was initiated to examine potential biases and statistical validity of the survey program (Jacobs and Cooney 1990, 1991, 1992, 1993). This (not yet completed) study involves stratified random sampling (SRS) to provide AUC estimates of coho spawning abundance throughout coastal Oregon north of Cape Blanco. All three survey data sets provide estimates of local spawner density in terms of spawners per stream mile. The PC estimates have been used to estimate coastwide spawner population size for fishery management purposes, but substantial biases in this approach led to the initiation of the SRS study. Preliminary results of this study provide statistically valid estimates of coastwide spawner abundance for the 1990-93 seasons (Jacobs and Cooney 1991, 1992, 1993; ODFW 1995).

Based on historical commercial landing statistics and estimated exploitation rates, Mullen (1981) estimated escapement of coho salmon in coastal Oregon to be nearly 1 million fish in the early 1900s, with harvest of nearly 400,000 fish. In a more extensive analysis of similar data, Lichatowich (1989) concluded that coho salmon abundance in the same region at that time was about 1.4 million fish. Lichatowich also concluded that current production potential (based on stock-recruit models) for coho salmon in coastal Oregon rivers was only about 800,000 fish, and he associated this decline with a reduction of nearly 50% in habitat capacity. Recent spawning escapement estimates based on SRS survey results (Table 9) indicate an average spawning escapement of about 39,000 adults. While the methods of estimating total escapement are not comparable between the historical and recent periods, these numbers suggest that current abundance of coho salmon on the Oregon coast may be less than 5% of that in the early part of this century. The ODFW (1995) presented estimates of coho salmon abundance at several points of time from 1900 to the present. These data show a decline of about 75% from 1900 to the 1950s, and a further decline of about 90% since the 1950s.

Trends in coastal Oregon coho salmon populations can best be assessed from spawner survey information. Long-term trend indications are available only from the PC survey standard segments (Fig. 47, 48). Statewide average peak spawners per mile have declined substantially since the early 1950s, but the majority of this decline occurred in the early 1970s, and spawner counts have remained relatively stable since that time. Since the late 1970s, stocks in the north and central portions of this ESU have exhibited stable to declining escapements, while those in the southern portion of the ESU (Umpqua and Coos-Coquille

Table 9. Population size of coastal coho spawners in geographic areas of the Oregon coast north of Cape Blanco in 1990-93, based on stratified random sampling spawner surveys (Jacobs and Cooney 1991, 1992, 1993). Data from ODFW (1995).

Group	1990	1991	1992	1993	Average
Necanicum-Nehalem	1,743	5,315	1,453	5,957	3,617
Tillamook-Nestucca	455	3,967	969	1,188	1,645
Salmon-Alsea	2,419	2,964	11,552	2,763	4,925
Yachats-Siuslaw	3,173	3,791	3,820	4,895	3,920
Umpqua	3,737	3,600	2,153	9,308	4,700
Coos-Coquille	4,985	9,464	17,741	23,337	13,882
River Total	16,512	29,101	37,688	47,448	32,687
Lakes	4,414	7,283	1,585	10,180	5,866
Total	20,926	36,384	39,273	57,628	38,553

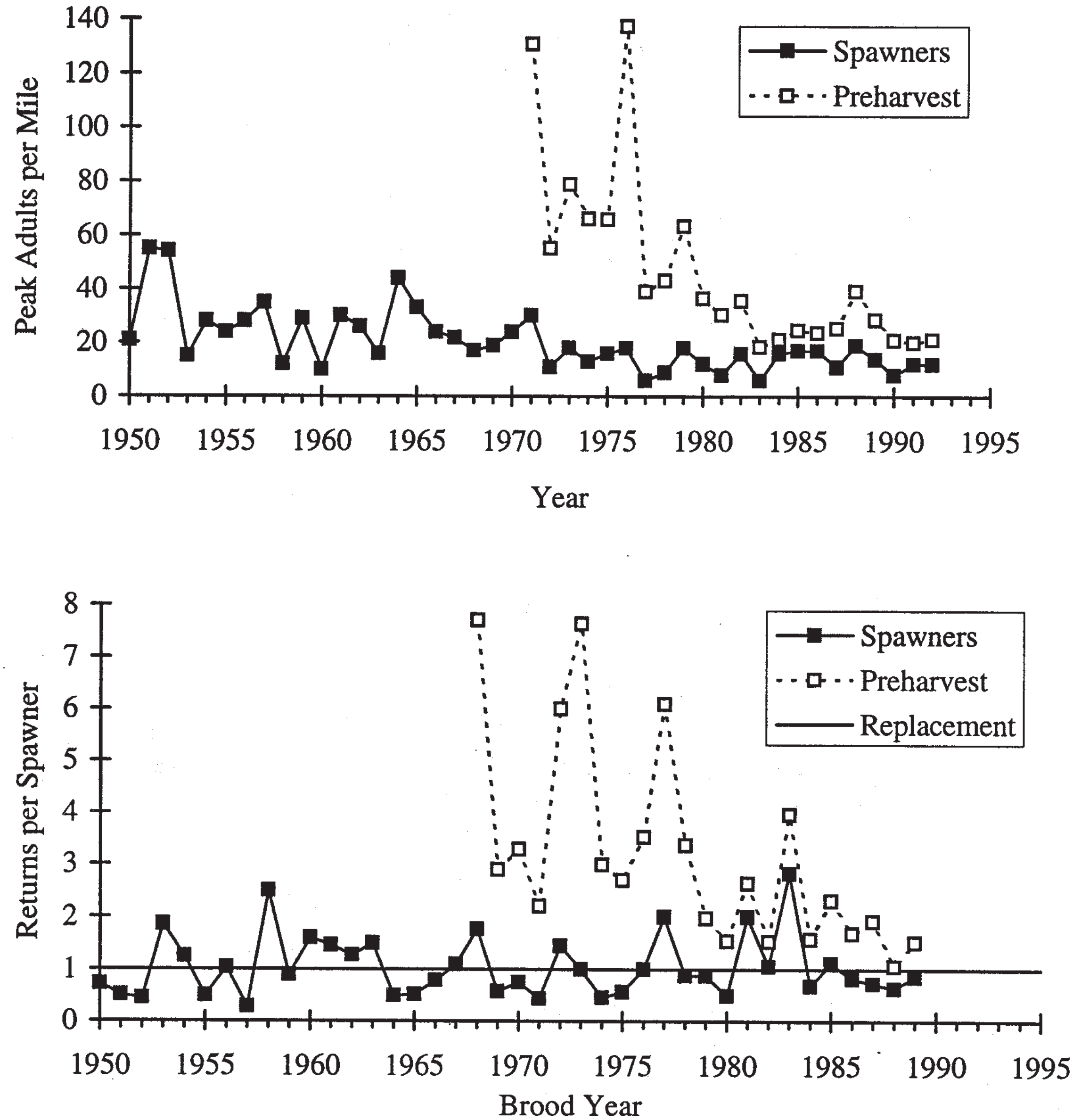

Figure 47. Estimated spawning escapement and preharvest recruitment from peak spawner surveys along the Oregon coast north of Cape Blanco (upper) and returns per spawner (lower). Based on data from Cooney and Jacobs (1994).

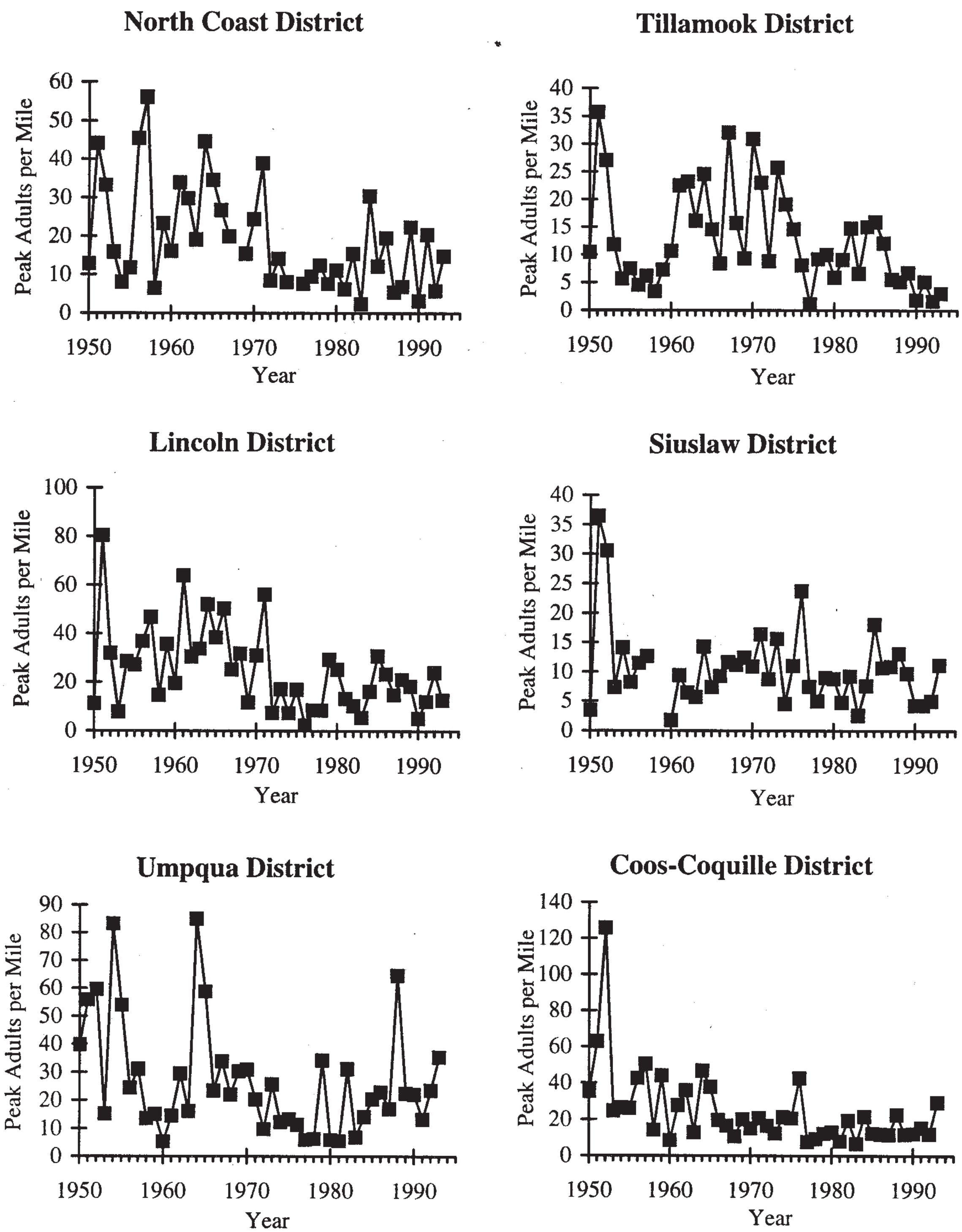

Figure 48. Estimated spawning escapement from peak spawner surveys along the Oregon coast north of Cape Blanco, by fishery management district. Data from S. Jacobs (1994b App.).

management districts) have exhibited increasing escapements (Fig. 48). Spawner-to-spawner return ratios based on peak counts (Fig. 47) have fluctuated around replacement over the entire data period but have been below replacement in 5 of the most recent 6 years for which we had data. Despite the relative stability of spawner densities after 1975, recruits to the fishery (estimated by dividing spawner density by 1 minus the ocean harvest rate) continued to decline until the mid-1980s. Based on these statewide average peak count data, preharvest recruit-to-spawner ratios also have been declining up to the present (Fig. 47), although this result is not consistent with results of Cramer's (1994) analysis of individual rivers that shows no recent decline in recruit-to-spawner ratios. The ODFW (1995) estimates that this decline in recruits per spawner averaged 5% per year for brood years 1978 to 1991.

More recent AUC estimates (Fig. 49) may provide a better indication of recent trends than do the peak counts. These estimates show little trend in either spawners or recruits since 1980, although recruits are low for the last 3 years. Return ratios based on AUC estimates are extremely low for the most recent 6 years for which we had data, with spawners failing to replace themselves in all 6 years. As for the PC estimates, return ratios based on AUC estimates also exhibit a decline since the 1980 brood year. We also examined statewide average PC and AUC spawner estimates based only on streams designated as "wild" coho salmon production by ODFW; trend and replacement ratio estimates for these streams were similar to those calculated for all streams.

The observed pattern of declining recruits per spawner is a serious concern. If the recent trend were to continue into the future, we could expect that recruitment would fall below replacement levels in the near future, even with no harvest. However, such a projection is uncertain. The harvest rate estimates used in this analysis are very inexact, since they are based on questionable assumptions regarding distribution of fishing effort and the relative magnitude of hatchery and wild production in the Oregon Production Index (OPI) area. Recent analyses by ODFW (1995) suggest that recent harvest rate estimates may be substantially revised when new methods based on analysis of stock-specific, coded-wire tagged returns are used. Also, we have not attempted to evaluate the causes for this apparent decline in recruits per spawner, so we cannot evaluate the likelihood that those causes will continue into the future. The ODFW (1995) suggests that changes in ocean production since 1976 are largely responsible for the decline in return ratios and concludes (p. 49) that "there is no clear indication of trends in the post-1975 period and no indication of an impending switch to better conditions." However, there are other factors that could contribute to declining production of coho salmon along the Oregon coast, including loss and degradation of freshwater habitat (Lawson 1993). Lacking knowledge of these factors, their effects and future direction, our best estimate of the future is a simple projection of past trends. Based on information available at this time, our projection suggests a substantial risk that coho salmon in this ESU may soon face recruitment failure.

Kostow et al. (1994) provided estimates of hatchery composition of naturally spawning coho salmon in several coastal Oregon rivers, ranging from 18 to 62% (Table 10). These estimates are for rivers known to have high hatchery influence and, therefore, do not represent the average condition along the Oregon coast. We compiled hatchery composition estimates for a larger sample of rivers and lakes, which show a wide range from less than 10% hatchery

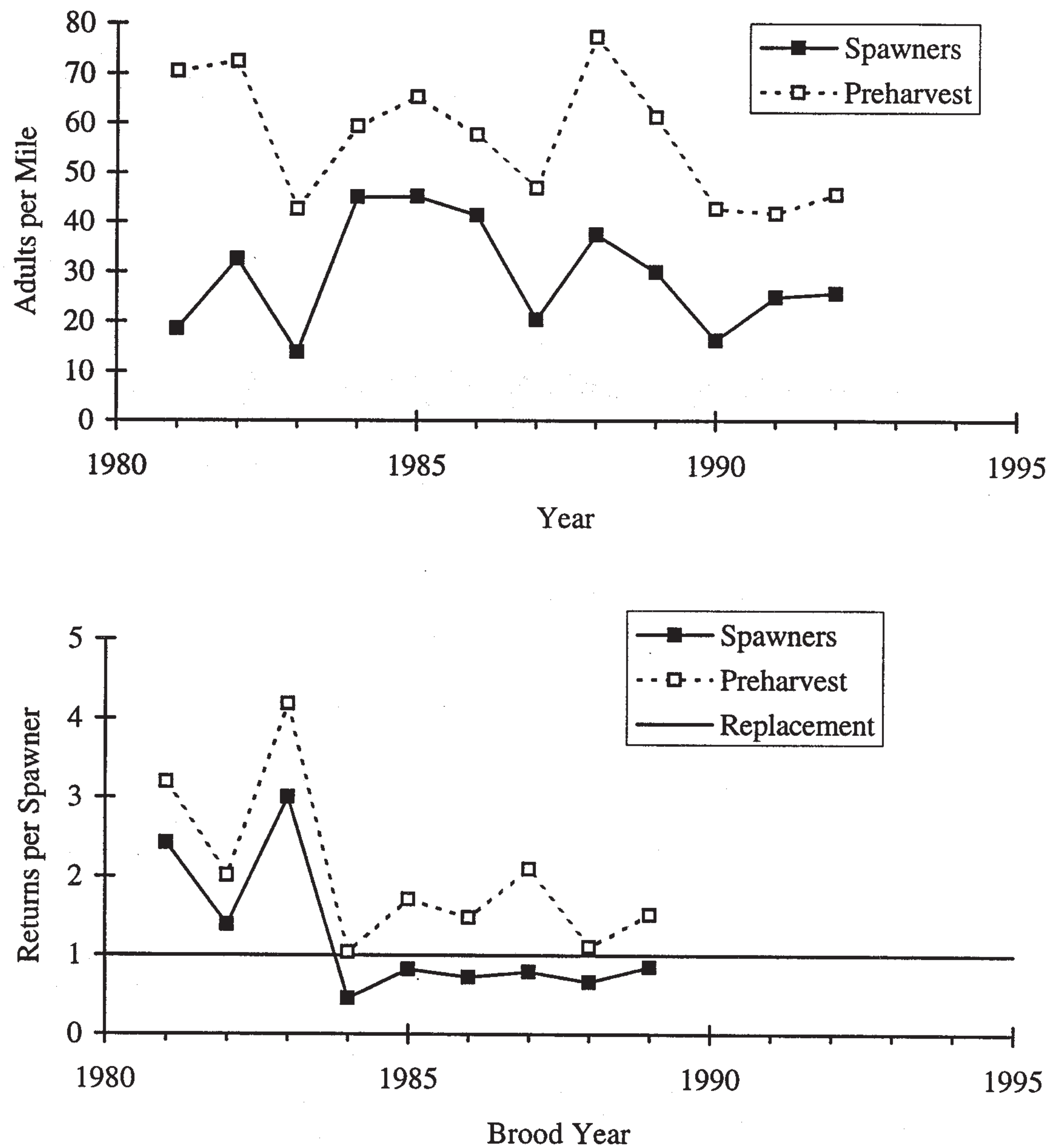

Figure 49. Estimated spawning escapement and preharvest recruitment (upper) and returns per spawner (lower) from area-under-the-curve spawner surveys along the Oregon coast north of Cape Blanco. Based on data from Cooney and Jacobs (1994).

fish in lake samples to more than 75% in two rivers (Table 11). These data also illustrate a general north-south trend of decreasing hatchery influence on natural spawning. The extensive presence of hatchery-origin adults spawning in several coastal rivers is a cause for concern about the sustainability of natural production in these systems.

4) Lower Columbia River/Southwest Washington Coast

The status of lower Columbia River coho salmon stocks outside of the Willamette River Basin was reviewed extensively by Johnson et al. (1991) and is not reconsidered here. The ODFW conducts annual coho salmon spawning surveys in the lower Columbia River Basin (Fennell 1993). These surveys indicated that natural spawning of coho salmon in this region declined precipitously in the early 1970s and has remained at extremely low levels.

As noted earlier, the Clackamas River, a tributary of the Willamette River, may support a native run of coho salmon that is a remnant run of fish native to the lower Columbia River Basin (Cramer and Cramer 1994). Abundance of this run has been measured since 1950 by adult passage at River Mill (1950-57) and North Fork (1958-present) Dams, and total run size (native and hatchery) has ranged from 416 (1950) to 4,700 (1968). The “native” portion of the run has ranged from 309 (1958) to 3,588 (1968) (Fig. 50).

Cramer and Cramer concluded that production of the “native” population is depressed due to a variety of factors. They further concluded that under current harvest rates, the population is likely to remain stable but is vulnerable to overharvest. Johnson et al. (1991) briefly reviewed abundance data for this population and, although they concluded that it had a low risk of extinction if population parameters remained stable, they recommended close monitoring of the population.

In the Columbia River Basin, all coho salmon stocks above Bonneville Dam (except Hood River) were classified by Nehlsen et al. (1991) as extinct. Hood River, Sandy River, and all other lower Columbia River tributary stocks were classified as at high risk of extinction, except the Clackamas River stock, which was classified as at moderate risk of extinction. This historic ESU also included portions of the southwest Washington coast. Nehlsen et al. (1991) identified coho salmon stocks in Willapa Bay as at high risk of extinction. WDF et al. (1993) identified the Willapa Bay stocks as of unknown status, but of mixed origin and composite production. They identified all stocks in Grays Harbor tributaries as healthy, but of mixed origin and composite production.

The largest production of coho salmon in this area is in the Chehalis River Basin. Hiss and Knudsen (1993) estimated current coho salmon run sizes (before terminal harvest) in this basin (including the Humptulips River) at about 266,000 adults, of which 135,000 are naturally produced and 131,000 are of hatchery origin. They noted that hatchery influence on these runs has increased rapidly since 1970.

Coho salmon in the Chehalis River basin exhibit two run timings: “normal,” with spawning in early December throughout the basin, and “late,” with spawning in January and February in lower Chehalis River tributaries. Hiss and Knudsen (1993) suggested that the

Table 10. Percentage of hatchery produced adult coho salmon estimated on spawning grounds in selected Oregon river basins. Data from Kostow et al. (1994).

River basin	Percent hatchery
North Nehalem River	53
Salmon River	56
Siletz River	62
N. F. Umpqua River	50
S. F. Umpqua River	18

Table 11. Estimated average (1989-91) percent of hatchery fish on spawning grounds in Oregon coastal river basins and lakes, based on scale analysis. Only basins with total sample sizes of greater than 10 fish are included. Based on data presented by Borgerson (1991, 1992).

Basin	Sample size	Percent hatchery
Nehalem River	287	66
Trask River	142	87
Wilson River	16	19
Salmon River	113	76
Devils Lake	15	7
Siletz River	222	68
Yaquina River	59	36
Alsea River	65	11
Siuslaw River	129	37
Siltcoos Lake	179	2
Tahkenitch Lake	256	0
Umpqua River	114	20
Tenmile Lakes	123	2
Coos River	52	21
Coquille River	117	13

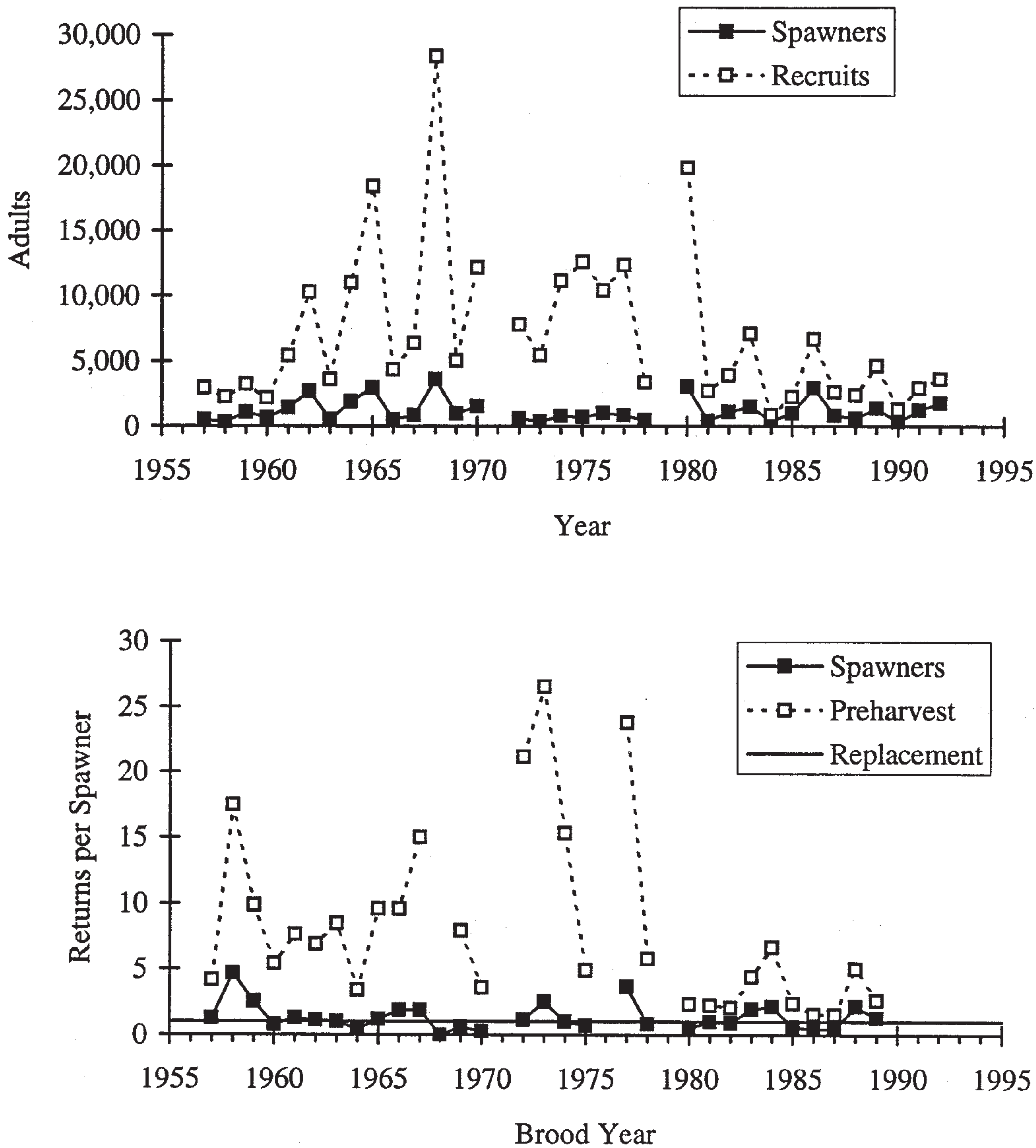

Figure 50. Estimated spawning escapement and preharvest recruitment (upper) and returns per spawner (lower) for late-run coho salmon in the Clackamas River. Based on data from Cramer and Cramer (1994).

normal run is composed of a mixture of hatchery and wild fish, while the late run is virtually all wild fish (but they did not specify whether “wild” implies native fish, or simply natural production regardless of origin). The two runs were treated as a single stock for fishery management purposes, and we have no separate abundance estimates for them. Hiss and Knudsen (1993) identified three streams known to have late-run fish (Bingham Creek, the upper Wynoochee River, and the Wishkah River) and noted that this run has always been less abundant than the normal run but has been particularly small in recent years. No escapement estimates are available for other streams in Grays Harbor or Willapa Bay.

5) Olympic Peninsula

Data on terminal run size for stocks in this ESU are collected cooperatively by WDFW and the coastal tribes. Spawning escapements to most streams are estimated from cumulative redd counts on index reaches of the streams, assuming each redd represents the spawning activity of 1 female, and a 1:1 sex ratio. Peak counts in supplemental reaches are multiplied by the ratio of cumulative counts to peak counts in the index reaches. Escapement to a basin is calculated by multiplying the estimated escapement in surveyed (index + supplemental) areas by the ratio of surveyed spawning habitat to total habitat in the basin.

The WDFW and tribal biologists believe that redd counts provide the most reliable estimates of total escapement in these coastal streams, which typically have highly variable flows during the spawning season (PFMC 1990). These natural escapement estimates, combined with hatchery escapements, form the basis for escapement summaries for the Olympic Peninsula (WDF et al. 1993, PFMC 1994). However, no attempt was made to estimate the number of hatchery produced fish that spawn naturally.

We reviewed assessments of these stocks by Nehlsen et al. (1991) and WDF et al. (1993). Nehlsen et al. (1991) identified only one at-risk coho salmon stock (Lake Ozette) in this area, as of special concern. Most coho salmon stocks in this area were considered by WDF et al. (1993) to be healthy or of unknown status, representing a mixture of native, mixed, and non-native origins, and wild or composite production. Some stocks along the Strait of Juan de Fuca were identified as depressed. The WDF et al. (1993) report identified eight stocks of native origin with wild production in this ESU, four of healthy status and four of unknown status.

Other evidence examined for this ESU included trends in terminal run size, hatchery contribution, trends in ocean exploitation rate, and trends in the size of fish in terminal landings. No trends were detected in terminal run size, and there is no evidence for trends in ocean exploitation rates. In the stock complexes monitored and reported by PFMC, hatchery returns accounted for 50% of the spawning escapement in the period from 1982 through 1992 (Table 12), with the majority of hatchery production contributing to the Quillayute summer-run, Quinault, and Queets stocks (PFMC 1994).

Of these stocks, the Quinault and the Salmon River (tributary of the Queets) were identified by WDF et al. (1993) as of mixed origin, while the majority of other stocks were

Table 12. Average terminal run sizes of Olympic Peninsula coho salmon stock complexes (1981 to 1992). Based on data from PFMC (1994).

Stock	Natural	Hatchery	Total
Quinault	7,900	15,500	23,400
Queets	6,600	7,600	14,200
Hoh	5,000	500	5,500
Quillayute summer	1,800	7,600	9,400
Quillayute fall1	2,500	3,000	15,500
Total	33,800	34,200	68,000

identified as of native origin. Average recent run sizes for some of these stocks are given in Table 12. The total average terminal run size for these main stocks is about 34,000 natural and 34,000 hatchery fish. We have found no historical run-size estimates for these stock complexes to compare with recent abundance, but there have presumably been substantial declines in coho salmon production as a result of well-documented habitat degradation since European settlement.

6) Puget Sound/Strait of Georgia

Spawning escapements in Puget Sound are estimated primarily by AUC estimates of live spawners in index reaches of selected streams. Spawner surveys are conducted by WDFW. Estimates of spawning escapement are obtained by multiplying the mark-recapture estimate of spawning escapement in a base year by the ratio of AUC index to the AUC index in the base year (PFMC 1990).

We reviewed assessments of these stocks by Nehlsen et al. (1991) and WDF et al. (1993). Nehlsen et al. (1991) identified three coho salmon stocks in this region as at high risk of extinction, and one (Nooksack River) to be possibly extinct. Stocks in this region were considered by WDF et al. (1993) to range from healthy to critical in status, be predominantly of mixed origin, and be predominantly of composite production. None of the stocks in this region that they identify as healthy were of strictly native origin. Two stocks (Deer Creek and Sumas/Chilliwack) were identified as of native origin with wild production but were of unknown status.

Other lines of evidence included long-term trends in escapement to counting facilities, hatchery contribution rates, ocean and total exploitation rates, and trends in the size of fish in the terminal landings. Only three rivers have long-term (extending back to the 1930s or 1940s) escapement data from which to estimate trends. Long-term trap counts at Baker River and White River generally showed declining trends in the 1960s and 1970s, with some evidence of recovery in the 1980s. The number of adults passed above the hatchery racks on the Samish River showed neither increasing nor decreasing trends over a 55-year period. More recent spawner survey data are available for numerous rivers within this ESU, but no reliable breakdown of natural and hatchery production is available for these data.

Trends in abundance for additional stocks were evaluated by examining terminal run size derived from cohort reconstruction (WDF et al. 1993). Terminal run data included terminal harvest within Puget Sound, but not harvest in ocean fisheries. In addition to naturally produced fish, terminal runs included hatchery fish from hatchery and off-station releases. Of the stocks identified by WDF et al. (1993), abundance estimates were available for the period from 1965 through 1993 for 17 stocks. Trends in abundance for these stocks were estimated by fitting an exponential trend to time series of terminal run size. Of the stocks examined for this review, two stocks had significant downward trends, five had significant upward trends, and the remainder had no significant trend (Table 13).

Ocean exploitation rates on wild coho salmon from the Deschutes River, Snohomish River, and Big Beef Creek declined from the late 1970s through the mid-1980s and have

Table 13. Average Puget Sound run size from 1965 through 1993, and trends in abundance for selected Puget Sound stocks. Runs size estimated by run reconstruction. Data from WDF et al. (1993).

Stock	Average run size	Annual percent change	
Area 12A	2,766	-1.71	
North Hood Canal (Area 12)	1,810	0.55	
Admiralty Inlet (Area 9)	1,000	-3.12	*
Chambers Creek	1,152	7.21	*
Deschutes River	20,834	6.37	*
Dungeness River	2,841	-3.42	
Mid-sound tributaries	8,614	4.81	*
Elwha River	543	-1.26	
Green River	11,979	-0.22	
Lake Washington	25,310	-2.74	
Nisqually River	15,410	-1.93	
Puyallup River	28,166	-1.61	
Samish River	11,962	10.89	*
Skagit River	35,307	-2.57	*
Skokomish River	11,469	0.42	
South Sound (13-13B)	31,466	6.04	*
Stillaguamish	30,166	-1.26	

* denotes trends that significantly ($P < 0.05$) differ from zero.

increased since then but remained in the range of 0.3 to 0.5. Total exploitation rates have shown no apparent trend but have fluctuated in the range of 0.6 to 0.9. The average hatchery contribution rate for stocks monitored and reported by the PFMC for the period 1981 to 1992 has been 62%, with Nooksack/Samish and South Puget Sound stock complexes managed for, and clearly dominated by, hatchery production.

Average recent run sizes are summarized for major stock complexes in the ESU in Table 14. The total average run size for these main stocks is about 479,000 natural and 776,000 hatchery fish. Bledsoe et al. (1989) examined changes in run sizes of Puget Sound salmon since 1896. They did not find a statistically significant general decline in run sizes for wild runs of coho salmon in this period, although they did report a dramatic 85% decline of coho salmon terminal runs in south Puget Sound from 1935 to 1975. They attributed this decline at least in part to an increasing catch in nonterminal fisheries.

Overall, catches of coho salmon in Puget Sound fisheries show a substantial decrease from 1896 to the early 1940s, but this is largely attributed to the prohibition of fishing for this species with purse seines and fish traps starting in 1935. Overall catch within Puget Sound has increased gradually since that time, but has not returned to earlier levels, possibly as a result of greater interceptions of coho salmon in ocean fisheries (Bledsoe et al. 1989).

As noted above, between 1972 and 1993 the average size of fish in the terminal landings underwent a sharp decline, from an average of about 4 kg to about 2 kg (Fig. 16). This dramatic decline in average fish size, which could result from any of several causes, could seriously reduce the fecundity and fitness of naturally spawning fish.

The ESU that includes Puget Sound extends into southern British Columbia, for which we have not received detailed abundance information. Northcote and Atagi (in press) have reviewed abundance trends for all salmon species in various regions of British Columbia, two of their regions include parts of this ESU. Coho salmon have shown both historical (1800s to 1953-92 average) and recent (1953 to 1992) declines both on Vancouver Island and along the south-central British Columbia coast (excluding the Fraser River).

In both areas, the historical decline was roughly twofold. On Vancouver Island, coho salmon escapements have recently declined from more than 300,000 in the mid-1950s to about 150,000 at present. Along the south-central British Columbia coast, escapement declines in the same period have been more dramatic, from about 500,000 in the mid-1950s to less than 100,000 at present. This is a much more severe decline than the trends documented in the U.S. portion of the ESU.

Northcote and Atagi did not address levels of hatchery production for British Columbia coho salmon. However, there has been a substantial increase in coho salmon releases from British Columbia hatcheries since 1975 (Hilborn and Winton 1993).

Table 14. Average terminal run sizes of Puget Sound coho salmon stock complexes (1981 to 1992). Based on data from PFMC (1994).

Stock	Natural	Hatchery	Total
Strait of Juan de Fuca	8,100	15,800	23,900
Nooksack/Samish	27,500	147,600	153,100
Skagit	31,400	23,000	54,400
Hood Canal	40,400	52,900	93,300
Stillaguamish/Snohomish	164,200	63,400	227,600
South Puget Sound	207,700	473,400	681,100
Total	479,300	776,100	1,255,400

Conclusions

In general, there is a geographic trend in the status of coho salmon stocks south of the Canadian border, with the southernmost and easternmost stocks in the worst condition. Throughout the regions reviewed, there have been recent declines in coho salmon abundance, and 1994 runs were predicted to be the worst on record in many river basins. (At the time of this report, we have received no 1994 run-size or escapement estimates for most river basins.) Conclusions for specific ESUs follow and are summarized in Table 15.

1) Central California Coast

All coho salmon stocks south of Punta Gorda are depressed relative to past abundance, but there are limited data to assess population numbers or trends. The main stocks in this region have been heavily influenced by hatcheries, and there are apparently few native coho salmon left in this region. The apparent low escapements in these rivers and streams, in conjunction with heavy historical hatchery production, suggest that natural populations there are not self-sustaining. The status of coho salmon stocks in most small coastal tributaries is not well known, but these populations are small. There was unanimous agreement among the BRT members that natural populations of coho salmon in this ESU are presently in danger of extinction.

2) Southern Oregon/Northern California Coasts

All coho salmon stocks between Punta Gorda and Cape Blanco are depressed relative to past abundance, but again there are limited data to assess population numbers or trends. The main stocks in this region (Rogue River, Klamath River, and Trinity River) are heavily influenced by hatcheries and, apparently, have little natural production in mainstem rivers. The apparent declines in production in these rivers, in conjunction with heavy hatchery production, suggest that the natural populations are not self-sustaining. The status of coho salmon stocks in most small coastal tributaries is not well known, but these populations are small. There was unanimous agreement among the BRT that coho salmon in this ESU are not in danger of extinction but are likely to become endangered in the foreseeable future if present trends continue.

3) Oregon Coast

There are extensive survey data available for coho salmon stocks in this region. Overall, spawning escapements have declined substantially during this century and may now be at less than 5% of their abundance in the early 1900s. Average spawner abundance has been relatively constant since the late 1970s, but preharvest abundance has declined. Average recruits-per-spawner may also be declining. Coho salmon populations in most major rivers have heavy hatchery influence, but some tributaries may sustain native stocks. The BRT concluded that coho salmon in this ESU are not at immediate risk of extinction but are likely to become endangered in the future if present trends continue.

Table 15. Summary of risk considerations for six coho salmon evolutionarily significant units(ESUs).

