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SUMMARY

This report summarizes biological information on coho salmon *(Oncorhynchus kisutch)* from the lower Columbia River* (LCR) gathered in conjunction with a U.S. Endangered Species Act (ESA) status review. Under the ESA, any “distinct population segment” of fishes qualifies as a “species” and is eligible for protection if it is threatened or endangered. National Marine Fisheries Service (NMFS) policy 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 (Waples 1991). The ESA evaluation of coho salmon is complicated because the LCR has sustained intense human perturbation in the last century. Commercial exploitation of coho salmon and degradation of salmon spawning habitat reduced coho salmon numbers to near extinction around the middle of this century. The advent of extensive artificial propagation of the species in hatcheries has “rebuilt” the runs to at or above historic levels. However, this process has changed the coho salmon runs in the LCR from predominantly naturally spawning fish to predominantly hatchery-maintained fish. Native runs, if they persist, would exist only as small remnant populations.

Life History

Coho salmon represent one of five species of anadromous Pacific salmon native to North America. Throughout their range, native coho salmon populations return to their natal streams to spawn from early fall to late spring. Fry emerge from

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*LCR is defined in this document as the Columbia River and its tributaries below Bonneville Dam, exclusive of the Willamette River. The mid Columbia River is defined as the area from Bonneville Dam to the confluence of the Snake and Columbia Rivers. The upper Columbia River is the area above this confluence, including the area above Grand Coulee Dam.

egg nests (redds) between early March and July, rear in fresh water for a year, migrate to sea the next season, and return to spawn after 5 to 20 months of feeding in the open ocean.

The NMFS Northwest Region Biological Review Team (BRT) evaluated studies on natural history of coho salmon to determine if there are distinct differences between populations. The BRT also evaluated whether the characteristics of the life history of coho salmon might indicate that native populations could persist, considering the extensive hatchery releases, outplantings, overharvest, and habitat destruction in the LCR over the last 100 years.

Fidelity of homing in coho salmon under natural conditions is similar to that demonstrated for other species of Pacific salmon and appears sufficient to maintain populations with a similar level of distinctiveness. Different coho salmon populations show timing differences from fry emergence to time of adult spawner returns. Coho salmon show freshwater, estuarine, and ocean migratory patterns apparently determined by the geographic area of their natal streams. Homing and spawning behavior is complex and would suggest a selection mechanism that appears sufficient to reduce gene flow from nonnative populations. However, the BRT determined, from the available evidence, that the massive and extensive disruptions documented in coho salmon populations in the LCR have depleted native populations enough that population differences have been largely eliminated.

Historical and Current Abundance

Prior to the 1900s, naturally produced coho salmon were widespread in the Columbia River Basin, with a historical center of abundance in the LCR. There were also large runs of coho salmon in the middle and upper reaches of the Columbia River and in the Snake River. All upper, middle, and Snake River runs were drastically reduced or destroyed by various factors prior to the 1950s, including overharvest and habitat destruction or blockage (Cramer et al. 1991).

It is impossible to accurately estimate the decline in LCR stocks of coho salmon, but the BRT estimated that the runs may have been reduced to less than 5% of historic levels by the late 1950s.

The drastic decline in coho salmon abundance initiated a widespread hatchery enhancement program after 1960 (ODFW 1990a,b; VTDF 1991a). This program increased coho salmon populations in the Columbia River to or above historic levels. The total return to the river often exceeded 400,000 fish in recent years (Howell et al. 1985, CBFWA 1990, PFMC 1991).

The causes of the original decline in coho salmon were not eliminated by this extensive hatchery production. Overharvest, habitat blockage and destruction, and other activities detrimental to natural production continued. The result was a continued decline in naturally spawning runs while exploitation of hatchery fish continued at increased levels. The Columbia River is now managed almost entirely for commercial exploitation of hatchery fish.

In the early 1980s, it was estimated that less than 25,000 coho salmon were spawning naturally in the Columbia River Basin (Wahle and Pearson 1987; CBFWA 1990). These fish were thought to have been mainly feral hatchery fish and returns from hatchery outplants in streams away from hatcheries, although some were naturally produced fish. The BRT found no data to suggest these numbers have changed significantly to the present.

It is believed that the majority of naturally produced coho salmon return to the LCR to spawn between early December and March (ODFW 1990b, 1991a,b; Cramer et al. 1991). The Oregon Department of Fish and Wildlife (ODFW) estimates there may be less than 195 of these fish in Oregon and that they may exist only as small, isolated populations in the Lewis and Clark and Sandy River systems (ODFW 1991c). No detailed information was available from the Washington Department of Fisheries (WDF) on possible locations where natural spawning may occur or on numbers of nonhatchery origin coho salmon that may spawn. The BRT estimated there may be only about 100 post-December spawning coho salmon in lower Columbia River tributaries in Washington.

There is a post-December run of naturally spawning fish that return to the North Fork of the Clackamas River in Oregon (Cramer 1991). Counts over the North Fork Dam fluctuated substantially between 1957 and 1989, but there is no apparent trend in abundance. This run was not part of the original petition for lower Columbia River coho salmon, but was reviewed by the BRT as a special case. Computer modeling indicates this population has less than a 0.1% chance of extinction during the next 100 years assuming no change to population parameters.

Effects of Artificial Propagation

The BRT evaluated the outplanting history of hatchery populations in the LCR to determine if these populations could represent the historical ESU. The BRT determined that the history of hatchery populations shows an infusion of stocks from throughout the basin and coastal regions in Oregon and Washington (ODFW 1990a,b; 1991c; VTDF 1991a,d). Most hatcheries in the basin manage their hatchery populations for stocks which have either a predominately northern or southern ocean distribution from the mouth of the Columbia River (Cramer et al. 1991; VTDF 1991a). These stocl-,s themselves are a mixture of populations, and the BRT was unable to determine if any LCR hatchery stocks represent historically distinct LCR populations.

Genetic Analysis

The NMFS Northwest Fisheries Center collected coho salmon samples from t LCR for electrophoretic analysis. The BRT analysis and a review of the scientific literature of other genetic studies on LCR coho salmon were inconclusive in determining whether distinct coho salmon populations existed in the LCR.

Effects of Parasitism

Ceratomyxa shasta is a protozoan parasite of coho salmon which can cause large losses of adult fish. Stocks of coho salmon in the LCR, and some populations in coastal Oregon and Washington, are presumed to have an inherited resistance to the parasite. Studies suggest the presence of *C. shasta* may act to reduce introgression in LCR stocks from populations that lack resistance to the parasite.

Conclusions

The BRT concluded that the available data fail to identify an existing evolutionarily significant unit in the lower Columbia River. If one or more coho salmon ESUs are present in the Columbia River, fishery management actions and research studies have inadequately documented these populations.

ACKNOWLEDGMENTS

The status review for the lower Columbia River coho salmon was conducted by the NMFS Northwest Region Biological Review Team (BRT). The extensive public record developed pursuant to this review and discussions of that record by the ESA Technical Committee formed the basis for this report. Members of the BRT for LCR coho salmon were David Damkaer, Thomas Flagg, Elizabeth Gaar, Lee Harrell, Orlay Johnson, Robert Jones, Conrad Mahnken, Gene Matthews, Desmond Maynard, George Milner, Gerald Monan, Ben Sandford, Michael Schiewe, Grant Thompson, Merritt Tuttle, William Waknitz, Robin Waples, John Williams, and Gary Winans.

INTRODUCTION

Coho salmon *(Oncorhynchus kisutch)* are native to the Columbia River Basin and its tributaries (Fig. 1). They once were abundant throughout most of this large, complex drainage, with naturally spawning populations of over 600,000 fish. Two-thirds of the historical Columbia River coho salmon production may have originated in the lower Columbia River and its tributaries (LCR) (Mullan 1984). Present population estimates of "wild,"[1] naturally spawning fish in the LCR are around 25,000. The majority of these are feral hatchery fish, and only 600 may be of non-hatchery origin. This situation prompted Oregon Trout, Oregon Natural Resources Council, Northwest Environmental Defense Center, American Rivers, and the Oregon and Idaho Chapters of the American Fisheries Society to petition the National Marine Fisheries Service (NMFS) to list LCR coho salmon as threatened or endangered "species" under the Endangered Species Act (ESA). This report summarizes the review of the status of these fish conducted by the NMFS Northwest Regional Biological Review Team (BRT).

KEY QUESTIONS IN ESA EVALUATIONS

Two questions must be addressed in a determination of whether a listing for a petitioned group of fish is appropriate under the ESA: 1) Is the petitioned stock a "species" as defined by the ESA? 2) If so, is the "species" threatened or endangered?

The "Species" Question

The ESA of 1973 was designed to identify and protect plant and animal species whose numbers and habitats had become sufficiently depleted to critically

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[1] As used in this report and in common usage on the LCR, "wild" fish are progeny of naturally spawning fish. In other regions of the Columbia and Snake Rivers, "wild" usually refers only to indigenous fish unaffected by artificial propagation.

threaten their survival. The Act as amended in 1978 allows protection of three biological categories: species, subspecies, and “distinct population segments” of vertebrates. However, the Act provides no guidance for determining what constitutes a distinct population. To clarify the issue for Pacific salmon, NMFS published an interim policy describing how the definition of “species” in the Act will be applied to anadromous salmonids (Federal Register Docket No. 910248-1048; 13 March 1991). A more detailed description of this topic appears in the NMFS “Definition of Species” paper (Waples 1991).

NMFS policy for Pacific salmon stipulates that a salmon population or group of populations will be considered “distinct” for purposes of the Act if it represents an evolutionarily significant unit (ESU) of the biological species. There are two criteria a population must meet to be considered an ESU. The first is that the population must demonstrate reproductive isolation from other conspecific populations. The second is that the population represents an important component in the evolutionary legacy of the biological species.

Types of information that can be useful in determining the degree of reproductive isolation include incidence of straying, rates of recolonization, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance can be provided by data on phenotypic, life-history, and protein or DNA characteristics; habitat differences; and the effects of stock transfers or supplementation efforts.

Hatchery Fish

In the ESA evaluation of LCR coho salmon, the question of whether hatchery fish should be included in the species and threshold determinations must be addressed. Abundance levels of coho salmon in the LCR are probably at or above historical levels, but these coho salmon are largely fish of hatchery origin. The ESA has as its first stated purpose “to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved.” The Department of Commerce is mandated to conserve endangered and threatened species in their natural habitats. Therefore, NMFS policy is to consider only naturally- spawning populations in determining whether a population is a “species” for the purposes of the Act (Waples 1991).