Risk category	ESU 1 - Central California	ESU 2 - Southern Oregon/Northern California coasts	ESU 3 - Oregon coast
Absolute numbers (Recent average)	Escapement ca. 6,000, ca. 160 "native" with no history of hatchery influence.	Run size ca. 10,000 natural, 20,000 hatchery. Current production largely in the Rogue and Klamath basins.	Escapement ca. 39,000 natural, unknown hatchery.
Numbers relative to historical abundance and carrying capacity	Abundance substantially below historical levels. More than 50% of coho streams no longer have spawning runs. Widespread habitat degradation.	Substantially below historical levels. In California portion of ESU, ca. 36% of coho streams no longer have spawning runs. Widespread habitat degradation.	Natural production ca. 5-10% of historical levels, near 50% of current capacity. Widespread habitat degradation.
Trends in abundance and production	Long-term trends clearly downward. No data to estimate recent trends.	Long-term trends clearly downward. Main data are for Rogue River basin, where runs declined to very low levels in 1960s and 1970s, then increased with start of hatchery production.	Long-term trends clearly downward. Escapement declined substantially since early 1950s, but majority of decline was in early 1970s. Recent average spawner-to-spawner ratios below replacement. Recruits-per-spawner show a continuous decline up to present. Southern portion of ESU recently increasing.
Variability factors	Low abundance or degraded habitat may increase variability.	Low abundance or degraded habitat may increase variability.	Low abundance or degraded habitat may increase variability.
Threats to genetic integrity	Most existing populations have history of hatchery plantings, with many out-of-state stock transfers.	Most existing populations have hatchery plantings, with many out-of-state stock transfers in California portion of the ESU.	Most existing populations have hatchery plantings, with many out-of-basin (but largely within-ESU) stock transfers. Magnitude of hatchery influence declines from north to south.
Recent events	Recent droughts and change in ocean production have probably reduced run sizes.	Recent droughts and change in ocean production have probably reduced run sizes.	Recent droughts and change in ocean production have probably reduced run sizes.
Other Factors	None identified.	None identified.	None identified.
Conclusion	Presently in danger of extinction.	Not presently in danger of extinction, but likely to become so.	Not presently in danger of extinction, but likely to become so.

Table 15. Continued.

Risk category	ESU 4 - Lower Columbia River/ Southwest Washington	ESU 5 - Olympic Peninsula	ESU 6 - Puget Sound/Strait of Georgia
Absolute numbers (Recent average)	Total natural production unknown. Late Clackamas River run is less than 4,000.	Run size ca. 34,000 natural, 34,000 hatchery.	Run size ca. 479,000 natural, 776,000 hatchery.
Numbers relative to historical abundance and carrying capacity	Native, natural production near zero in much of the geographic area. Unable to identify extant natural populations, except possibly in Clackamas River. Widespread habitat degradation.	Substantially below historical levels. Widespread habitat degradation in most of geographic range, but headwater areas within Olympic National Park protected.	Total run is near historical levels, natural run is substantially below historical levels. Widespread habitat degradation.
Trends in abundance and production	Long-term trend in natural production is clearly downward. No substantial recent upward or downward trend in Clackamas River.	No substantial upward or downward trends were detected in terminal run size or in ocean exploitation rates.	Long-term trends in total run size relatively flat in WA portion of ESU, downward in BC portion. Recent escapement trends are mixed upward and downward, majority of stocks show no substantial trend.
Variability factors	Low abundance or degraded habitat may increase variability.	Low abundance or degraded habitat may increase variability.	Degraded habitat may increase variability.
Threats to genetic integrity	Widespread hatchery production far exceeds that for any other ESU, with many out-of-basin (but largely within-ESU) stock transfers.	Some populations have continuing hatchery plantings, largely within-basin although numerous small out-of-ESU transfers have occured. Hatchery influence restricted to a few major rivers; several stocks have little or no hatchery influence.	Most existing populations have continuing hatchery plantings, with many out-of-basin (but largely within-ESU) stock transfers. Average hatchery contribution rate to runs is 62%, with largest effect on the Nooksack-Samish and South Puget Sound stock complexes.
Recent events	Recent droughts and change in ocean production have probably reduced run sizes.	Recent droughts and change in ocean production have probably reduced run sizes.	Recent droughts and change in ocean production have probably reduced run sizes.
Other Factors	Harvest rates have been very high, but declining in recent years.	None identified.	Sharp decline in adult coho body size. Recent harvest rates have been high.
Conclusion	If ESU still exists, it is not presently in danger of extinction, but is likely to become so.	Not presently in danger of extinction, nor likely to become so.	Not presently in danger of extinction, but likely to become so.

4) Lower Columbia River/Southwest Washington Coast

The BRT concluded that we cannot at present identify any remaining natural populations of coho salmon in the lower Columbia River (excluding the Clackamas River) or along the Washington coast south of Point Grenville that warrant protection under the ESA, although this conclusion would warrant reconsideration if new information becomes available. The Clackamas River produces moderate numbers of natural coho salmon. The Clackamas River late-run coho salmon population is relatively stable under present conditions, but depressed and vulnerable to overharvest. Its small geographic range and low abundance make it particularly vulnerable to environmental fluctuations and catastrophes, so this population may be at risk of extinction despite relatively stable spawning escapements in the recent past. As noted above, the BRT could not reach a definite conclusion regarding the relationship of Clackamas River late-run coho salmon to the historic lower Columbia River ESU. However, the BRT did conclude that if the Clackamas River late-run coho salmon is a native run that represents a remnant of a lower Columbia River ESU, the ESU is not presently in danger of extinction but is likely to become so in the foreseeable future if present conditions continue.

5) Olympic Peninsula

Coho salmon abundance within this ESU is moderate, but stable. These stocks have been reduced from historical levels by large-scale habitat degradation in the lower river basins, but there is a significant portion of coho salmon habitat in several rivers protected within the boundaries of Olympic National Park. This habitat refuge, along with the relatively moderate use of hatchery production (primarily with native stocks), appears to have protected these coho salmon stocks from the serious losses experienced in its adjacent regions. While there is continuing cause for concern about habitat destruction and hatchery practices within this ESU, the BRT concluded that there is sufficient native, natural, self-sustaining production of coho salmon that this ESU is not in danger of extinction and is not likely to become endangered in the foreseeable future unless conditions change substantially.

6) Puget Sound/Strait of Georgia

Coho salmon within this ESU are abundant and, with some exceptions, run sizes and natural spawning escapements have been generally stable. However, artificial propagation of coho salmon appears to have had a substantial impact on native, natural coho salmon populations, to the point that it is difficult to identify self-sustaining, native stocks within this region. In addition, continuing loss of habitat, extremely high harvest rates, and a severe recent decline in average size of spawners indicate that there are substantial risks to whatever native production remains. There is concern that if present trends continue, this ESU is likely to become endangered in the foreseeable future. However, the size data examined are heavily influenced by fishery data from the Puget Sound. These fisheries target primarily hatchery stocks, and it is not known at this time to what extent the trends in size are influenced by hatchery fish. The extent of hatchery contribution to the natural spawning escapement and to natural production is unclear, as are the potential effects this contribution may have on the population genetics and ecology of this ESU. Further consideration of this ESU is warranted to attempt to clarify some of these uncertainties.

CITATIONS

Adair, R., W. Harper, G. Rankel, and J. Smith. 1982. Annual report, Klamath River fisheries investigation program. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California, p. 89-122. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Adair, R., W. Harper, J. Smith, S. Eggers, and S. Klemp. 1983. Annual Report, Klamath River fisheries investigation program, 1982. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California, p. 109-116. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Adair, R., W. Harper, R. Edwards, J. Larson, K. Lutz, and C. Tuss. 1984. Annual Report, Klamath River fisheries investigation program, 1983. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California, p. 107-113. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Adair, R., C. Tuss, R. Edwards, J. Larson, K. Lutz, P. Dalka, and M. Messenger. 1985. Annual Report, Klamath River fisheries investigation program, 1984. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California, Rep. FR1-FAO-85-20, p. 108-117. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Aebersold, P. B., G. A. Winans, D. J. Teel, G. B. Milner, and F. M. Utter. 1987. Manual for starch gel electrophoresis: A method for the detection of genetic variation. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 61, 19 p.

Allen, G. H. 1959. Growth of marked silver salmon (*Oncorhynchus kisutch*) of the 1950 brood in Puget Sound. Trans. Am. Fish. Soc. 60:310-318.

Allen, J. E., M. Burns, and S. C. Sargent. 1986. Cataclysms on the Columbia, A Layman's guide to the features produced by the catastrophic Bretz floods in the Pacific Northwest. Timber Press, Portland, OR, 213 p.

Allen, J. T. 1958. Report of first season's operations, 1957-58, Pudding Creek silver salmon egg collecting station, Mendocino County. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 58-12. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814. Same for other reports in this series.)

Allen, M. J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 66, 151 p.

Allendorf, F. W., and N. Ryman. 1987. Genetic management of hatchery stocks. *In* N. Ryman and F. Utter (editors), Population genetics & fishery management, p. 141-159. Univ. Washington Press, Seattle.

Alt, D., and D. W. Hyndman. 1984. Roadside geology of Washington. Mountain Press Publ. Co., Missoula, MT, 289 p.

Anderson, D., and H. McGuire. 1994. Redwood Creek Basin 1991-1992 spawning and carcass survey: Annual Prog. Rep. Redwood Natl. Park, Fish Wildl. Res. Resource Manage Div., Arcata, 33 p. (Available from Redwood National Park, 1125 16th St., Arcata, CA 95521.)

Anderson, J. D., and D. A. Milward. 1992. Results of the South Puget Sound coho test fishery, 1985-1990. Wash. Dep. Fish. Prog. Rep. 295, 105 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091. Same for other reports in this series.)

Argue, A. W., and R. W. Armstrong. 1977. Coho smolt coded-wire tagging and enumeration (1971 to 1973 broods) on three small tributaries in the Squamish River system. Can. Dep. Fish. Oceans, Fish. & Mar. Serv., Data Record Series PAC/D-77-11, p. 51-57. (Available from Canadian Department of Fisheries and Oceans, Fisheries & Marine Service, 1090 West Pender St., Vancouver, B. C. V6E 2P1.)

Argue, A. W., L. M. Patterson, and R. W. Armstrong. 1979. Trapping and coded-wire tagging of wild coho, chinook, and steelhead juveniles from the Cowichan-Koksilah River system, 1976. Can. Fish. & Mar. Serv. Tech. Rep. 850, 116 p.

Armstrong, R. W., and A. W. Argue. 1977. Trapping and coded-wire tagging of wild coho and chinook juveniles from the Cowichan River system, 1975. Can. Dep. Fish. Environ., Tech. Rep. Series PAC/T-77-14, 58 p. (Available from Canadian Department of Fisheries and Oceans, Fisheries & Environment, 1090 West Pender St., Vancouver, B. C. V6E 2P1.)

Arnold, J. R. 1971. A study of the silver salmon and steelhead trout in Redwood Creek, Marin County, California. Rep. to U.S. Natl. Park Serv., Contract 14-10-9-990-22. (Available from Redwood National Park, 1125 16th St., Arcata, CA 95521.)

Arnold, E. E. 1972a. Annual Report, Iron Gate salmon and steelhead hatchery, Sixth year of operation, 1970-71. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 72-10, 22 p. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814. Same for other reports in this series.)

Arnold, E. E. 1972b. Annual Report, Iron Gate salmon and steelhead hatchery, Seventh year of operation, 1971-72. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 72-11, 20 p.

Arnold, E. E. 1974. Annual Report, Iron Gate salmon and steelhead hatchery, Eighth year of operation, 1972-73. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 74-3, 20 p.

Arnold, E. E. 1975. Annual Report, Iron Gate salmon and steelhead hatchery, 1973-74. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 75-2, 20 p.

Arnold, E. E. 1977a. Annual Report, Iron Gate salmon and steelhead hatchery, 1974-75. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 77-9, 19 p.

Arnold, E. E. 1977b. Annual Report, Iron Gate salmon and steelhead hatchery, 1975-76. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 77-10, 20 p.

Arnold, E. E. 1977c. Annual Report, Iron Gate salmon and steelhead hatchery, 1976-77. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 77-11, 20 p.

Aro, K. V. 1979. Transfers of eggs and young of Pacific salmon within British Columbia. Can. Dep. Fish Oceans, Fish. & Mar. Serv. Tech. Rep. 86, 147 p.

Aro, K. V., and M. P. Shepard. 1967. Salmon of the North Pacific Ocean--Part IV. Spawning populations of North Pacific salmon, 5. Pacific salmon in Canada. Bull. Int. North Pac. Fish. Comm. 23:225-327.

Bakun, A. 1973. Coastal upwelling indices, West Coast of North America, 1946-71. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-671, 103 p.

Bakun, A. 1975. Daily and weekly upwelling indices, West Coast of North America, 1967-73. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-693, 114 p.

Bams, R. A. 1993. Coho salmon smolt production from Kelvin Creek (Cowichan River watershed) B.C., during four years of colonization with hatchery and salvaged wild fry. Can. Tech. Rep. Fish. Aquat. Sci. 1933:5-15.

Barbour, M. G., and J. Major (editors). 1977. Terrestrial vegetation of California. Wiley, New York, 1002 p.

Barngrover, B. G. 1983. Annual Report, Mad River salmon and steelhead hatchery, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 83-13, 21 p.

Barngrover, B. G. 1986. Annual Report, Mad River salmon and steelhead hatchery, 1983-84. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 86-02, 18 p.

Barngrover, B. G. 1987a. Annual Report, Mad River salmon and steelhead hatchery, 1984-85. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-4, 21 p.

Barngrover, B. G. 1987b. Annual Report, Mad River salmon and steelhead hatchery, 1985-86. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-10, 11 p.

Barngrover, B. G. 1988. Annual Report, Mad River salmon and steelhead hatchery, 1986-87. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 88-3.

Barngrover, B. G. 1990a. Annual Report, Mad River salmon and steelhead hatchery, 1986-87. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-2, 14 p.

Barngrover, B. G. 1990b. Annual Report, Mad River salmon and steelhead hatchery, 1988-89. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-14, 14 p.

Barngrover, B. G. 1991. Annual Report, Mad River salmon and steelhead hatchery, 1989-90. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-9, 15 p.

Barngrover, B. G. 1992. Annual Report, Mad River salmon and steelhead hatchery, 1990-91. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 92-10, 14 p.

Bartholomew, J. L., J. S. Rohovec, and J. L. Fryer. 1989. *Ceratomyxa shasta*, a Myxosporean parasite of salmonids. U.S. Fish Wildl. Serv. Fish Dis. Leafl. 80, 8 p.

Bartholomew, J. L., J. L. Fryer, and J. S. Rohovec. 1992. Impact of the myxosporean parasite *Ceratomyxa shasta* on survival of migrating Columbia River basin salmonids. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 111, p. 33-41.

Bartley, D. M., B. Bentley, P. G. Olin, and G. A. E. Gall. 1992. Population structure of coho salmon (*Oncorhynchus kisutch*) in California. Calif. Fish Game 78(3):88-104.

Beacham, T. D. 1982. Fecundity of coho salmon (*Oncorhynchus kisutch*) and chum salmon (*O. keta*) in the northeast Pacific Ocean. Can. J. Zool. 60:1463-1469.

Beacham, T. D., and C. B. Murray. 1987. Adaptive variation in body size, age, morphology, egg size, and developmental biology of chum salmon (*Oncorhynchus keta*) in British Columbia. Can. J. Fish. Aquat. Sci. 44:244-261.

Beamish, R. J., and D. R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Can. J. Fish. Aquat. Sci. 50:1002-1016.

Beauchamp, D. A. 1986. Snohomish River juvenile salmon outmigration study 1986. Prepared for U.S. Dep. Navy, Contract N62474-B6-C-0991, 43 p. plus charts. (Available from the Tulalip Tribes, 6700 Totem Beach Rd., Marysville, WA 98270.)

Beauchamp, D. A., D. E. Pflug, and G. Lucchetti. 1987. Snohomish River juvenile salmon outmigration study 1987. Prepared for U.S. Dep. Navy, Contract N62474-B6-C-0991, 42 p. plus charts. (Available from the Tulalip Tribes, 6700 Totem Beach Rd., Marysville, WA 98270.)

Bedell, G. W. 1970a. Annual Report, Trinity River salmon and steelhead hatchery, Eleventh year of operation, 1968-69. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 70-5, 22 p.

Bedell, G. W. 1970b. Annual Report, Trinity River salmon and steelhead hatchery, Twelfth year of operation, 1969-70. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 70-19, 29 p.

Bedell, G. W. 1972a. Annual Report, Trinity River salmon and steelhead hatchery, Thirteenth year of operation, 1970-71. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 72-4, 29 p.

Bedell, G. W. 1972b. Annual Report, Trinity River salmon and steelhead hatchery, Fourteenth year of operation, 1971-72. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 72-14, 25 p.

Bedell, G. W. 1974. Annual Report, Trinity River salmon and steelhead hatchery, 1972-73. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 74-4, 26 p.

Bedell, G. W. 1975. Annual Report, Trinity River salmon and steelhead hatchery, 1973-74. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 75-4, 25 p.

Bedell, G. W. 1976. Annual Report, Trinity River salmon and steelhead hatchery, 1974-75. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 76-6, 22 p.

Bedell, G. W. 1978a. Annual Report, Trinity River salmon and steelhead hatchery, 1975-76. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 78-1, 22 p.

Bedell, G. W. 1978b. Annual Report, Trinity River salmon and steelhead hatchery, 1976-77. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 78-2, 22 p.

Bedell, G. W. 1979. Annual Report, Trinity River salmon and steelhead hatchery, 1977-78. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 79-2, 22 p.

Bedell, G. W. 1980. Annual Report, Trinity River salmon and steelhead hatchery, 1978-79. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 80-14, 23 p.

Bedell, G. W. 1982. Annual Report, Trinity River salmon and steelhead hatchery, 1979-80. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-3, 21 p.

Bedell, G. W. 1983a. Annual Report, Trinity River salmon and steelhead hatchery, 1980-81. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 83-3, 24 p.

Bedell, G. W. 1983b. Annual Report, Trinity River salmon and steelhead hatchery, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. (unnumbered), 21 p.

Bedell, G. W. 1984. Annual Report, Trinity River salmon and steelhead hatchery, 1983-84. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 84-05, 20 p.

Bedell, G. W. 1987a. Annual Report, Trinity River salmon and steelhead hatchery, 1984-85. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-5, 27 p.

Bedell, G. W. 1987b. Annual Report, Trinity River salmon and steelhead hatchery, 1985-86. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-13, 30 p.

Bedell, G. W. 1990a. Annual Report, Trinity River salmon and steelhead hatchery, 1986-87. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-17, 27 p.

Bedell, G. W. 1990b. Annual Report, Trinity River salmon and steelhead hatchery, 1987-88. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-11, 14 p.

Bedell, G. W. 1990c. Annual Report, Trinity River salmon and steelhead hatchery, 1988-89. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-12, 14 p.

Bedell, G. W. 1991a. Annual Report, Trinity River salmon and steelhead hatchery, 1989-90. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-8, 15 p.

Bedell, G. W. 1991b. Annual Report, Trinity River salmon and steelhead hatchery, 1990-91. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-17, 13 p.

Bernatchez, L., and J. J. Dodson. 1987. Relationship between bioenergetics and behavior in anadromous fish migrations. Can. J. Fish. Aquat. Sci. 44:399-407.

Bigler, B., and J. H. Helle. 1994. Decreasing size of North Pacific salmon (*Oncorhynchus* sp.): Possible causes and consequences. Document submitted to the Annual Meeting of the North Pacific Anadromous Fish Commission, October 1994, Vladivostok, Russia, 34 p. (Available from Wards Cove Packing Co., P.O. Box C-5030, Seattle, WA 98105.)

Blankenship, L., and R. Tivel. 1980. Puget Sound wild stock coho trapping and tagging, 1973-1979. Wash. Dep. Fish. Prog. Rep. 111, 62 p.

Blankenship, L., P. Hanratty, and R. Tivel. 1983. Puget Sound wild stock coho trapping and tagging, 1980-1982. Wash. Dep. Fish. Prog. Rep. 198, 34 p.

Bledsoe, L. J., D. A. Somerton, and C. M. Lynde. 1989. The Puget Sound runs of salmon: An examination of the changes in run size since 1896. *In* C. D. Levings, L. B. Holtby, and M. A. Henderson (editors), Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks, May 6-8, 1987, Nanaimo, B.C., p. 50-61. Can. Spec. Publ. Fish. Aquat. Sci. 105.

Booth, D. B. 1991. Urbanization and the natural drainage system--Impacts, solutions, and prognoses. Northwest Environ. J. 7:93-118.

Borgerson, L. A. 1991. Scale analysis. Oreg. Dep. Fish Wildl., Annual Prog. Rep., Fish Res. Proj. F-144-R-2, 32 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Borgerson, L. A. 1992. Scale analysis. Oreg. Dep. Fish Wildl., Annual Prog. Rep., Fish Res. Proj. F-144-R-4, 22 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Borgerson, L. A., N. E. Stewart, K. K. Jones, and S. R. Mamoyac. 1991. Yaquina River Basin fish management plan. Oreg. Dep. Fish Wildl., 17 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Bratovich, P. M., H. Brooks, and D. Kelley. 1984. Investigations on Lagunitas Creek, Marin County, California. Second progress report. Report to the Marin Municipal Water District. (Available from Marin Municipal Water District, 220 Nellen Ave., Corte Madera, CA 94925.)

Bratovich, P. M., and D. Kelley. 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California. Volume 1. Migration, spawning, embryo incubation and emergence, juvenile rearing, and emigration. Report to the Marin Municipal Water District. (Available from Marin Municipal Water District, 220 Nellen Ave., Corte Madera, CA 94925.)

Breckon, G. J., and M. G. Barbour. 1974. Review of North American Pacific Coast beach vegetation. Madrono 22:333-360.

Briggs, J. C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif. Dep. Fish Game, Fish Bull. 94:1-62.

Brix, R. 1981. Data report of Grays Harbor juvenile salmon seining program, 1973-1980. Wash. Dep. Fish. Prog. Rep. 141, 78 p.

Brix, R., and D. Seiler. 1977. Upper Chehalis River smolt trapping study, 1976. Wash. Dep. Fish. Prog. Rep. 25, 14 p.

Brix, R., and D. Seiler. 1978. Upper Chehalis River smolt trapping study, 1977. Wash. Dep. Fish. Prog. Rep. 48, 16 p.

Brown, L. R., and P. B. Moyle. 1991. Status of coho salmon in California. Report to the National Marine Fisheries Service, 114 p. (Available from Environmental and Technical Services Division, U.S. Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. N. Am. J. Fish. Manage. 14:237-261.

Brusca, R. C., and B. R. Wallerstein. 1979. Zoogeographic patterns of idoteid isopods in the Northeast Pacific, with a review of shallow water zoogeography of the area. Bull. Biol. Soc. Wash. 3:67-105.

Bryant, G. J. 1994. Status review of coho salmon in Scott Creek and Waddell Creek, Santa Cruz County, California. Natl. Mar. Fish. Serv., SW Region, Protected Species Management Division, 102 p. (Available from Natl. Mar. Fish. Serv., Southwest Region, 501 W. Ocean Blvd., Suite 4200, Long Beach, CA 90802.)

Burner, C. J. 1951. Characteristics of spawning nests of Columbia River salmon. Fish. Bull., U.S. 52:95-110.

Busby, P. J., T. C. Wainwright, and R. S. Waples. 1994. Status Review for Klamath Mountains Province Steelhead. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-19, 130 p.

California Advisory Committee on Salmon and Steelhead Trout. 1988. Restoring the balance. Annual Report. 124-J, 84 p. (Available from California Advisory Committee on Salmon and Steelhead Trout, 120 Schoonmaker Point, Sausalito, CA 94965.)

California Department of Fish and Game (CDFG). 1965. California fish and wildlife plan, Volume I: Summary, 110 p.; Volume II: Fish and Wildlife Plans, 216 p.; Volume III: Supporting data, 1802 p. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814.)

California Department of Fish and Game (CDFG). 1994. Petition to the California Board of Forestry to list coho salmon (*Oncorhynchus kisutch*) as a sensitive species. Calif. Dep. Fish Game Rep., 35 p. plus appendices. (Available from California Board of Forestry, 1416 Ninth, Sacramento, CA 95814.)

California State Lands Commission. 1993. California's rivers: A public trust report. Second edition, California State Lands Commission, 334 p. (Available from California State Lands Commission, 1807 13th St., Sacramento, CA 95814.)

Cartwright, W. F. 1992. Annual Report, Warm Springs salmon and steelhead hatchery, 1990-91. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 92-5, 10 p.

Caughley, G. 1994. Directions in conservation biology. J. Anim. Ecol. 63:215-244.

Cavalli-Sforza, L. L., and A. W. F. Edwards. 1967. Phylogenetic analysis: Models and estimation procedures. Evolution 21:550-570.

Chan, J. R., and M. Longenbaugh. 1994. Progress report for investigations on Blue Creek. U.S. Fish Wildl. Serv., Coastal Calif. Fish. Resource Off., Arcata, California, Rep. AFF1-FRO-93-12, 36 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resources Office, P.O. Box 1006, Yreka, CA 96097.)

Chapman, D. W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Board Can. 19:1047-1080.

Chapman, D. W. 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Am. Fish. Soc. 94(1):40-52.

Chapman, W. M. 1940. The average weight of food fish taken by the commercial fishery in the Columbia River. Wash. Dep. Fish. Biol. Rep. 39A, 30 p. plus figures. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Chapman, W. M., R. T. Smith, and C. H. Ellis. 1936. The 1935 salmon fishery in the State of Washington with the daily statistics of the catch. Wash. Dep. Fish. Biol. Rep. 35A, 27 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Chilcote, M., C. Dale, K. Kostow, H. Schaller, and H. Weeks. 1992. Wild fish management policy. Biennial Progress Report., Oreg. Dep. Fish Wildl., 49 p. plus appendices. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Columbia River Coordinated Information System (CIS). 1992. Stock Summary Reports for Columbia River Anadromous Salmonids, 5 volumes. Prepared for U.S. Department of Energy, Bonneville Power Administration, Contract DE-FC79-89BP94402. (Available from U.S. Department of Energy, Bonneville Power Administration, Public Information Office - ALP-22, P.O. Box 3621, Portland, OR 97208.)

Conrad, J. F., and M. Decew. 1966. First report of *Ceratomyxa* in juvenile salmonids in Oregon. Prog. Fish-Cult. 28:238.

Cook, F. R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Natural Sciences, National Museums of Canada, Ottawa, 200 p.

Cooney, C. X., and S. E. Jacobs. 1990. Oregon coastal salmon spawning surveys, 1989. Oregon Dep. Fish Wildl. Info. Annual Prog. Rep., 67 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Cooney, C. X., and S. E. Jacobs. 1992. Oregon coastal salmon spawning surveys, 1990. Oregon Dep. Fish Wildl. Info. Rep. 92-2, 73 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207. Same for other reports in this series.)

Cooney, C. X., and S. E. Jacobs. 1993. Oregon coastal salmon spawning surveys, 1991. Oregon Dep. Fish Wildl. Info. Rep. 93-1, 81 p.

Cooney, C. X., and S. E. Jacobs. 1994. Oregon coastal salmon spawning surveys, 1992. Oregon Dep. Fish Wildl. Info. Rep. 94-2, 103 p.

Coots, M. 1958. Shasta River king salmon count, 1957. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 58-4.

Craig, J. L. 1991. Klamath River fisheries assessment program-Klamath River Basin juvenile salmonid fisheries investigation, 1989. U.S. Fish Wildl. Serv. Coastal Calif. Fish. Resource Off., Arcata, California, Rep. AFF-1-FRO-91-3, 66 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Craig, J. L. 1992. Klamath River fisheries assessment program, Juvenile salmonid trapping on the mainstem Trinity River at Willow Creek and on the Klamath River at Big Bar, 1990. U.S. Fish Wildl. Serv. Coastal Calif. Fish. Resource Off., Arcata, California, Annual Rep. AFF-1-FRO-92-13, 49 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Craig, J. L., and T. S. Fletcher. 1994. Annual Report, Klamath River fisheries assessment program, 1992. U.S. Fish Wildl. Serv. Coastal Calif. Fish. Resource Off., Arcata, California, Rep. AFF1-FRO-94-03, p. 8-50. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Cramer, D. P., and S. P. Cramer. 1994. Status and population dynamics of coho salmon in the Clackamas River. Tech. Rep., Portland General Electric Co., 105 p. (Available from Portland General Electric Co., 33831 SE Faraday Rd., Estacada, OR 97023.)

Cramer, S. P. 1994. Status of Oregon’s coastal coho and measures for population rebuilding. Final Report, May 1994. Submitted to National Marine Fisheries Service by S. P. Cramer and Associates, Gresham, Oregon, 142 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 NE Oregon St., Portland, OR 97232.)

Cramer, S. P., T. D. Satterthwaite, R. B. Boyce, and B. P. McPherson. 1985. Lost Creek Dam fisheries evaluation phase I completion report. Volume I: Impacts of Lost Creek Dam on the biology of anadromous salmonids in the Rogue River. Submitted to U.S. Army Corps of Engineers, Contract DACW57-77-C-0027, 271 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Crone, R. A., and C. E. Bond. 1976. Life history of coho salmon, *Oncorhynchus kisutch*, in Sashin Creek, southeastern Alaska. Fish. Bull., U.S., 74(4):897-923.

Cross, C. L., L. Lapi, and E. A. Perry. 1991. Production of chinook and coho salmon from British Columbia hatcheries, 1971 through 1989. Can. Tech. Rep. Fish. Aquat. Sci. 1816:1-48.

Currens, K. P., and D. Farnsworth. 1993. Mitochondrial DNA variation in Oregon coho salmon. Report to Oregon Department of Fish and Wildlife, 16 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Denman, K. L., D. L. Mackas, H. J. Freeland, M. J. Austin, and S. H. Hill. 1981. Persistent upwelling and mesoscale zones of high productivity off the west coast of Vancouver Island, Canada. *In* F. A. Richards (editor), Coastal Upwelling, p. 514-521. American Geophysical Union, Washington DC.

Dilley, S. J., and R. C. Wunderlich. 1992. Juvenile anadromous fish passage at Howard Hanson Project, Green River, Washington, 1991. U.S. Fish Wildl. Serv., Proj. Rep., West. Wash. Fish. Resour. Off., Olympia, WA. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmont Lane, Bldg. A, Olympia, WA 98502-5751.)

Dilley, S. J., and R. C. Wunderlich. 1993. Juvenile anadromous fish passage at Howard Hanson Dam and reservoir, Green River, Washington, 1992. U.S. Fish Wildl. Serv. Proj. Rep., West. Wash. Fish. Resour. Off., Olympia, WA. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmont Lane, Bldg. A, Olympia, WA 98502-5751.)

Donaldson, L. R., and G. H. Allen. 1958. Return of silver salmon, *Oncorhynchus kisutch* (Walbaum) to point of release. Trans. Am. Fish. Soc. 1957:13-22

Drucker, B. 1972. Some life history characteristics of coho salmon of the Karluk River system, Kodiak Island, Alaska. Fish. Bull, U.S., 70:79-94.

Ducey, R. D. 1980. Annual Report, Mad River salmon and steelhead hatchery, 1978-79. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 80-10, 22 p.

Ducey, R. D. 1982a. Annual Report, Mad River salmon and steelhead hatchery, 1979-80. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-1, 20 p.

Ducey, R. D. 1982b. Annual Report, Mad River salmon and steelhead hatchery, 1980-81. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-4, 21 p.

Ducey, R. D. 1982c. Annual Report, Mad River salmon and steelhead hatchery, 1981-82. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-27, 19 p.

Ducey, R. D. 1983. Annual Report, Mad River salmon and steelhead hatchery, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 83-13, 21 p.

Dunn, C. A. 1978. Evaluation of downstream fish passage through multi-level outlet pipes at Wynoochee Dam. Wash. Dep. Fish. Prog. Rep. 45, 92 p.

Eames, M., T. Quinn, K. Reidinger, and D. Haring. 1981. Northern Puget Sound 1976 adult coho and chum tagging studies. Wash. Dep. Fish. Tech. Rep. 64, 136 p.

Estey, D. F. 1982a. Annual Report, Warm Springs salmon and steelhead hatchery, 1980-81. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-14, 11 p.

Estey, D. F. 1982b. Annual Report, Warm Springs salmon and steelhead hatchery, 1981-82. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-30, 19 p.

Estey, D. F. 1983. Annual Report, Warm Springs salmon and steelhead hatchery, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 83-15, 17 p.

Estey, D. F. 1984. Annual Report, Warm Springs salmon and steelhead hatchery, 1983-84. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 84-04, 20 p.

Estey, D. F. 1986. Annual Report, Warm Springs salmon and steelhead hatchery, 1984-85. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 86-03, 18 p.

Exeter Software. 1993. NTSYS-PC, Version 1.80. (Computer program). (Available from Exeter Software, 100 N. Country Rd., Bldg. B, Setauket, NY 11733.)

Fagen, R., and W. W. Smoker. 1989. How large-capacity hatcheries can alter interannual variability of salmon production. Fish. Res. 8:1-11.

Farley, A. L. 1979. Atlas of British Columbia. Univ. British Columbia Press, Vancouver, 136 p.

Fennell, K. 1993. Results of the 1991 Oregon lower Columbia River coho spawning ground surveys with comparison to 1949-90 and the 1992 coho juvenile seining with comparison to 1972-85 and 1990-91. Oreg. Dep. Fish Wildl. Columbia River Manage., Proj. Rep., 13 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Flagg, T. A., F. W. Waknitz, D. J. Maynard, G. B. Milner, and C. V. Mahnken. 1995. The effect of hatcheries on native coho salmon populations in the lower Columbia River. *In* H. Schramm and B. Piper (editors), Proceedings of the American Fisheries Society Symposium on the uses and effects of cultured fishes in aquatic ecosystems, March 12-17, 1994, Albuquerque, NM. Am. Fish. Soc. Symp. 15:366-375.

Fleming, I. A., and M. R. Gross. 1989. Evolution of adult female life history and morphology in a Pacific salmon (coho: *Oncorhynchus kisutch*). Evolution 43:141-157.

Fleming, I. A., and M. R. Gross. 1990. Latitudinal clines: A trade-off between egg number and size in Pacific salmon. Ecology 71(1):1-11.

Flint, T., and G. Zillges. 1980. Little Bear Creek coho salmon stream life study. Wash. Dep. Fish. Prog. Rep. 124, 40 p.

Foerster, R. E. 1952. The seaward-migrating sockeye and coho salmon from Lakelse Lake, 1952. Fish. Res. Board Can. Prog. Rep. Pac. Coast Station 93:30-32.

Foerster, R. E. 1955. The Pacific salmon (Genus *Oncorhynchus*) of the Canadian Pacific coast, with particular reference to their occurrence in or near fresh water. Int. N. Pac. Fish. Comm. Bull. 1, 56 p.

Foerster, R. E., and W. E. Ricker. 1953. The coho salmon of Cultus Lake and Sweltzer Creek. J. Fish. Res. Board Can. 10(6):293-319.

Forbes, S., K. Knudsen, and F. Allendorf. 1993. Genetic variation in DNA of coho salmon from the Lower Columbia River. Final Report to the U.S. Dep. Energy, Bonneville Power Administration, Division of Fish and Wildlife, Contract DE-BI79-92BP 30198, 25 p. (Available from U.S. Department of Energy, Bonneville Power Administration, Public Information Office - ALP-22, P.O. Box 3621, Portland, OR 97208.)

Forstall, R. L. (editor). 1969. The international atlas. Rand McNally, Chicago, 223 p.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Tech. Rep. PNW-8, 417 p. U.S. Gov. Printing Office, Washington, DC.

Fraser, F. J., E. A. Perry, and D. T. Lightly. 1983. Big Qualicum River salmon development project, Volume I: A biological assessment, 1959-1972. Can. Tech. Rep. Fish. Aquat. Sci. 1189, 198 p.

French, R. R., R. G. Bakkala, and D. F. Sutherland. 1975. Ocean distribution of stocks of Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdnerii*, as shown by tagging experiments. U.S. Dep. Commer., NOAA Tech. Rep NMFS SSRF-689, 89 p.

Frissell, C. A. 1993. Topology of extinction and decline of native fishes in the Pacific Northwest and California (U.S.A.). Conserv. Biol. 7:342-354.

Fuss, H. J., C. Ashbrook, and D. Knutzen. 1993. Operation plans for Washington Department of Fisheries Anadromous Fish Production Facilities Annual Report, Volume I: Puget Sound, 403 p., Volume II: Washington Coast, 171 p. Wash. Dep. Fish., Salmon Culture Div., Olympia. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way, Olympia, WA 98504.)

Gallagher, K. I. 1992. Annual Report, Mad River salmon and steelhead hatchery, 1990-91. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 92-10, 14 p.

Gard, R., B. Drucker, and R. Fagen. 1987. Differentiation of subpopulations of sockeye salmon (*Oncorhynchus nerka*), Karluk River System, Alaska. *In* H. D. Smith, L. Margolis, and C. C. Wood, (editors), Sockeye salmon (*Oncorhynchus nerka*) population biology and future management, p. 408-418. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Garrison, R. L. 1985. Stock assessment of anadromous salmonids. Oreg. Dep. Fish Wildl., Annual Prog. Rep., Fish Res. Proj. AFC-130 and AFCS-113-1, 28 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Garrison, R. L., and R. W. Carmichael. 1982. Stock assessment and genetic studies of anadromous salmonids. Oreg. Dep. Fish Wildl., Annu. Prog. Rep., Fish Res. Proj. AFS-112-1, 47 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Gilbert, C. H. 1912. Age at maturity of the Pacific coast salmon of the genus *Oncorhynchus.* Fish Bull., U.S. 32:3-22.

Gilpin, M. E., and M. E. Soulé. 1986. Minimum viable populations: the processes of species extinctions. *In* M. E. Soulé (editor), Conservation biology: The science of scarcity and diversity, p. 13-34. Sinauer Associates, Sunderland, MA.

Gilroy, I. B., M. Longenbaugh, and J. C. Polos. 1992. Annual Report, Progress report for investigations on Blue Creek, FY 1990-1991. U.S. Fish Wildl. Serv., Coastal Calif. Fish. Resour. Off., Arcata, California, 66 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Godfrey, H. 1965. Coho salmon. Int. North Pac. Fish. Comm. Bull. 16, 39 p.

Godfrey, H., K. A. Henry, and S. Machidori. 1975. Distribution and abundance of coho salmon in offshore waters of the North Pacific Ocean. Int. North Pac. Fish. Comm. Bull. 31, 80 p.

Goldsmith, G. H. 1993. Annual Report, Klamath River fisheries assessment program, juvenile salmonid monitoring on the Trinity and Klamath Rivers, 1991. U.S. Fish Wildl. Serv., Coastal Calif. Fish. Resour. Off., Arcata, California, Rep. AFF-1-FRO-93-14, 58 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Graves, D. S., and J. W. Burns. 1970. Comparison of the yields of downstream migrant salmonids before and after logging road construction on the south fork Caspar Creek, Mendocino County. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 70-3.

Grass, A. 1982. Annual Report, Noyo River egg collecting station, 1980-81. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-19, 4 p.

Grass, A. 1990. Annual Report, Noyo River egg collecting station, 1987-88. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-3, 6 p.

Grass, A. 1991. Annual Report, Noyo River egg collecting station, 1988-89. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-13, 4 p.

Grass, A. 1992a. Annual Report, Noyo River egg collecting station, 1989-90. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 92-1, 6 p.

Grass, A. 1992b. Annual Report, Noyo River egg collecting station, 1990-91. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 92-12, 6 p.

Gunter, E. R. 1988a. Annual Report, Warm Springs salmon and steelhead hatchery, 1985-86. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 88-4, 7 p.

Gunter, E. R. 1988b. Annual Report, Warm Springs salmon and steelhead hatchery, 1986-87. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 88-5, 9 p.

Gunter, E. R. 1990a. Annual Report, Warm Springs salmon and steelhead hatchery, 1987-88. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 90-4, 12 p.

Gunter, E. R. 1990b. Annual Report, Warm Springs salmon and steelhead hatchery, 1988-89. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 90-8, 11 p.

Gunter, E. R. 1991. Annual Report, Warm Springs salmon and steelhead hatchery, 1989-90. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 91-14, 10 p.

Hall, C. A. 1964. Shallow-water marine climates and molluscan provinces. Ecology 45(2):226-234.

Hard, J. J., R. P. Jones, M. R. Delarm, and R. S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWFSC-2, 56 p.

Hartman, G. F., L. B. Holtby, and J. C. Scrivener. 1984. Some effects of natural and logging-related winter stream temperature changes on the early life history of coho salmon (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. *In* W. R. Meehan, T. R. Merrill, Jr., and T. A. Hanley (editors), Fish and wildlife relationships in old-growth forests, p. 141-149. Am. Instit. Fish. Biologists.

Hartt, A. C. 1980. Juvenile salmonids in the oceanic ecosystem- the critical first summer. *In* W. J. McNeil, and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific, p. 25-57. Oreg. State Univ. Press and Oreg. State Univ. Sea Grant College Prog., Corvallis.

Hartt, A. C. and M. B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. Int. North Pac. Fish. Comm. Bull. 46, 105 p.

Haux, S., and D. Anderson. 1992. Redwood Creek Basin 1990-1991 spawning and carcass survey: Annual Prog. Rep. Redwood Natl. Park, Fish Wildl. Manage. Div., Orick, California, 44 p. (Available from Redwood National Park, 1125 16th St., Arcata, CA 95521.)

Hayden, B. P., and R. Dolan. 1976. Coastal marine fauna and marine climates of the Americas. J. Biogeogr. 3:71-81.

Haymes, J. D., and P. H. Dygert. 1988. Skokomish River coho indicator stock study, 1988. Point No Point Treaty Council Tech. Rep. TR 88-4, 14 p. (Available from Point No Point Treaty Council, 7850 NE Little Boston Road, Kingston, WA 98346.)

Haymes, J. D., and E. J. Tierney. 1993. 1993 Quillayute River wild coho supplementation project progress report. Quileute Indian Tribe, Nat. Resources Dep., 18 p. (Available from Quileute Indian Tribe, P. O. Box 187, La Push, WA 98350.)

Healey, M. C. 1986. Optimum size and age at maturity in Pacific salmon and effects of size-selective fisheries. *In* D. J. Meerburg (editor), Salmonid age at maturity, p. 39-52. Can. Spec. Publ. Fish. Aquat. Sci. 89.

Healey, T. P. 1973. Studies of steelhead and salmon emigration in the Trinity River. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 73-1, 37 p.

Hemmingsen, A. R., R. A. Holt, and R. D. Ewing. 1986. Susceptibility of progeny from crosses among three stocks of coho salmon to infection by *Ceratomyxa shasta*. Trans. Am. Fish. Soc. 115:492-495.

Hershberger, W. K., J. M. Myers, R. N. Iwamoto, W. C. McAuley, and A. M. Saxton. 1990. Genetic changes in the growth of coho salmon (*Oncorhynchus kisutch*) in marine net-pens, produced by ten years of selection. Aquaculture 85(1990):187-197.

Higgins, P., S. Dobush, and D. Fuller. 1992. Factors in northern California threatening stocks with extinction. Unpubl. manuscr., Humboldt Chapter Am. Fish. Soc., 24 p. (Available from Humboldt Chapter of the American Fisheries Society, P.O. Box 210, Arcata, CA 95521.)

Hilborn, R., and J. Winton. 1993. Learning to enhance salmon production: Lessons from the Salmonid Enhancement Program. Can. J. Fish. Aquat. Sci. 50:2043-2056.

Hiser, C. A. 1979. Annual Report, Iron Gate salmon and steelhead hatchery, 1977-78. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 79-8, 23 p.

Hiser, C. A. 1982a. Annual Report, Iron Gate salmon and steelhead hatchery, 1978-79. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-22, 24 p.

Hiser, C. A. 1982b. Annual Report, Iron Gate salmon and steelhead hatchery, 1979-80. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-28, 23 p.

Hiser, C. A. 1982c. Annual Report, Iron Gate salmon and steelhead hatchery, 1980-81. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-20, 27 p.

Hiser, C. A. 1983. Annual Report, Iron Gate salmon and steelhead hatchery, 1981-82. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 84-1, 25 p.

Hiser, C. A. 1985a. Annual Report, Iron Gate salmon and steelhead hatchery, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 85-02, 34 p.

Hiser, C. A. 1985b. Annual Report, Iron Gate salmon and steelhead hatchery, 1983-84. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 85-01, 31 p.

Hiser, C. A. 1987a. Annual Report, Iron Gate salmon and steelhead hatchery, 1984-85. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-6, 27 p.

Hiser, C. A. 1987b. Annual Report, Iron Gate salmon and steelhead hatchery, 1985-86. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-14, 18 p.

Hiser, C. A. 1990. Annual Report, Iron Gate salmon and steelhead hatchery, 1986-87. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 90-16, 17 p.

Hiser, C. A. 1991a. Annual Report, Iron Gate salmon and steelhead hatchery, 1987-88. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-5, 16 p.

Hiser, C. A. 1991b. Annual Report, Iron Gate salmon and steelhead hatchery, 1988-89. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-6, 15 p.

Hiser, C. A. 1991c. Annual Report, Iron Gate salmon and steelhead hatchery, 1989-90. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 91-7, 15 p.

Hiser, C. A. 1992. Annual Report, Iron Gate salmon and steelhead hatchery, 1990-91. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 92-2, 15 p.

Hiser, C. A. 1993. Annual Report, Iron Gate salmon and steelhead hatchery, 1991-92. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 93-2, 14 p.

Hiss, J. M., and E. E. Knudsen. 1992. Status, trends, and restoration of Chehalis River Basin fishery resources. Draft Report, U.S. Fish and Wildlife Service, Olympia WA. (Later published by Hiss and Knudsen as “Chehalis River Basin fishery resources: Status, trends, and restoration,” See below).

Hiss, J. M., and E. E. Knudsen. 1993. Chehalis River Basin fishery resources: Status, trends, and restoration. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA, 128 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmont Lane, Bldg. A, Olympia, WA 98502-5751.)

Hjort, R. C., and C. B. Schreck. 1982. Phenotypic differences among stocks of hatchery and wild coho salmon, *Oncorhynchus kisutch*, in Oregon, Washington, and California. Fish. Bull., U.S. 80:105-119.

Hoffmaster, J. J., J. E. Sanders, J. S. Rohovec, J. L. Fryer, and D. G. Stevens. 1988. Geographic distribution of the myxosporean parasite, *Ceratomyxa shasta* Noble, 1950, in the Columbia River Basin, USA. J. Fish Dis. 11:97-100.

Hofstra, T. D., and D. G. Anderson. 1989. Survey of salmonid fish and their habitat in Redwood Creek, Marin County, California. Redwood Natl. Park, Tech. Serv. Div., Arcata, California. (Available from Redwood National Park, 1125 16th St., Arcata, CA 95521.)

Hoines, L. 1994. Washington state statistical report, 1991. Wash. Dep. Fish. Wildl., 80 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Holtby, L. B. 1987. The effects of logging on the coho salmon of Carnation Creek, British Columbia. *In* T. W. Chamberlin (editor), Proceedings of the workshop: Applying 15 years of Carnation Creek results, p. 159-174. Pacific Biological Station, Nanaimo, British Columbia. (Available from J. C. Scrivener, Pacific Biological Station, Box 100, Nanaimo, B. C., Canada V9R 5K6.)

Holtby, L. B., B. C. Andersen, and R. K. Kadowaki. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 47:2181-2194.

Holtby, L. B. and M. C. Healey. 1986. Selection for adult size in female coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 43:1946-1959.

Holtby, L. B., and J. C. Scrivener. 1989. Observed and simulated effects of climatic variability, clear-cut logging, and fishing on the numbers of chum salmon (*Oncorhynchus keta*) and coho salmon (*O. kisutch*) returning to Carnation Creek, British Columbia. *In* C. D. Levings, L. B. Holtby, and M. A. Henderson (editors), Proceedings of the national workshop on effects of habitat alteration on salmonid stocks, p. 62-81. Can. Spec. Publ. Fish. Aquat. Sci. 105.

Hopley, C. W. Undated. Historical production of coho salmon from Washington State hatcheries on the lower Columbia River. Report submitted to ESA Administrative Record for coho salmon, April 1991, 13 p. plus appendices. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Hopley, C. W., P. R. Seidel, H. G. Senn, and R. C. Hager. 1978. Results of 1970 and 1972 brood Columbia River coho studies. Wash. Dep. Fish Prog. Rep. 46, 36 p.

Horn, M. H., and L. G. Allen. 1978. A distributional analysis of California coastal marine fishes. J. Biogeogr. 5:23-42.

Houston, D. B. 1983. Anadromous fish in Olympic National Park: A status report. Natl. Park Serv. Pacific Northwest Region, 72 p. (Available from Olympic National Park, 600 East Park Avenue, Port Angeles, WA 98362.)

Howell, P., K. Jones, D. Scarnecchia, L. LaVoy, W. Kendra, and D. Ortmann. 1985. Stock assessment of Columbia River anadromous salmonids, Volume I: Chinook, coho, chum, and sockeye salmon stock summaries. Final report to U.S. Dep. Energy, Bonneville Power Administration, Contract DE-AI79-84BP12737, 558 p. plus appendices. (Available from U.S. Dep. Energy, Bonneville Power Administration, Fish and Wildlife, P.O. Box 3621, Portland, OR 97208.)

Hughes, R. M., E. Rexstad, and C. E. Bond. 1987. The relationship of aquatic ecoregions, river basins, and physiographic provinces to the ichthyogeographic regions of Oregon. Copeia 1987:423-432.

Hull, D., J. Ellinwood, C. Toole, and T. Flannigan. 1989. Humboldt Fish Action Council Final Report covering actions at: Freshwater Creek salmon trapping and spawning station, Cochran Creek salmon rearing ponds, and seawater salmon rearing facility. Report submitted to Harvey Reading, Calif. Dep. Fish and Game, Project No. C-1538, 26 p. (Available from Humboldt Fish Action Council, P.O. Box 154, Eureka, CA 95501.)

Hydrosphere Data Products, Inc. 1993. Hydrodata Regional CD-ROMs: U.S. Geological Survey daily values, Vols. West 1, West 2. (Available from Hydrosphere Data Products Inc., 1002 Walnut, Suite 200, Boulder, CO 80302.)

Irvine, J. R., and B. R. Ward. 1989. Patterns of timing and size of wild coho salmon (*Oncorhynchus kisutch*) smolts migrating from the Keogh River Watershed on northern Vancouver Island. Can. J. Fish. Aquat. Sci. 46:1086-1094.

Ishida, Y., S. Ito, M. Kaeriyama, S. McKinnell, and K. Nagasawa. 1993. Recent changes in age and size of chum salmon (*Oncorhynchus keta*) in the North Pacific Ocean and possible causes. Can. J. Fish. Aquat. Sci. 50: 290-295.

Iwamoto, R. N., B. A. Alexander, and W. K. Hershberger. 1984. Genotypic and environmental effects on the incidence of sexual precocity in coho salmon (*Oncorhynchus kisutch*). Aquaculture 43(1984):105-121.

Jacobs, S. E. 1988a. Oregon coastal salmon spawning surveys, 1985. Oreg. Dep. Fish Wildl., Fish Div., 56 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Jacobs, S. E. 1988b. Straying in Oregon by adult salmon of hatchery origin, 1985. Oreg. Dep. Fish Wildl. Info Rep. 88-5, 53 p.

Jacobs, S. E. 1989. Oregon coastal salmon spawning surveys, 1986-1989. Oreg. Dep. Fish Wildl., Fish Div., Prog. Reps. 1987-1989, 115 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207. Same for other reports in this series.)

Jacobs, S. E., and C. X. Cooney. 1990. Improvement of methods used to estimate the spawning escapement of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1990, 17 p.

Jacobs, S. E., and C. X. Cooney. 1991. Improvement of methods used to estimate the spawning of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1991, 24 p.

Jacobs, S. E., and C. X. Cooney. 1992. Improvement of methods used to estimate the spawning escapement of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1992, 23 p.

Jacobs, S. E., and C. X. Cooney. 1993. Improvement of methods used to estimate the spawning escapement of Oregon coastal natural coho salmon. Oreg. Dep. Fish Wildl., Fish Div. Prog. Rep. 1993, 28 p.

Jensen, P. T. 1971. Fishery contribution and escapement of hatchery-produced silver salmon in California. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 71-10, 11 p.

Jessop, B. M. 1993. Fecundity of anadromous alewives and blueback herring in New Brunswick and Nova Scotia. Trans. Am. Fish. Soc. 122:85-98.

Johansen, R. R. 1975. San Lorenzo River (Santa Cruz County) winter steelhead and salmon fishery, 1971-72 and 1972-73 seasons. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 75-6, 14 p.

Johnson, M. L. 1964. San Lorenzo River system, Santa Cruz County. Calif. Dep. Fish Game, Region 3 file report (Unpubl. rep.), 8 p. (Available from California Department of Fish and Game, 1416 Ninth, Sacramento, CA 95814.)

Johnson, O. W., T. A. Flagg, D. J. Maynard, G. B. Milner, and F. W. Waknitz. 1991. Status review for lower Columbia River coho salmon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-202, 94 p.

Johnson, S. L. 1988. The effects of the 1983 El Niño on Oregon's coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon. Fish. Res. 6:105-123.

Johnson, S. L., M. F. Solazzi, and J. D. Rogers. 1993. Development and evaluation of techniques to rehabilitate Oregon's wild salmonids. Oreg. Dep. Fish Wildl. Fish Research Proj. F-125-R-5, Annual Rep, 12 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Johnson, T., and R. Cooper. 1993. Snow Creek anadromous fish research, July 1, 1990- June 30, 1992. Wash. Dep. Fish. Annual Performance Rep. 93-15, 78 p.

Jonsson, B., and J. H. L'Abée-Lund. 1993. Latitudinal clines in life-history variable of anadromous brown trout in Europe. J. Fish Biol. 43(Suppl. A):1-16.

Kelley, D. and Associates and Entrix, Inc. 1992. Habitat recommendations for Lagunitas Creek, California. Report prepared for the Marin Municipal Water District, Corte Madera, California. (Available from Entrix, Inc., 590 Ygnacio Valley Rd., Suite 200, Walnut Creek, CA 94596.)

Kenworthy, B. R. 1986a. Progress report of national fish hatchery programming and evaluation activities Puget Sound and Coastal Washington, 1984-85. U.S. Fish Wildl. Serv., 40 p. (Available U.S. Fish and Wildlife Service, Western Washington Fisheries Assistance Office, Olympia, WA, 98501.)

Kenworthy, B. R. 1986b. Progress report of national fish hatchery programming and evaluation activities Puget Sound and Coastal Washington, 1985-86. U.S. Fish Wildl. Serv., 26 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fisheries Assistance Office, Olympia, WA, 98501.)

King, D., and R. Young. 1986a. An evaluation of three groundwater-fed side channels of the East Fork Satsop River, spring 1984 outmigrants. Wash. Dep. Fish. Tech. Rep. 89, 47 p.

King, D., and R. Young. 1986b. An evaluation of four groundwater-fed side channels of the East Fork Satsop River, spring 1985 outmigrants. Wash. Dep. Fish. Tech. Rep. 90, 73 p.

Kirby, G., K. Nelson, G. Lucchetti, and K. Rawson. 1988. Stillaguamish wild coho indicator stock study, Annual Report: FY88. Tulalip Fish. Dep., 12 p. plus figures. (Available from Tulalip Fisheries Department, 3901 Totem Beach Rd., Marysville, WA 98270.)

Kirby, G., G. Lucchetti, and V. Tsoodle. 1990. Wild coho salmon indicator stock study for the Stillaguamish River system, 1989 Annual Report. Tulalip Fish. Dep., 12 p. plus figures. (Available from Tulalip Fisheries Department, 3901 Totem Beach Rd., Marysville, WA 98270.)

Kirby, G., G. Lucchetti, and V. Tsoodle. 1991. Wild coho salmon indicator stock study for the Stillaguamish River system, 1990 Annual Report. Tulalip Fish. Dep., 13 p. plus figures. (Available from Tulalip Fisheries Department, 3901 Totem Beach Rd., Marysville, WA 98270.)

Kisanuki, T., J. Polos, and D. Willis. 1991. Annual Report, Klamath River fisheries assessment program, 1989. U.S. Fish Wildl. Serv. Coast. Calif. Fish. Resource Off., Arcata, California, Rep. AFF1-FRO-91-14. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Knight, N. J. 1979. Factors affecting the smolt yield of coho salmon (*Oncorhynchus kisutch*) in three Oregon streams. M.S. Thesis, Oregon State Univ., 105 p.

Koski, K. V. 1965. The survival of coho salmon. M.S. Thesis, Oregon State Univ., 84 p.

Kostow, K., and 13 coauthors. 1994. The natural production program, 1994 biennial report on the status of wild fish in Oregon and the implementation of fish conservation policies. Oreg. Dep. Fish Wildl., Portland, 165 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

L'Abée-Lund, J. H. 1991. Variation within and between rivers in adult size and sea age at maturity of anadromous brown trout, *Salmo trutta*. Can. J. Fish. Aquat. Sci. 48:1015-1021.

Labelle, M. 1990. A comparative study of coho salmon populations of SE Vancouver Island, British Columbia: Juvenile outmigration, coded-wire tagging and recovery, escapement enumeration, and stock composition at Black Creek, Trent River and French Creek, 1984-1988. Can. Tech. Rep. Fish. Aquat. Sci. 1722, 123 p.

Labelle, M. 1992. Straying patterns of coho salmon (*Oncorhynchus kisutch*) stocks from southeast Vancouver Island, British Columbia. Can. J. Fish. Aquat. Sci. 49:1843-1855.

Landry, M. R., J. R. Postel, W. K. Peterson, and J. Newman. 1989. Broad-scale distributional patterns of hydrographic variables on the Washington/Oregon shelf. *In* M. R. Landry and B. M. Hickey (editors), Coastal oceanography of Washington and Oregon, p. 1-40. Elsevier, New York.

Laufle, J. C., G. B Pauley, and M. F. Shepard. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): coho salmon. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.48), 18 p.

Lawson, P. W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. Fisheries 18(8):6-10.

Leidy, R. A., and G. R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River Basin, northwestern California. U.S. Fish and Wildlife Service, Sacramento, California, 38 p. (Available U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento Field Office, 2800 Cottage Way, Rm. 1803, Sacramento, CA 95825.)

LeMier, E. 1955. Marked silver salmon returns (1959 brood) at the Toutle River Hatchery and in the fishery. Wash. Dep. Fish. Columbia River Prog. Rep., p. 87-93. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Lenzi, J. 1983. Coho smolt enumeration on several small Puget Sound streams, 1978-1981. Wash. Dep. Fish. Prog. Rep. 199, 91 p.

Lenzi, J. 1985. Coho smolt enumeration on several small Puget Sound streams, 1982-1984. Wash. Dep. Fish. Prog. Rep. 232, 61 p.

Lenzi, J. 1987. Coho smolt enumeration on several small Puget Sound streams, 1985-1987. Wash. Dep. Fish. Prog. Rep. 262, 59 p.

Leonard, W. P., H. A. Brown, L. L. Jones, K. R. McAllister, and R. M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, 168 p.

Lestelle, L. C., M. L. Rowse, and C. Weller. 1993. Evaluation of natural stock improvement measures for Hood Canal coho salmon, FY 92 Rep. Point No Point Treaty Council Tech. Rep. TR 93-1, 173 p. plus appendices. (Available from Point No Point Treaty Council, 7999 NE Salish Lane, Kingston, WA 98346.)

Lestelle, L. C., and C. Weller. 1994. Summary report: Hoko and Skokomish River coho salmon indicator stock studies 1986-1989. Point No Point Treaty Council Tech. Rep. TR 94-1, 13 p. plus appendices. (Available from Point No Point Treaty Council, 7999 NE Salish Lane, Kingston, WA 98346.)

Lichatowich, J. A. 1989. Habitat alteration and changes in abundance of coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon in Oregon's coastal streams. *In* C. D. Levings, L. B. Holtby, and M. A. Henderson (editors), Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks, May 6-8, 1987, Nanaimo, B.C., p. 92-99. Can. Spec. Publ. Fish. Aquat. Sci. 105.

Lichatowich, J. A., and J. W. Nicholas. In press. Oregon's first century of hatchery intervention in salmon production: Evolution of the hatchery program, legacy of a utilitarian philosophy, and management recommendations. *In* Proceedings of the International Symposium on Biological Interactions of Enhanced and Wild Salmonids, 17-20 June, 1991, Nanaimo, B.C. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Linth, J., and D. Hooper. 1984. Data report of Grays Harbor juvenile salmon seining program, 1981-1984. Wash. Dep. Fish. Supplemental Prog. Rep., 44 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Lintz, J. D., and T. T. Kisanuki. 1991. Progress report for investigations on the lower tributaries to the Klamath River, FY 1991. U.S. Fish Wildl. Serv. Coast. Calif. Fish. Resource Off., Arcata, California, 41 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Lintz, J. D., and S. M. Noble. 1990. Progress report for investigations on the lower tributaries to the Klamath River, FY 1990. U.S. Fish Wildl. Serv. Coast. Calif. Fish. Resource Off., Arcata, California, 35 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Lister, D. B., L. M. Thorson, and I. Wallace. 1981. Chinook and coho salmon escapements and coded-wire tag returns to the Cowichan-Koksilah river system, 1976-1979. Can. Manuscript Rep. Fish. Aquat. Sci. 1608, 168 p.

Loeffel, R. E., and W. O. Forster. 1970. Determination of movement and identity of stocks of coho salmon in the ocean using the radionuclide Zinc-65. Res. Rep. Fish Comm. Oregon, 2(1):1-13.

Loeffel, R. E., and H. O. Wendler. 1968. Review of the Pacific coast chinook and coho salmon resources with special emphasis on the troll fishery. Prepared by the U.S. working group of the Informal Committee on Chinook and Coho, 107 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Lyons, J. 1989. Correspondence between the distribution of fish assemblages in Wisconsin streams and Omernik's ecoregions. Am. Midl. Nat. 122:163-182.

Maahs, M., and J. Gilleard. 1994. Anadromous salmonid resources of Mendocino coastal and inland rivers 1990-91 through 1991-92: An evaluation of rehabilitation efforts based on carcass recovery and spawning activity. Report to Calif. Dep. Fish Game, Fish. Div., Fish. Restor. Prog., Contract F-9364, 66 p. (Available from California Department of Fish and Game, 1416 Ninth, Sacramento, CA 95814.)

Marr, J. C. 1943. Age, length, and weight studies of three species of Columbia River salmon *(Oncorhynchus keta, O. gorbuscha,* and *O. kisutch)*. Stanford Ichthyol. Bull. 2(6):157-197.

Marshall, L. E. 1970. Annual Report, Iron Gate salmon and steelhead hatchery, fifth year of operation, 1969-70. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 70-17, 22 p.

Martenson, G. A., and P. H. Dygert. 1989. Skokomish river coho indicator stock study, 1989. Point No Point Treaty Council Tech. Rep. TR 88-4, 15 p. (Available from Point No Point Treaty Council, 7999 NE Salish Lane, Kingston, WA 98346.)

Mason, J. C. 1975. Seaward movement of juvenile fishes, including lunar periodicity in the movement of coho salmon (*Oncorhynchus kisutch*) fry. J. Fish. Res. Board Can. 32:2542-2547.

May, K. 1954. A biological survey of Redwood Creek, Muir Woods National Monument, Mill Valley, California. (Available from U.S. Dep. Interior, Golden Gate National Recreation Area, Fort Cronkhite, Bldg. 1056, Sausalito, CA 94965.)

McCormick, R. B. 1958. Observations on the sport fishery for salmon in tidewater of the Klamath River, 1954. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 58-25.

McGie, A. M. 1970. Research and management studies of Oregon coastal salmon. Annual Report, July 1, 1969, to June 30, 1970. Fish. Comm. Oregon, Div. Manage. Res., Coastal Rivers Invest., 107 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1971. Salmon research on coastal streams and reservoirs. Annual Report July 1, 1970 to June 30, 1971. Fish. Comm. Oregon, Div. Manage. Res., Coastal Rivers Invest., 55 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1972. Salmon research on coastal streams and reservoirs. Annual Report, July 1, 1971 to June 30, 1972. Fish. Comm. Oregon, Div. Manage. Res., Coastal Rivers Invest., 41 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1973. Salmon research on coastal streams and reservoirs. Annual Report July 1, 1972 to June 30, 1973. Fish. Comm. Oregon, Div. Manage. Res., Coastal Rivers Invest., 31 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1975. Research on anadromous fish in coastal watersheds of Oregon. Annual Report, July 1, 1974 to June 30, 1975. Fish. Comm. Oregon, Div. Manage. Res., Coastal Rivers Invest., 19 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1977. Anadromous fish research in Oregon's coastal watersheds. Oreg. Fish Commission Federal Aid Progress Rep., Fisheries. Fish. Comm. Oregon, Div. Manage. Res., Coastal Rivers Invest., 55 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1983. Oregon coastal salmon spawning surveys and straying of private hatchery coho salmon from Yaquina and Coos Bays, 1982. Oreg. Dep. Fish Wildl., Res. Develop. Sec., 56 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McGie, A. M. 1984. Oregon coastal salmon spawning surveys and straying of private hatchery coho salmon from Yaquina and Coos Bays, 1983. Oreg. Dep. Fish Wildl., Res. Develop. Sec., 57 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

McLaughlin, S. P. 1989. Natural floristic areas of the western United States. J. Biogeogr. 16:239-248.

McMahon, T. E., and L. B. Holtby. 1992. Behavior, habitat use, and movements of coho salmon (*Oncorhynchus kisutch*) smolts during seaward migration. Can. J. Fish. Aquat. Sci. 49:1478-1485.

McPhail, J. D., and C. C. Lindsey. 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north to the Sitkine). *In* C. H. Hocutt and E. O. Wiley (editors), Zoogeography of North American freshwater fishes, p. 615-637. Wiley Interscience Publications, New York.

Meehan, W. R., and D. B. Siniff. 1962. A study of the downstream migrations of anadromous fishes in the Taku River, Alaska. Trans. Am. Fish. Soc. 91(4):399-407.

Miller, D. R., J. G. Williams, and C. W. Sims. 1983. Distribution, abundance and growth of juvenile salmonids off the coast of Oregon and Washington, summer 1980. Fish. Res., 2:1-17.

Miller, W. H. 1990. Analysis of salmon and steelhead supplementation. Report to Dworshak Fish. Assist. Off., U.S. Fish Wildl. Serv. Tech. Rep. 1990, Contract DE-A179-88BP92663, Proj. 88-100, 202 p. plus appendices. (Available from Bonneville Power Administration, Division of Fish and Wildlife-PJ, P. O. Box 3621, Portland, OR 97208.)

Milligan, D. R. 1986. Annual Report, Noyo River egg collecting station, 1984-85. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 86-04, 5 p.

Milligan, D. R. 1987. Annual Report, Noyo River egg collecting station, 1985-86. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 87-17, 4 p.

Milne, D. J. 1957. Recent British Columbia spring and coho salmon tagging experiments, and a comparison with those conducted from 1925 to 1930. Can. Fish. Res. Board Bull. 113:1-56.

Milner, G. B. 1993. Isozyme variation of coho salmon (*Oncorhynchus kisutch*) and its potential to estimate stock compositions of mixed stock fisheries. *In* L. Berg and P. W. Delaney (editors), Proceedings of the Coho Workshop, Nanaimo, B. C., May 26-28, 1992, p. 182-192. (Available from Canadian Department of Fisheries and Oceans, Habitat Management Sector, Policy and Information Unit, 327-555 W. Hastings St., Vancouver, B.C. V6B 5G3.)

Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: Description and relationships to intracontinental tectonism. *In* C. H. Hocutt and E. O. Wiley (editors), Zoogeography of North American freshwater fishes, p. 519-613. Wiley Interscience Publications, New York.

Monaco, M. E., T. A. Lowery, and R. L. Emmett. 1992. Assemblages of U.S. West Coast estuaries based on the distribution of fishes. J. Biogeogr. 19:251-267.

Morgan, A. R., and F. C. Cleaver. 1954. The 1951 Alsea River silver salmon tagging program. Fish Comm. Oreg., Contribution 21, 30 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Morgan, A. R., and K. A. Henry. 1959. The 1955-1956 silver salmon run into the Tenmile Lakes system. Fish. Comm. Oregon, Res. Briefs 7(1):57-77.

Moring, J. R., and R. L. Lantz. 1975. The Alsea watershed study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I- Biological studies. Oreg. Dep. Fish Wildl., Fish. Res. Rep. 9, 66 p.

Mosley, R. A. 1993. North coastal wild coho broodstock collection project, 1986-1989. Wash. Dep. Fish. Prog. Rep. 306, 54 p.

Moyle, P. B. 1976. Inland fishes of California. Univ. California Press, Berkeley, 405 p.

Mullan, J. W. 1984. Overview of artificial and natural propagation of coho salmon (*Oncorhynchus kisutch*) on the mid-Columbia River. U.S. Fish Wildl. Serv. Rep. FRI/FAO 84-4.

Mullen, R. E. 1981. Oregon's commercial harvest of coho salmon, *Oncorhynchus kisutch* (Walbaum), 1982-1960. Oreg. Dep. Fish Wildl. Info. Rep. 81-3, 24 p.

Murphy, G. I., and L. Shapovalov. 1952. A preliminary analysis of northern California salmon and steelhead runs. Calif. Fish Game 37:497-507.

Murray, C. B., T. D. Beacham, and J. D. McPhail. 1990. Influence of parental stock and incubation on the early development of coho salmon (*Oncorhynchus kisutch*) in British Columbia. Can. J. Zool. 68:347-358.

Murray, R. 1959. The Lewiston fish trapping facilities: First year of operation, 1958-59. Calif. Fish and Game, Region 1, Inland Fish. Branch Admin. Rep. 59-13, 20 p. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814. Same for other reports in this series.)

Murray, R. 1961. The Lewiston fish trapping facilities: Second year of operation, 1959-60. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 61-16.

Murray, R. 1962a. Annual Report, Trinity River salmon and steelhead hatchery, third year of operation, 1960-61. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 62-2.

Murray, R. 1962b. Annual Report, Trinity River salmon and steelhead hatchery, fourth year of operation, 1961-62. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 62-11.

Murray, R. 1964. Annual Report, Trinity River salmon and steelhead hatchery, fifth year of operation, 1962-63. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 64-1.

Murray, R. 1965. Annual Report, Trinity River salmon and steelhead hatchery, sixth year of operation, 1963-64. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 65-5.

Murray, R. 1966a. Annual Report, Trinity River salmon and steelhead hatchery, seventh year of operation, 1964-65. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 66-1.

Murray, R. 1966b. Annual Report, Trinity River salmon and steelhead hatchery, eighth year of operation, 1965-66. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 66-13.

Murray, R. 1967. Annual Report, Trinity River salmon and steelhead hatchery, ninth year of operation, 1966-67. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 67-11.

Murray, R. 1968. Annual Report, Trinity River salmon and steelhead hatchery, tenth year of operation, 1967-68. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 68-9.

Murtagh, T., R. Rohrer, M. Gray, E. Olsen, T. Rien, J. Massey. 1992. Clackamas subbasin fish management plan. Oreg. Dep. Fish Wildl., 173 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

National Marine Fisheries Service (NMFS). 1991a. Endangered and threatened species; lower Columbia River coho salmon. Federal Register [Docket 910648-1148, 27 June 1991] 56(124):29553-29554.

National Marine Fisheries Service (NMFS). 1991b. Notice of policy: Policy on applying the definition of species under the Endangered Species Act to Pacific salmon. Federal Register [Docket 910248-1255, 20 November 1991] 56(224):58612-58618.

National Marine Fisheries Service (NMFS). 1993. Listing endangered and threatened species and designating critical habitat: Petition to list five stocks of Oregon coho salmon. Federal Register [Docket 93-26365, 27 October 1993] 58(206):57770-57771.

National Marine Fisheries Service (NMFS). 1994. Endangered and threatened species; coho salmon in Scott and Waddell Creeks, CA. Federal Register [Docket 940408-4108, 26 April 1994] 59(80):21744-21746.

Natural Resources Consultants, Inc (NRC). 1995. Database of artificially propagated anadromous salmon (database). Prepared for NMFS Conservation Biology Program, Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center, Contract No. 50ABNF400128. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583-590.

Nelson, J. 1993. South central coastal stream coho salmon and steelhead trout population inventory and habitat assessment. Calif. Dep. Fish Game, Annual Performance Rep. F-51-R-5. 52 p. (Available from California Department of Fish and Game, 1416 Ninth, Sacramento, CA 95814.)

Nelson, J. 1994. Coho salmon and steelhead habitat and population surveys of Scott Creek, Santa Cruz, California, 1993. Calif. Dep. Fish Game, Annual Report, 52 p. (Available from California Department of Fish and Game, 1416 Ninth, Sacramento, CA 95814.)

Nelson, K. 1992. Wild coho salmon indicator stock study for the Stillaguamish River system. 1991 Annual Report. Tulalip Fish. Dep., 15 p. (Available from Tulalip Fisheries Department, 3901 Totem Beach Rd., Marysville, WA 98270.)

Nicholas, J. W., and D. G. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins: Description of life histories and assessment of recent trends in run strengths. Oreg. Dep. Fish Wildl., Info. Rep. 88-1, p. 20-21.

Nicholas, J. W., L. Van Dyke, and R. C. Buckman. 1982. Straying by hatchery-reared coho salmon released in Yaquina Bay, Oregon. Oreg. Dep. Fish Wildl., Info. Rep. 82-6, 22 p.

Nickelson, T. E., J. W. Nicholas, A. M. McGie, R. B. Lindsay, D. L. Bottom, R. J. Kaiser, and S. E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Oreg. Dep. Fish. Wildl., Res. Develop. Sect. and Ocean Salmon Manage., 83 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Nickelson, T. E., M. F. Solazzi, and S. L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 43:2443-2449.

Nielsen, J. L . 1994. Invasive cohorts: Impacts of hatchery-reared coho salmon on the trophic, developmental, and genetic ecology of wild stocks. *In* D. J. Stouder, K. L. Fresh, R. J. Feller (editors), Theory and application in fish feeding ecology, Vol. 18 of The Belle W. Baruch Library in Marine Science, p. 361-385. Univ. S. Carolina Press, Columbia.