The decision to focus on wild fish is based entirely on ecosystem considerations; the question of the relative merits of hatchery and wild fish is a separate issue. Fish are not excluded from ESA consideration simply because some of their direct ancestors may have spent time in a fish hatchery, nor does identifying a group of fish as “wild” as defined here automatically mean that they are part of an ESU.

Once a wild component of a population has been identified, the next step is to determine whether this population component is “distinct” for purposes of the ESA. In making this determination, we used guidelines in the NMFS “Definition of Species” paper (Waples 1991). We considered factors outlined in Section IIIC (Effects of supplementation and other human activities) to determine the extent to which artificial propagation may have affected the wild fish, through either direct supplementation or straying of hatchery fish. Thus, although naturally spawning fish may meet the definition of “wild” adopted here, they may be excluded from ESA considerations for any of several reasons.

Threshold determinations also focused on wild fish, on the premise that an ESU is not viable unless a population exists in the natural habitat. In developing recovery plans for “species” listed as threatened or endangered, the use of artificial propagation may be considered. If an existing hatchery is associated with the listed 11 species,” an important question to address in formulating a recovery plan is whether the hatchery population is similar enough to the wild population that it can be considered part of an ESU. Factors to consider in this regard include origin of donor stock(s), brood-stock practices, evidence for domestication or artificial selection, population size, and the number of generations the stock has been cultured. In general, hatchery populations that have been substantially changed as a result of these factors should not be considered part of an ESU.

Thresholds for Threatened or Endangered Status

Neither the National Marine Fisheries Service nor the U.S. Fish and Wildlife Service (USFWS), which share authority for administering the ESA, has an official policy regarding thresholds for considering ESA “species” as threatened or endangered. The Northwest Region of NMFS has published a Technical Memorandum on this topic (Thompson 1991). Written comments received by NMFS and extensive discussions in ESA Technical Committee meetings stressed the importance of incorporating the concepts of Population Viability Analysis (PVA) into threshold considerations. However, the field is rapidly evolving and a definitive policy position on this issue is not expected in the near future. Furthermore, most of the PVA models developed to date require. substantial life-history information that often will not be available for Pacific salmon populations.

Therefore, instead of using a single, numerical threshold value, we used a variety of information in evaluating the level of risk faced by an ESU. Important factors considered included 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and current 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., from strays or outplants from hatchery programs); and 6) recent events (e.g., a drought or improvements in main-stem passage) that have predictable short-term consequences for abundance of an ESU. In addition, until a more comprehensive PVA model becomes available for Pacific salmon, we used the stochastic extinction model of Dennis et al. (1991) to provide some idea of the likely status of the population in the future. This model is useful for identifying outcomes that are likely if no protective measures are taken because it assumes that future fluctuations in population abundance are determined by parameters of the population measured in the recent past.

GEOGRAPHIC AREA

The BRT’s status review focused on populations of coho salmon in the LCR. Preliminary reviews were conducted on other stocks of coho salmon from the entire Columbia River and its tributaries. Under time constraints imposed by the ESA, it was impossible to evaluate the potential for ESA status of any non-LCR populations. The petition for listing coho salmon explicitly defined the stocks as “coho populations *spawning in* tributaries below Bonneville Dam, except the Willamette River” (Petition, 30 May 1990, ESA record II.B.1).

BIOLOGICAL INFORMATION

Life History

Coho salmon are native to North America and range throughout temperate waters of the northern Pacific Ocean. They are anadromous and return to spawn in natal streams beginning in early fall. Historically, the Columbia River probably represented one of the major centers of naturally produced coho salmon.

Throughout their range, local populations of coho salmon emerge from redds (gravel nests) over a 3-week period between early March and late July, rear in fresh water for a year, migrate to sea the next season, and return in 5 to 20 months to spawn (Godfrey 1965). Although early and late emerging populations often exist sympatrically within a stream system, proper timing of emergence has distinct survival advantages. Within a week of emergence, coho salmon fry become aggressive and territorial (Hoar 1951, Chapman 1962, Mason 1966). As prior residents are always dominant in territorial disputes (Chapman 1962), later emerging fry are forced to establish and defend territories in vacant habitat. Many later-emerging fry, finding no vacant territory, form schools of subordinate fish that survive either by swamping territory holders or drifting downstream in search of vacant habitat. As no returning adult coho salmon have been observed without a freshwater annulus (scale mark), it appears that all coho salmon fi-Y must find some freshwater habitat for their first year of life or perish (Shapovalov and Taft 1954; Mason 1975).

Outmigration of coho salmon in the Columbia River peaks in May, but extends from early April through June (Niska and Willis 1963, Willis 1962, Dawley et al. 1986). As smolts outmigrate, they cluster in large schools and demonstrate a variety of survival behaviors. In the Columbia River estuary, most coho salmon smolts spend midmorning to late afternoon near shore, and they are found in midriver areas at dawn and dusk. Schools intermingle as they cross paths during the smolt outmigration, but apparently resegregate once in the ocean, as less than 10% of the marine juveniles caught with purse seines come from different freshwater rearing areas (Emlen et al. 1990).