Niska, E. L., and R. A. Willis. 1963. A study of the early life history of stream and hatchery reared coho salmon in Cedar and Big Creeks and north fork of the Klaskanine River. Fish. Comm. Oregon, Res. Div., Clackamas, Oregon, 64 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Noble, S. M., and J. D. Lintz. 1989. Progress report for investigations on the lower tributaries to the Klamath River, FY 1989. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California, 35 p. (Available from U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Northcote, T. C., and D. Y. Atagi. In press. Pacific salmon abundance trends in the Fraser River watershed compared with other British Columbia systems. *In* D. J. Stouder, P. A. Bisson, and R. J. Naiman (editors), Pacific salmon and their ecosystems, status and future options. Chapman and Hall, Inc., New York.

Olin, P. G. 1984. Genetic variability in hatchery and wild populations of coho salmon, *Oncorhynchus kisutch*, in Oregon. M.S. Thesis, Univ. California Davis, 73 p.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geographers 77(1):118-125.

Omernik, J. M., and A. L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. Environ. Protec. Agen. Rep. EPA/600/3-86/033, 39 p. (Available from U.S. Environmental Protection Agency, Environmental Reseach Laboratory, 200 SW 35th St., Corvallis, OR 97333.)

Oregon Department of Fish and Wildlife (ODFW). 1982. Comprehensive plan for production and management of Oregon's anadromous salmon and trout, Part II. Coho salmon plan. Oreg. Dep. Fish Wildl. Fish Div. Anad. Fish Sec. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Oregon Department of Fish and Wildlife (ODFW). 1989. Effects of Lost Creek Dam on coho salmon in the Rogue River. Phase II completion report. Report to the U.S. Army Corps of Engineers, Contract DACW57-77-C-0033, 58 p. (Released as U.S. Army Corps of Engineers and Oregon Department of Fish and Wildlife. 1991. Rogue Basin Fisheries Evaluation, Effects of Lost Creek Dam on coho salmon in the Rogue River, Phase II completion report.) (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Oregon Department of Fish and Wildlife (ODFW). 1991. Lower Columbia River coho salmon, evaluation of stock status, causes of decline, and critical habitat-- Part II. Report to ESA Administrative Record for lower Columbia River salmon, February 1991. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Oregon Department of Fish and Wildlife (ODFW). 1992. Oregon salmon and steelhead catch data, 1979-91. Unpubl. report, Oreg. Dep. Fish Wildl. Fish Div., 22 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Oregon Department of Fish and Wildlife (ODFW). 1993a. Coastal coho liberations, 1980-1993. Propagation program release records organized by basin and river system. Unpubl. data, Oreg. Dep. Fish Wildl., Fish Division, 26 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Oregon Department of Fish and Wildlife (ODFW). 1993b. Oregon salmon and steelhead catch data, 1980-92. Unpubl. report, Oreg. Dep. Fish Wildl., Fish Division, 21 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Oregon Department of Fish and Wildlife (ODFW). 1995. Oregon coho salmon biological status assessment and staff conclusion for listing under the Oregon Endangered Species Act. (Commission decision draft.) Oreg. Dep. Fish Wildl., Portland, February 22, 1995, 59 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fisheries (WDF). 1993. Status report: Columbia River fish runs and fisheries, 1938-92. ODFW, Portland and WDF, Olympia, 189 p. (Available from Oregon Department of Fish and Wildlife, P. O. Box 59, Portland, OR 97207.)

Oregon Trout, Oregon Natural Resources Council, Northwest Environmental Defense Center, Idaho Chapter American Fisheries Society, and Oregon Chapter American Fisheries Society. 1990. Petitions for a rule to list the lower Columbia River coho under the Endangered Species Act and to designate critical habitat. Petition to U.S. Secretary of Commerce, Washington D.C., May 1990, 9 p. (Available from Oregon Trout, 5331 SW Macadam Ave., No. 228, Portland, OR 97201.)

Oregon Trout, Portland Audubon Society, and Siskiyou Regional Education Project. 1993. Petitions for listing species of Pacific coast *Oncorhynchus kisutch* pursuant to the Endangered Species Act of 1973 as amended. Petition to U.S. Dep. Commer., Natl. Mar. Fish. Serv., Northwest Region, Seattle, Washington, July 1993, 17 p. plus appendices. (Available from Oregon Trout, 5331 SW Macadam Ave., No. 228, Portland, OR 97201.)

Pacific Fishery Management Council (PFMC). 1990. Scientific and Statistical Committee (SSC) review of Washington coastal and Puget Sound coho salmon escapement estimation methodologies: Summary and recommendations. SSC supplemental report B.5-2 from the PFMC meeting March 1990. (Available from Pacific Fishery Management Council, 2000 SW First Ave., Suite 420, Portland, OR 97201-5344.)

Pacific Fishery Management Council (PFMC). 1993a. Final Amendment 11 to the fishery management plan for commercial and recreation salmon fisheries off the coasts of Washington, Oregon, and California commencing in 1978. PFMC, Portland, 74 p. (Available from Pacific Fishery Management Council, 2000 SW First Ave., Suite 420, Portland, OR 97201-5344.)

Pacific Fishery Management Council (PFMC). 1993b. Historical ocean salmon fishery data for Washington, Oregon and California. PFMC Salmon Technical Team, Portland, 401 p. (Available from Pacific Fishery Management Council, 2000 SW First Ave., Suite 420, Portland, OR 97201-5344.)

Pacific Fishery Management Council (PFMC). 1993c. Preseason report I: Stock abundance analysis for 1993 ocean salmon fisheries. PFMC, Portland. (Available from Pacific Fishery Management Council, 2000 SW First Ave., Suite 420, Portland, OR 97201-5344.)

Pacific Fishery Management Council (PFMC). 1994. Review of 1993 ocean salmon fisheries. PFMC, Portland, February 1994, 124 p. plus appendices. (Available from Pacific Fishery Management Council, 2000 SW First Ave., Suite 420, Portland, OR 97201-5344.)

Pacific Fishery Management Council (PFMC). 1995. Review of 1994 ocean salmon fisheries. PFMC, Portland, 109 p. plus appendices. (Available from Pacific Fishery Management Council, 2000 SW First Ave., Suite 420, Portland, OR 97201-5344.)

Pacific Rivers Council and 22 co-authors. 1993. Petition for a rule to list, for designation of critical habitat, and for a status review of coho salmon throughout its range under the Endangered Species Act. Petition to U.S. Dep. Commer., Natl. Marine Fish. Serv., Northwest Region, Seattle, Washington, October 1993, 33 p. (Available from Pacific Rivers Council, P.O. Box 309, Eugene, OR 97440.)

Pacific States Marine Fisheries Commission (PSMFC). 1994. Regional Mark Information System (RMIS) Coded-wire tag on-line database. (Available from Pacific States Marine Fisheries Commission, 45 SE 82nd Dr., Suite 100, Gladstone, OR 97027-2522.)

Pearce, T. A., J. H. Meyer, and R. S. Boomer. 1982. Distribution and food habits of juvenile salmon in the Nisqually Estuary, Washington, 1979-1980. U.S. Fish Wildl. Serv., Fish. Assist. Off., Olympia, WA, 77 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmount Lane, Bldg. A, Olympia, WA 98502-5751.)

Pearcy, W. G. 1992. Ocean ecology of North Pacific salmonids. Univ. Washington Press, Seattle, 179 p.

Pearcy, W. G., and J. P. Fisher. 1988. Migrations of coho salmon, *Oncorhynchus kisutch,* during their first summer in the ocean. Fish. Bull., U.S. 86(2):173-186.

Pettit, R. 1993. Lower Columbia River coho enhancement project evaluation, 1985-1987. Wash. Dep. Fish., Planning, Res., Harvest Manage. Prog. Columbia River Lab. Prog. Rep 93-22, 10 p. plus figures. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Phinney, L. A., and P. Bucknell. 1975. A catalog of Washington streams and salmon utilization--Volume 2, Coastal region. Wash. Dep. Fish., Olympia. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Poe, S. D. 1984. Annual Report, Noyo River egg collecting station, 1983-84. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 84-06, 5 p.

Poe, S. D. 1988. Annual Report, Noyo River egg collecting station, 1986-87. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 88-2, 7 p.

Pratschner, G. A. 1978. The relative resistance of six transferrin phenotypes of coho salmon (*Oncorhynchus kisutch*) to cytophagosis, furunculosis, and vibriosis. M.S. Thesis, Univ. Washington, Seattle, 71 p.

Pritchard, A. L. 1940. Studies on the age of the coho salmon (*Oncorhynchus kisutch*) and the spring salmon (*Oncorhynchus tschawytscha*) in British Columbia. Trans. R. Soc. Can., Serv. 3, 34(V):99-120.

Puckett, L. K. 1976. Observations on the downstream migrations of anadromous fishes within the Eel River system. Calif. Dep. Fish Game, Memo. Rep., 35 p. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814.)

Quinn, T. P., and G. M. Tolson. 1986. Evidence of chemically mediated population recognition in coho salmon (*Oncorhynchus kisutch*). Can. J. Zool. 64:84-87.

Quinn, W. W., and J. T. Allen. 1969a. Downstream migrant fish trapping operations, 1964, Nicasio Creek, Marin County. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 69-2, 15 p.

Quinn, W. W., and J. T. Allen. 1969b. Downstream migrant fish trapping operations, 1965, Nicasio Creek, Marin County. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 69-3, 14 p.

Ramsden, G. R. 1993. Annual Report, Trinity River salmon and steelhead hatchery, 1991-92. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 93-3, 13 p.

Ratliff, D. E. 1983. *Ceratomyxa shasta*: Longevity, distribution, timing, and abundance of the infective stage in central Oregon. Can. J. Fish. Aquat. Sci. 40:1622-1632.

Redwood National Park. 1994. Summary of reports relating to coho salmon (*Oncorhynchus kisutch*) in the Redwood Creek Basin. 7 p. plus attachments. (Available from Environmental Technical Services Division, Natl. Mar. Fish. Serv., 525 NE Oregon St., Portland, OR 97232.)

Reimers, P. E. 1971. The movement of yearling coho salmon through Sixes River Estuary. Fish Comm. Oregon, Coastal Rivers Investigation Info. Rep. 71-2, 15 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Reimers, P., R. Bender, J. Muck, T. Rumreich, R. Smith, and M. Manion. 1993. Fish management review, Southwest Region, Tenmile, Coos, Coquille District, February 9-10, 1993, p. 1-6. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Reisenbichler, R. R., and S. R. Phelps. 1987. Genetic variation in chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon from the north coast of Washington. Fish. Bull., U.S. 85(4):681-701.

Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. *In* R. C. Simon and P. A. Larkin (editors), The stock concept in Pacific salmon, p. 19-160. H. R. MacMillan Lectures in Fisheries, Univ. British Columbia, Vancouver.

Ricker, W. E. 1981. Changes in average size and average age of Pacific salmon. Can. J. Fish. Aquat. Sci. 38:1636-1656.

Riddell, B. E., and W. C. Leggett. 1981. Evidence of and adaptive basis for geographic variation in body morphology and time of downstream migration of juvenile Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 38:308-320.

Riggs, L. A. 1990. Principles for genetic conservation and production quality. Report to Northwest Power Planning Council, Portland, OR. (Available from Northwest Power Planning Council, 851 SW Sixth, Suite 1100, Portland, OR 97204-1348.)

Riley, J. O., Jr. 1967a. Annual Report, Iron Gate salmon and steelhead hatchery, 1965-66. California Department of Fish and Game, Region 1, Inland Fish. Branch Admin. Rep. 67-18.

Riley, J. O., Jr. 1967b. Annual Report, Iron Gate salmon and steelhead hatchery, 1966-67. Calif. Dep. Fish Game, Region 1, Inland Fish. Admin. Rep. 67-15.

Riley, J. O., Jr. 1968. Annual Report, Iron Gate salmon and steelhead hatchery, 1967-68. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 68-10.

Riley, J. O., Jr. 1970. Annual Report, Iron Gate salmon and steelhead hatchery, 1968-69. Calif. Dep. Fish Game, Region 1, Inland Fish. Branch Admin. Rep. 70-2.

Rodgers, J. D., R. D. Ewing, and J. D. Hall. 1987. Physiological changes during seaward migration of wild juvenile coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 44(2):452-457.

Rodgers, J. D., S. L. Johnson, T. E. Nickelson, and M. F. Solazzi. 1993. The seasonal use of natural and constructed habitat by juvenile coho salmon (*Oncorhynchus kisutch*) and preliminary results from two habitat improvement projects on smolt production in Oregon coastal streams. *In* L. Berg and P. W. Delaney (editors), Proceedings of the Coho Workshop, Nanaimo, B. C., May 26-28, 1992, p. 344-351. (Available from Department of Fisheries and Oceans, Habitat Management Sector, Policy and Information Unit, 327-555 West Hastings Street, Vancouver, BC V6B 5G3.)

Rogers, D. W. 1973. King salmon (*Oncorhynchus tshawytscha*) and silver salmon (*Oncorhynchus kisutch*) spawning escapement and spawning habitat in the upper Trinity River, 1970. Calif. Dep. Fish Game, Region 1, Anadromous Fish. Branch Admin. Rep. 73-10, 14 p.

Rounsefell, G. A. 1957. Fecundity of North American salmonidae. Fish Bull., U.S. 122:451-468.

Rueth, J. C., T. T. Kisanuki, and J. C. Polos. 1992. Annual Report, Klamath River fisheries assessment program, FY 1990-1991. U.S. Fish Wildl. Serv. Coast. Calif. Fish. Resource Off., Arcata, California, Rep. AFF1-FRO-92-05, p. 63-65.

Salo, E., and W. H. Bayliff. 1958. Artificial and natural production of silver salmon, *Oncorhynchus kisutch*, at Minter Creek, Washington. Wash. Dep. Fish. Res. Bull. 4, 76 p.

Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). *In* C. Groot and L. Margolis (editors), Pacific salmon life histories, p. 396-445. Univ. British Columbia Press, Vancouver.

Sanders, J. E., J. L. Fryer, and R. W. Gould. 1970. Occurrence of the myxosporidian parasite *Ceratomyxa shasta*, in salmonid fish from the Columbia River basin and Oregon coastal streams. *In* S. F. Snieszko (editor), A symposium on disease of fishes and shellfishes, p. 133-141. Am. Fish. Soc. Spec. Publ. 5.

Sanders, S. W. 1980. Annual Report, Noyo River egg collecting station, 1978-79. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 80-8, 3 p.

Sanders, S. W. 1982a. Annual Report, Hollow Tree Creek egg taking station, 1979-80. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-7, 4 p.

Sanders, S. W. 1982b. Annual Report, Hollow Tree Creek egg taking station, 1980-81. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-15, 5 p.

Sanders, S. W. 1982c. Annual Report, Hollow Tree Creek egg taking station, 1981-82. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-38, 4 p.

Sanders, S. W. 1982d. Annual Report, Noyo River egg collecting station, 1979-80. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-12, 5 p.

Sanders, S. W. 1982e. Annual Report, Noyo River egg collecting station, 1981-82. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 82-21, 5 p.

Sanders, S. W. 1983a. Annual Report, Hollow Tree Creek egg taking station, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 83-7, 5 p.

Sanders, S. W. 1983b. Annual Report, Noyo River egg collecting station, 1982-83. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 83-6, 7 p.

Santa Cruz County Planning Department (SCCPD). 1979. The San Lorenzo River watershed management plan. Santa Cruz County Planning Department, Office of Watershed Management, 237 p. plus appendices. (Available from Santa Cruz County Planning Department, 701 Ocean St., Santa Cruz, CA 95060.)

Santa Cruz County Planning Department (SCCPD). 1993. Petition to list central California coast coho salmon as an endangered species. Petition to Natl. Mar. Fish. Serv., Southwest Region, 3 March 1993, 32 p. plus attachments. (Available from National Marine Fisheries Service, Southwest Region, 501 W. Ocean Blvd., Suite 4200, Long Beach, CA 90802.)

Satterthwaite, T. D. 1992. Rogue River studies. Oreg. Dep. Fish Wildl., Annual Prog. Rep., Fish Res. Proj. F-155-R-1, 25 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Schafer, W. E. 1968. Studies on the epizootiology of the myxosporidian *Ceratomyxa shasta* Noble. Calif. Fish Game 54:90-99.

Schroder, S., and K. Fresh (editors). 1992. Results of the Grays Harbor coho survival investigations, 1987-1990. Wash. Dep. Fish Tech. Rep. 118, 413 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Schubert, N. D. 1982a. A bio-physical survey of thirty Lower Fraser Valley streams. Can. Manuscr. Rep. Fish. Aquat. Sci. 1644, 131 p.

Schubert, N. D. 1982b. Trapping and coded wire tagging of wild coho salmon smolts in the Salmon River (Langley) 1978 to 1980. Can. Manuscr. Rep. Fish. Aquat. Sci. 1672, 68 p.

Schubert, N. D., G. E. Rosberg, R. J. Cook, and G. M. W. Cronkite. 1985. A coded wire tag assessment of Birkenhead River coho salmon: 1982 tag application and 1984 spawner enumeration. Can. Manuscr. Rep. Fish. Aquat. Sci. 1816, 55 p.

Scrivener, J. C., and B. C. Andersen. 1984. Logging impacts and some mechanisms that determine the size of spring and summer populations of coho salmon fry (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. Can. J. Fish. Aquat. Sci. 41:1097-1105.

Seiler, D., S. Neuhauser, and M. Ackley. 1981. Upstream/downstream salmonid trapping project, 1977-1980. Wash. Dep. Fish. Prog. Rep. 144, 197 p.

Seiler, D., S. Neuhauser, and M. Ackley. 1984. Upstream/downstream salmonid trapping project, 1980-1982. Wash. Dep. Fish. Prog. Rep. 200, 151 p.

Shaklee, J. B., F. W. Allendorf, D. C. Morizot, and G. S. Whitt. 1990. Gene nomenclature for protein-coding loci in fish. Trans. Am. Fish. Soc. 119:2-15.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game, Fish Bull. 98, 375 p.

Shepard, M. P., C. D. Shepard, and A. W. Argue. 1985. Historic statistics of salmon production around the Pacific Rim. Can. Manuscr. Rep., Fish. and Aquat. Sci. 1819, 297 p.

Silverstein, J. T., and W. K. Hershberger. 1992. Precocious maturation in coho salmon (*Oncorhynchus kisutch*): Estimation of the additive genetic variance. J. Heredity 83:282-286.

Simon, R. C., J. D. McIntyre, and A. R. Hemmingsen. 1986. Family size and effective population size in a hatchery stock of coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 43:2434-2443.

Skeesick, D. G. 1970. The fall immigration of juvenile coho salmon into a small tributary. Fish Comm. Oregon Res. Rep. 2(1):1-6.

Smith, G. E. 1975. Anadromous salmonid spawning escapements in the upper Trinity River, California, 1969. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 75-7, 17 p.

Smith, J. J. 1992. Distribution and abundance of juvenile coho salmon and steelhead in Waddell, Scott, and Gazos Creeks in 1992. San Jose State Univ., Department of Biological Sciences, San Jose, California. (Unpubl. rep.), 13 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)

Smith, J. J. 1993. Summary of trapping results on Waddell Creek for 1992-1993. San Jose State Univ., Department of Biological Sciences, San Jose, California. (Unpubl. rep.), 16 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)

Smith, R. L. 1983. Physical features of coastal upwelling systems. Washington Sea Grant, Tech. Rep. WSG 83-2, 34 p.

Snider, W. M. 1984. An assessment of coho salmon and steelhead resource requirements in Redwood Creek, Marin County, California. Calif. Dep. Fish Game, Environmental Services Branch Admin. Rep. 84-1. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814.)

Snyder, J. O. 1931. Salmon of the Klamath River, California. Calif. Fish Game, Fish Bull. 34, 130 p.

Snyder, R. U., and S. W. Sanders. 1979. Summary of operations, Noyo River egg collecting station, 1964-65 through 1977-78. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 79-7, 36 p.

Solazzi, M. F. 1986. Electrophoretic stock characterization of coho salmon populations in Oregon and Washington, and coastal chinook salmon populations in Oregon. Oreg. Dep. Fish Wildl., Info. Rep. 86-5, 16 p.

Solazzi, M. F., T. E. Nickelson, and S. L. Johnson. 1990. An evaluation of the use of coho salmon presmolts to supplement wild production in Oregon coastal streams. Oreg. Dep. Fish Wildl., Fish. Res. Rep. 10, 22 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Stebbins, R. C. 1966. A field guide to western reptiles and amphibians. The Peterson field guide series, Houghton Mifflin, Boston, 279 p.

Stern, G. R., and S. M. Noble. 1990. Progress report for investigation on Blue Creek, FY 1989. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California, 28 p. (Available U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Steward, C. R., and T. C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: A synthesis of published literature. U.S. Dep. Energy, Bonneville Power Administration, Tech. Rep. 90-1. (Available from U.S. Dep. Energy, Bonneville Power Administration, Fish and Wildlife, P.O. Box 3621, Portland, OR 97208.)

Streig, D. 1991. History of fish cultural activities in Santa Cruz County with special reference to Scott and Waddell Creeks. Monterey Bay Salmon and Trout Project, Davenport, California (Unpubl. rep.), 9 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)

Streig, D. 1993. The Monterey Bay salmon and trout project: Project background and description. Monterey Bay Salmon and Trout Project, Davenport, California (Unpubl. rep.), 24 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)

Strohschein, W. E. 1961. The 1960-61 operations at Pudding Creek silver salmon egg collecting station, Mendocino County. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Rep. 61-18.

Sumner, F. H. 1953. Migrations of salmonids in Sand Creek, Oregon. Trans. Am. Fish. Soc. 82:139-149.

Suzumoto, B. K., C. B. Schreck, and J. D. McIntyre. 1977. Relative resistance of three transferrin genotypes of coho salmon (*Oncorhynchus kisutch*) and their hematological responses to bacterial kidney disease. J. Fish. Res. Board Can. 34(1):1-8.

Swain, D. P., and L. B. Holtby. 1989. Differences in morphology and behavior between juvenile coho salmon (*Oncorhynchus kisutch*) rearing in a lake and in its tributary stream. Can. J. Fish. Aquat. Sci. 46:1406-1414.

Swales, S., F. Caron, J. R. Irvine, and C. D. Levings. 1988. Overwintering habitats of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in the Keogh River system, British Columbia. Can. J. Zool. 66:254-261.

Taylor, E. B. 1991. A review of local adaptation in Salmonidae, with particular reference to Pacific and Atlantic salmon. Aquaculture 98:185-207.

Taylor, E. B., and J. D. McPhail. 1985. Variation in body morphology among British Columbia populations of coho salmon, *Oncorhynchus kisutch*. Can. J. Fish. Aquat. Sci. 42:2020-2028.

Thedinga, J. F., and K. V. Koski. 1984. A stream ecosystem in an old-growth forest in southeast Alaska, Part VI: The production of coho salmon, *Oncorhynchus kisutch*, smolts and adults from Porcupine Creek. *In* W. R. Meehan, T. R. Merrell, and T. A. Hanley (editors), Fish and wildlife relationships in old-growth forests, p. 99-108. Proceedings of a symposium held in Juneau, Alaska, 12-15 April, 1982. (Available from J. W. Reintjes, Rt. 4, Box 85, Morehead City, NC 28557.)

Thiele, S. A., C. W. Kiilsgaard, and J. M. Omernik. 1992. The subdivision of the coast range ecoregion of Oregon and Washington. U.S. E.P.A., draft document, unnumbered. (Available from U.S. Environmental Protection Agency, Experimental Research Laboratory, 200 SW 35th St., Corvallis, OR 97333.)

Thompson, G. G. 1991. Determining minimum viable populations under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-198, 78 p.

Thompson, R. E. 1981. Oceanography of the British Columbia coast. Can. Spec. Publ. Fish. Aquat. Sci. 56, 291 p.

Tuss, C., J. Larson, T. Kisanuki, J. Polos, and J. Craig. 1989. Annual Report. Klamath River Fisheries Assessment Program, 1988. U.S. Fish Wildl. Serv., Fish. Assist. Off., Arcata, California. Rep. AFF-FAO-89-13, p. 61-66. (Available from U.S. Fish and Wildlife Service, Klamath River Fisheries Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Udey, L. R., J. L. Fryer, and K. S. Pilcher. 1975. Relation of water temperature to *ceratomyxosis* in rainbow trout (*Salmo gairdneri*) and coho salmon (*Oncorhynchus kisutch*). J. Fish. Res. Board. Can. 32:1545-1551.

U.S. Department of Commerce. 1968. (Natl. Oceanic Atmos. Admin. reprint 1983.) Climate atlas of the United States. Natl. Climatic Data Center, Asheville, NC, 80 p.

U.S. Department of the Interior. 1959. Columbia River fishery development program, Hatchery production and distribution data through fiscal year 1959. U.S. Dep. Inter., Fish Wildl. Serv., Bureau Commercial Fish. Portland, OR, 84 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.)

U.S. Fish and Wildlife Service (USFWS). 1985. Progress report of national fish hatchery programming and evaluation activities, Puget Sound and coastal Washington, 1983-84. U.S. Fish Wildl. Serv., p. 1-28. (Available from U.S. Fish and Wildlife Service, Western Washington Fisheries Assistance Office, 2625 Parkmont Lane, Bldg. A, Olympia, WA 98501.)

U.S. Fish and Wildlife Service (USFWS). 1989. Klamath River fisheries assessment program, Juvenile salmonid production monitoring, 1988. U.S. Fish Wildl. Serv. Fish. Assist. Off., Arcata, California, Rep. AFF-FAO-89-12, p. 1-10. (Available from U.S. Fish and Wildlife Service, Klamath River Fisheries Resource Office, P.O. Box 1006, Yreka, CA 96097.)

Ursitti, V. L. 1989. Residualism of juvenile coho salmon in Eel Lake, Oregon. Oreg. Dep. Fish Wildl., Fish Div. Info. Rep. 89-9, 15 p.

Valentine, J. W. 1966. Numerical analysis of marine molluscan ranges on the extratropical northeastern Pacific shelf. Limnol. Oceanogr. 11:198-211.

van den Berghe, E. P., and M. R. Gross. 1984. Female size and nest depth in coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 412:204-206.

van den Berghe, E. P., and M. R. Gross. 1989. Natural selection resulting from female breeding competition in a Pacific salmon (coho: *Oncorhynchus kisutch*). Evolution 43(1):125-140.

Viereck, L. A., and E. L. Little. 1972. Alaska trees and shrubs. U.S. Forest Service, Agriculture Handbook 410. U.S. Gov. Printing, Washington DC, 265 p.

Wagoner, L. J., K. K. Jones, R. E. Bender, J. A. Butler, D. E. Demory, T. F. Gaumer, J. A. Hurtado, W. G. Mullarkey, P. E. Reimers, N. T. Richmond, T. J. Rumreich. 1990. Coos River basin fish management plan. Oreg. Dep. Fish Wildl., 129 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wahle, R. J., and R. E. Pearson. 1987. A listing of Pacific Coast spawning streams and hatcheries producing chinook and coho salmon. U.S. Dep. Commer., NOAA Tech. Memo., NMFS, F/NWC-122, 37 p. plus appendices.

Waldvogel, J. 1988. Fall chinook salmon spawning escapement estimate for a tributary of the Smith River, 1980-1987, California. University of California Cooperative Extension Sea Grant, UCSGEP 88-5.

Wallis, J. 1961a. An evaluation of the Coos River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 98 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1961b. An evaluation of the Nehalem River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 68 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1961c. An evaluation of the S. Santiam River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 73 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1963a. An evaluation of the Alsea River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 74 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1963b. An evaluation of the Big Creek Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 64 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1963c. An evaluation of the Klaskanine River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 83 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1963d. An evaluation of the Siletz River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 41 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1963e. An evaluation of the Trask River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 77 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1964a. An evaluation of the Bonneville Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 90 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1964b. An evaluation of the Oxbow Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 69 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Wallis, J. 1966. An evaluation of the Sandy River Salmon Hatchery. Oreg. Fish Comm. Res. Lab., Clackamas, OR, 76 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Waples, R. S. 1991a. Definition of “species” under the Endangered Species Act: Application to Pacific salmon. U.S. Dep. Commer., NOAA Tech. Memo., NMFS, F/NWC-194, 29 p.

Waples, R. S. 1991b. Pacific salmon, *Oncorhynchus* spp., and the definition of “species” under the Endangered Species Act. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev. 53(3):11-22.

Waples, R. S., and D. J. Teel. 1990. Conservation genetics of Pacific salmon. I. Temporal changes in allele frequency. Conserv. Biol. 4:144-156.

Washington Department of Fish and Game (WDFG). 1928. Thirty-sixth and thirty-seventh Annual Reports of State Department of Fisheries and Game, Division of Fisheries for the period from April 1, 1925, to March 31, 1927. Wash. Dep. Fish. Game, p. 7-11. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fish and Wildlife (WDFW). 1994a. Historical commercial catch and effort database, in-river harvest data for selected Washington rivers, 1972-93. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fish and Wildlife (WDFW). 1994b. History (Historical Database): Historical releases of juvenile salmon into Washington waters, Coho salmon 1967-93. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fish and Wildlife (WDFW). 1994c. Salmon spawning ground survey database, coho salmon spawning data for selected Washington rivers, 1952-93/94. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF). 1951. Lower Columbia River Fisheries Development Program: Planning reports for Grays River area, Elokomin area, Abernathy area, Cowlitz area, Kalama River area, Lewis River area, Washougal River area, Wind River area, Little White Salmon area, Big White Salmon area, and Klickitat River area. Preliminary draft, unnumbered. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF). 1966. Coastal investigations, coastal gill net fishery, coho. Wash. Dep. Fish., 1966 Annu. Rep., p. 134-35. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF). 1973. Review Draft, Fisheries resources in southwest Washington. Southwest Washington river basins study, 174 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF). 1977. 1972-Brood Toutle River coho time/size at release study. Wash. Dep. Fish., Salmon Culture Division, 11 p. plus appendices. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF). 1981. 1981 Fisheries statistical report. WDF, Olympia, 79 p. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF). 1991. Overview of Washington Department of Fisheries Columbia River hatchery coho production. Report to ESA Administrative Record for lower Columbia River coho salmon, February 1991. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Portland, OR 97232.)

Washington Department of Fisheries (WDF), Puget Sound Treaty Indian Tribes, and Northwest Indian Fisheries Commission. 1992. 1992 Puget Sound coho salmon forecasts and management recommendations. WDF, Olympia, 49 p. plus appendices. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), and Western Washington Treaty Indian Tribes (WWTIT). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Wash. Dep. Fish Wildl., Olympia, 212 p. plus three Appendices: Appendix One--Hood Canal and Strait of Juan de Fuca (December 1994, 424 p.), North Puget Sound (June 1994, 418 p.), and South Puget Sound (September 1994, 371 p.) Volumes; Appendix Two--Coastal stocks (August 1994, 587 p.); and Appendix Three--Columbia River stocks (June 1993, 580 p.). (Available Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Wehrhahn, C. F., and R. Powell. 1987. Electrophoretic variation, regional differences, and gene flow in the coho salmon (*Oncorhynchus kisutch*) of southern British Columbia. Can. J. Fish. Aquat. Sci. 44:822-831.

Whitney, S. 1985. The Audubon Society nature guides. Western forests. Knopf, New York, 671 p.

Wilderness Society. 1993. The living landscape, Vol. 2: Pacific salmon and federal lands. Bolle Center for Forest Ecosystem Management, 87 p. (Available from The Wilderness Society, 900 Seventeenth Street, N.W., Washington, DC 20406-2596.)

Will, R. D. 1973a. Annual Report, Mad River salmon and steelhead hatchery, first year of operation, 1970-71. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 73-12, 15 p.

Will, R. D. 1973b. Annual Report, Mad River salmon and steelhead hatchery, second year of operation, 1971-72. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 74-1, 22 p.

Will, R. D. 1973c. Annual Report, Mad River salmon and steelhead hatchery, third year of operation, 1972-73. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 74-2, 23 p.

Will, R. D. 1975. Annual Report, Mad River salmon and steelhead hatchery, 1973-74. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 75-1, 21 p.

Will, R. D. 1976. Annual Report, Mad River salmon and steelhead hatchery, 1974-75. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 76-7, 24 p.

Will, R. D. 1978a. Annual Report, Mad River salmon and steelhead hatchery, 1975-76. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 78-16, 22 p.

Will, R. D. 1978b. Annual Report, Mad River salmon and steelhead hatchery, 1976-77. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 78-17, 22 p.

Will, R. D. 1979. Annual Report, Mad River salmon and steelhead hatchery, 1977-78. Calif. Dep. Fish Game, Anadromous Fish. Branch Admin. Rep. 79-3, 25 p.

Williams, R. W., R. M. Laramie, and J. Ames. 1975. A catalog of Washington streams and salmon utilization--Volume 1, Puget Sound region. Wash. Dep. Fish., Olympia. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)

Willis, M. J. 1979. Out-system transfers of coho salmon stocks in coastal river systems 1960-79. Oreg. Dep. Fish Wildl. Info. Rep. Serv., Fish. 79-9, 12 p.

Willis, R. A. 1954. The length of time that silver salmon spent before death on the spawning grounds at Spring Creek, Wilson River, in 1951-52. Fish. Comm. Oregon Res. Briefs 5:27-31.

Willis, R. A. 1962. Gnat Creek weir studies. Final Report. Fish. Comm. Oregon, Res. Div. Clackamas, Oregon, 71 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

Winter, G. W., C. B. Schreck, and J. D. McIntyre. 1980. Resistance of different stocks and transferrin genotypes of coho salmon, *Oncorhynchus kisutch*, and steelhead trout, *Salmo gairdneri*, to bacterial kidney disease and vibriosis. Fish. Bull., U.S. 77:795-802.

Withler, R. E. 1988. Genetic consequences of fertilizing chinook salmon (*Oncorhynchus tshawytscha*) eggs with pooled milt. Aquaculture 68:15-25.

Wright, S. G. 1970. Size, age, and maturity of coho salmon in Washington's ocean troll fishery. Wash. Dep. Fish., Fish. Res. Papers 3(2):63-71.

Wunderlich, R. C., S. J. Dilley, and E. E. Knudsen. 1989. Timing, exit selection, and survival of steelhead and coho smolts at Glines Canyon Dam. U.S. Fish Wildl. Serv. Fish. Assist. Off. Olympia, WA, 40 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmont Lane, Bldg. A., Olympia, WA 98502-5751.)

Yasutake, W. T., J. D. McIntyre, and A. R. Hemmingsen. 1986. Parasite burdens in experiments families of coho salmon. Trans. Am. Fish. Soc. 115:636-640.

Zajac, D. P. 1988. Progress report of national fish hatchery programming and evaluation activities Puget Sound and coastal Washington, 1986-1987. U.S. Fish Wildl. Serv., 26 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA 98501.)

Zajac, D. P. 1989. Progress report of national fish hatchery programming and evaluation activities Puget Sound and coastal Washington, 1987-1988. U.S. Fish Wildl. Serv., 26 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA 98501.)

Zajac, D. P. 1990. Progress report of national fish hatchery programming and evaluation activities Puget Sound and coastal Washington, 1988-1989. U.S. Fish Wildl. Serv., 31 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmont Lane, Bldg. A, Olympia, WA 98501.)

Zajac, D. P. 1991. Progress report of national fish hatchery programming and evaluation activities Puget Sound and coastal Washington, 1989-1990. U.S. Fish Wildl. Serv., 29 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, 2625 Parkmont Lane, Bldg. A, Olympia, WA 98501.)

Zajac, D. P. 1992. Progress report of national fish hatchery programming and evaluation activities Puget Sound and coastal Washington, 1990-1991. U.S. Fish Wildl. Serv., 32 p. (Available from U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, WA 98501.)

Zinn, J. L., K. A. Johnson, J. E. Sanders, and J. L. Fryer. 1977. Susceptibility of salmonid species and hatchery strains of chinook salmon (*Oncorhynchus tshawytscha*). J. Fish. Res. Board Can. 34:933-936.

Zuspan, M., B. Heubach, M. Lau, M. Boucke, C. Wilson, T. Mills, and B. Aguilar. 1992a. Annual report, Trinity River basin salmon and steelhead monitoring project, 1989-1990 season. Calif. Dep. Fish Game, Inland Fish. Div., 140 p. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814.)

Zuspan, M., B. Heubach, M. Lau, M. Boucke, C. Wilson, T. Mills, and B. Aguilar. 1992b. Annual report, Trinity River basin salmon and steelhead monitoring project, 1990-1991 season. Calif. Dep. Fish Game, Inland Fish. Div., 135 p. (Available from California Department of Fish and Game, 1416 Ninth St., Sacramento, CA 95814.)

Appendix A

Glossary

GLOSSARY

allele

An **allele** is an alternate form of a **gene** (the basic unit of heredity passed from parent to offspring). By convention, the "**100 allele**" is the most common allele in a population and is the reference for the electrophoretic mobility of other alleles of the same gene. Other genetic terms used in this document include **allozymes** (alternate forms of an enzyme produced by different alleles and often detected by protein electrophoresis); **dendrogram** (a branching diagram, sometimes resembling a tree, that provides one way of visualizing similarities between different groups or samples); **gene locus** (pl. **loci**; the site on a chromosome where a gene is found); **genetic distance** (**D**) (a quantitative measure of genetic differences between a pair of samples); and **introgression** (introduction of genes from one population or species into another). *See also* **DNA**, **electrophoresis**, and **transferrin.**

artificial propagation

See **hatchery**.

Biological Review Team (BRT)

The team of scientists from National Marine Fisheries Service formed to conduct the status review.

Cape Blanco

A geographic feature on the Oregon coast at 43°50′N.

Cape Mendocino

A geographic feature on the California coast at 40°25′N.

Ceratomyxa shasta

A freshwater myxosporean parasite of salmonids that causes high mortalities in susceptible strains of fish. Other common diseases of Pacific salmon include **vibriosus**, **cold water disease**, **bacterial kidney disease**, and **furunculosis**.

coded-wire tag (CWT)

A small piece of wire, marked with a binary code, that is normally inserted into the nasal cartilage of juvenile fish. Because the tag is not externally visible, the adipose fin of coded wire-tagged fish is removed to indicate the presence of the tag. Groups of thousands to hundreds of thousands of fish are marked with the same code number to indicate stock, place of origin, or other distinguishing traits for production releases and experimental groups.

DNA (deoxyribonucleic acid)

DNA is a complex molecule that carries an organism's heritable information. The two types of DNA commonly used to examine genetic variation are **mitochondrial DNA** (**mtDNA**), a circular molecule that is maternally inherited, and **nuclear DNA**, which is organized into a set of chromosomes. *See also* **allele**, **electrophoresis,** and **transferrin.**

electrophoresis

Electrophoresis refers to the movement of charged particles in an electric field. It has proven to be a very useful analytical tool for biochemical characters because molecules can be separated on the basis of differences in size or net charge. **Protein electrophoresis**, which measures differences in the amino acid composition of proteins from different individuals, has been used for over two decades to study natural populations, including all species of anadromous Pacific salmonids. Because the amino acid sequence of proteins is coded for by DNA, data provided by protein electrophoresis provide insight into levels of genetic variability within populations and the extent of genetic differentiation between them. Genetic techniques that focus directly on variation in DNA also routinely use electrophoresis to separate fragments formed by cutting DNA with special enzymes (**restriction endonucleases**). *See also* **allele**, **DNA,** and **transferrin**.

ESA

The U.S. Endangered Species Act.

escapement

The number of fish that survive to reach the spawning grounds or hatcheries. The escapement plus the number of fish removed by harvest form the **total run size**.

evolutionarily significant unit (ESU)

A "distinct" population of Pacific salmon, and hence a species, under the Endangered Species Act.

hatchery

Salmon hatcheries typically spawn adults in captivity and raise the resulting progeny in fresh water for release into the natural environment. In some cases, fertilized eggs are outplanted (usually in "hatch-boxes"), but it is more common to release **fry** (young juveniles) or **smolts** (juveniles that are physiologically prepared to undergo the migration into salt water). The fish are released either at the hatchery (**on-station release**) or away from the hatchery (**off-station release**). Releases may also be classified as **within basin** (occurring within the river basin in which the hatchery is located or the stock originated from) or **out-of-basin** (occurring in a river basin other than that in which the hatchery is located or the stock originated from).

The broodstock of some hatcheries is based on adults that return to the hatchery each year; others rely on fish or eggs from other hatcheries, or capture adults in the wild each year.

jacks

Male salmon that return from the ocean to spawn one or more years before full-sized adults return. For coho salmon in California, Oregon, Washington, and southern British Columbia, jacks are 2 years old, having spent only 6 months in the ocean, in contrast to adults, which are 3 years old after spending 1½ years in the ocean.

Point Grenville

A geographic feature of the Washington coast located at 47°17'N.

polymorphic

Having more than one form (e.g., polymorphic gene loci have more than one allele).

principal component analysis (**PCA**)

A statistical technique that attempts to explain variation among several (*n*) variables in terms of a smaller number of composite independent factors called **principal components**. These principal components are represented by **eigenvectors**, or the perpendicular axes of central trend that pass through the clouds of points represented in *n*-dimensional space. The matrix of eigenvectors and the **matrix of correlations** of independent variables are used with linear algebra to calculate the equations describing the principal components that account for the greatest amount of the variation expressed in the original variables. Principal component one (**PC1**) is defined as a linear combination of the *n* variables that accounts for more of the variance in the data than any other linear combination of variables. Second (**PC2**) and subsequent components are defined as linear combinations that account for residual variance after the effect of the first (and subsequent) component(s) is removed from the data. PC values or "scores" are calculated for each individual and subjected to statistical analysis.

Punta Gorda

A geographic feature of the California coast at 40^{o}15'N.

Queen Charlotte Strait

The body of water separating the northern portion of Vancouver Island and the British Columbia mainland. The strait extends south from the Pacific Ocean at the north tip of Vancouver Island to approximately Gilford Island and the Broughton Island Archipelago.

river kilometer (RKm)

Distance, in kilometers, from the mouth of the indicated river. Usually used to identify the location of a physical feature, such as a confluence, dam, waterfall, or spawning area.

Salt Creek

A small creek on the south shore of the Strait of Juan de Fuca that flows into Crescent Bay. Salt Creek is adjacent and to the west of the Elwha River.

smolt

verb- The physiological process that prepares a juvenile anadromous fish to survive the transition from fresh water to salt water.

noun- A juvenile anadromous fish that has smolted.

spawner surveys

Spawner surveys utilize counts of **redds** (nests dug by females in which they deposit their eggs) and fish carcasses to estimate spawner escapement and identify habitat being used by spawning fish. Annual surveys can be used to compare the relative magnitude of spawning activity between years. Surveys are conducted on a regular basis on **standard stream segments**, groups of which form a spawner **index**, and are occasionally conducted on **supplemental stream segments** (those that are not part of the standard surveying plan).

Several methodologies have been used to estimate trends in spawner abundance based on the results of redd counts or spawner surveys. The **peak count (PC)** methodology simply uses the largest number of fish observed during the peak of spawning activity. The **area under the curve (AUC)** approach estimates the number of “fish days” (one “fish day” is equal to one fish (spawner) present on the spawning ground for one day) for a given stream segment; AUC is calculated from the total number of spawners observed over the course of the season, divided by the average residence time of spawners on the spawning ground. **Stratified random sampling (SRS)** provides an estimate of the number of spawners in a given area based on spawner counts in both standard and supplemental surveys.

spawner-to-spawner ratio

Several measures are employed to estimate the productivity of salmon populations. The **spawner-to-spawner ratio** estimates the number of spawners (those fish that reproduced or were expected to reproduce) in one generation produced by the previous generation’s spawners. A spawner-to-spawner ratio of 1.0 indicates that, on average, each spawner produced one offspring that survived to spawn. The **recruit-to-spawner ratio** estimates the number of **recruits** (fish that are available for harvest in addition to those that bypass the fishery to spawn) produced by the previous generation’s spawners.

Strait of Georgia

The body of water separating the southern portion of Vancouver Island and the British Columbia mainland. The strait extends from Cortes Island and Desolation Sound in the north to the San Juan Islands in the south.

Strait of Juan de Fuca

The body of water separating the southern portion of Vancouver Island and the Olympic Peninsula in Washington. The strait extends from the Pacific Ocean east to the San Juan and Whidbey Islands.

transferrin

Transferrin is a serum protein that is characterized by its specific ability to reversibly bind iron and other metal ions and exhibits a high degree of polymorphism.

west coast coho salmon

For the purposes of this document, west coast coho salmon are defined as coho salmon originating from fresh waters of British Columbia, Washington, Oregon, and California.

Appendix B

Environmental Information

Appendix Table B-1. Location of gauging stations, years sampled, number of years sampled, and river flow parameters for selected river basins in Washington (WA), Oregon (OR), and California (CA). Based on USGS streamflow data (Hydrosphere Data Products, Inc. 1993).

State	River	Gauging station location	Years covered	Number of years sampled	Month of peak flow[a]	Number of peaks	Duration of peak flow[b] (months)	Flow per area[c] ($m^3 s^{-1} km^{-2}$)	Minimum flow as percent of maximum flow[d]
WA	Nooksack	Ferndale	1967-92	26	Dec	2	10	0.054	36.8
WA	Samish	Burlington	1943-72	30	Jan	1	6	0.030	7.5
WA	Skagit	Mount Vernon	1941-92	52	Dec	2	9	0.059	37.8
WA	Stillaguamish	Silvana	1975-76	2	Dec	2	8	0.079	15.4
WA	Snohomish	Monroe	1963-92	30	Dec	2	9	0.068	23.1
WA	Cedar	Renton	1945-92	48	Jan	1	8	0.040	18.1
WA	Green	Tukwila	1961-87	27	Jan	2	7	0.037	14.1
WA	Puyallup	Puyallup	1914-92	79	Dec	2	9	0.038	38.3
WA	Nisqually	McKenna	1948-92	37	Dec	2	7	0.027	18.1
WA	Deschutes	Olympia	1945-64	19	Feb	1	6	0.027	12.3
WA	Skokomish	Potlatch	1943-91	49	Dec	1	6	0.057	11.0
WA	Dewatto	Dewatto	1947-75	26	Jan	1	5	0.042	9.3
WA	Hamma Hamma	Eldon	1951-71	21	Dec	2	9	0.078	19.0
WA	Duckabush	Brinnon	1938-92	55	Dec	2	9	0.068	23.1
WA	Dosewallips	Brinnon	1931-51	20	Dec	2	6	0.052	21.9
WA	Big Beef Cr.	Seabeck	1969-92	24	Dec	1	4	0.023	4.5
WA	Dungeness	Sequim	1923-91	63	Dec	2	6	0.027	24.8
WA	Morse Cr.	Port Angeles	1966-77	12	Jan	2	8	0.029	16.8
WA	Elwha	Port Angeles	1898-1992	80	Dec	2	9	0.061	27.0
WA	Lyre	Piedmont	1918-27	10	Jan	1	5	0.048	13.7
WA	Hoko	Seiku	1962-92	24	Jan	1	5	0.071	4.8
WA	Waatch	Neah Bay	1976-79	4	Dec	2	5	0.047	9.5
WA	Sooes	Ozette	1976-86	11	Nov	2	3	0.067	9.4
WA	Dickey	La Push	1962-80	17	Dec	1	5	0.067	3.7
WA	Soleduck	Fairholm	1929-92	64	Dec	2	5	0.081	13.3
WA	Calawah	Forks	1898-1992	20	Dec	2	5	0.087	8.3
WA	Bogachiel	Forks	1975-80	6	Dec	2	3	0.094	9.4
WA	Hoh	Forks	1961-92	32	Dec	2	8	0.109	29.7

Appendix Table B-1. Continued.

State	River	Gauging station location	Years covered	Number of years sampled	Month of peak flow[a]	Number of peaks	Duration of peak flow[b] (months)	Flow per area[c] ($m^3 s^{-1} km^{-2}$)	Minimum flow as percent of maximum flow[d]
WA	Queets	Clearwater	1931-92	39	Dec	1	6	0.105	13.1
WA	Clearwater	Clearwater	1964-76	13	Dec	2	5	0.090	7.2
WA	Raft	Queets	1974-81	8	Dec	2	5	0.078	11.1
WA	Quinault	Lake Quinault	1912-92	77	Dec	2	8	0.118	19.4
WA	Moclips	Moclips	1975-81	7	Dec	2	5	0.063	6.2
WA	Humptulips	Humptulips	1933-79	41	Dec	1	5	0.112	8.9
WA	Wynoochee	Aberdeen	1952-92	41	Dec	1	5	0.120	16.8
WA	Chehalis	Porter	1952-91	38	Jan	1	5	0.034	4.2
WA	Satsop	Satsop	1929-92	64	Dec	1	6	0.070	8.0
WA	North	Raymond	1927-77	51	Dec	1	5	0.048	3.8
WA	Willapa	Willapa	1948-92	40	Dec	1	5	0.053	3.4
WA	N. Nemah	South Bend	1946-77	15	Jan	1	5	0.070	6.7
WA	Naselle	Naselle	1929-92	64	Dec	1	5	0.084	5.7
WA	Grays	Grays	1956-76	21	Jan	1	5	0.094	5.8
WA	Elochoman	Cathlamet	1941-72	32	Dec	1	5	0.062	5.4
WA	Cowlitz	Castle Rock	1927-92	64	Dec	2	8	0.045	18.0
WA	Toutle	Silver Lake	1910-82	57	Dec	1	7	0.047	14.5
WA	Kalama	Kalama	1947-83	34	Jan	1	6	0.069	13.6
WA	Washougal	Washougal	1945-81	37	Dec	1	6	0.088	6.0
WA	White Salmon	Underwood	1913-92	75	Feb	2	9	0.031	41.8
WA	Klickitat	Pitt	1909-92	68	May	1	7	0.013	30.1
OR	Deschutes	Culver	1952-92	41	Feb	1	7	0.000	38.2
OR	Sandy	Marmot	1911-92	82	Dec	2	8	0.056	20.5
OR	Willamette	Salem	1910-90	75	Jan	1	6	0.035	12.0
OR	Youngs	Astoria	1928-58	31	Dec	1	5	0.049	2.4
OR	Nehalem	Foss	1940-90	51	Jan	1	5	0.044	2.3
OR	Trask	Tillamook	1931-72	36	Dec	1	5	0.074	4.9
OR	Nestucca	Beaver	1965-90	26	Dec	1	5	0.064	4.5
OR	Siletz	Siletz	1906-90	74	Dec	1	5	0.083	4.0
OR	Yaquina	Chitwood	1973-90	18	Dec	1	5	0.039	2.4
OR	N. Fork Beaver Cr.	Seal Rock	1965-67	3	Jan	2	4	0.049	2.4

Appendix Table B-1. Continued.

State	River	Gauging station location	Years covered	Number of years sampled	Month of peak flow[a]	Number of peaks	Duration of peak flow[b] (months)	Flow per area[c] ($m^3 s^{-1} km^{-2}$)	Minimum flow as percent of maximum flow[d]
OR	Alsea	Tidewater	1940-90	51	Jan	1	4	0.049	3.3
OR	Siuslaw	Mapleton	1968-90	23	Jan	1	4	0.039	3.2
OR	Umpqua	Elkton	1906-90	85	Jan	1	5	0.022	7.4
OR	Tenmile Lake	Lakeside	1958-77	20	Jan	1	4	0.042	2.1
OR	S. Fork Coquille	Powers	1957-70	14	Jan	1	6	0.051	1.9
OR	Rogue	Agness	1961-89	29	Jan	1	5	0.017	13.4
OR	Chetco	Brookings	1970-89	20	Dec	1	5	0.093	2.2
CA	Smith	Crescent City	1932-92	61	Jan	1	6	0.067	4.0
CA	Klamath	Klamath	1911-92	58	Feb	1	6	0.016	9.2
CA	Trinity	Hoopa	1912-92	65	Feb	1	6	0.020	5.2
CA	Salmon	Somes Bar	1912-92	69	Feb	2	7	0.026	6.6
CA	Redwood Cr.	Orick	1911-92	42	Jan	1	4	0.040	1.7
CA	Mad	Arcata	1911-92	45	Jan	1	4	0.031	1.3
CA	Eel	Fort Seward	1955-92	38	Feb	1	4	0.025	0.4
CA	Mattole	Petrolia	1912-92	44	Jan	1	4	0.059	1.5
CA	Noyo	Fort Bragg	1952-92	41	Jan	1	4	0.021	1.1
CA	Garcia	Point Arena	1962-83	22	Jan	1	4	0.037	1.3
CA	Russian	Guerneville	1940-92	53	Feb	1	4	0.018	2.5
CA	Salmon Cr.	Bodega	1962-76	15	Jan	1	3	0.016	0.1
CA	Lagunitas Cr.	Point Reyes Station	1975-92	18	Feb	1	3	0.010	1.4
CA	Napa	Napa	1930-92	36	Feb	1	3	0.009	0.4
CA	Arroya de Laguna	Pleasanton	1912-92	37	Feb	1	3	0.001	4.1
CA	Scott Cr.	Davenport	1959-74	16	Feb	1	3	0.014	1.8
CA	San Lorenzo	Big Trees	1937-92	56	Feb	1	3	0.013	4.7

[a]For rivers with two peaks, the indicated month is the timing of the first peak which is generally the larger of the two. The second peak is larger than the first peak for the Stillaguamish, Puyallup, Dosewallips, Dungeness, Elwha, Waatch, Sooes, and White Salmon Rivers.
[b]Duration of peak flow is defined as the number of months when flow is equal to or exceeds 50% of peak flow.
[c]Flow per area is expressed as the average annual flow divided by the gauged area reported for the gauging station.
[d]Minimum flow as a percentage of maximum flow is calculated as the ratio of minimum to maximum flows multiplied by 100 to create a percentage.

Appendix Table B-2. Location of sampling stations, years sampled, number of years sampled, and minimum and maximum water temperatures for selected river basins in Washington (WA), Oregon (OR), and California (CA). Based on USGS water data (Hydrosphere Data Products, Inc. 1993).

State	River	Sampling station location	Years covered	Number of years sampled	Average monthly temperature (°C) Minimum[a]	Maximum[b]
WA	N. Fork Nooksack	Deming	1968-70	3	2.2	13.5
WA	Samish	Burlington	1973-74	2	3.6	16.6
WA	Skagit	Mount Vernon	1962-82	18	4.1	14.5
WA	Skagit	Sedro Woolley	1975-80	6	3.7	14.3
WA	Skagit	Marblemount	1953-86	34	4.2	11.0
WA	Cascade (Skagit)	Marblemount	1952-73	21	3.1	11.6
WA	Sauk (Skagit)	Sauk	1970-71	2	2.5	15.3
WA	N. Fork Stillaguamish	Darrington	1952-57	5	3.9	13.5
WA	Pilchuck Cr. (Stillaguamish)	Bryant	1952-72	21	3.4	18.1
WA	Tulalip Cr. (Puget Sound)	Tulalip	1975-76	2	3.8	18.7
WA	Mission Cr. (Puget Sound)	Tulalip	1975-76	2	3.9	19.0
WA	Snohomish	Snohomish	1960-61	2	4.5	18.2
WA	Skykomish (Snohomish)	Monroe	1967-70	3	3.9	17.8
WA	Sultan (Skykomish)	Sultan	1984-92	9	3.7	12.4
WA	Snoqualmie (Snohomish)	Carnation	1967-70	3	5.2	18.6
WA	M. Fork Snoqualmie (Snohomish)	Tanner	1979-80	2	1.7	16.2
WA	N. Fork Snoqualmie (Snohomish)	Snoqualmie Falls	1979-80	2	3.7	17.5
WA	Sammamish	Woodinville	1965-67	3	3.6	20.0
WA	Cedar	Renton	1965-92	18	4.8	18.0
WA	Cedar	Landsburg	1954-86	33	4.6	13.4
WA	Duwamish	Tukwila	1960-62	3	5.2	20.1
WA	Green	Auburn	1952-87	36	4.6	17.7
WA	Puyallup	Puyallup	1965-67	3	4.2	16.5
WA	White (Puyallup)	Greenwater	1965-68	4	1.0	6.4
WA	White (Puyallup)	Buckley	1971-72	2	1.3	15.0
WA	Nisqually	La Grande	1966-82	17	4.0	11.5
WA	Nisqually	National	1952-82	31	2.7	13.4
WA	Purdy Cr. (Skokomish)	Union	1955-60	6	5.8	11.3
WA	Skokomish	Potlatch	1956-82	26	5.5	13.6
WA	N. Fork Skokomish	Potlatch	1965-82	18	5.1	15.0
WA	N. Fork Skokomish	Hoodsport	1965-90	20	3.0	11.7
WA	S. Fork Skokomish	Potlatch	1956-67	9	4.2	15.0
WA	S. Fork Skokomish	Hoodsport	1965-71	6	3.6	11.8
WA	Dewatto	Dewatto	1968-71	3	2.3	14.4
WA	Dosewallips	Brinnon	1970-71	2	3.9	12.5
WA	Dungeness	Sequim	1968-71	3	0.9	11.8
WA	Elwha	Port Angeles	1976-77	2	2.6	13.4
WA	N. Fork Quinault	Amanda Park	1965-80	16	3.0	11.1
WA	Chehalis	Grand Mount	1957-74	22	4.9	20.4
WA	Wynoochee (Chehalis)	Montesano	1970-87	18	5.3	18.1
WA	M. Fork Satsop (Chehalis)	Satsop	1972-73	2	4.9	19.0
WA	Cloquallum (Chehalis)	Elma	1972-73	2	5.2	17.4

Appenidx Table B-2. Continued.

State	River	Sampling station location	Years covered	Number of years sampled	Average monthly temperature (°C) Minimum[a]	Maximum[b]
WA	North	Raymond	1963-73	11	5.5	18.8
WA	Willapa	Lebam	1952-71	19	5.5	17.1
WA	N. Nemah (Willapa Bay)	S. Bend	1970-71	2	5.6	17.0
WA	Naselle	Naselle	1963-73	11	6.0	17.7
WA	Bear Branch (Willapa Bay)	Naselle	1963-66	4	6.0	15.0
WA	W. Fork Grays	Grays R.	1955-70	14	5.5	16.2
WA	Elochoman	Cathlamet	1955-72	18	5.1	17.9
WA	Abernathy Creek	Longview	1952-57	6	4.9	15.3
WA	Cowlitz	Castle Rock	1965-82	20	5.0	17.2
WA	Cowlitz	Randle	1969-82	14	3.3	15.2
WA	Cispus (Cowlitz)	Randle	1951-72	22	3.0	13.2
WA	N. Fork Toutle (Cowlitz)	Kid Valley	1982-91	4	4.5	19.1
WA	Green (Toutle)	Kid Valley	1981-91	7	4.0	23.0
WA	Coweeman	Kelso	1951-72	22	4.7	20.1
WA	Kalama	Kalama	1970-79	10	4.0	16.6
WA	Lewis	Ariel	1955-63	8	5.1	13.7
WA	E. Fork Lewis	Heisson	1951-72	21	4.4	17.7
WA	White Salmon	Underwood	1968-69	2	3.4	11.5
WA	Klickitat	Pitt	1950-71	22	3.1	16.9
OR	Deschutes	Culver	1955-74	19	4.9	14.0
OR	Deschutes	Madras	1952-88	24	6.8	13.8
OR	Deschutes	Biggs	1955-82	25	5.1	19.1
OR	Bull Run (Sandy)	Multnomah Falls	1978-91	14	2.5	13.7
OR	Fir Cr. (Sandy)	Brightwood	1978-92	15	3.3	12.3
OR	Clackamas	Clackamas	1963-76	14	4.7	24.4
OR	Willamette	Harrisburg	1961-88	28	5.5	18.2
OR	Willamette	Oregon City	1963-67	5	6.3	22.0
OR	Willamette	Portland	1976-81	6	5.1	21.5
OR	Columbia	Rainier	1971-79	9	4.1	21.0
OR	Columbia	Quincy	1967-71	5	3.9	19.9
OR	Bear Cr. (Columbia)	Svensen	1965-75	11	5.5	12.3
OR	Columbia	Altoona	1971-80	10	3.7	20.7
OR	Nehalem	Foss	1975-82	8	4.6	19.9
OR	Trask	Tillamook	1962-71	10	5.7	17.8
OR	Nestucca	Beaver	1965-87	23	6.4	18.7
OR	Siletz	Siletz	1979-86	8	6.3	20.0
OR	Big Rock Cr. (Siletz)	Valsetz	1979-86	8	5.6	15.8
OR	N. Fork Beaver (Pacific Ocean)	Seal Rock	1965-67	3	7.1	15.9
OR	Alsea	Tidewater	1980-82	3	7.5	20.7
OR	N. Fork Alsea	Alsea	1958-67	10	6.6	19.8
OR	Deer Cr. (Alsea)	Salado	1959-73	15	7.0	13.9
OR	Needle Branch (Alsea)	Salado	1959-74	16	7.2	15.4
OR	Drift Cr. (Alsea)	Salado	1959-70	11	7.1	18.7
OR	Flynn Cr. (Alsea)	Salado	1959-73	15	7.2	13.0

Appenidx Table B-2. Continued.

State	River	Sampling station location	Years covered	Number of years sampled	Average monthly temperature (°C) Minimum[a]	Maximum[b]
OR	Fall Cr. (Alsea)	Alsea	1958-59	2	8.0	16.9
OR	S. Fork Alsea	Alsea	1958-63	6	5.5	19.6
OR	Siuslaw	Mapleton	1970-82	11	6.2	22.6
OR	Umpqua	Elkton	1971-91	21	5.4	23.7
OR	N. Umpqua	Winchester	1971-91	21	4.3	21.4
OR	S. Umpqua	Roseburg	1971-91	21	5.4	26.0
OR	S. Fork Coquille	Powers	1957-70	14	5.4	20.8
OR	S. Fork Coquille	Illahe	1971-74	4	3.7	19.4
OR	Rogue	Agness	1961-88	28	5.5	22.7
OR	Rogue	Marial	1974-88	15	5.4	21.5
OR	Rogue	Grants Pass	1973-87	15	4.4	18.8
OR	Rogue	Central Point	1973-91	19	4.1	17.7
OR	Rogue	Eagle Point	1973-91	19	3.8	16.1
OR	S. Fork Rogue	Prospect	1969-91	23	3.4	14.9
OR	Illinois (Rogue)	Selma	1961-68	8	6.1	22.4
OR	Applegate (Rogue)	Applegate	1973-91	19	3.5	21.3
OR	Applegate (Rogue)	Wilderville	1978-91	14	4.8	23.7
CA	Middle Fork Applegate (Rogue)	Copper	1979-88	10	3.6	18.6
CA	Smith	Crescent City	1966-81	16	6.8	20.4
CA	Mill Cr. (Smith)	Crescent City	1974-81	8	7.7	19.0
CA	Klamath	Klamath	1966-81	16	6.4	22.4
CA	Klamath	Orleans	1966-82	17	5.0	23.9
CA	Klamath	Seiad Valley	1964-79	16	3.5	23.3
CA	Klamath	Below Iron Gate I	1963-80	18	2.8	20.4
CA	Blue Cr. (Klamath)	Klamath	1966-78	13	8.0	19.3
CA	Trinity	Hoopa	1964-84	17	6.0	22.9
CA	Trinity	Lewiston	1959-83	25	6.0	12.8
CA	S. Fork Trinity	Hyampton	1966-79	13	4.6	24.8
CA	Hayfork Cr. (Trinity)	Hyampton	1961-74	14	4.0	22.3
CA	Salmon (Klamath)	Somes Bar	1966-79	13	4.6	22.4
CA	Redwood Cr.	Orick	1966-79	14	7.3	20.1
CA	Redwood Cr.	Blue Lake	1974-81	8	5.5	25.9
CA	Mad	Arcata	1962-79	16	6.2	21.5
CA	Mad	Blue Lake	1973-76	4	6.0	23.7
CA	Mad	Kneeland	1966-74	9	6.6	23.4
CA	Mad	Forest Glen	1961-79	18	4.9	20.0
CA	Elk (Humbolt Bay)	Hearst	1965-73	9	5.5	26.8
CA	Eel	Scotia	1962-82	20	7.7	21.7
CA	Eel	Fort Seward	1961-79	16	6.5	26.3
CA	Eel	Dos Rios	1962-82	21	6.5	25.4
CA	Eel	Dos Rios	1967-77	11	6.7	25.6
CA	Van Duzen (Eel)	Bridgeville	1961-79	19	5.6	23.8
CA	Van Duzen (Eel)	Dinsmore	1966-74	9	3.5	22.2
CA	S. Fork Eel	Miranda	1961-83	23	7.7	25.2

Appendix C

Life History Trait Information

Appendix Table C-1. Smolt outmigration timing of selected coho salmon populations in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA).

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Sashin Cr.	AK	--	late May-early June	1967	Crone and Bond (1976)
Taku	AK	mid Apr-June	mid-late May	1961	Meehan and Siniff (1962)
Karluk	AK	mid May-July	early June	1961-67	Drucker (1972)
Skeena (Lakesle Lake)	BC	May-June	late May	1952	Foerster (1952)
Keogh (Vancouver Is.)	BC	mid Apr-mid June	mid May	1980-87	Irvine and Ward (1989)
Black Cr. (Vancouver Is.)	BC	Apr-late June	mid May	1985-87	Labelle (1990)
Trent (Vancouver Is.)	BC	Apr-late June	end May	1985-87	Labelle (1990)
Big Qualicum (Vancouver Is.)	BC	Mar-July	late May	1959-73	Fraser et al. (1983)
French Cr. (Vancouver Is.)	BC	Apr-late June	mid-late May	1985-87	Labelle (1990)
Cowichan (Vancouver Is.)	BC	Apr-mid June Feb-mid June	May mid May	1975 1987-90	Armstrong and Argue (1977) Bams (1993)
Lymn (Vancouver Is.)	BC	Apr-June	late May	1972	Mason (1975)
Carnation Cr. (Vancouver Is.)	BC	Mar-July Mar-July Mar-June	May[a] Apr[b] mid May	1971-76 1977-82 --	Scrivener and Andersen (1984) Scrivener and Andersen (1984) McMahon and Holtby (1992)
Squamish	BC	Apr-mid June	May	1973-75	Argue and Armstrong (1977)
Fraser (Sweltzer)	BC	May-June	early June	1937	Foerster and Ricker (1953)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Fraser (Salmon R.)	BC	Apr-June	ear-mid May	1978-80	Schubert (1982b)
Skagit	WA	late Mar-late July	early-mid May	1987-93	R. Hayman (1994 App.)
Stillaguamish	WA	--	mid May	1981-82	Seiler et al. (1984)
		--	mid May	1987-88	Kirby et al. (1988, 1990)
Snohomish	WA	--	mid May	1986-87	Beauchamp (1986), Beauchamp et al. (1987)
Snohomish (Little Pilchuck Cr.)	WA	--	early-mid May	1979-87	Lenzi (1983, 1985, 1987)
Snohomish (Griffin Cr.)	WA	--	early-mid May	1979-81	Blankenship et al. (1983)
Snohomish (Harris Cr.)	WA	--	early-mid May	1979-87	Blankenship et al. (1983), Lenzi (1985, 1987)
Snohomish (S. F. Skykomish)	WA	Apr-mid June	mid May	1978-82	Seiler et al. (1981, 1984)
Samamish (North Cr.)	WA	--	early May	1976-77	Blankenship and Tivel (1980)
Samamish (Little Bear Cr.)	WA	--	early May	1976-77	Blankenship and Tivel (1980)
Green	WA	Feb-June	late Apr-early May	1991-92	Dilley and Wunderlich (1992, 1993)
Wild Cat Cr. (Puget Sound)	WA	--	late Apr-early May	1979-87	Lenzi (1983, 1985, 1987)
Minter Cr. (Puget Sound)	WA	Mar-June	mid May	1938-55	Salo and Bayliff (1958)
Nisqually	WA	--	mid May	1979-80	Pearce et al. (1982)
Deschutes	WA	--	late Apr-early May	1977-82	Blankenship and Tivel (1980), Seiler et al. (1981, 1984)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Skookum Cr. (Puget Sound)	WA	--	late Apr-early May	1977-78	Blankenship and Tivel (1980)
Mill Cr. (Puget Sound)	WA	--	mid May	1976-87	Blankenship and Tivel (1980), Lenzi (1983, 1985, 1987)
Goldsborough Cr. (Puget Sound)	WA	--	early May	1975	Blankenship and Tivel (1980)
Union (Hood Canal)	WA	--	May	1979-81	Blankenship et al. (1983)
Bear Cr. (Union R.)	WA	--	early-mid May	1978-87, 1992	Lenzi (1983, 1985, 1987), Lestelle et al. (1993)
Courtney Cr. (Union R.)	WA	--	early-mid May	1976-87, 1992	Blankenship and Tivel (1980), Lenzi (1983, 1985, 1987), Lestelle et al. (1993)
Mission (Hood Canal)	WA	--	early-mid May	1978-87, 1992	Lenzi (1983, 1985, 1987), Blankenship et al. (1983), Lestelle et al. (1993)
Tahuya (Hood Canal)	WA	--	late Apr-mid May	1980-81	Blankenship et al. (1983)
Little Tahuya (Hood Canal)	WA	--	late Apr-early May	1978-87, 1992	Lenzi (1983, 1985, 1987), Lestelle et al. (1993)
Skokomish	WA	early Apr-mid June	early-mid May	1988-89	Haymes and Dygert (1988), Martenson and Dygert (1989)
Big Beef Cr. (Hood Canal)	WA	Mar-June	early-mid May	1975-82	Seiler et al. (1981, 1984)
Snow Cr. (Discovery Bay)	WA	Apr-June	mid May	1978-90	Johnson and Cooper (1993)
Elwha	WA	--	mid May	--	Wunderlich et al. (1989)
Dickey	WA	early Apr-early June	early May	1971-94	J. Haymes (1994 App.)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Soleduck	WA	Apr-early June	early May	1971-94	J. Haymes (1994 App.)
Calawah/Bogachiel	WA	early Apr-early June	early May	1971-94	J. Haymes (1994 App.)
Hoh	WA	--	May	--	Houston (1983)
Queets (Clearwater R.)	WA	--	late May-early June	1981-82	Seiler et al. (1984)
Humptulips	WA	--	mid May	1973-84	Brix (1981), Linth and Hooper (1984)
Chehalis	WA	--	mid May	--	WDF (1973)
		--	mid May	1973-80	Brix (1981)
		--	late Apr-early May	1981-84	Linth and Hooper (1984)
Chehalis (upper)	WA	early Apr-late May	late Apr-early May	1976-77	Brix and Seiler (1977, 1978)
Chehalis (Bingham Cr.)	WA	--	early-mid May	1982	Seiler et al. (1984)
Chehalis (Satsop R.)	WA	--	mid May	1973-84	Brix (1981), Linth and Hooper (1984)
		--	late Apr-early May	1984-85	King and Young (1986a, b)
Chehalis (Wynochee R.)	WA	--	mid May	1973-80	Dunn (1978), Brix (1981).
Grays Harbor	WA	--	mid May	1973-84	Brix (1981), Linth and Hooper (1984)
Willapa Bay	WA	--	Apr	--	WDF (1973)
Columbia (Grays R.)	WA	--	Apr	--	WDF (1973)
		--	mid May	--	R. Woodard (1994 App.)
Columbia (Elochoman R.)	WA	--	Apr	--	WDF (1973)
		--	mid May	--	R. Woodard (1994 App.)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Columbia (Cowlitz R.)	WA	--	May	--	WDF (1973)
		--	mid May	--	R. Woodard (1994 App.)
Columbia (Kalama R.)	WA	--	May	--	WDF (1973)
		--	mid May	--	R. Woodard (1994 App.)
Columbia (Lewis R.)	WA	--	May	--	WDF (1973)
		Mar-late June	mid May	1980-89	R. Woodard (1994 App.)
		--	early May	1985-87	Pettit (1993)
Columbia (Washougal R.)	WA	--	May	--	WDF (1951), R. Woodard (1994 App.)
Columbia (Sandy R./Cedar Cr.)	OR	--	May	1963	Niska and Willis (1963)
Columbia (Clackamas R., early)	OR	Mar-July	May-June	--	Murtagh et al. (1992)
		Apr-mid June	early-mid May	1987-92	Cramer and Cramer (1994)
Columbia (Clackamas R., late)	OR	Feb-July	May-June	1971-86	Murtagh et al. (1992)
		Feb-July	May-early June	1960-92	Cramer and Cramer (1994)
Columbia (Gnat Cr.)	OR	mid Feb-mid June	May	1954-59	Willis (1962)
Columbia (Big Cr.)	OR	--	late May	1962	Niska and Willis (1963)
Columbia (Klaskanine/Youngs R.)	OR	--	early May	1963	Niska and Willis (1963)
Wilson (Spring Cr.)	OR	Feb-June	Apr	1949-58	Skeesick (1970)
Tillamook (Sand Cr.)	OR	mid Mar-mid June	early May	1946-49	Sumner (1953)
Nestucca (East Cr.)	OR	--	late Apr	1988-91	Johnson et al. (1993), Rodgers et al. (1993), H. Weeks (1994 App.)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Nestucca (Moon Cr.)	OR	--	late Apr-early May	1988-91	Rodgers et al. (1993)
Salmon	OR	--	May	1975-76	McGie (1977)
Alsea	OR	Mar-May	Mar-Apr	1959-73	Moring and Lantz (1975)
Alsea (Lobster Cr.)	OR	Feb-June	late Mar-early Apr	1988-93	Johnson et al. (1993), Rodgers et al. (1993), H. Weeks (1994 App.)
Alsea (Drift Cr.)	OR	Feb-May	--	--	Chapman (1965)
Alsea (Crooked Cr.)	OR	--	May	1973-79	H. Weeks (1994 App.)
Tenmile Cr.	OR	--	May	1992-93	Johnson et al. (1993), H. Weeks (1994 App.)
Cummins Cr.	OR	--	late Apr-early May	1992-93	Johnson et al. (1993), H. Weeks (1994 App.)
Siuslaw	OR	Feb-June	mid May	1983	Rodgers et al. (1993)
Siuslaw (Triangle Lake)	OR	--	early May	1973	H. Weeks (1994 App.)
Tenmile Lake	OR	--	mid May	1970-75	McGie (1970-73, 1975)
Floras Lake	OR	--	mid May	1973	H. Weeks (1994 App.)
Coquille	OR	--	late Apr-early May	1979	H. Weeks (1994 App.)
Sixes	OR	Mar-June	early-mid May	1969	Reimers (1971)
Smith (Mill Cr.)	CA	Apr-May	early May	1993	T. Sloat (1994 App.)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Klamath	CA	Feb-June	Apr-May	--	Leidy and Leidy (1984)
		Apr-June	mid May	1971	Healey (1973)
		May-June	late May	1988-91	USFWS (1989), Craig (1991, 1992), Goldsmith (1993)
Klamath (Blue Cr.)	CA	Apr-June	mid May	1989-92	Stern and Noble (1990), Gilroy et al. (1992), Chan and Longenbaugh (1994)
Klamath (Hunter Cr.)	CA	Apr-May	May	1990	Lintz and Noble (1990)
Klamath (Turwar Cr.)	CA	mid Apr-May	early May	1989	Noble and Lintz (1989)
Klamath (Bear Cr.)	CA	mid Apr-June	mid May	1990	Lintz and Noble (1990)
Klamath (Ah Pah Cr.)	CA	late Mar-June	late May	1991	Lintz and Kisanuki (1991)
Klamath (Tectah Cr.)	CA	Mar-June	early May	1990	Lintz and Noble (1990)
Klamath (Roach Cr.)	CA	late Mar-July	Apr	1991	Lintz and Kisanuki (1991)
Trinity	CA	Apr-June	late May	1969-69	Healey (1973)
		Mar-mid June	late May	1988-91	Goldsmith (1993)
Redwood Cr.	CA	May-early June	mid Apr	1993-94	Redwood National Park (1994)
Mad	CA	Mar-early June	late May	--	L. Preston (1994 App.)
Eel	CA	Apr-June	late May	1973-74	Puckett (1976)
Eel (S. F.)	CA	Mar-early Aug	June	1966	Puckett (1976)
Eel (East Branch S. F.)	CA	June-early Aug	late June	1966	Puckett (1976)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Eel (Ten Mile Cr.)	CA	mid Mar-July	Apr	1966	Puckett (1976)
Eel (Redwood Cr.)	CA	Mar-mid Aug	early June	1966	Puckett (1976)
Mattole	CA	late Mar-May	late Apr	--	R. Barnhart (1994 App.)
Ten Mile	CA	early Apr-May	early May	--	W. Jones (1994 App.)
Noyo	CA	Mar-late May	late May	--	W. Jones (1994 App.)
Casper Cr.	CA	late Feb-June	early May	1964-68	Graves and Burns (1970)
Big	CA	Mar-early June	late Apr	--	W. Jones (1994 App.)
Navarro	CA	late Feb-June	late Apr	--	W. Jones (1994 App.)
Garcia	CA	early Mar-May	mid Apr	--	W. Jones (1994 App.)
Gualala	CA	late Feb-May	mid Apr	--	W. Jones (1994 App.)
Russian	CA	early Mar-June	late Apr	--	B. Cox (1994 App.)
Redwood Cr. (Pt. Bolinas)	CA	Apr-June	May	1954, 1967-68, 1971, 1984, 1989	May (1954), Arnold (1971), Snider (1984), Hofstra and Anderson (1989)
Lagunitas Cr.	CA	Mar-June	May	1982-85	Bratovich et al. (1984), Bratovich and Kelley (1988), Kelley and Associates and Entrix, Inc. (1992)
Lagunitas Cr. (Devils Gulch)	CA	Mar-June	May	1982-83	Bratovich et al. (1984)
Lagunitas (Nicasio Cr.)	CA	Apr-June	early-mid May	1964-65	Quinn and Allen (1969a, b)

Appendix Table C-1. Continued.