Coho salmon from different geographic areas appear to have their own migration patterns (Brannon 1984, Quinn and Tallman 1987). Columbia River juveniles apparently remain in coastal water (within about 35 km of shore) (Pearcy 1984, Pearey and Fisher 1988) and travel as far north as the northernmost tip of Vancouver Island and as far south as Eureka, California (Wright 1968).

A major factor in population cohesiveness is the fidelity with which adult salmon are able to home to their natal streams. Although ocean homing mechanisms are poorly understood, once near shore, salmon are guided to their natal stream by following a series of imprinted scents (see reviews by Hasler and Scholz 1983, Smith 1985, and Quinn and Tallman 1987).

Straying in coho salmon is well documented when access to natal streams is obstructed or damaged (Allen 1956, Martin 1984), but homing under normal conditions is fairly accurate (between 73 and 100% as reviewed by Quinn and Tallman 1987). Researchers reported no straying between populations of northern California coastal coho salmon when stream mouths were separated by about 32 km and only moderate straying between populations when the stream mouths were separated by 8 km (Taft and Shapovalov 1938). Ricker (1972) reviewed a study with Toutle River coho salmon outplanted on-station and at a site 80 km away in the Columbia River. All 377 returning adults from the on-station outplant entered only the Toutle Hatchery; however, large numbers of the outplanted fish returned to the Toutle Hatchery and other hatcheries.

Salo and Bayliff (1958) were the first to demonstrate that coho salmon inherit their adult return time. Hager and Hopley (1981) demonstrated the inheritance of adult timing within Columbia River coho salmon stocks.

Coho salmon in the LCR have a wide range of run times. Historically, coho salmon began their spawning migration by entering the river in early September and continued at least through February (reviewed in Cramer et al. 1991). Hirose (1983) observed coho salmon of apparent wild origin that returned to Gnat Creek in the Columbia River from mid-September to mid-February, with the peak of the run near the end of October. He suggested the actual spawning season for nonhatchery coho salmon in the LCR ranged from late November through early January. A run of naturally spawning fish to the North Fork of the Clackamas River returns from November through March (Cramer 1991).

Recent coho salmon runs in the LCR were primarily managed for hatchery fish with only two run-times. An early group or “S-Type” has a southerly marine distribution from the mouth of the Columbia River. It returns to the river in August and September and is the principal stock reared by the Oregon Department of Fish and Wildlife (ODFW) (Cramer et al. 1991). The late group or “N-Type” has a northerly marine distribution from the Columbia River. It returns to the river in October and November. This stock was first cultured at the Cowlitz Hatchery by the Washington Department of Fisheries (VVDF) in 1967 (Hager and Hopley 1981). Since the 1970s, it has been introduced into all WDF hatcheries of the LCR, although some VVDF hatcheries also culture early-run coho salmon (VTDF 1991d).

If populations of nonhatchery origin fish still exist in the LCR, they would probably spawn before or after the influx of returning hatchery fish. Unfortunately, little data are available on early and late spawning coho salmon. ODFW and VMF have conducted spawning ground surveys, but no surveys have been over the entire spawning period nor were they always consistent from year to year. WDF's surveys have been conducted since 1945, but before winter 1990-91, only occurred at the peak of the expected hatchery run and primarily on streams known to be influenced by hatchery fish. ODFWs surveys began in 1949 and cover 10 streams with little hatchery influence; however, in general, they only observe spawners once or twice during late November to late December.

In the winter of 1990-91, ODFW and VVDF expanded the number of streams they surveyed and extended the survey time to include post-December 15 spawners. Wild spawners were surveyed by ODFW from October to February, while WDF surveyed streams with suspected wild spawners only in January and February. During this time, ODFW surveyed 87 streams and found 514 coho salmon of which 57 were counted after 15 December. The post-December 15 spawners were counted in 11 streams (13% of streams surveyed). WDF surveyed 40 streams beginning 2 January and found 11 live and 10 dead coho salmon in 12 streams (30% of streams surveyed). ODFW also counted 121 redds in their post-December 15 counts, while WDF found 54 redds (ODFW 1991a, WDF 1991c).

WDF also conducted scale analysis on coho salmon harvested in October and on carcasses collected in the January-February stream surveys. WDF found that 1325% of the October fishery samples exhibited wild/natural scale patterns as did 100% (N = 5) of the stream-surveyed post-December fish (VVDF 1991e).

ODFW concluded that their surveys indicated distinct and well-separated populations of coho salmon on the spawning grounds only in the Lewis and Clark River and Skipanon River. The early runs peaked about the first week of November, whereas the late runs peaked about the middle of January. There was a 6-week separation between the two runs during which no fish were observed on the spawning grounds. This temporal separation should preclude gene flow between the early and late runs.

WDF drew no conclusions regarding whether their surveys identified distinct wild spawning populations, but a supplemental document (WDF 1991d, p. 13) concluded**:**

> Whether there are still small pockets of self-sustaining wild populations that have never been impacted by hatchery production in any Washington tributary is an unknown. To assume there are, given the record, would seem to be a most notable defiance of the odds.

A naturally spawning population of coho salmon occurs in the North Fork of the Clackamas River. The Clackamas River is a tributary of the Willamette River and was specifically excluded from the original ESA petition for LCR coho salmon. However, the BRT considered the Clackamas River coho salmon a "population of special concern," in part because this run may be the "last substantial remaining native coho stock in the Columbia River basin" (Nehlsen et al. 1991).