River (Tributary or location)	State/ province	Smolt outmigration duration	Peak smolt outmigration	Year(s) covered	Source
Lagunitas (San Geronimo Cr.)	CA	Mar-June	early May	1982-83	Bratovich et al. (1984)
Waddell Cr.	CA	late Mar-July	May	1933-42	Shapovalov and Taft (1954)
		Apr-June	mid May	1991-93	Smith (1992, 1993)
Scott Cr.	CA	Mar-May	mid May	1984-92	Nelson (1993, 1994), J. Nelson (1994 App.), D. Streig (1994 App.)
San Lorenzo	CA	Apr-mid Junee	mid May	1986-92	Nelson (1993), J. Nelson (1994 App.), J. Smith (1994 App.), D. Streig (1994 App.)

[a]Before logging.
[b]After logging.

Appendix Table C-2. Smolt sizes of selected coho salmon populations in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA). All measurements are fork length (mm) from fish reported as smolts.

River (Tributary or location)	State/ province	Smolt size range	Mean smolt size	Year(s) covered	Source
Taku	AK	25-129	93	1961	Meehan and Siniff (1962)
Karluk Lake	AK	--	107-114	1956-68	Drucker (1972)
Keogh (Vancouver Is.)	BC	85-130	104	1980-87	Irvine and Ward (1989)
Black Cr. (Vancouver Is.)	BC	78-172	110	1985-87	Labelle (1990)
Trent (Vancouver Is.)	BC	67-155	95	1985-87	Labelle (1990)
Big Qualicum (Vancouver Is.)	BC	--	98	1964-73	Fraser et al. (1983)
French Cr. (Vancouver Is.)	BC	68-168	93	1986-87	Labelle (1990)
Cowichan (Vancouver Is.)	BC	46-180	92	1975-76	Argue et al. (1979)
		--	101	1987-90	Bams (1993)
Carnation Cr. (Vancouver Is.)	BC	45-120	74	1971-83	Holtby and Healey (1986)
Squamish	BC	--	73-100	1973-75	Argue and Armstrong (1977)
Fraser (Sweltzer)	BC	--	110-120	1937	Foerster and Ricker (1953)
Fraser (Salmon R.)	BC	--	95	1978-80	Schubert (1982b)
Stillaguamish	WA	45-182	97	1981-82	Seiler et al. (1984)
		--	88-118	1988-89	Kirby et al. (1988, 1990)
Snohomish (Little Pilchuck Cr.)	WA	62-212	107	1977-87	Lenzi (1983, 1985, 1987)
Snohomish (Griffin Cr.)	WA	--	91	1979-81	Blankenship et al. (1983)

Appendix Table C-2. Continued.

River (Tributary or location)	State/ province	Smolt size range	Mean smolt size	Year(s) covered	Source
Snohomish (Harris Cr.)	WA	69-289	105	1979-87	Blankenship et al. (1983), Lenzi (1985, 1987)
Snohomish (S. F. Skykomish)	WA	48-148	89	1978-82	Seiler et al. (1981, 1984)
Snohomish	WA	--	100	1978-82	Seiler et al. (1981, 1984)
Sammamish (Little Bear Cr.)	WA	--	93	1976-78	Blankenship and Tivel (1980)
Sammamish (North)	WA	--	96	1976-77	Blankenship and Tivel (1980)
Green	WA	--	96-124	1991-92	Dilley and Wunderlich (1992, 1993)
Wild Cat Cr. (Puget Sound)	WA	70-202	101	1979-87	Lenzi (1983, 1985, 1987)
Lost Cr. (Puget Sound)	WA	70-186	98	1979-87	Lenzi (1983, 1985, 1987)
Minter Cr. (Puget Sound)	WA	--	95	1953	Salo and Bayliff (1958)
Mill Cr. (Puget Sound)	WA	--	115	1976-87	Blankenship and Tivel (1980), Lenzi (1983, 1985, 1987)
Skookum Cr. (Puget Sound)	WA	--	110	1976-77	Blankenship and Tivel (1980)
Goldsborough Cr. (Puget Sound)	WA	--	113	1976-77	Blankenship and Tivel (1980)
Deschutes	WA	81-200	115	1977-82	Seiler et al. (1981, 1984)
Union (Hood Canal)	WA	--	102	1979-81	Blankenship et al. (1983)
Bear Cr. (Union R.)	WA	70-171	96	1978-87, 1992	Lenzi (1983, 1985, 1987), Lestelle et al. (1993)
Courtney Cr. (Union R.)	WA	68-186	94	1976-87, 1992	Blankenship and Tivel (1980), Lenzi (1983, 1985, 1987) Lestelle et al. (1993)

Appendix Table C-2. Continued.

River (Tributary or location)	State/ province	Smolt size range	Mean smolt size	Year(s) covered	Source
Mission R. (Hood Canal)	WA	70-242	98	1978-87, 1992	Lenzi (1983, 1985, 1987), Blankenship et al. (1983), Lestelle et al. (1993)
Tahuya R. (Hood Canal)	WA	--	99	1980-81	Blankenship et al. (1983)
Little Tahuya R. (Hood Canal)	WA	62-251	106	1978-87, 1992	Lenzi (1983, 1985, 1987), Lestelle et al. (1993)
Skokomish	WA	61-142	100	1986-89	Lestelle and Weller (1994)
Big Beef Cr. (Hood Canal)	WA	55-247	109	1976-82	Blankenship and Tivel (1980), Seiler et al. (1981, 1984)
Snow Cr. (Discovery Bay)	WA	60-170	107	1978-90	Johnson and Cooper (1993)
Hoko R. (Strait of Juan de Fuca)	WA	69-140	106	1986-89	Lestelle and Weller (1994)
Dickey	WA	--	114	1992-93	Haymes and Tierney (1993)
Queets (Clearwater)	WA	76-188	124	1981-82	Seiler et al. (1984)
Humptulips	WA	82-137	--	1973-84	Brix (1981), Linth and Hooper (1984)
		95-120	--	1987-88	Schroder and Fresh (1992)
Chehalis	WA	92-138	--	1973-84	Brix (1981), Linth and Hooper (1984)
		106-135	--	1987-88	Schroder and Fresh (1992)
Chehalis (Bingham Cr.)	WA	78-182	112	1982	Seiler et al. (1984)
Chehalis (Satsop R.)	WA	86-141	--	1973-80	Brix (1981), Linth and Hooper (1984)
		--	115	1984-85	King and Young (1986a, b)
Chehalis (Wynochee R.)	WA	--	130	1973-75	Dunn (1978)
		80-143	--	1973-80	Brix (1981), Linth and Hooper (1984)

Appendix Table C-2. Continued.

River (Tributary or location)	State/ province	Smolt size range	Mean smolt size	Year(s) covered	Source
Grays Harbor	WA	108-151	--	1981-84	Linth and Hooper (1984)
Columbia (Lewis R.)	WA	100-140	121	1985-87	Pettit (1993)
Columbia (Sandy R./Cedar Cr.)	OR	70-120	99	1962-63	Niska and Willis (1963)
Columbia (Clackamas R. late)	OR	70-5	117	1965-92	Cramer and Cramer (1994)
Columbia (Gnat Cr.)	OR	51-175	115	1954-59	Willis (1962)
Columbia (Big Cr.)	OR	78-138	114	1962-63	Willis (1962)
Columbia (Klaskanine/Youngs)	OR	83-143	114	1962-63	Niska and Willis (1963)
Wilson	OR	--	100	1949-58	Skeesick (1970)
Tillamook (Sand Cr.)	OR	41-184	105-110	1946-49	Sumner (1953)
Nestucca (East Cr.)	OR	--	100[a]	1988-90	Rodgers et al. (1993)
		--	116[b]	1991-92	Rodgers et al. (1993)
Nestucca (Moon Cr.)	OR	--	97-102	1988-92	Rodgers et al. (1993)
Yaquina	OR	88-160	118	1980	Nicholas et al. (1982)
Alsea (Lobster Cr.)	OR	--	86[a]	1988-91	Rodgers et al. (1993),
		--	91[b]	1992-93	Rodgers et al. (1993), H. Weeks (1994 App.), Johnson et al. (1993)
Alsea (E. F. Lobster Cr.)	OR	--	82-83	1988-92	Rodgers et al. (1993)
Alsea (Drift Cr.)	OR	--	80-90	1959-62	Chapman (1965)

Appendix Table C-2. Continued.

River (Tributary or location)	State/ province	Smolt size range	Mean smolt size	Year(s) covered	Source
Alsea (Deer Cr.)	OR	--	97	1960-73	Knight (1979)
Alsea (Flynn Cr.)	OR	--	95	1960-73	Knight (1979)
Alsea (Needle Cr.)	OR	--	93	1960-73	Knight (1979)
Siuslaw	OR	--	100-107	1983	Rodgers et al. (1987)
Umpqua	OR	--	100	1991	B. Roper (1994 App.)
Tenmile Lake	OR	--	152	1970-75	McGie (1970-73, 1975)
Sixes	OR	88-150	120	1969	Reimers (1971)
Rogue	OR	--	108-139	1975-81	Cramer et al. (1985)
Klamath	CA	95-170	143	1989-91	Craig (1991, 1992), Goldsmith (1993),
Klamath (Blue Cr.)	CA	91-124	104	1989-92	Stern and Noble (1990), Gilroy et al. (1992), Chan and Longenbaugh (1994)
Klamath (Turwar Cr.)	CA	93-130	115	1989	Noble and Lintz (1989)
Trinity	CA	106-188 90-200	147 141	1968 1989-91	Healey (1973) Craig (1991, 1992), Goldsmith (1993)
Casper Cr.	CA	83-95	92	1964, 1968	Graves and Burns (1970)
Redwood Cr. (Pt. Bolinas)	CA	78-148	96	1967-68	Arnold (1971)
Lagunitas Cr. (Tomales Bay)	CA	70-194	130	1983	Bratovich et al. (1984)

Appendix Table C-2. Continued.

River (Tributary or location)	State/ province	Smolt size range	Mean smolt size	Year(s) covered	Source
Lagunitas Cr. (Nacascio)	CA	101-140	121	1964	Quinn and Allen (1969a)
Waddell Cr.	CA	100-120	110	1933-41	Shapovalov and Taft (1954)
Scott Cr.	CA	90-125	114	1933-41	Shapovalov and Taft (1954)

[a]Prior to habitat restoration.
[b]After habitat restoration.

Appendix Table C-3. River entry timing of selected coho salmon populations in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA).

River (Tributary or location)	State/ province	River entry duration[a]	Peak river entry[a]	Year(s) covered	Source
Sashin Cr.	AK	Aug-mid Oct	Sep	1934-67	Crone and Bond (1976)
Black Cr. (Vancouver Is.)	BC	late Oct-late Nov	early Nov	1985-88	Labelle (1990)
Trent (Vancouver Is.)	BC	early Oct-late Nov	early Nov	1985-88	Labelle (1990)
Big Qualicum (Vancouver Is.)	BC	mid Sep-late Dec	late Oct	1959-72	Fraser et al. (1983)
French Cr. (Vancouver Is.)	BC	mid Oct-late Nov	late Oct	1985-88	Labelle (1990)
Cowichan (Vancouver Is.)	BC	--	mid Oct-mid Nov	1976-77	Lister et al. (1981)
Fraser	BC	Sep-Oct	Oct	--	Aro and Shepard (1967)
Fraser (Birkenhead R.)	BC	--	mid Oct-mid Nov	1984	Schubert et al. (1985)
Nooksack	WA	Sep-Dec	mid Sep	1935	Chapman et al. (1936)
		--	early Oct	1977-93	WDFW (1994a)
		early Sep-early Nov	--	--	WDF et al. (1993)
Samish	WA	mid Aug-late Nov	--	--	WDF et al. (1993)
Skagit	WA	mid Aug-Dec	mid Sep	1935	Chapman et al. (1936)
		--	late Sep	1978-93	WDFW (1994a)
		mid July-late Dec	--	--	WDF et al. (1993)
		--	late Oct-early Nov	--	R. Hayman (1994 App.)
Skagit (Baker)	WA	late July-late Sep	--	--	WDF et al. (1993)
Stillaguamish	WA	--	mid Oct	1980-93	WDFW (1994a)
		early Sep-early Nov	--	--	WDF et al. (1993)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Snohomish	WA	Sep-Nov	early Oct	1935	Chapman et al. (1936)
		early Sep-late Oct	--	--	WDF et al. (1993)
Snohomish (Skykomish)	WA	Sep-early Dec	Oct	1978-81	Seiler et al. (1981, 1984)
Cedar	WA	mid Sep-early Nov	--	--	WDF et al. (1993)
Duwamish	WA	--	early Oct	1972-93	WDFW (1994a)
Green	WA	late Sep-early Nov	--	--	WDF et al. (1993)
Puyallup	WA	--	mid-late Sep	1972-93	WDFW (1994a)
		mid Aug-late Oct	--	--	WDF et al. (1993)
Minter Cr. (Puget Sound)	WA	Oct-Jan	mid Nov	1937-39	Salo and Bayliff (1958)
Nisqually	WA	--	mid Oct	1972-93	WDFW (1994a)
		mid Sep-early Dec	--	--	WDF et al. (1993)
Deschutes	WA	late Sep-mid Dec	late Oct-early Nov	1978-81	Seiler et al. (1981, 1984)
		mid Sep-mid Nov	--	--	WDF et al. (1993)
Skokomish	WA	--	early Oct	1979-90	WDFW (1994a)
		mid Sep-mid Nov	--	--	WDF et al. (1993)
Hamma Hamma (Hood Canal)	WA	mid Sep-mid Nov	--	--	WDF et al. (1993)
Duckabush (Hood Canal)	WA	mid Sep-mid Nov	--	--	WDF et al. (1993)
Dosewallips (Hood Canal)	WA	mid Sep-early Nov	--	--	WDF et al. (1993)
Big Beef Cr. (Hood Canal)	WA	mid Oct-early Jan	late Oct-early Nov	1978-81	Seiler et al. (1981, 1984)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Discovery Bay	WA	early Oct-mid Dec	--	--	WDF et al. (1993)
Dungeness	WA	--	mid Oct	1975-83	WDFW (1994a)
		mid Sep-late Nov	--	--	WDF et al. (1993)
Elwha	WA	--	mid Oct	1977-93	WDFW (1994a)
		mid Sep-early Dec	--	--	WDF et al. (1993)
Pysht (Strait of Juan de Fuca)	WA	mid Sep-early Nov	--	--	WDF et al. (1993)
Hoko (Strait of Juan de Fuca)	WA	mid Sep-mid Nov	--	--	WDF et al. (1993)
Sekiu (Strait of Juan de Fuca)	WA	mid Sep-mid Nov	--	--	WDF et al. (1993)
Sooes/Waatch (Pacific)	WA	early Sep-mid Jan	--	--	WDF et al. (1993)
Quillayute	WA	--	early Oct	1972-93	WDFW (1994a)
		--	early Nov	--	J. Haymes (1994 App.)
		early Sep-early Dec	--	--	WDF et al. (1993)
Quillayute (Dickey)	WA	late Sept-mid Jan	early Nov	1971-94	J. Haymes (1994 App.)
Quillayute (Soleduck summer)	WA	early Aug-mid Sep	--	--	WDF et al. (1993)
		--	early Sep	--	J. Haymes (1994 App.).
Quillayute (Calawah/ Bogachiel)	WA	late Sept-mid Jan	early Nov	1971-94	J. Haymes (1994 App.)
Hoh	WA	--	mid Oct	1972-93	WDFW (1994a)
Queets	WA	--	early Oct	1972-93	WDFW (1994a)
		mid Sep-early Dec	--	--	WDF et al. (1993)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Quinault	WA	Sep-Dec	mid Oct-mid Nov	1935	Chapman et al. (1936)
		--	mid Oct	1972-93	WDFW (1994a)
		mid Sep-late Dec	--	--	WDF et al. (1993)
Grays Harbor	WA	Sep-mid Dec	mid Oct-mid Nov	1935	Chapman et al. (1936)
Humptulips	WA	early Oct-late Dec	--	--	WDF et al. (1993)
Chehalis	WA	--	late Oct	1977-93	WDFW (1994a)
		early Oct-mid Dec	--	--	WDF et al. (1993)
Chehalis (early run)	WA	mid Aug-Sep	--	--	WDF (1951)
Chehalis (late run)	WA	Oct-Dec	--	--	WDF (1951)
Willapa Bay	WA	Oct-Dec	mid Nov	1935	Chapman et al. (1936)
		mid Sep-mid Dec	--	--	WDF et al. (1993)
Columbia	WA	Sep-Dec	mid Sep-mid Dec	1935	Chapman et al. (1936)
Columbia (early run)	WA	--	Oct	--	Mullen (1981)
Columbia (Grays R.)	WA	Oct-Dec	--	--	WDF (1951)
		mid Aug-Feb	Oct-late Nov	--	R. Woodard (1994 App.)
		mid Aug-late Dec	--	--	WDF et al. (1993)
Columbia (Elochoman R.)	WA	mid Aug-late Jan	Oct-late Nov	1980-89	R. Woodard (1994 App.)
		mid Aug-late Dec	--	--	WDF et al. (1993)
Columbia (Abernathy Cr.)	WA	Oct-Jan	--	--	WDF (1951)
		mid Aug-late Dec	--	--	WDF et al. (1993)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Columbia (Cowlitz R.)	WA	--	Jan	--	WDF (1973)
		mid Aug-late Jan	Oct-late Dec	1980-89	R. Woodard (1994 App.)
		late Oct-late Nov	--	--	WDF et al. (1993)
Columbia (Toutle R.)	WA	--	mid Aug-Sep	--	LeMier (1955)
		mid Aug-late Dec	--	--	WDF et al. (1993)
Columbia (Kalama R.)	WA	--	Oct	--	WDF (1973)
		mid Aug-late June	Oct-late Nov	1980-89	R. Woodard (1994 App.)
		early Sep-late Dec	--	--	WDF et al. (1993)
Columbia (Kalama R. early)	WA	mid Aug-Sep	--	--	WDF (1951)
Columbia (Kalama R. late)	WA	Oct-Dec	--	--	WDF (1951)
Columbia (Lewis R.)	WA	--	Oct	--	WDF (1973)
		mid Aug-late Dec	--	--	WDF et al. (1993)
Columbia (Lewis R. early)	WA	mid Aug-Sep	--	--	WDF (1951)
		mid Aug-late Jan	Oct-late Nov	1980-89	R. Woodard (1994 App.)
Columbia (Lewis R. late)	WA	Oct-Dec	--	--	WDF (1951)
Columbia (Washougal R.)	WA	Oct-Dec	--	--	WDF (1951)
		--	Oct	--	WDF (1973)
		mid Aug-late Jan	Oct-late Nov	1980-89	R. Woodard (1994 App.)
		mid Aug-late Dec	--	--	WDF et al. (1993)
Columbia (Sandy R.)	OR	Sep-Feb	Oct-Nov	1960-83	Howell et al. (1985)
Columbia (Clackamas R. early)	OR	Oct-Nov	mid Oct	--	Mullan (1984)
		late Aug-late Nov	Sep	1988-92	Cramer and Cramer (1994)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Columbia (Clackamas R. late)	OR	Aug-Sep	early Sep	--	Mullan (1984)
		Aug-Mar	Nov	1959-69	Howell et al. (1985)
		late Dec-Mar	Feb	1988-92	Cramer and Cramer (1994)
Columbia (Gnat Cr.)	OR	mid Sep-mid Feb	late Oct	1955-62	Willis (1962)
Nehalem	OR	--	Oct	1923-56	Mullen (1981)
Tillamook Bay	OR	--	Oct	1923-56	Mullen (1981)
Tillamook (Sandy Cr.)	OR	Oct-Jan	Nov-Dec	1946-49	Sumner (1953)
Nestucca	OR	--	Oct	1923-26	Mullen (1981)
Salmon	OR	--	Oct	1923-36	Mullen (1981)
Siletz	OR	--	Oct	1923-56	Mullen (1981)
Yaquina	OR	--	Oct	1923-56	Mullen (1981)
Alsea	OR	--	Oct	1923-56	Mullen (1981)
Siuslaw	OR	--	Oct	1923-56	Mullen (1981)
Umpqua	OR	--	Oct	1923-47	Mullen (1981)
Tenmile Lake	OR	Oct-early Feb	late Oct-early Jan	1955-56	Morgan and Henry (1959)
Coos	OR	--	Oct	1923-46	Mullen (1981)
Coquille	OR	--	Oct	1923-56	Mullen (1981)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Rogue	OR	Sep-Oct	early Oct	1977-82	Cramer et al. (1985)
Smith (Mill Cr.)	CA	Dec-mid Feb	late Dec	1980-87	Waldvogel (1988)
		Dec-Feb	late Dec-mid Jan	1993-94	T. Sloat (1994 App.)
Klamath	CA	late Sep-Nov	mid Oct	1919	Snyder (1931)
		mid Sep-Oct	mid Sep	1953-54	McCormick (1958)
		Nov-Jan	late Dec	--	Leidy and Leidy (1984)
		late Aug-Sep	mid Sep	1985-92	J. Polos (1994 App.)
Klamath (Shasta R.)	CA	Sep-Oct	late Oct	1957	Coots (1958)
Klamath (Salmon R.)	CA	Sep-mid Jan	Nov	1968-91	M. Pisano (1994 App.)
Klamath (Small tributaries)	CA	--	Dec	1988, 1990	B. Bemis (1994 App.)
Trinity	CA	Oct-mid Jan	mid Nov	1994	R. Barnhart (1994 App.)
Trinity (Rush Cr.)	CA	Oct-Dec	mid Nov	1992	E. Miller (1994 App.)
Trinity (Deadwood Cr.)	CA	Nov-Dec	Nov	1992	E. Miller (1994 App.)
Trinity (Junection City)	CA	Oct-mid Dec	mid Nov	1989-91	Zuspan et al. (1992a, b)
Trinity (Dry Cr.)	CA	late Oct-Jan	early Jan	1986-87	Gunter (1988b)
Trinity (North Fork)	CA	late Oct-Dec	late Nov	1964-68	Murray (1966a-68)
		Oct-Jan	early Jan	1969-70	Smith (1975)
		Oct-early Jan	late Nov	1984-86	Bedell (1987a, b)
		mid Oct-Jan	early Dec	1989-91	Zuspan et al. (1992a, b)
Trinity (South Fork)	CA	Oct-Dec	late Nov	1985, 1990-93	M. Dean (1994 App.)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Redwood Cr.	CA	Oct-early Feb	early Dec	1972-83	Redwood National Park (1994), D. Anderson (1994 App.)
Redwood (Prairie and Lost Man Cr.)	CA	Sep-Feb	mid Jan	1972-83	Redwood National Park (1994), D. Anderson (1994 App.)
Mad	CA	Oct-Feb	mid Dec	1938-53	Murphy and Shapovalov (1952), Shapovalov and Taft (1954)
		mid Oct-Jan	mid Nov	1983-87	Barngrover (1986; 1987a, b; 1988)
Eel	CA	Nov-early Feb	late Nov-early Dec	1938-44	Shapovalov and Taft (1954)
Eel (South Fork)	CA	Nov-Feb	mid Dec	1938-49	Murphy and Shapovalov (1952), Shapovalov and Taft (1954)
Ten Mile	CA	Dec-Feb	late Dec	1990-91	Maahs and Gilleard (1994)
Pudding Cr.	CA	Oct-Feb Nov-Feb Dec-Feb	early Dec early Dec Jan	1957-58 1960-61 1990-92	Allen (1958) Strohschein (1961) Maahs and Gilleard (1994)
Noyo	CA	late Nov-Jan Dec-Feb	early Jan late Dec	1985-87 1990-92	Milligan (1987), Poe (1988) Maahs and Gilleard (1994)
Casper Cr.	CA	Dec-Feb	early Jan	1990-91	Maahs and Gilleard (1994)
Little	CA	Dec-Feb	mid Jan	1990-91	Maahs and Gilleard (1994)
Russian	CA	mid Nov-Feb	early Jan	1986-87	Gunter (1988b), B. Cox (1994 App.)
Redwood Cr. (Pt. Bolinas)	CA	Nov-mid Feb	late Dec	1944-51, 1961, 1967-68, 1984, 1988, 1994	Arnold (1971), Snider (1984), Hofstra and Anderson (1989), D. Hatch (1994 App.)

Appendix Table C-3. Continued.

River (Tributary or location)	State/ province	River entry duration	Peak river entry	Year(s) covered	Source
Lagunitas Cr.	CA	late Nov-Jan	late Dec	1982-83	Bratovich et al. (1984)
		late Nov-Feb	early Jan	1983-85	Bratovich and Kelley (1988)
Lagunitas Cr. (Devils Gulch)	CA	late Nov-Jan	late Dec	1982-83	Bratovich et al. (1984)
Lagunitas Cr. (Haggerty Gulch)	CA	late Nov-Feb	early Jan	1982-83	Bratovich et al. (1984)
Lagunitas (Nicasio Cr.)	CA	late Nov-Feb	mid-late Dec	1949, 1951-56, 1958-62	D. Hatch (1994 App.)
		late Nov-Feb	late Dec	1982-83	Bratovich et al. (1984)
Lagunitas Cr. (San Geronimo Cr.)	CA	late Nov-Feb	mid Jan	1982-83	Bratovich et al. (1984)
Lagunitas (Olema Cr.)	CA	mid Nov-Feb	mid Jan	1984-93	D. Hatch (1994 App.)
Waddell Cr.	CA	late Sep-Feb	mid Dec	1933-41	Shapovalov and Taft (1954)
		late Nov-Feb	mid-late Jan	1991-93	Smith (1992), Nelson (1993)
Scott Cr.	CA	late Sep-Feb	mid Dec	1934-41	Shapovalov and Taft (1954)
		late Nov-Feb	mid Jan	1983-93	Streig (1991), Nelson (1993)
San Lorenzo	CA	late Sep-Feb	mid Dec	1964	Johnson (1964)
		late Nov-Feb	mid Jan	1970-73	Johansen (1975)
		late Sep-Mar	mid Feb	1976-77	Santa Cruz County (1979)
		mid Nov-Feb	early Jan	1983-93	Streig (1993)

[a]River entry was taken from reports which specifically listed it or was based on the timing of in-river catches of coho salmon. For timings based on in-river catch records, durations of river entry was estimated as the temporal range of in-river catches, while peak river entry was estimated as the time when the most fish were caught.

Appendix Table C-4. Spawn timing of selected coho salmon populations in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA).

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Sashin Cr.	AK	Oct-mid Nov	mid Oct	1967	Crone and Bond (1976)
Big Qualicum (Vancouver Is.)	BC	--	late Nov	1959-72	Fraser et al. (1983)
Cowichan (Vancouver Is.)	BC	--	mid Nov-early Jan	1976-77	Lister et al. (1981)
		Oct-Dec	Nov	--	Aro and Shepard (1967)
Fraser tributaries	BC	Oct-Jan	Nov	--	Aro and Shepard (1967)
		late Oct-Mar	early Dec-mid Feb	1977-78	Schubert (1982a)
Fraser (Birkenhead)	BC	late Nov-Feb	mid Dec	1984	Schubert et al. (1985)
Fraser (Cultus Lake)	BC	--	Dec	--	Foerster and Ricker (1953)
Boundary Bay tributaries	BC	late Oct-mid Jan	mid Nov-mid Dec	1977-78	Schubert (1982a)
Nooksack	WA	Oct-mid Jan	--	--	Williams et al. (1975)
		late Oct-Jan[a]	mid Dec[a]	1979-92	WDFW (1994c)
		mid Oct-mid Jan	--	--	WDF et al. (1993)
Samish	WA	--	mid Dec	1979-92	WDFW (1994c)
		mid Sep-late Jan	--	--	WDF et al. (1993)
Skagit	WA	Oct-mid Jan	--	--	Williams et al. (1975)
		--	mid Dec-mid Jan	1985-90	R. Hayman (1994 App.)
		mid Oct-early Feb	mid Dec	1979-92	WDFW (1994c)
		late Sep-mid Feb	--	--	WDF et al. (1993)
Skagit (Baker R.)	WA	Jan	--	--	WDF et al. (1993)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Stillaguamish	WA	Oct-Jan	--	--	Williams et al. (1975)
		late Oct-early Feb	early-mid Dec	1979-92	WDFW (1994c)
		--	late Nov	--	Nelson (1992)
		mid Nov-late Jan	--	--	WDF et al. (1993)
Snohomish	WA	mid Oct-mid Jan	--	--	Williams et al. (1975), WDF et al. (1993)
		mid Oct-early Mar	early-mid Dec	1979-92	WDFW (1994c)
Lake Washington basin	WA	mid Oct-Feb	--	--	Williams et al. (1975)
		mid Oct-early Feb	mid Nov-early Dec	1979-92	WDFW (1994c)
Duwamish	WA	late Sep-early Jan	mid Nov-early Dec	1979-92	WDFW (1994c)
Cedar	WA	mid Oct-early Mar	--	--	WDF et al. (1993)
Green	WA	mid Oct-Feb	--	--	Williams et al. (1975)
		late Oct-early Dec	--	--	WDF et al. (1993)
Puyallup	WA	mid Oct-Jan	--	--	Williams et al. (1975)
		Oct-Jan	mid Nov	1979-92	WDFW (1994c)
		mid Oct-mid Jan	--	--	WDF et al. (1993)
Nisqually	WA	mid Sep-mid Jan	--	--	Williams et al. (1975)
		late Oct-Feb	mid Dec	1979-92	WDFW (1994c)
		mid Nov-mid Jan	--	--	WDF et al. (1993)
Deschutes	WA	mid Oct-early Jan	--	--	Williams et al. (1975), WDF et al. (1993)
		late Oct-Feb	late Nov-early Dec	1979-92	WDFW (1994c)
Union (Hood Canal)	WA	Nov-mid Dec	mid-late Nov	1979-92	WDFW (1994c)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Skokomish	WA	mid Nov-mid Jan	mid Dec	1979-92	WDFW (1994c)
		late Oct-mid Jan	--	--	WDF et al. (1993)
Dewatto (Hood Canal)	WA	mid Oct-mid Dec	mid Nov	1979-92	WDFW (1994c)
		late Oct-early Jan	--	--	WDF et al. (1993)
Hamma Hamma	WA	mid Oct-mid Dec	late Oct-Nov	1979-92	WDFW (1994c)
		early Nov-late Dec	--	--	WDF et al. (1993)
Duckabush (Hood Canal)	WA	Oct-Dec	late Nov-early Dec	1979-92	WDFW (1994c)
		early Nov-mid Jan	--	--	WDF et al. (1993)
Dosewallips (Hood Canal)	WA	mid Nov-early Dec	mid-late Nov	1979-92	WDFW (1994c)
		early Nov-late Dec	--	--	WDF et al. (1993)
Big Beef Cr. (Hood Canal)	WA	Nov-Dec	early Dec	1979-92	WDFW (1994c)
Quilcene (Hood Canal)	WA	Oct-mid Dec	late Oct-mid Nov	1979-92	WDFW (1994c)
Discovery Bay	WA	late Oct-early Jan	--	--	WDF et al. (1993)
Dungeness	WA	mid Sep-mid Dec	mid Oct-Nov	1979-92	WDFW (1994c)
		late Oct-early Jan	--	--	WDF et al. (1993)
Elwha	WA	Nov-early Feb	--	--	Williams et al. (1975)
		mid Sep-mid Dec	mid Oct	1979-72	WDFW (1994c)
		late Oct-early Jan	--	--	WDF et al. (1993)
Pysht (Strait of Juan de Fuca)	WA	late Nov-early Jan	early Dec	1979-92	WDFW (1994c)
		early Nov-mid Jan	--	--	WDF et al. (1993)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Hoko (Strait of Juan de Fuca)	WA	Oct-Dec	mid Dec	1979-92	WDFW (1994c)
		early Nov-mid Jan	--	--	WDF et al. (1993)
Lyre (Strait of Juan de Fuca)	WA	mid Oct-Jan	--	--	Phinney and Bucknell (1975)
		mid Oct-mid Dec	early Dec	1979-92	WDFW (1994c)
Sekiu (Strait of Juan de Fuca)	WA	early Nov-early Jan	--	--	WDF et al. (1993)
Sooes/Waatch	WA	early Sep-mid Jan	--	--	WDF et al. (1993)
Quillayute	WA	mid Nov-Jan	mid Dec-mid Jan	1985-89	Mosley (1993)
		early Oct-mid Feb	mid Dec	1971-94	J. Haymes (1994 App.)
		mid Nov-mid Jan	--	--	WDF et al. (1993)
Quillayute (Soleduck)	WA	mid Sep-mid Dec	early Nov	1991-93	J. Meyer (1994 App.)
Quillayute (Soleduck fall)	WA	mid Nov-mid Jan	mid Dec	1979-92	WDFW (1994c)
Quillayute (Soleduck summer)	WA	mid Oct-mid Nov	--	--	Houston (1983)
		mid Oct-mid Nov	late Oct	1979-92	WDFW (1994c)
		--	mid Nov	1971-93	J. Haymes (1994 App.)
		late Oct-early Dec	--	--	WDF et al. (1993)
Quillayute (Calawah/Bogachiel)	WA	early Oct-mid Nov	mid Dec	1971-94	J. Haymes (1994 App.)
Hoh	WA	mid Oct-Jan	--	--	Phinney and Bucknell (1975)
		mid Nov-Jan	mid Dec	1979-92	WDFW (1994c)
		late Oct-mid Feb	--	--	WDF et al. (1993)
		mid Nov-Jan	mid Dec-mid Jan	1985-92	Mosley (1993)
Queets	WA	mid Nov-late Jan	--	--	WDF et al. (1993)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Queets/Quinault	WA	mid Oct-Jan	--	--	Phinney and Bucknell (1975)
		mid Oct-early Feb	mid-late Dec	1979-92	WDFW (1994c)
Quinault	WA	early Nov-mid Feb	--	--	WDF et al. (1993)
Humptulips	WA	Nov-early Feb	mid Nov	1979-92	WDFW (1994c)
		mid Nov-late Feb	--	--	WDF et al. (1993)
Chehalis	WA	mid Oct-Jan	--	--	Phinney and Bucknell (1975)
		Nov-early Feb	mid Nov-early Dec	1979-92	WDFW (1994c)
		mid Nov-late Feb	--	--	WDF et al. (1993)
Chehalis (Hoquiam R.)	WA	mid Nov-early Feb	mid-late Dec	1979-92	WDFW (1994c)
Willapa	WA	late Nov-Jan	--	--	Phinney and Bucknell (1975), WDF et al. (1993)
Columbia (lower)	WA	late Nov-Jan	--	--	Howell et al. 1985
Columbia (early)	WA	Oct-Nov	late Oct-early Nov	--	Mullan (1984)
Columbia (late)	WA	late Nov-Mar	Dec-early Jan	--	Mullan (1984)
Columbia (Grays R.)	WA	Oct-late Junee	Oct-Nov	--	R. Woodard (1994 App.)
		late Sep-late Jan	--	--	WDF et al. (1993)
Columbia (Elochoman R.)	WA	Oct-late Jan	Oct-late Nov	1980-89	R. Woodard (1994 App.)
		late Sep-late Jan	--	--	WDF et al. (1993)
Columbia (Abernathy Cr.)	WA	late Nov-Mar	Jan	--	WDF (1951)
		late Sep-late Jan	--	--	WDF et al. (1993)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Columbia (Cowlitz)	WA	--	Jan-Mar	--	WDF (1973)
		--	Oct-Nov	--	R. Woodard (1994 App.)
		late Oct-early Jan	--	--	WDF et al. (1993)
Columbia (Cowlitz/Toutle R.)	WA	--	mid Oct	1938	Burner (1951)
Columbia (Cowlitz R. early)	WA	late Oct-Nov	--	--	WDF (1951)
Columbia (Cowlitz R. late)	WA	late Nov-Mar	--	--	WDF (1951)
Columbia (Kalama)	WA	--	Nov	--	WDF (1973)
		Oct-late Jan	Nov	1980-89	R. Woodard (1994 App.)
		late Sep-late Jan	--	--	WDF et al. (1993)
Columbia (Kalama R. early)	WA	late Oct-Nov	--	--	WDF (1951)
Columbia (Kalama R. late)	WA	late Nov-Mar	--	--	WDF (1951)
Columbia (Lewis R.)	WA	--	Dec	--	WDF (1973)
		late Sep-late Jan	--	--	WDF et al. (1993)
Columbia (Lewis R. early)	WA	late Oct-late Nov	--	--	WDF (1951)
Columbia (Lewis R. late)	WA	late Nov-Mar	--	--	WDF (1951)
Columbia (Washougal)	WA	--	Oct-Nov	--	WDF (1951)
		Oct-late Jan	Oct-late Dec	1980-89	R. Woodard (1994 App.)
		late Sep-late Jan	--	--	WDF et al. (1993)
Columbia (Washougal R. late)	WA	Nov-Mar	--	--	WDF (1973)
Columbia (Hood R.)	OR	Oct-Nov	--	--	Howell et al. (1985)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Columbia (Clackamas R. early)	OR	Sep-Dec	Oct-Nov	--	Murtagh et al. (1992), Cramer and Cramer (1994)
Columbia (Clackamas R. late)	OR	late Oct-early Jan	--	--	Howell et al. (1985)
		late Jan-mid Mar	mid Feb	1985-89	Cramer and Cramer (1994)
		mid Jan-late Mar	Feb-Mar	--	Murtagh et al. (1992)
Columbia (Gnat Cr.)	OR	early Oct-Feb	late Oct-early Nov	1955-61	Willis (1962)
Necanicum	OR	early Nov-late Dec[b]	late Nov[b]	1982-92[c]	ODFW spawning surveys[d]
Nehalem	OR	early Nov-late Jan	late Nov/early Dec	1982-92	ODFW spawning surveys
Miami	OR	early Nov-early Dec	mid Nov	1982-92	ODFW spawning surveys
Kilchis	OR	early Nov-mid Dec	mid Nov	1982-92	ODFW spawning surveys
Wilson	OR	late Dec-Feb	--	--	Willis (1954)
		early Nov-mid Jan	early Dec	1982-92	ODFW spawning surveys
Tillamook (Sand Cr.)	OR	Oct-mid Feb	Nov-Dec	1946-49	Sumner (1953)
Tillamook	OR	late Oct-late Dec	late Oct, Dec	1982-92	ODFW spawning surveys
Nestucca	OR	mid Nov-mid Dec	late Nov/early Dec	1982-92	ODFW spawning surveys
Salmon	OR	Oct-Feb	Nov, Jan	1975-77	McGie (1977)
		late Oct-late Nov	late Nov	1982-92	ODFW spawning surveys
Siletz	OR	early Nov-early Jan	late Nov	1982-92	ODFW spawning surveys
Yaquina	OR	early Nov-early Jan	late Nov	1982-92	ODFW spawning surveys