The adult coho salmon runs at North Fork Dam on the Clackamas River peak in September and again in January (Cramer 1991). The late-run coho salmon are presumed to be the progeny of naturally spawning adults, since no known hatcheries propagate coho salmon with this late run-timing. This run of late fish has shifted from November, during 1958 to 1963, to January, during 1985 to 1989 (Howell et al. 1985, Cramer 1991). The two runs overlap, but reportedly there is a break of several weeks between the time spawning ends in the early group and begins in the late group (Cramer 1991). However, the Clackamas River system has experienced extensive coho salmon outplantings, and genetic studies indicate that the juvenile portions of the run have electrophoretic patterns similar to those from hatchery fish outplanted into the river in previous years (see "Genetics" section).

Dam counts of returning coho salmon on the Clackamas River also present a pattern which is common throughout the LCR and which demonstrates the difficulty in determining the evolutionary lineage of late-run fish. Dam counts of coho salmon returning to the North Fork of the Clackamas River have been compiled since the 1950s (Cramer 1991). Table 1 presents these data in 3-year blocks as percent per period per month of fish over the dam. This reveals that the early run and the late run have both experienced reductions in the mid-part of their runs with consequent increases in the tails. In the time period 1987-89, over 5% of the early-run hatchery fish returned in August (in previous years this was less than 0.1%) and almost 9% of the late-run “wild” fish returned in March (in previous years this was 0.2% or less). Presumably the early-run hatchery fish demonstrate a similar tail in December and January. Thus, unless tagging data are available on differences in actual spawning times between the runs, it is difficult not to speculate that a major portion of the late-run is the tail of the early-run hatchery fish, forced later and later by fishery management practices during the October to November harvest season.

Historical and Current Abundance

Until the early 1900s, naturally produced coho salmon were widespread throughout the Columbia River Basin. Historical abundance is believed to have centered in the LCR; however, some stocks migrated to the Spokane River, over 435 km upriver (Mullan 1984).

Most estimates of the historical population size of the Columbia River coho salmon rely on commercial catch data. Mullan (1984) suggested early harvest amounted to between 300,000 and 400,000 fish annually. Beiningen (1976) indicated the catch between 1894 and 1920 averaged 476,000 fish annually. More accurate estimates of historical abundance combine commercial catch data with theoretical harvest rate and fish size to project total population size. Chapman (1986) suggested an average fish size of 3.18 kg, adjusted the estimated catch by a (theoretical) optimum sustained yield (harvest) of 77%, and estimated a peak (5-year average) pre-1900 abundance of 618,000 adult coho salmon entering the Columbia River system annually.

The inriver harvest of Columbia River coho salmon reached a peak of 3,599,550 kg (about 880,000 fish) in 1925, after which the fishery experienced an almost-continuous decline to the 1960s (Fig. 2) (Beiningen 1976, Mullan 1984, PFMC 1991). The decline in production was widespread throughout the river system and was, undoubtedly, attributable to combinations of overharvest and habitat loss.

All middle and upper Columbia River stocks of coho salmon were drastically reduced or destroyed by construction of impassable mill dams, unscreened irrigation diversions, habitat loss, and overharvest prior to completion of Grand Coulee Dam in 1941 (Mullan 1984). All coho salmon stocks spawning above Grand Coulee Dam were eliminated with the completion of the dam as no facilities were provided for fish passage. The extent that the middle and upper Columbia River stocks declined during the early part of the century is indicated by counts at the first Columbia River main-stem dam (Rock Island Dam) of 183, 69, 10, 0, 58, 78, 13, 12, 29, 1, and 22, from 1933 to 1943, respectively (Mullan 1984).

Counts of coho salmon passing Bonneville Dam after its completion in 1938 indicated a total minimum upstream run of 12,000 to 18,000 fish annually between 1938 and 1942 (Fig. 3) (COE 1990). Coho salmon passing Bonneville Dam continued to decline, reaching lows of under 3,000 fish in the late 1950s. Between the 1940s and late 1950s, many of the fish migrating above Bonneville Dam were lower river stock (Bonneville Hatchery) produced at the U.S. Fish and Wildlife Leavenworth National Fish Hatchery on the Wenatchee River (Mullan 1984).

The abundance of coho salmon in the Snake River was also drastically reduced (to about 3,000 fish) by the time upstream adult counts were available at Ice Harbor Dam in 1962 (COE 1990). The last known coho salmon stocks were eliminated from the Snake River system by 1986 (COE 1990).

Mullan (1984) indicated that two-thirds of the historical Columbia River coho salmon production may have originated in the LCR, with a likely historic peak abundance of over 400,000 coho salmon originating in the LCR prior to the 1920s.

It is impossible to accurately estimate the decline in LCR stocks of coho salmon below Bonneville Dam. Dam counts and spawning surveys are only available for a few tributaries. However, river harvest reached a low of 15,000 to 19,000 fish annually from 1958 to 1960 (CBFWA 1990). This suggests the decline in LCR stocks followed a pattern similar to stocks in the middle and upper parts of the Columbia River Basin.

The BRT developed an estimate of the minimum returns of coho salmon to the Columbia River from peak harvest in 1925 to the present (Fig. 2 and Table 2). For the period 1925 to 1960, we used total inriver harvest (Beiningen 1976) adjusted for harvest rate and average fish size. For the period 1925 to 1950, we used a (perhaps conservative) harvest rate of 77% as suggested by Chapman (1986). From 1950 to 1960, we used actual harvest rates (ODFW 1990b). We used an estimate (probably optimistic) of 4.08 kg average fish size for this entire period as suggested by the Oregon Fish Commission (1975). From 1938 to 1959, Bonneville Dam counts were added to the estimate. For the period 1960 to 1990, we used a population estimate that accounted for river commercial and sport harvest, hatchery returns, and Bonneville Dam and lower river tributary dam counts (PFMC 1991).

The BRT estimate indicates the numbers of coho salmon returning to the Columbia River may have been reduced to fewer than 25,000 fish by the late 1950s (Fig. 2 and Table 2). This suggests that by the late 1950s, the abundance of returning coho salmon produced from the Columbia River had been reduced to less than 5% of historic levels (25,000/618,000).

The BRT used a computer model developed by Dennis et al. (1991), to simulate the population dynamics of the annual Columbia River coho salmon runs. The model estimates the probability of extinction during the next 100 years assuming continuation of population abundance trends and parameters from the period modeled to the future. Using this model, there was a 39.2% probability of extinction from the period of peak harvest in 1925 to the (first) population low in 1943 (Table 2). The run temporarily stabilized in the mid-1940s (Fig. 2 and Table 2). However, overall, the run continued to decline from 1943 to 1959, with the chance of extinction increasing to 73.3% (Table 3). There was some production of coho salmon at state and federal fish hatcheries in the Columbia River Basin from the 1940s through the 1950s (Mullan 1984, ODFV 1990a). This hatchery production may have contributed to stabilization of the run.

The drastic decline in abundance of LCR coho salmon initiated a widespread hatchery enhancement program after 1960 (ODFW 1990a,b; WDF 1991a). This program included increased production of coho salmon at existing fish hatcheries and construction of new facilities. Since the 1960s, the vast majority of coho salmon returning to the Columbia River have been of hatchery origin (CBFWA 1990). BRT computer modeling suggests the current (hatchery-based) population of coho salmon in the Columbia River is stable (it has less than 0.1% probability of extinction in the next 100 years) (Table 3).

The hatchery enhancement program built a population of historic proportions (Fig. 2 and Table 2). Returns of coho salmon to the Columbia River increased quickly after the 1960s. The total return to the river often exceeded 400,000 fish in recent years (Howell et al. 1985, CBFWA 1990, PFMC 1991). During the 1980s, the run ranged from 138,000 to 501,000 fish between 1980 and 1984, and from 382,000 to a historic high of 1,553,000 fish between 1985 and 1989 (CBFWA 1990). These fluctuations in run size were attributed to variations in hatchery smolt production, smolt quality, juvenile-to-adult survival, and harvest (CBFWA 1990).

The majority (about 85%) of hatchery production of coho salmon in the Columbia River system has centered in the LCR (CBFWA 1990). However, there are hatcheries on the Bonneville Dam pool that produce coho salmon. Counts of coho salmon passing Bonneville Dam have exceeded 12,000 annually since 1962 and averaged 46,530 annually during the 1980s (Fig. 3) (COE 1990).

The hatchery-based coho salmon enhancement program for the LCR has allowed development of large-scale sport, commercial, and tribal fisheries. However, the dynamics and structure of the population have been altered dramatically. Almost the entire population of (perhaps 500,000) coho salmon now returning annually to the Columbia River system are hatchery fish. The number of naturally spawning coho salmon returning to the LCR is limited.

Wahle and Pearson (1987) indicated that in the early 1980s, less than 25,000 coho salmon were spawning naturally in the Columbia River Basin (Tables 4-8). CBFWA (1990) indicated the number of naturally spawning coho salmon in the Columbia River Basin continued to exceed 23,000 during the late 1980s (Tables 4-8). These fish include feral hatchery fish spawning in streams near hatcheries, returns from hatchery outplants in streams away from hatcheries, and naturally produced fish. The BRT has found no data to suggest these numbers have changed significantly to the present.

It appears that the current number of coho salmon spawning in streams in the LCR is less than 6% of historic abundance (<25,000/400,000). The BRT believes there are two important components of naturally spawning coho salmon in the LCR: fish of first generation hatchery origin and fish from naturally spawning parents (which may include both hatchery and nonhatchery origin fish).

Up to 30,000,000 hatchery reared juvenile coho salmon are released annually on the Washington side of the LCR (Table 4) (VVDF 1991a). Appro3dmately two-thirds of this production is released into streams near hatcheries, and the remainder is released into tributaries away from hatcheries (mostly as fry outplants). WDF maintains in excess of 70,000 adult coho salmon returning to their LCR fish hatcheries (WDF 1991a) (Table 4). It is common for VVDF to release in excess of 15,000 of these adult hatchery fish to spawn naturally in streams near the hatcheries (these are fish counted over hatchery weirs or released from adult collection ponds) (Table 4).