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Beaver Cr.	OR	early Nov-late Jan	mid Dec	1982-92	ODFW spawning surveys
Alsea	OR	late Oct-Jan	mid Dec	1951-52	Morgan and Cleaver (1954)
		mid Nov-Feb	Dec	1959-73	Moring and Lantz (1975)
		early Nov-late Jan	mid Dec	1982-92	ODFW spawning surveys
Alsea (Deer, Flynn, Needle Cr.)	OR	--	late Dec-early Jan	1963-64	Koski (1965)
Yachats	OR	mid Nov-late Jan	mid Dec	1982-92	ODFW spawning surveys
Siuslaw	OR	late Oct-late Jan	mid Dec	1982-92	ODFW spawning surveys
Siltcoos	OR	mid Dec-late Jan	early Jan	1982-92	ODFW spawning surveys
Tahkenitch	OR	early Dec-late Jan	late Dec	1982-92	ODFW spawning surveys
Umpqua	OR	late Oct-early Jan	early Dec	1982-92	ODFW spawning surveys
Tenmile Lake	OR	mid Nov-early Feb	late Nov-early Dec	1955-56	Morgan and Henry (1959)
		early Dec-late Jan	early Jan	1982-92	ODFW spawning surveys
Coos	OR	mid Nov-late Jan	mid Dec	1982-92	ODFW spawning surveys
Coquille	OR	mid Nov-early Feb	mid Dec	1982-92	ODFW spawning surveys
Smith (Mill Cr.)	CA	Dec-Feb	mid Jan	1980-87, 1993-94	Waldvogel (1988), T. Sloat (1994 App.)
Klamath	CA	Nov-Dec	early Dec	1953-54	McCormick (1958)
		Nov-Feb	Jan	--	Leidy and Leidy (1984)
		Nov-Dec	mid Dec	1985-92	J. Polos (1994 App.)
Klamath (Shasta)	CA	Nov-Jan	late Dec	1957	Coots (1958)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Klamath (Salmon)	CA	Nov-Jan	Dec	1968-91	M. Pisano (1994 App.)
Klamath (Small Tributaries)	CA	--	Dec	1988, 1990	B. Bemis (1994 App.)
Trinity	CA	Nov-Jan	Dec	1994	R. Barnhart (1994 App)
Trinity (Rush Cr.)	CA	Nov-mid Jan	Dec	1992	E. Miller (1994 App.)
Trinity (Deadwood Cr.)	CA	Nov-Dec	late Nov	1992	E. Miller (1994 App.)
Trinity (Junection City)	CA	Nov-Dec	mid Nov	1989-91	Zuspan et al. (1992a, b)
Trinity (North Fork)	CA	Nov-Jan Nov-Dec Nov-mid Jan	early Jan early Dec mid Dec	1964-70, 1974 1984-86 1989-91	Murray (1966a-68), Smith (1975) Bedell (1987a, b) Zuspan et al. (1992a, b)
Trinity (South Fork)	CA	Nov-Jan	early Jan	1985, 1990-93	M. Dean (1994 App.)
Redwood Cr.	CA	Nov-Jan	early Dec	1972-83	Redwood National Park (1994), D. Anderson (1994 App.)
Redwood Cr. (Prairie and Lost Man Cr.)	CA	mid Nov-early Feb Nov-Jan	Dec early Dec	1948-53 1972-83	Briggs (1953) Redwood National Park (1994)
Mad	CA	Nov-Feb	early Dec	1938-53	Murphy and Shapovalov (1952), Shapovalov and Taft (1954)
Eel	CA	Nov-mid Mar	early Dec	1938-44	Shapovalov and Taft (1954)
Eel (South Fork)	CA	Nov-Mar	Dec	1938-49	Murphy and Shapovalov (1952), Shapovalov and Taft (1954)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Ten Mile	CA	Dec-Feb	early Jan	1990-91	Maahs and Gilleard (1994)
Pudding	CA	Nov-Feb	mid Dec	1957-61	Allen (1958), Strohschein (1961)
		Dec-Feb	Jan	1990-91	Maahs and Gilleard (1994)
Noyo	CA	Nov-Feb	late Dec-early Jan	1985-87	Milligan (1987), Poe (1988)
		Dec-Feb	early Jan	1990-92	Maahs and Gilleard (1994)
Casper Cr.	CA	Dec-Feb	Jan	1990-91	Maahs and Gilleard (1994)
Little	CA	Dec-Feb	Jan	1990-91	Maahs and Gilleard (1994)
Russian	CA	Nov-mid Feb	late Dec-mid Jan	1986-87, 1994	Gunter (1988b), B. Cox (1994 App.)
Redwood Cr. (Pt. Bolinas)	CA	Nov-mid Feb	late Dec	1967-68, 1984, 1988	Arnold (1971), Snider (1984), Hofstra and Anderson (1989)
		late Nov-late Feb	--	1944-51, 1961, 1994	D. Hatch (1994 App.)
Lagunitas Cr.	CA	late Nov-Jan	late Dec	1982-83	Bratovich et al. (1984)
		late Nov-Feb	early Jan	1983-85	Bratovich and Kelley (1988)
Lagunitas Cr. (Devils Gulch)	CA	Dec-Jan	late Dec	1982-83	Bratovich et al. (1984)
Lagunitas Cr. (Haggerty Gulch)	CA	Dec-Jan	early Jan	1982-83	Bratovich et al. (1984)
Lagunitas Cr. (Nicasio Cr.)	CA	Dec-Feb	mid-late Dec	1949, 1951-56, 1958-62, 1982-83	D. Hatch (1994 App.), Bratovich et al. (1984)
Lagunitas Cr. (San Geronimo Cr.)	CA	Dec-Feb	late Dec	1982-83	Bratovich et al. (1984)
Lagunitas Cr. (Olema Cr.)	CA	mid Nov-late Feb	early Jan	1987-94	D. Hatch (1994 App.)

Appendix Table C-4. Continued.

River (Tributary or location)	State/ province	Spawn timing duration	Peak spawn timing	Year(s) covered	Source
Waddell Cr.	CA	late Nov-Feb	mid Dec-mid Jan	1933-41	Shapovalov and Taft (1954)
		Dec-Feb	mid-late Jan	1991-93	Smith (1992), Nelson (1993)
Scott Cr.	CA	late Nov-Feb	mid Dec-mid Jan	1934-41	Shapovalov and Taft (1954)
		Dec-Feb	mid-late Jan	1983-93	Streig (1991), Nelson (1993)
San Lorenzo	CA	Dec-Feb	mid Dec	1964	Johnson (1964)
		late Nov-Feb	mid Jan	1970-73	Johansen (1975)
		mid Dec-Mar	mid Feb	1976-77	Santa Cruz County (1979)
		Dec-Feb	early Jan	1983-93	Streig (1993)

[a]Duration of spawning and peak spawning timing reported for the Washington Department of Fish and Wildlife spawner survey database (WDFW 1994c) were estimated from the combined frequency of peaks in spawning activity in all survey areas within a given river basin, all years combined. Duration of spawning was estimated as the temporal range of these spawning peaks, while peak spawning timing was estimated as the time when the most spawning peaks occurred.

[b]Duration of spawning and peak spawning timing reported for Oregon Department of Fish and Wildlife (ODFW) spawner surveys were estimated from the combined frequency of peaks in spawning activity in all survey areas within a given river basin, all years combined. Duration of spawning was estimated as the temporal range of these spawning peaks, while peak spawning timing was estimated as the time when the most spawning peaks occurred.

[c]ODFW spawning survey data for 1984 was not available for any of the rivers surveyed by ODFW.

[d]ODFW coastal spawning survey data was compiled from annual coastal spawning suveys (McGie 1983, 1984, Jacobs 1988a, 1989; Cooney and Jacobs 1990, 1992, 1993, 1994).

Appendix Table C-5. Spawner sizes of selected coho salmon populations in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA). All measurements are fork length (cm).

River (Tributary or location)	State/ province	Spawner size range	Mean spawner size	Year(s) covered	Source
Karluk Lake	AK	--	74.5	1966	Drucker (1972)
Sashin Cr.	AK	--	68.6	1965-69	Crone and Bond (1976)
Nakussin	AK	--	65.8	1966-72	Crone and Bond (1976)
Porcupine Cr.	AK	--	65.9	1979-80	Thedinga and Koski (1984)
Skeena	BC	--	66.4	1974-76	Beacham (1982)
Quinsam (Vancouver Is.)	BC	--	65.6	1974-76	Beacham (1982)
Oyster (Vancouver Is.)	BC	--	65.4[a]	1988	Fleming and Gross (1990)
Black Cr. (Vancouver Is.)	BC	37.9-87.3[a]	61.2[a]	1984-88	Labelle (1990)
		--	62.8[a]	1988	Fleming and Gross (1990)
Trent (Vancouver Is.)	BC	37.9-66.0[a]	57.9[a]	1984-88	Labelle (1990)
Big Qualicum (Vancouver Is.)	BC	--	67.1	1959-80	Beacham (1982), Fraser et al. (1983)
French Cr. (Vancouver Is.)	BC	36.7-66.0[a]	56.4[a]	1984-88	Labelle (1990)
Cowichan (Vancouver Is.)	BC	--	64.5[a]	1976-77	Lister et al. (1981)
Fraser	BC	--	65.3	--	Rounsefell (1957)
		--	66.4	1978	Beacham (1982)
Fraser (lower tributaries)	BC	--	58.9[a]	1977-78	Schubert (1982a)
Fraser (Birkenhead R.)	BC	--	63.6[a]	1984	Schubert et al. (1985)

Appendix Table C-5. Continued.

River (Tributary or location)	State/ province	Spawner size range	Mean spawner size	Year(s) covered	Source
Fraser (various tributaries)	BC	--	59.1[a]-63.3[a]	1984	Fleming and Gross (1990)
Boundary Bay tributaries	BC	--	58.4[a]	1977-78	Schubert (1982a)
Skagit	WA	29.0-96.0	58.0	1984-90	R. Hayman (1994 App.)
Stillaguamish	WA	--	53.0	1988-91	Kirby et al. (1988, 1990-91), Nelson (1992)
Snohomish (Deer Cr.)	WA	39.5-76.0	58.04[b]	1981-84	van den Berghe and Gross (1984, 1989), Fleming and Gross (1990)
Snohomish (Skykomish R.)	WA	--	59.0	1984	Fleming and Gross (1990)
Snohomish (S. F. Skykomish)	WA	39.0-83.0	61.5	1978-81	Seiler et al. (1981, 1984)
Snohomish (Griffin Cr.)	WA	--	57.9	1980-82	Blankenship et al. (1983)
Snohomish (Harris Cr.)	WA	--	57.6	1980-82	Blankenship et al. (1983)
Snohomish (Peyton Cr.)	WA	--	59.0[a, b]	1984	Fleming and Gross (1990)
Snohomish (Pilchuck R.)	WA	--	62.0	1976-79	Blankenship and Tivel (1980)
Sammamish (Little Bear Cr.)	WA	--	56.7	1978	Flint and Zillges (1980)
Sammamish (North Cr.)	WA	--	57.1	1977-78	Blankenship and Tivel (1980)
Deschutes	WA	--	61.5	1978-81	Seiler et al. (1981, 1984)
Mill Cr. (Puget Sound)	WA	--	60.2	1977-79	Blankenship and Tivel (1980)
Goldsborough Cr. (Puget Sound)	WA	--	60.0	1976	Blankenship and Tivel (1980)

Appendix Table C-5. Continued.

River (Tributary or location)	State/ province	Spawner size range	Mean spawner size	Year(s) covered	Source
Big Beef Cr. (Hood Canal)	WA	--	57.9	1977-81	Blankenship and Tivel (1980), Seiler et al. (1981, 1984)
Union (Hood Canal)	WA	--	55.8	1981-82	Blankenship et al. (1983)
Mission (Hood Canal)	WA	--	61.8	1982	Blankenship et al. (1983)
Quillayute	WA	--	67.2	1989-93	J. Haymes (1994 App.)
Quillayute (Soleduck fall)	WA	--	61.1	--	J. Meyer (1994 App.)
		--	73.8[a]	1973	Fleming and Gross (1990)
Quillayute (Soleduck summer)	WA	--	63.1	1989-93	J. Haymes (1994 App.)
Chehalis (Bingham Cr.)	WA	--	73.2	1978-81	Seiler et al. (1981, 1984)
Chehalis (Wynochee R.)	WA	--	69.9	1974-76	Dunn (1978)
Columbia	WA	--	75.9	1914	Marr (1943)
Columbia (Elochoman R.)	WA	--	71.8	1970	Hopley et al. (1978)
Columbia (Cowlitz R.)	WA	--	64.9	1970	Hopley et al. (1978)
Columbia (Toutle R.)	WA	--	68.0	1974	WDF (1977)
Columbia (Clackamas R. late)	OR	--	71.3	1985-88	Cramer and Cramer (1994)
Columbia (Gnat Cr.)	OR	--	53.6	1955-61	Willis (1962)
Nehalem	OR	--	69.5	1978-92	S. Jacobs (1994a App.)

Appendix Table C-5. Continued.

River (Tributary or location)	State/ province	Spawner size range	Mean spawner size	Year(s) covered	Source
Tillamook (Sand Cr.)	OR	32.5-94.7	54.6	1946-49	Sumner (1953)
Yaquina	OR	36.0-70.0	55.7	1980	Nicholas et al. (1982)
Alsea	OR	55.4-61.0	69.6	1959-73	Moring and Lantz (1975)
		--	65.8	1978-92	S. Jacobs (1994a App.)
Alsea (Deer Cr.)	OR	--	70.5	1963-64	Koski (1965)
Alsea (Flynn Cr.)	OR	--	69.2	1963-64	Koski (1965)
Tenmile Lake	OR	--	71.1	1955	Morgan and Henry (1959)
		--	71.0	1969-73, 1975	McGie (1970-73, 1975)
		--	60.0	1976-86	Ursitti (1989)
Coquille	OR	--	71.2	1978-92	S. Jacobs (1994a App.)
Rogue	OR	47.2-63.4	56.4	1976-86	ODFW (1989)
Klamath	CA	55.0-77.5	68.0	1953-54	McCormick (1958)
		55.0-84.0	63.6	1981-90, 1992	Adair et al. (1982-85), Tuss et al. (1989), Kisanuki et al. (1991), Rueth et al. (1992), Craig and Fletcher (1994)
Trinity (Willow Cr.)	CA	52.0-78.0	64.6	1990-91	Zuspan et al. (1992a, b)
Trinity (Junection City)	CA	48.0-73.0	62.2	1990-91	Zuspan et al. (1992a, b)
Trinity (North Fork)	CA	45.7-96.5	72.4	1970-71	Rogers (1973)
		30.0-75.0	64.0	1993	M. Zuspan (1994 App.)

Appendix Table C-5. Continued.

River (Tributary or location)	State/ province	Spawner size range	Mean spawner size	Year(s) covered	Source
Redwood Cr. (Prairie Cr.)	CA	--	76.1	1950-51	Briggs (1953),
		55.0-75.0	64.3	1990-92	Haux and Anderson (1992), Anderson and McGuire (1994), Redwood National Park (1994)
Redwood Cr. (Lost Man Cr.)	CA	--	63.0	1990-93	Haux and Anderson (1992), Anderson and McGuire (1994), Redwood National Park (1994)
Pudding Cr.	CA	33.0-81.0	65.7	1960-61	Strohschein (1961)
Olema Cr.	CA	45.7-63.5	--	--	D. Hatch (1994 App.)
Redwood Cr. (Pt. Bolinas)	CA	46.0-91.4	63.5	--	D. Hatch (1994 App.)
Waddell Cr.	CA	--	64.0	1933-41	Shapovalov and Taft (1954)

[a]Converted from post orbital-hypural length using Beacham (1982).
[b]Mean of female adult sizes; male sizes not reported.

Appendix Table C-6. Marine recoveries of coded-wire tags, expanded for sampling, from selected production facilities in Alaska (AK), British Columbia (BC), Washington (WA), Oregon (OR), and California (CA) by release location, including years released, expanded number of tags recovered by state or province, total number of tags recovered, and percent recoveries by state or province. Data from PSMFC 1994.

Hatchery	State/ province	Brood years	Expanded number of marine recoveries (% of total)					Total
			AK	BC	WA	OR	CA	
Crystal Lake	AK	1975, 78-89	15,409.9 (98.7)	198.3 (1.3)	3.7 (0.0)	0.0 (0.0)	0.0 (0.0)	15,611.9
Little Port Walter	AK	1974, 77-82	6,818.6 (98.8)	85.3 (1.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	6,903.9
Kitimat River	BC	1983-89	4,641.0 (38.7)	7,340.4 (61.2)	3.1 (0.0)	0.0 (0.0)	0.0 (0.0)	11,984.5
Bella Bella	BC	1985-89	745.9 (15.1)	4,201.4 (84.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4,947.3
Port Hardy	BC	1983-84, 89	55.8 (1.2)	4,695.0 (98.7)	5.9 (0.1)	0.0 (0.0)	0.0 (0.0)	4,756.7
Puntledge River	BC	1976-89	96.8 (0.2)	53,229.3 (96.7)	1,656.7 (3.0)	35.8 (0.1)	0.0 (0.0)	55,018.6
Rosewall Creek	BC	1972-74, 76-78, 84-87	12.6 (0.0)	42,917.6 (93.2)	3,091.3 (6.7)	13.4 (0.0)	0.0 (0.0)	46,034.9
Robertson Creek	BC	1972-89	221.9 (0.6)	35,009.7 (96.5)	1,022.7 (2.8)	14.5 (0.0)	0.0 (0.0)	36,268.8
Big Qualicum River	BC	1971-89	30.3 (0.0)	124,531.9 (95.2)	6,199.1 (4.7)	36.7 (0.0)	1.0 (0.0)	130,799.0
Capilano River	BC	1971-73, 75-89	35.8 (0.0)	157,048.5 (90.2)	16,229.3 (9.3)	883.4 (0.5)	1.0 (0.0)	174,198.0
Seymour River	BC	1979-80, 82	0.0 (0.0)	4,223.0 (92.4)	277.5 (6.1)	69.6 (1.5)	0.0 (0.0)	4,570.1
Chilliwack River	BC	1980-89	62.5 (0.1)	73,860.6 (92.0)	6,231.9 (7.8)	155.8 (0.2)	0.0 (0.0)	80,310.8
Nooksack	WA	1973-74, 80-89	9.1 (0.0)	30,885.8 (55.5)	24,629.1 (44.2)	164.8 (0.3)	9.0 (0.0)	55,697.8
Skookum Creek	WA	1973-79, 84-89	1.0 (0.0)	55,193.8 (54.8)	44,546.2 (44.3)	913.3 (0.9)	2.0 (0.0)	100,656.3
Samish	WA	1973-74, 76	0.0 (0.0)	3,999.9 (54.3)	3,295.1 (44.7)	69.9 (0.9)	0.0 (0.0)	7,364.9
Skagit (Clark Creek)	WA	1971-75, 79, 81-89	1.0 (0.0)	31,585.4 (56.1)	24,037.0 (42.7)	669.8 (1.2)	3.0 (0.0)	56,296.2
Skykomish	WA	1971, 73-74, 81-89	0.0 (0.0)	29,140.4 (57.6)	20,506.2 (40.6)	882.2 (1.7)	22.9 (0.0)	50,551.7
Issaquah	WA	1971-74, 77-79	0.0 (0.0)	8,238.1 (39.9)	12,041.9 (58.4)	348.9 (1.7)	1.0 (0.0)	20,629.9
Green River	WA	1971-89	7.6 (0.0)	59,998.5 (44.5)	72,021.1 (53.5)	2,578.8 (1.9)	74.1 (0.1)	134,680.1
Puyallup	WA	1972-89	0.0 (0.0)	42,563.0 (39.2)	64,135.1 (59.1)	1,759.7 (1.6)	30.9 (0.0)	108,488.7
Garrison Springs	WA	1973, 75, 77-79, 89	0.0 (0.0)	5,802.1 (43.7)	7,132.0 (53.8)	330.5 (2.5)	2.4 (0.0)	13,267.0
Minter Creek	WA	1970-71, 73-74, 77-83	0.0 (0.0)	10,846.4 (26.8)	29,033.8 (71.8)	539.7 (1.3)	2.0 (0.0)	40,421.9
George Adams	WA	1971, 73, 77-89	2.4 (0.0)	15,913.4 (50.7)	15,020.0 (47.9)	440.6 (1.4)	0.0 (0.0)	31,376.4
Hood Canal	WA	1971, 73, 77, 80-83	0.0 (0.0)	2,160.3 (42.9)	2,817.3 (55.9)	63.2 (1.3)	0.0 (0.0)	5,040.8
Quilcene NFH	WA	1974-81, 87-89	0.0 (0.0)	11,756.9 (57.1)	8,483.6 (41.2)	340.4 (1.7)	0.0 (0.0)	20,580.9
Dungeness	WA	1970-72, 75-80, 83, 86, 89	32.8 (0.1)	24,098.0 (53.0)	20,314.3 (44.7)	999.3 (2.2)	20.1 (0.0)	45,464.5
Lower Elwha	WA	1979-82, 85-89	98.8 (2.0)	3,711.3 (73.8)	1,159.5 (23.1)	60.5 (1.2)	0.0 (0.0)	5,030.1
Makah NFH	WA	1980, 86, 88-89	53.6 (0.5)	7,453.7 (73.6)	1,862.1 (18.4)	749.2 (7.4)	3.7 (0.0)	10,122.3
Soleduck	WA	1971-72, 74-76, 80-88	38.5 (0.2)	11,225.3 (54.1)	7,858.5 (37.9)	1,577.5 (7.6)	32.4 (0.2)	20,732.2
Quinault NFH	WA	1973-89	16.1 (0.1)	7,315.0 (58.8)	3,515.3 (28.3)	1,575.0 (12.7)	17.6 (0.1)	12,439.0
Humptulips	WA	1980, 82-89	94.3 (0.6)	9,806.8 (66.6)	3,184.8 (21.6)	1,637.7 (11.1)	0.0 (0.0)	14,723.6
Simpson	WA	1971-75, 80-89	65.5 (0.4)	6,431.8 (44.0)	7,709.2 (52.7)	407.4 (2.8)	8.0 (0.1)	14,621.9
Willapa	WA	1974, 80-86	34.5 (0.2)	7,556.9 (40.6)	7,245.5 (46.9)	2,716.1 (12.0)	17.4 (0.2)	17,570.4

Appendix Table C-6. Continued.

Hatchery	State/ province	Brood years	Expanded number of marine recoveries (% of total) AK		BC		WA		OR		CA		Total
Nemah	WA	1972, 80-83	13.3	(0.0)	1,999.5	(6.1)	2,561.0	(21.9)	868.8	(58.3)	35.8	(13.2)	5,478.4
Naselle	WA	1980-83	21.9	(0.2)	4,384.7	(43.0)	5,064.5	(41.2)	1,293.9	(15.5)	24.6	(0.1)	10,789.6
Grays River	WA	1974-85, 88-89	1.0	(0.2)	820.4	(36.5)	2,946.4	(46.7)	7,844.5	(15.9)	1,771.3	(0.7)	13,464.6
Elokomin	WA	1972, 74, 83-85, 88-89	0.0	(0.0)	500.6	(6.9)	2,819.6	(39.1)	3,455.7	(47.9)	437.7	(6.1)	7,213.6
Cowlitz	WA	1972, 80-89	1.0	(0.0)	3,838.6	(13.3)	13,948.2	(48.5)	10,612.3	(36.9)	376.4	(1.3)	28,776.5
Toutle	WA	1972, 77-78, 86-89	0.0	(0.0)	778.9	(4.3)	9,696.1	(53.0)	7,282.6	(39.8)	545.9	(3.0)	18,303.5
Kalama Falls	WA	1973, 83-85, 88-89	0.0	(0.0)	1,339.7	(9.4)	4,852.1	(34.0)	7,482.4	(52.4)	611.5	(4.3)	14,285.7
Lower Kalama	WA	1974, 80-81, 88-89	3.0	(0.1)	488.8	(16.1)	1,252.5	(41.1)	1,098.7	(36.1)	201.4	(6.6)	3,044.4
Lewis River	WA	1976, 84, 86-89	1.0	(0.0)	1,385.6	(11.8)	4,317.4	(36.9)	5,545.5	(47.4)	453.9	(3.9)	11,703.4
Speelyai	WA	1980-82, 85	0.0	(0.0)	202.5	(6.3)	762.9	(23.9)	2,050.9	(64.2)	179.1	(5.6)	3,195.4
Willard NFH	WA	1975-76, 78, 81-82, 88-89	0.0	(0.0)	113.8	(2.4)	1,183.5	(24.7)	2,945.6	(61.4)	554.0	(11.5)	4,796.9
Klickitat	WA	1972, 74-77, 83-89	0.0	(0.0)	553.6	(5.5)	5,519.6	(54.4)	3,693.6	(36.4)	374.2	(3.7)	10,141.0
Oxbow	OR	1981-86	0.0	(0.0)	231.6	(2.5)	2,701.6	(29.6)	5,630.1	(61.6)	569.9	(6.2)	9,133.2
Cascade	OR	1974-75, 77-89	0.0	(0.0)	810.5	(4.5)	4,188.5	(23.4)	11,667.4	(65.3)	1,196.4	(6.7)	17,862.8
Bonneville	OR	1975, 81-89	0.0	(0.0)	266.6	(4.5)	1,560.4	(26.6)	3,587.0	(61.2)	450.0	(7.7)	5,864.0
Eagle Creek NFH	OR	1974-77, 79-81, 87-89	0.0	(0.0)	627.3	(2.6)	5,605.5	(23.2)	14,663.1	(60.6)	3,311.8	(13.7)	24,207.7
Sandy	OR	1975-89	9.8	(0.0)	5,312.5	(5.2)	22,768.1	(22.2)	63,951.5	(62.3)	10,574.5	(10.3)	102,616.4
Big Creek	OR	1972-89	6.0	(0.0)	1,444.6	(3.9)	7,954.9	(21.6)	24,765.8	(67.1)	2,712.6	(7.4)	36,883.9
Klaskanine	OR	1973-74, 78-79, 81-89	0.0	(0.0)	451.8	(5.1)	2,141.9	(24.1)	5,403.5	(60.7)	907.3	(10.2)	8,904.5
SF Klaskanine	OR	1986-89	5.2	(0.2)	163.4	(5.3)	763.1	(24.6)	1,698.2	(54.6)	478.4	(15.4)	3,108.3
Nehalem	OR	1977-89	5.1	(0.1)	594.5	(6.3)	794.1	(8.4)	5,512.4	(58.5)	2,512.9	(26.7)	9,419.0
Trask	OR	1977-89	2.0	(0.0)	387.9	(5.0)	632.9	(8.1)	4,501.9	(57.9)	2,255.3	(29.0)	7,780.0
Salmon River	OR	1976-89	0.0	(0.0)	376.2	(5.9)	557.2	(8.8)	3,690.1	(58.1)	1,732.3	(27.3)	6,355.8
Siletz	OR	1977-85	0.0	(0.0)	231.1	(3.6)	332.7	(5.2)	3,811.6	(59.9)	1,993.1	(31.3)	6,368.5
Fall Creek	OR	1973-89	4.7	(0.0)	986.9	(3.8)	1,868.8	(7.1)	15,194.1	(57.9)	8,201.8	(31.2)	26,256.3
Rock Creek	OR	1980-89	0.0	(0.0)	246.6	(2.6)	177.6	(1.9)	5,677.2	(59.3)	3,470.0	(36.3)	9,571.4
Butte Falls	OR	1978-89	21.0	(0.2)	208.4	(1.8)	209.2	(1.8)	6,626.8	(57.2)	4,513.7	(39.0)	11,579.1
Cole Rivers	OR	1976-89	0.0	(0.0)	66.6	(0.6)	49.1	(0.4)	3,747.5	(33.8)	7,229.3	(65.2)	11,092.5
Iron Gate	CA	1974, 77-84, 88-89	0.0	(0.0)	6.4	(0.1)	14.5	(0.2)	1,715.6	(19.4)	7,098.5	(80.3)	8,835.0
Trinity River	CA	1976-85, 89	0.0	(0.0)	4.0	(0.0)	27.5	(0.1)	4,610.5	(22.5)	15,820.5	(77.3)	20,462.5
Mad River	CA	1975, 78-79, 84-86	0.0	(0.0)	1.1	(0.0)	16.3	(0.7)	495.2	(20.2)	1,933.1	(79.0)	2,445.7
Warm Springs	CA	1984-87	0.0	(0.0)	0.0	(0.0)	2.7	(0.3)	59.9	(7.2)	764.0	(92.4)	826.6
Total expanded tags recovered by state or province			28,681.3		921,848.5		522,559.2		261,217.6		83,539.7		1,817,927.3

Appendix D

Personal Communication and Unpublished Information Citations and Questionnaire Responses

APPENDIX D

This appendix contains citations for unpublished information submitted to the Endangered Species Act Administrative Record for West Coast Coho Salmon, responses to the NMFS Biological Review Team coho salmon stock questionnaire, and personal communications with NMFS personnel. All material cited here is available from Environmental Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon St., Portland, OR 97232.

Allen, S. (Pacific States Marine Fisheries Commission, Portland, OR). 1994. Letter to L. Weitkamp (NMFS), Enclosed hatchery release data from ODFW.

Anderson, D. (Redwood National Park, Orick, CA). 1994. Conversation with G. Bryant (NMFS), 4/94.

Barnhart, R. (U.S. Fish and Wildlife Service, California Cooperative Fisheries Research Unit, Arcata, CA). 1994. Conversation with G. Bryant (NMFS), 5/94.

Beamesderfer, R. (Oregon Department of Fish and Wildlife, Portland, OR). 1994. Letter to L. Weitkamp (NMFS), 12/16/94, Enclosed summaries of released of hatchery-reared fish in Oregon for 1986-92.

Bemis, B. (U.S. Forest Service). 1994. Questionnaires completed for Bear, China, Clear, Cougar, Dillon, Doolittle, East Fork Elk, South Fork Indian, Independence, Irving, Little Grider, Mill, Oak Flat, Swillup, Thompson, Ukonom, and Wooley Creeks, and all Klamath River tributaries, CA.

Berry, R. (Oregon Department of Fish and Wildlife, Portland, OR). 1994. Letter to L. Weitkamp (NMFS), 7/27/94, List of potential composition of Oregon coast coho hatchery stocks.

Boessow, S. (Washington Department of Fish and Wildlife). 1994. Letter to L. Weitkamp (NMFS), 7/8/94, Subject: Coho length frequency data from northern area 10 (WA) test fisheries.

Cox, B. (California Department of Fish and Game, Inland Fish Division, Region 3, Sebastopol, CA). 1994. Conversation with G. Bryant (NMFS), 4/94.

Dailey, D. (Makah Indian Tribe). 1994. Information given to L. Weitkamp (NMFS), 5/17/94, data reports.

Dean, M. (California Department of Fish and Game, Inland Fish Division, Region 1, Weaverville, CA). 1994. Questionnaires completed for Olsen, Pelletreu, Butter, Rattlesnake, Ectapom, and Hayfork Creeks, and South Fork Trinity River, CA.

DeLong, J. (Northwest Indian Fisheries Commission). 1994. FAX to L. Weitkamp 12/13/94, Attached information on coded-wire tag recoveries of coho salmon from Puget Sound hatcheries.

Feldmann, C. (Puget Power). 1994. Letter to Merritt Tuttle (NMFS), 3/25/94, Comments submitted in response to 59 Fed. Reg. 3662.

Fuss, H. (Washington Department of Fish and Wildlife, Olympia, WA). 1994. Conversation with L. Weitkamp (NMFS), 7/94.

Harp, J. (Quinault Indian Nation). 1994. Information given to L. Weitkamp (NMFS), 5/17/94, data reports.

Hatch, D. (National Park Service, Golden Gate National Recreation Area). 1994. Questionnaires completed for Olema and Redwood Creeks, CA.

Hayman, R. (Skagit System Cooperative, LaConner, WA). 1994. Questionnaire completed for the Skagit River, WA.

Haymes, J. (Quileute Natural Resources Department, Quileute Indian Tribe). 1994. Questionnaires completed for the Bogachiel, Calawah, Dickey, and Soleduck Rivers, WA.

Jacobs, S. (Oregon Department of Fish and Wildlife, Portland, OR). 1994a. Letter to L. Weitkamp (NMFS) 6/17/94, Information on size of adult coho salmon from Oregon streams.

Jacobs, S. (Oregon Department of Fish and Wildlife, Portland, OR). 1994b. Conversation with T. Wainwright (NMFS) 7/94.

Jones, W. (California Department of Fish and Game). 1994. Conversation with G. Bryant (NMFS), 4/94.

Jorgensen, J. (Hoh Indian Tribe). 1994. Information given to L. Weitkamp (NMFS), 5/94, concerning the Hoh River, WA.

Kane, T., and P. Wampler (U.S. Fish and Wildlife Service, Olympia). 1994. Questionnaire completed for the Big Quilcene River, WA.

King, S. (Oregon Department of Fish and Wildlife, Portland, OR). 1994. Letter to L. Weitkamp (NMFS), 6/94. Enclosed disc with coho length data from Columbia River gillnet fishery below Bonneville Dam (Zones 1-5), September only, 1976-1993.