Typically, less than 10,000,000 hatchery reared juvenile coho salmon were released annually on the Oregon side of the LCR during the 1980s (Howell et al. 1985, Cramer and Chapman 1990, ODFW 1991a). Most coho salmon reared in hatcheries in Oregon are now released as smolts into streams near hatcheries. However, ODFW has a long history of off-station outplanting of fry, juveniles, and prespawning adults to streams away from hatcheries (ODFW 1991a). The BRT does not have information to indicate the number of Oregon hatchery fish allowed to spawn naturally in streams near hatcheries; however, the number may exceed 4,000 (Wahle and Pearson 1987).

A primary concern is that surveys of small tributary index spawning areas indicated continued decline in natural production of coho salmon in the LCR in areas away from hatcheries (Cramer and Chapman 1990, ODFW 1990b, WDF 1991a). The BRT developed a comparison of average spawners/km from 1951 to 1990 for 10 Oregon and 13 Washington index streams. The BRT selected 1951 to coincide with data presented by ODFW (1990b) and because few streams were surveyed in Washington prior to that date (WDF 1991b). We averaged WDF index area counts for pre- and post-December surveys. The BRT also reviewed 1990-91 spawning ground surveys of 87 ODFW index streams and 40 VTDF index streams in the LCR basin (ODFW 1991a, WDF 1991c).

Most adult coho salmon of first generation hatchery origin return to spawn between early October and late November each year. WDF surveys indicate the October to December segment of coho salmon spawning in streams away from hatcheries has been in decline for the past 40 years (VVDF 1991b). From the 1950s to the present, this run segment has been reduced from between 31 to 62 fish/km to about 6 fish/km. However, the actual magnitude of decline from historic levels is undoubtedly greater since the early spawning ground surveys coincide with periods of historic low returns of coho salmon to the Columbia River. Computer modeling suggests this run segment of coho salmon spawning in the LCR away from hatcheries in October to December has a 12.9% chance of extinction in the next 100 years if population parameters remain stable. This run segment may be somewhat stabilized through hatchery outplants.

The BRT does not have long-term information concerning the number of fish spawning naturally away from hatcheries in October to December in Oregon. However, in 1990, ODFW counted 3 fish/km in surveys of 10 standard index streams during this time period (Table 9) (ODFW 1991a).

The BRT used data from Fulton (1970) and estimated there are about 544 km of coho salmon spawning habitat on the Washington side of the LCR and about 402 km on the Oregon side. However, ODFW (1991a) indicated there may be up to 944 km of coho salmon spawning habitat on the Oregon side of the LCR. As previously indicated, VIDF surveys averaged 6 spawners/km while similar ODFW surveys averaged 3 spawners/km. Therefore, it is possible that there are approximately 3,000 coho salmon spawning between October and December in the LCR away from hatcheries in Washington and between 1,100 and 2,600 in Oregon.

Another important run component consists of coho salmon returning to the Columbia River between early December and March. These fish return after the major influx of the hatchery-based (October to November spawning) population. This run component may consist mainly of fish of nonhatchery origin (Cramer and Chapman 1990; ODFW 1990b, 1991a,b; Cramer 1991).

WDF (1991b) and ODFW (1990b, 1991a) surveys indicate this post-December component of coho salmon spawning in the LCR away from hatcheries has also been in a steady decline for the past 40 years (Fig. 4). From the 1950s to the present, this component had been reduced from between 31 to 50 fish/km to under 0.6 fish/km. VIDF and ODFW 1990-91 surveys of post-December spawning coho salmon suggested that there are currently 0.3 spawners/km on the Oregon side of the LCR and 0.2 spawners/km on the Washington side (ODFW 1991a, VTDF 1991c). Computer modeling suggests this post-December spawning run segment of coho salmon in Washington tributaries of the LCR has, almost a 90% chance of extinction in the next 100 years (Table 3). Computer modeling indicates this post-December spawning run segment of coho salmon in Oregon tributaries of the LCR has a 100% chance of extinction during the next 100 years (Table 3).

ODFW (1991c) estimated that there are now less than 195 post-December spawning coho salmon on the Oregon side of the LCR excluding the Willamette River system. The majority of these fish may exist as small populations in the Lewis and Clark River and Sandy River or in other small tributaries (ODFW 1991c).

The BRT does not have detailed population information for LCR post-December spawning coho salmon in Washington. However, based on the BRT estimate of 544 km of spawning habitat in Washington and the current 0.2 spawner/km estimate, it is possible there are now only about 100 post-December spawning coho salmon in the LCR in Washington.

A late-returning (post-December) component of the coho salmon run in the North Fork of the Clackamas River may also be of nonhatchery origin (ODFW 1990b, Cramer 1991, Nehlsen et al. 1991). Computer modeling indicates this population has less than a 0.1% chance of extinction during the next 100 years, if population parameters remain stable (Table 3). However, the 1991 return of post-December spawning coho salmon to the North Fork of the Clackamas River is projected to be at a recent low of only about 300 fish (Cramer 1991). Therefore, this population deserves continued monitoring.

In summary, even though there is a large hatchery-based population averaging about 500,000 coho salmon returning yearly to the LCR, all information indicates a steady decline (to present lows) in natural production away from hatcheries. The BRT identified from the literature several components of the current coho salmon population spawning in the LCR. In October to December, about 20,000 feral hatchery fish spawn in streams near hatcheries. Also at this time, about 6,000 fish spawn in streams away from hatcheries, and post-December, after the hatchery runs have passed, about 600 fish spawn in tributaries away from hatcheries.