Knudsen. C. (Washington Department of Fish and Wildlife, Olympia, WA). 1995. Letter to L. Weitkamp (NMFS), 1/25/95, Enclosed data regarding trends in coho salmon fecundity and length over time.

Kostow, K. (Oregon Department of Fish and Wildlife, Portland, OR). 1994. Conversation with T. Wainwright (NMFS), 12/94.

Markey, S. (Washington Department of Fish and Wildlife). 1994. Letter to L. Weitkamp (NMFS), 5/5/94, Enclosed information on coho salmon coded-wire tag recoveries from return years 1973-1993.

Meyer, J. (Olympic National Park, Port Angeles, WA). 1994. Questionnaire completed for the Soleduck River, WA.

Miller, E. (California Department of Fish and Game, Inland Fish Division, Region 1, Weaverville, CA). 1994. Questionnaires completed for Rush, Deadwood, and Browns Creeks, CA.

Nelson, J. (California Department of Fish and Game, Inland Fish Division, Region 3, Monterey, CA). 1994. Questionnaires completed for Scott and Waddell Creeks, and the San Lorenzo River, CA.

Pisano, M. (California Department of Fish and Game, Inland Fish Division, Region 1, Eureka, CA). 1994. Questionnaires completed for Bluff, Slate, Red Cap, Boise, Camp, Dillon, Ukonom, Clear, China, Elk, Indian, Thompson, Grider, West Fork Grider, Seiad, Horse, Barkhouse, Beaver, Humbug, Cottonwood, Willow, Swillup, Independence, Irving, Bogus, and Big Springs Creeks, and Shasta, Scott, and Salmon Rivers, CA.

Polos, J. (Yurok Tribal Fisheries Program). 1994. Memo to Greg Bryant (NMFS), 5/7/94, Subject: Coho data collected during harvest monitoring activities on Yurok Indian Reservation, CA.

Preston, L. (California Department of Fish and Game, Eureka, CA). 1994. Conversation with G. Bryant (NMFS), 4/94.

Roper, B. (U.S. Forest Service, Tiller Ranger District). 1994. Letter to L. Weitkamp (NMFS) 5/28/94, Enclosed information reflects current understanding of juvenile coho salmon within the upper south Umpqua Basin, OR.

Sloat, T. (Rellim Redwood Co., Crescent City, CA). 1994. Letter to G. Bryant (NMFS), Information about salmon monitoring and habitat on Miller Timber Co. lands, CA.

Smith, J. (California State University, San Jose, CA). 1994. Conversation with G. Bryant (NMFS), 5/94.

Spence, B. (U.S. Environmental Protection Agency, Corvallis, OR). 1994. Conversation with L. Weitkamp (NMFS), 9/94.

Streig, D. (Monterey Bay Salmon and Trout Project, Davenport, CA). 1994. Conversation with G. Bryant (NMFS), 4/94.

Weeks, H. (Oregon Department of Fish and Wildlife, Portland, OR). 1994. Letter to L. Weitkamp (NMFS) 5/4/94, Information on Oregon coho salmon life history characteristics.

Woodard, R. (Washington Department of Fisheries). 1994. Questionnaires completed for the Cowlitz, Elochoman, Grays, Kalama, Lewis, and Washougal Rivers, WA.

Wunderlich, R. (USFWS). 1994. Letter to G. Griffin (NMFS) 3/23/94, Summaries of coho salmon stock transfers at Quilcene Nation Fish Hatchery in Hood Canal, WA.

Zuspan, M. (California Department of Fish and Game, Inland Fish Division, Region 1, Arcata, CA). 1994. Questionnaires completed for Trinity River to Lewiston, Weaver Creek, CA.

Appendix E
Records of Hatchery Outplants

Appendix Table E-1. Releases of fry (F) and yearlings (Y) of out-of-basin coho salmon stocks in selected Oregon and Washinton river basins, arranged from south to north by evolutionarily significant units (ESUs). Multiple stocks from the same basin are included in the entire basin number (i.e., plants of Baker River and Clark Creek fish are included as Skagit plants).

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Southern Oregon/northern California coasts ESU			
Chetco	Coos	57	F	50,210	1
Rogue	Coos	58	F	75,210	1
		Oregon coast ESU			
New	Alsea	62, 65, 69-71	F, Y	2,052,201	5
	Bonneville	69-70	F	--[a]	2
	Cascade	69-70	F	--[a]	2
	Coos	57, 58	F	223,525	2
	Coquille	85	F	28,277	1
	Elk R.	69-70, 72-73	F, Y	769,872[b]	4
	Trask	69-71	F, Y	816,563	3
Umpqua	Alsea	64-68	F	1,685,574	5
	Coos	47-50, 52	F	355,020	5
	Cole Rivers (Rogue)	86	Y	8,554	1
	Nehalem	76	F	281,383	1
Siuslaw	Alsea/Fall Cr.	36, 51, 54, 64-74, 78, 80-87	F, Y	12,972,448[b]	24
	Carson	56	F	45,000	1
	Coos	50, 52-55, 57-58, 88-93	F, Y	840,917	13
	Floras Cr./New R.	82	F	12,000	1
	Siltcoos	92-94	F, Y	126,521	3
	Trask	61, 70, 73-74	F	1,879,132[b]	4
	Umpqua R.	85	Y	199,772	1
Coquille	Alsea	65-69, 71	F	3,741,943	6
	Coos	19, 24, 26, 48-53, 57-58	F	6,447,339	11
	Cole Rivers (Rogue)	82	F	16,000	1
Coos	Alsea	60, 62-70	F, Y	2,975,418[b]	10
	Bonneville	70	F, Y	--[a]	1
	Cascade	70	F, Y	--[a]	1
	Coquille	46, 83-93	Y	826,380[b]	12
	Elk R.	70	Y	--[a]	1
	Trask	61, 71	F, Y	274,108	2
	Necanicum	34	F	--[a]	1
	Tenmile	35	F	--[a]	1
	Klaskanine	46, 48-50	F	--[a]	4
Yachats	Siletz	58	F	36,842	1
Alsea	Nehalem	68, 70	F	--[a]	2
	Siletz	65	F	79,257	1
	Trask	68, 70, 72-75	F, Y	3,201,210[b]	6
Yaquina	Alsea/Fall Cr.	26, 34-36, 38, 54, 62, 68-70, 73, 80-83, 88	F, Y	1,913,989[b]	15

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Oregon coast ESU, continued			
Yaquina (cont.)	Nehalem	53	F	14,400	1
	Siletz	49, 50?, 51, 57-58, 65-66, 90	F, Y	592,866[b]	8?
	Tahkenich	38	F	--[a]	1
	Klaskanine	45-46, 50?	F, Y?	--[a]	3?
Siletz	Alsea/Fall Cr.	70, 74, 80-86	F, Y	2,316,667[b]	9
	Nehalem	33, 53, 83	F	95,500	3
	Salmon	78, 80-82, 84, 88	F, Y	849,672[b]	6
	Trask	30-31, 70, 72, 74-76, 78-79	F, Y	2,681,203[b]	9
Salmon	Nehalem	36	F	40,000	1
	Siletz	64	F	40,140	1
	Trask	29, 31, 40, 44	F	185,000	4
Nestucca	Alsea	72, 76	F	91,334	2
	Bonneville	58	F	315,000	1
	Nehalem	71	F	1,427,004	1
	Trask	29-30, 50-51, 55, 57, 63-73, 77-92	F, Y	5,370,925	33
Tillamook	Bonneville	58, 59	F, Y	250,000	2
	Klaskanine	50	Y	50,000	1
	Nehalem	81	Y	5,083	1
	Nestucca	80-81	F, Y	210,349	2
	Trask	41, 50-52, 55, 57, 65, 69, 77-79, 85	F, Y	959,811	12
Trask	Alsea	72	F	--[a]	1
	Bonneville	58-59	F, Y	730,000	2
	Nestucca	80-81	F, Y	1,335,986	2
	Sandy R.	82	Y	4,950	1
	Siletz	72	F	--[a]	1
Wilson	Alsea	76	F	1,000	1
	Bonneville	58, 59	F, Y	467,500	2
	Klaskanine	48, 50	F, Y	126,797	2
	Nehalem	35-36, 69-70, 78	F, Y	797,950	5
	Nestucca	81	Y	25,015	1
	Trask	31, 41, 50-52, 55, 57, 62-66, 69-70, 72-74, 78-82, 86	F, Y	5,190,434	23
Kilchis	Big Cr.	48	Y	85,800	1
	Bonneville	58-59	F, Y	160,000	2
	Klaskanine	50	Y	50,000	1
	Nehalem	36	F	160,000	1
	Trask	50-52, 55, 57, 61-68, 70-73, 80-82	F, Y	1,085,547	20
Miami	Big Cr.	48	Y	11,600	1
	Klaskanine	49	Y	16,112	1
	Nehalem	36, 50-53, 55, 58, 63-64	F	667,566	9
	Trask	31, 53, 61-62, 65, 69, 80-82	F, Y	776,158	10

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Oregon coast ESU, continued			
Nehalem	Alsea	74	F	229,582	1
	Big Cr.	53, 83	F	44,551	2
	Bonneville	18	F	247,600	1
	Klaskanine	47-50	F, Y	258,031	4
	Trask	28, 63, 65-66, 68-70, 79	F, Y	1,561,226	8
Necanicum	Klaskanine	48, 50-51	F, Y	148,194	3
	Nehalem	41, 55, 70, 78-83	F, Y	1,537,808	9
	Trask	76	Y	6,191	1
		Lower Columbia River/southwest Washington coast ESU			
Lewis and Clark	Bonneville	81, 87	F	110,280	2
	Klaskanine	48, 50-52	F, Y	391,504	4
	Sandy R.	80-83	F, Y	993,278	4
Youngs	Big Cr.	53, 59, 87, 91-92	F, Y	669,289	5
	Clackamas R. (early)	88-93	F, Y	5,561,484	6
	Cowlitz (Wash.).	84	F	110,176	1
	Kalama Falls	92	Y	405,976	1
	Sandy R.	83, 89, 92	Y	1,210,965	3
	Bonneville	87, 93	F, Y	1,470,403	2
	Klaskanine	51, 55, 58	Y	278,371	3
Klaskanine	Big Cr.	53, 82-83, 89	F, Y	1,865,284	4
	Bonneville	81, 84, 86-87, 89	F, Y	4,857,320	5
	Clackamas (early)	88-89	Y	671,922	2
	Cowlitz (Wash.)	84	F	61,651	1
	Eagle Cr.	81-82	Y	686,247	2
	Sandy R.	81-83, 87, 89-91	F, Y	2,839,393	7
	Siletz R.	90	Y	37,603	1
	Trask	57	Y	56,586	1
Big Cr.	Bonneville	86	Y	844,434	1
Gnat Cr.	Big Cr.	52, 56	F	37,914	2
Claskanie	Big Cr.	49, 51-53, 55-59	F	695,324	9
	Cowlitz (Wash.)	84	F	109,037	1
	Sandy R.	80, 82-83, 88	F, Y	969,774	4
	Bonneville	81, 87	F	992,337	2
Clackamas	Bonneville	36, 49, 52, 67-68, 82, 85, 87	F	2,603,675	8
	Cascade	83	F	402,447	1
	Cowlitz (Wash.)	84	F	140,429	1
	Gnat Cr.	83	F	395,776	1
	Oxbow	81, 84, 86-87	F	1,541,870	4
	Sandy	65-68, 70, 73-74, 81, 83-91	F, Y	5,448,809	17
	Trask	67	F	165,000	1
Sandy	Bonneville	18-19, 36, 38, 52	F	518,725	5

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
	Lower Columbia River/southwest Washington coast ESU, continued				
Big White Salmon	Cowlitz	85, 87	F	629,880	2
	Type N (Cowlitz)	81-87	F, Y	2,630,650	7
	Type S (Toutle)	71, 80	F, Y	1,047,841	2
	Unknown	73	F	336,704	1
Wind	Unknown	77, 79	F	416,890	2
	Carson	73	Y	1,540,600	1
	Lewis River	51, 53-54	F	407,598	3
	Type N (Cowlitz)	82	F	59,064	1
	Type S (Toutle)	67-68, 71, 73, 80	F	4,212,293	5
	Willard	87-88	F, Y	2,930,468	2
Washougal	Big Cr. (Oregon)	62	F	565,553	1
	Eagle Cr. (Oregon)	61	Y	60,000	1
	Green River	54	F	70,022	1
	Lewis River	54	F	100,000	1
	Toutle	55, 58-59, 65	F, Y	1,942,243	4
	Type N (Cowlitz)	74-77, 79-92	F, Y	30,046,629	18
	Type S (Toutle)	67-87, 89	F, Y	41,062,608	22
Lewis	Abernathy	63	F	518,056	1
	Big Cr. (Oregon)	65	Y	163,548	1
	Eagle Cr. (Oregon)	63	F	2,624,122	1
	Kalama Falls	63, 66	F, Y	167,152	2
	Klaskanine (Oregon)	62, 65	F, Y	272,148	2
	Toutle	58	Y	15,878	1
	Type N (Cowlitz)	75-92	F, Y	65,681,281	18
	Type S (Toutle)	67-92	F, Y	58,287,123	26
	Washougal	63	F	96,110	1
Kalama	Klaskanine (Oregon)	62, 65	F, Y	139,024	2
	Lewis River	54, 57	F	195,382	2
	Toutle	56-57, 59-64, 66	F, Y	2,681,290	9
	Type N (Cowlitz)	73-77, 79-92	F, Y	20,173,931	19
	Type S (Toutle)	67-75, 77-79, 81-82, 84-92	F, Y	37,655,135	24
	Washougal	60-61	F, Y	1,635,134	2
Cowlitz	Big Cr. (Oregon)	56-57, 64	F, Y	98,952	3
	Green River	54, 58-59, 64, 66	F, Y	569,724	5
	Kalama	65-66	Y	328,004	2
	Klaskanine (Oregon)	62, 65	F, Y	669,756	2
	Lewis River	54, 58, 90	F, Y	249,246	3
Elochoman	Ancient wild stock	63	Y	97,696	1
	Big Creek (Oregon)	56	F	51,327	1
	Eagle Cr. (Oregon)	61	Y	896,668	1
	Green River	54, 57, 61	F	289,803	3
	Klaskanine (Oregon)	62-65	F, Y	2,706,042	4
	Lewis River	57	F	100,701	1
	Toutle	55, 58, 61	F	162,213	3

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Lower Columbia River/southwest Washington coast ESU, continued			
Elochoman (cont.)	Type N (Cowlitz)	72, 74-87, 89-92	F, Y	30,135,913	19
	Type S (Toutle)	66, 68-81, 86, 90-92	F, Y	25,558,411	19
	Washougal	59, 60	F, Y	100,061	2
Grays	Ancient wild stock	51	F	16,800	1
	Big Cr. (Oregon)	56-57	F, Y	138,072	2
	Columbia River	81, 83, 85-89, 92-93	F, Y	5,881,394	9
	Elokomin	58, 81	F	119,526	2
	Green River	54	F	140,037	1
	Klaskanine (Oregon)	63-64	Y	1,374,284	2
	Lewis River	57	F	42,986	1
	Toutle	55, 60-61	F, Y	393,930	3
	Type N (Cowlitz)	73-78, 80-81	F, Y	4,573,325	8
	Type S (Toutle)	56, 62, 76-87, 90-91	F, Y	9,992,648	16
	Washougal	77	Y	446,031	1
Naselle	Unknown	72	F	52,193	1
	Ancient wild stock	51-54, 62, 65	F, Y	867,903	6
	Dungeness	56, 81-82	F, Y	678,220	3
	Green River	52, 54-56	F, Y	338,352	4
	Humptulips	80-81, 83	F, Y	1,828,710	3
	Nemah	56-59, 61-62, 66, 68-77, 79-82, 85	F, Y	10,269,112	22
	Satsop (Chehalis)	73	Y	57,134	1
	Simpson	63-64	F	202,880	2
	Soleduck	81	F	1,029,282	1
	Type N (Cowlitz)	91	Y	89,000	1
	Type S (Toutle)	70, 80	F	256,000	2
	Willapa	78, 80, 89	F, Y	1,888,461	3
Willapa	Ancient wild stock	51-59, 61-71	F, Y	8,850,762	20
	Dungeness	56-57	F, Y	313,310	2
	Green River	52-57	F, Y	621,688	6
	Humptulips	82	F	498,800	1
	Naselle	85-87	F	695,827	3
	Nemah	57, 59, 62, 71, 74, 77, 86	F, Y	1,018,656	7
	Soleduck (Lake Cr.)	61	F	56,245	1
	Satsop (Chehalis)	73	Y	58,520	1
	Simpson	59, 63	F	77,602	2
	Type N (Cowlitz)	90-91	F, Y	180,075	2
North	Ancient wild stock	53, 58, 61-62, 65-66, 68-71	F, Y	1,511,276	10
	Dungeness	56-57	F, Y	98,693	2
	Green River	52, 54-57	F, Y	208,569	5
	Naselle	83, 85-87	F	2,943,156	4
	Nemah	57, 59, 75-77, 80, 82, 86	F, Y	2,569,460	8
	Simpson	63, 85	F	72,958	2
	Willapa	72-73, 75-81, 89-91	F, Y	2,658,842	12

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Lower Columbia River/southwest Washington coast ESU, continued			
Chehalis	Unknown	74-78	F, Y	315,352	5
	Ancient wild stock	58, 69-71	F, Y	3,719,030	4
	Dungeness	57, 81	F	168,724	2
	George Adams	73	Y	3,060	1
	Green River	51-57, 91	F, Y	1,482,012	8
	Hood Canal	78-79	F, Y	1,316,618	2
	Humptulips	79-92	F, Y	26,684,614	14
	Naselle	83-84	F	608,000	2
	Nemah	68, 71, 73-76, 84	F, Y	2,973,579	7
	Quinault	78	Y	49,996	1
	Samish	56	F	70,280	1
	Skagit	76, 83	F, Y	61,070	3
	Skokomish	76	F	525,000	1
	Soleduck	61, 81	F, Y	1,836,380	2
	Soleduck (summer)	81-82	Y	310,660	2
	Sooes	86	F	17,134	1
	Type S (Toutle)	80	F	500,000	1
	Willapa	72-74, 78, 81, 83-84	F, Y	3,027,430	7
	Wishkah (Grays Hbr)	82	F	80,000	1
Humptulips	Green River	55	F	15,080	1
	Naselle	83	F	69,600	1
	Nemah	77, 79	Y	78,062[b]	2
	Satsop Spr (Chehalis)	91	F	1,000	1
	Simpson	51, 58, 61, 63-65, 72, 75, 77, 82, 84,	F, Y	591,888[b]	12
	Soleduck	81	Y	950,331	1
	Willapa	78-81	F, Y	815,916	4
	Willapa x Humptulips	78	Y	342,780	1
	Wishkah (Grays Hrbr.)	92-93	F	4,100	2
	Wynoochee (Chehalis)	78, 91	F, Y	521,080	2
Copalis	Humptulips	80, 82, 85, 89-90	F, Y	1,812,839	5
	Quinault	87	F	99,864	1
	Simpson	88	F	104,832	1
	Soleduck	81	F	124,478	1
	Willapa	75	Y	100,014	1
Moclips	Purdy Cr.	65	F	22,790	1
	Quilcene	63-69	F, Y	644,180	7
	Queets	85, 92	F	76,200	2
	Quinault	79-80, 83, 85, 87, 89-92	F	1,477,845	9
	Quinault x Queets	85	F	60,000	1
	Soleduck	63, 75	F, Y	176,730	2
	Willapa x Quinault	76	Y	50,000	1
		Olympic Peninsula ESU			
Quinault	Unknown	72, 77, 79	F, Y	1,142,220	3
	Cowlitz	77	F	419,000	1
	George Adams	77	F	864,000	1

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Olympic Peninsula ESU, continued			
Quinault (cont.)	Humptulips	80, 85, 90-91	F	121,450	4
	Mixed local	77-79, 83, 90	F, Y	2,028,285	4
	Queets	83, 85, 89-92	F, Y	1,248,804	6
	Quinault x Queets	85, 90	F, Y	1,689,383	2
	Simpson	68-69	F	21,500	2
	Soleduck	81	F	10,900	1
Queets	Unknown	79	F	105,000	1
	Mixed local	79, 83	F, Y	240,622	2
	Quillayute	74-77, 81, 84	F	1,149,676	6
	Quinault	73, 78, 80-91	F, Y	7,307,708	13
	Quinault x Queets	85-86, 90	Y	855,848	3
	Soleduck (summer)	78	F	21,824	1
	Willapa	87	Y	229,843	1
Hoh	Unknown	62, 77, 79	F, Y	221,899	2
	Dungeness	59, 61	F, Y	46,700	2
	Green x Quinault	77	Y	150,000	1
	Mixed local	79	Y	103,700	1
	Quinault	78-82	Y	684,570	5
	Skagit	61	Y	5,330	1
	Soleduck	81	F	7,560	1
	Willapa	75-76	Y	480,000	2
Quillayute	Dungeness	54-55, 57-59, 61, 63-67, 69, 71, 76-77	F, Y	5,264,482	15
	Eagle Cr. (Oregon)	86	Y	6,371	1
	George Adams	77	F	200,000	1
	Green River	56, 64-66	F, Y	235,365	4
	Hoh River	88	F	1,975	1
	Quilcene	81	F	220,000	1
	Simpson	57	Y	51,135	1
	Skagit	61	Y	18,900	1
	Type N (Cowlitz)	74	Y	229,992	1
Sooes	Unknown	72, 79	Y	275,068	2
	Dungeness	59, 77	F, Y	429,788	2
	George Adams	75, 77	F	450,470	2
	Quilcene	69-82	F, Y	3,593,549	14
	Quinault	82-85, 90-92	F, Y	1,802,569	7
	Soleduck	81	F	300,000	1
Waatch	George Adams	73	F	250,050	1
	Makah/Sooes	83-88, 91	F, Y	895,774[b]	8
	Quilcene	67, 70-74, 76-77, 79-80, 82, 84-85	F, Y	2,109,223	13
	Quinault	83-86, 91	F, Y	250,097[b]	5
Sekiu	Dungeness	57, 70-72, 84	F, Y	462,006	5
	Elwha	82, 84, 86	F	547,401	3

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Olympic Peninsula ESU, continued			
Sekiu (cont.)	George Adams	77	F	90,000	1
	Soleduck	72, 79	F, Y	91,645	2
Hoko	Dungeness	52-54, 57-60, 67, 70-71, 76, 84	F, Y	845,089	12
	Elwha	82, 85-88	F, Y	1,349,065	5
	George Adams	77	F	190,000	1
	Green River	66	Y	105,856	1
	Soleduck	72, 75, 79	F, Y	176,556	3
Clallum	Dungeness	53, 58-59, 62-65, 67, 70-71, 87, 89	F, Y	323,862	12
	Elwha	82	F	97,400	1
	George Adams	77	F	200,000	1
	Green River	66	Y	75,010	1
	Soleduck	72, 75-76	F, Y	228,495	3
Pysht	Dungeness	52-55, 57-61, 64-65, 67, 69-71, 84	F, Y	778,929	16
	Elwha	79, 82-83, 85-86	F	626,150	5
	George Adams	77	F	190,000	1
	Green River	56-57, 66	F, Y	107,958	3
	Skagit	61	Y	5,330	1
	Soleduck (Lake Cr.)	63	Y	39,520	1
Lyre	Dungeness	54-55, 57-60, 62, 67, 69-71	F, Y	651,764	11
	Green River	56	Y	10,450	1
	Skagit	61	Y	12,593	1
		Puget Sound/Strait of Georgia ESU			
Elwha	Ancient wild stock	65	Y	12,740	1
	Dungeness	52-54, 56-57, 59, 62-63, 69-71, 76-78, 82, 84-85, 87-92	F, Y	4,710,072	23
	Green River	55-56	F, Y	143,792	2
	Simpson	76	Y	465,868	1
	Soleduck	81	Y	29,410	1
Dungeness	Unknown	79	F	11,781	1
	Elwha	78-82, 84, 87, 89	F, Y	1,839,051	8
	George Adams	80	F	762,450	1
	Green River	56	Y	155,131	1
	Puyallup	80	F	232,875	1
	Skagit	60	F	24,770	1
	Toutle	74	Y	72,800	1
Little Quilcene	Dungeness	72, 77-82, 86, 92	F, Y	601,350	9
	Elwha	86	Y	31,500	1
	George Adams	73	F	50,000	1
	Green River	57, 63-64	F, Y	49,838	3
	Hood Canal	59, 61, 65-66	F, Y	67,604	4
	Quilcene	54, 56, 58, 85-90	F, Y	513,720	9
	Samish	57	Y	18,095	1
	Skykomish	61	Y	11,760	1

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Puget Sound/Strait of Georgia ESU, continued			
Big Quilcene	Eagle Cr. (Oregon)	61	Y	164,311	1
	George Adams	75	Y	72,150	1
	Hood Canal	75	Y	243,800	1
Big Beef Cr.	George Adams	65-66	F, Y	71,104	2
	Green River	56	Y	8,220	1
	Minter Cr.	58, 62	Y	49,358	2
	Quilcene	55	Y	12,300	1
	Skykomish	57	Y	24,992	1
Dosewallips	Dungeness	52-54, 77-80	F, Y	450,300	7
	George Adams	71, 85-86	F, Y	98,700	3
	Green River	57-58, 63, 68	F, Y	157,824	4
	Hood Canal	59-64, 66	F, Y	220,055	7
	Minter Cr.	76	Y	99,550	1
	Quilcene	54-55, 58-59	F	183,228	4
	Samish	56	F	30,254	1
Duckabush	Dungeness	51-52, 54, 79-80	F, Y	435,890	5
	George Adams	70-71	F	191,000	2
	Green River	57, 66	F, Y	111,542	2
	Hood Canal	59, 61-64, 66	F, Y	245,388	6
	Minter Cr.	76	Y	44,000	1
	Puyallup	52	F	50,000	1
	Quilcene	54-56, 58	F, Y	227,169	4
	Samish	57	Y	31,940	1
	Skykomish	61	Y	14,625	1
Hamma	Dungeness	52, 54, 73, 79-80	F, Y	515,015	5
Hamma	George Adams	70-71, 85-86	F, Y	342,300	4
	Green River	57, 66	F, Y	88,952	2
	Hood Canal	59-64, 66	F, Y	230,601	7
	Minter Cr.	76	Y	30,250	1
	Quilcene	54-55, 58	F	113,595	3
	Samish	56	F	47,502	1
Dewatto	Dungeness	77-79	Y	97,451	3
	George Adams	64-66, 69, 71	F, Y	480,349	5
	Green River	56	Y	11,724	1
	Minter Cr.	54, 57, 75-79	F, Y	1,174,335	7
	Quilcene	55	Y	15,400	1
	Skykomish	57	Y	16,000	1
Skokomish	Ancient wild stock	61	F	54,452	1
	Capilano (B. C.)	89-90	F, Y	132,586	2
	Dungeness	51-52, 73, 79-80	F, Y	885,681	5
	Green River	57, 62, 64-67	F, Y	680,843	6
	Hood Canal	60-62, 65-68	F, Y	1,537,463	7
	Minter Cr.	71, 79, 81-82	F, Y	724,961	4
	Puyallup	70, 80-81	F, Y	360,084	3

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Puget Sound/Strait of Georgia ESU, continued			
Skokomish (cont.)	Quilcene	54, 58-59	F	146,346	3
	Samish	56	F	23,310	1
	Skagit (Baker)	91-92	Y	160,100	2
	Skykomish	60	F	22,100	1
	Soleduck	80-81	F, Y	1,124,366	2
Tahuya	George Adams	63-66, 69, 71, 73, 82, 84	F, Y	1,232,805	9
	Green River	56, 66	Y	77,892	2
	Minter Cr.	52-54, 57, 75-82	F, Y	1,173,247	12
	Quilcene	55	Y	16,750	1
	Skykomish	57	Y	4,080	1
Union	Dungeness	76	Y	39,400	1
	George Adams	65-66, 69, 71, 73, 76	F, Y	625,963	6
	Green River	56, 60	Y	48,968	2
	Minter Cr.	52-54, 57-59, 62, 65, 75-76	F, Y	524,850	10
	Quilcene	55	Y	16,750	1
	Skykomish	57	Y	13,200	1
Goldborough Cr.	Dungeness	81	F	653,332	1
	George Adams	77, 79, 82-83, 85, 87-89	F, Y	3,319,704	8
	Green River	56, 58, 61, 65-66	F, Y	268,873	5
	Hood Canal	65, 85	F, Y	138,100	2
	Minter Cr.	78, 82, 84-88, 90-93	F, Y	2,679,121	11
	Puyallup	80	F	455,052	1
	Quilcene	55, 58	F, Y	33,900	2
Deschutes	Ancient wild stock	64	F	299,894	1
	George Adams	77, 79-81	F, Y	156,440	4
	Green River	51-54, 56-58, 61-62, 69, 85	F, Y	1,550,824	11
	Minter Cr.	78, 81, 85-86, 90-91	F, Y	547,414	6
	Puyallup	78, 80-85	F, Y	976,486	7
	Simpson	51	F	10,125	1
	Skykomish	76, 79	Y	131,180	2
	Soleduck	81	Y	3,839	1
Minter Cr.	Unknown	78	F	47,642	1
	Ancient wild stock	62	F	257,498	1
	Bonneville (Oregon)	70	Y	70,370	1
	George Adams	66	F	25,978	1
	Green River	58-61, 77, 79-88, 90-92	F, Y	5,681,298[b]	18
	Mixed local	75	Y	2,094,341	1
	Nooksack	82	Y	227,494	1
	Quilcene	56	Y	28,025	1
	Skagit	77-80	Y	1,438,542[b]	4
	Skykomish	57	Y	144,327	1
	Toutle	72	F	41,881	1

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Puget Sound/Strait of Georgia ESU, continued			
Nisqually	George Adams	74, 81, 87-92	F, Y	3,254,891	8
	Green River	51-54, 56-58, 60, 62-63, 65, 69-73, 75, 77-78, 80-81, 83	F, Y	5,882,732	22
	Issaquah	71	Y	122,400	1
	Kalama Falls	89, 92	F	15,400	2
	Minter Cr.	65, 73, 81-82, 85-87, 91	F, Y	2,423,180	8
	Puyallup	51-55, 57-58, 62, 64, 70-71, 74, 76-85, 87-92	F, Y	12,037,256	28
	Skagit	61, 79, 87	F, Y	1,300,906	3
	Skykomish	82-84, 86-92	F, Y	4,271,842	10
Puyallup	Unknown	77	F	3,177	1
	Garrison Springs	82	F	205,500	1
	George Adams	70, 76	F, Y	253,904[b]	2
	Green River	52-65, 69, 71-73, 75, 77-81, 83, 85, 87-88, 91-92	F, Y	9,187,722	30
	Issaquah	55, 75	Y	81,288	2
	Minter Cr.	65, 73, 75, 82, 87, 89	F, Y	1,525,786	6
	Skagit	61	F	126,052	1
	Skykomish	76, 83-84	Y	361,500	3
	Washougal	74	Y	349,162	1
Green	Bonneville (Oregon)	63	F	22,248	1
	Green x Puyallup	75	Y	411,117	1
	Green x Simpson	75-77	Y	116,173	3
	Green x Skykomish	75-77	Y	115,122	3
	Issaquah	52, 55, 68-69, 75	F, Y	602,353	5
	Minter Cr.	75, 78, 83-84	F, Y	4,542,713	4
	Mixed local	75, 77	Y	27,798	2
	Nooksack	58	F	6,844	1
	Puyallup	71, 76, 78, 80-81	F, Y	1,393,075	5
	Simpson	72-73, 75-77	F, Y	97,988	5
	Skykomish	75-77	Y	175,842	3
	Skykomish x Simpson	75-77	Y	110,638	3
	Toutle	73	Y	78,484	1
	Toutle x Chambers Cr.	73	Y	91,826	1
Sammamish	George Adams	70	F	153,670	1
	Green River	52-61, 63-64, 69-71, 82, 92	F, Y	4,646,731	17
	Minter Cr.	76, 81	F	143,240	2
	Puyallup	81	F	248,800	1
	Samish	56-57	F, Y	110,224	2
	Skagit (Baker)	73-74	Y	61,820	2
	Skykomish	59-61, 66	F	621,562	4
	Toutle x Chambers	73	Y	450,341	1
Snohomish	Unknown	74-75	F	243,270	2
	Green River	52, 54-55, 57-59, 62, 64	F, Y	1,578,987	8
	Issaquah	52-58, 61-66, 68-73, 76-79, 86	F, Y	7,234,269	24

Appendix Table E-1. Continued

River	Stock	Years planted	Stages planted	Total planted	No. yrs planted
		Puget Sound/Strait of Georgia ESU, continued			
Snohomish (cont.)	Minter Cr.	80	Y	9,354	1
	Samish	56	F	401,018	1
	Skagit	54, 61, 75, 78, 80, 82	F, Y	1,819,375	6
	Soleduck	81	Y	55,000	1
	Univ. Washington	57	F	30,084	1
Stillaguamish	Green River	52, 56-59, 65, 69	F, Y	1,089,163	7
	Issaquah	52, 57, 63-65	F	551,264	5
	Samish	56-59, 61, 63-64, 72-73, 78	F, Y	2,096,747	10
	Skagit	51-54, 56, 58-62, 64, 69, 72, 75, 77-79, 81	F, Y	5,237,455	18
	Skykomish	57-59, 61-62, 64-66, 69-71, 79-80, 90-91	F, Y	2,387,210	15
Skagit	George Adams	70	Y	56,408	1
	Green River	52, 55-59, 65	F, Y	3,083,295	7
	Minter Cr.	70	Y	52,896	1
	Nooksack	59, 74	F	550,128	2
	Puyallup	70	Y	4,393	1
	Samish	52-54, 56-59, 61, 63, 65-66, 72-73, 78	F, Y	1,487,134	14
	Skykomish	59, 69, 74, 77, 80-81	F, Y	764,908	6
Samish	Big Beef Cr.	77	F	10,770	1
	Green River	55-56, 59	F, Y	125,340	3
	Nooksack	81, 84	F	136,000	2
	Pilchuck	77	F	10,848	1
	Skagit	60, 72, 75-80	F, Y	2,976,168	8
	Skykomish	76, 80	Y	841,258	2
Nooksack	Unknown	78-79	F	80,214	2
	Cascade (Oregon)	74	Y	192,000	1
	Green R.	56-57, 63	F, Y	305,604	3
	Kalama Falls	76	Y	25,615	1
	Samish	52-57, 59, 61-63, 65, 73, 79, 80, 82	F, Y	1,239,144	15
	Skagit	60-62, 78-87, 91-92	F, Y	15,681,679	15
	Skykomish	80-81, 84, 92	Y	2,784,144	4
	Soleduck (Lake Cr.)	63	F	91,200	1

[a]Number released not given.
[b]Total does not include mixed-stock releases.

Sources: Wallis 1961-1964b, 1966; Willis 1979; USFWS 1985; Kenworthy 1986a, 1986b; Zajac 1988, 1989, 1990, 1992; Borgerson et al. 1991, Wagoner et al 1990; ODFW 1992, 1993; D. Dailey 1994 App.; J. Harp 1994 App.; J. Jorgenson 1994 App.; R. Wunderlich 1994 App.; WDFW 1994c; NRC 1995.

Appendix Table E-2. Releases of adults of out-of-basin stocks in selected Oregon river basins, arranged from south to north by evolutionarily significant unit (ESU).

River	Stock	Years planted	Total number planted	No. Years planted
		Southern Oregon/northern California coasts ESU		
Rogue	Alsea	66, 68-69, 71	950	4
		Oregon coast ESU		
Umpqua	Alsea	60, 65-73	19,730	10
	Siletz	64, 66, 69	1,857	3
Siuslaw	Alsea	64-74	17,894	11
	Siletz	65-66	2,167	2
Coquille	Alsea	64-65, 67-69, 71, 73	4,635	7
	Siletz	66, 69	682	2
Coos	Alsea	67, 69, 71	800	3
	Siletz	69	200	1
Yaquina	Alsea	65, 71	300	2
	Siletz	64-70, 73	2,598	8
Siletz	Alsea	64, 66	1,168	2
	Trask	68-69, 71	3,100	3
Salmon	Alsea	65	400	1
	Siletz	65-67, 69	1,160	4
	Trask	68-71	1,300	4
Nestucca	Siletz	69	300	1
	Trask	64-68, 70-71, 73	7,286	8
Tillamook	Trask	64, 67, 76	900	3
Wilson	Alsea	64	134	1
	Nehalem	76	222	1
	Trask	64-71, 76	5,730	9
Miami	Nehalem	76	1,068	1
	Trask	64-69, 73	3,642	7
Nehalem	Klaskanine	65	1,302	1
Necanicum	Klaskanine	64-65	512	2
	Nehalem	69-70, 73	610	3
	Siletz	69	160	1
		Lower Columbia River/southwest Washington coast ESU		
Clackamas	Big Cr.	71	965	1
	Bonneville	67-69, 71-72	5,316	5
	Cascade	67, 71	536	2
	Sandy	67-69, 71, 84-86	4,842	7

Sources: Wallis 1961a-c, 1963a-64b, 1966; Willis 1979; Borgerson et al. 1991, Wagoner et al 1990; ODFW 1992, 1993a.