It has been suggested that these declines in natural production are coincident with high harvest rates on abundant hatchery stocks (Cramer and Chapman 1990; ODFW 1990b, 1991a). However, declines may also be influenced by outplants of large numbers of hatchery fry (ODFW 1991a) or by continued habitat degradation.

History of Hatchery Stocks and Outplantings

One of the major issues the BRT considered in determining whether a coho salmon ESU remains in the LCR is the extent of hatchery programs in the lower river basin. The BRT considered three principal points: 1) history and numbers of hatchery releases, 2) composition of hatchery stocks, and 3) geographic areas of hatchery releases. This brief summary only focuses on reports from a few hatchery programs, but it is representative of the extensive documentation of hatchery practices in the Columbia River reviewed by members of the BRT.

Coho salmon hatcheries have operated on the Columbia River since the 1890s (WDF 1991d). In the early years, hatcheries mined wild runs for eggs, but little success was realized in juvenile production. Beginning in the 1930s, hatcheries improved juvenile survival, and by the 1960s, the success of juvenile rearing was greatly increased. Coho salmon smolt production in Washington increased from about 2.5 million in 1960 to 23.5 million in 1987. There are now 16 hatcheries rearing coho salmon in the LCR (Table 10).

Hatcheries not only release fish at the hatchery (on-station releases), but also outplant them to other tributaries and even other drainages (off-station outplants). This has occurred since the 1890s when there was no knowledge of genetic population integrity. Salmon eggs were transferred into the LCR from coastal rivers (ODFW 1990a, WDF 1991d) and moved from the lower- and mid-river sites to upriver locations (WDFG 1902).

Currently, tens of millions of juvenile coho salmon are released each year into the LCR (Tables 11-13). If these hatchery stocks were derived directly from local indigenous wild stocks, could they represent the only remaining LCR ESU, if distinct populations have been eliminated in the wild? Unfortunately, coho salmon outplanted into the LCR are the progeny of numerous previous stock transfers over multiple generations and may carry the genetic material of a broad spectrum of ancestral stocks, often from different watersheds; some were not even of Columbia River origin.

In Oregon, stock composition of the major hatchery complexes includes coastal (e.g., Coos Bay, Yaquina River), Washington LCR (e.g., Lewis, Toutle, Grays, Elokomin, and Kalama Rivers), and native runs of coho salmon (Table 14). Stocks of coho salmon in Washington hatcheries are of a similarly mixed lineage (WDF 1991d).

These mixtures of hatchery stocks were not simply released at hatcheries and into adjacent tributaries, but were scattered throughout the Columbia River Basin (even to upriver hatcheries). The recent outplanting history of Oregon LCR streams is presented in Table 15. Often, a single stream will receive fish from two, three, or more hatcheries in any given year. In addition, excess hatchery adults were occasionally released into nonhatchery streams in the region (Table 16). Data for specific stock movements on the Washington side are not presented here, but closely resemble those in Oregon (WDF 1991d).

Transplantation was extensive even in river systems with tributaries now managed for “natural spawners.” Histories of “wild” coho salmon streams in Oregon during the 1980s (Table 17) reveal extensive outplants as late as 1987 in two of five streams investigated. Even the Clackamas River, the one system in the entire river which is regarded as having a remnant “wild” run of coho salmon (Nehlsen et al.

1991), received smolts and presmolts in 1987 (Table 18). An examination of the stocking histories, depicted as a likely “family tree” of two of these Oregon streams the Clackamas River and Still Creek, emphasizes this amalgamation of coho salmon stocks (Figs. 5 and 6) (ODFW 1991a).

Although returns to tributaries outplanted with hatchery fish are often poor (Tables 19-20), this practice is extensive and has occurred for decades.

The BRT compared outplanting records of VTDF and ODFW with topographical maps of the area and determined that many streams/tributaries below Bonneville Dam have no recorded outplants of hatchery coho salmon since 1980 (Table 21). Few of these streams have been monitored for adult coho salmon (Table 22), and no reliable scientific data exist that could confirm whether or not adults, if present, are genetically distinct from hatchery stocks.

Genetics

Background

Several protein electrophoretic studies have demonstrated distinct population structure between some coho salmon populations. In early genetic studies focusing on single loci, the transferrin locus was found to be polymorphic; several studies found a significantly lower frequency of the B allele of transferrin in Fraser River and Columbia River coho salmon compared to all other sampled populations (Utter et al. 1970, 1973, 1980; May 1975; Allendorf and Utter 1979). 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. Thus, transferrin polymorphisms may be maintained by a selective mechanism and may reflect adaptive properties of the different genotypes rather than ancestral relationships.

Most other loci examined in coho salmon have been less informative. May (1975) reported a variant allele of lactate dehydrogenase (LDH-4, now called LDH-B2*) which showed a clear separation between south Puget Sound (including Hood Canal) and north Puget Sound coho salmon stocks. Utter et al. (1980) reported data from several studies on unusual allelic variants in coho salmon from the Feather River Hatchery, California, and suggested that these variants occur widely in the southern part of the coho salmon range. On the Oregon coast, Olin (1984) identified four distinct allelic groupings. Wehrhahn and Powell (1987) found distinct allelic frequency differences between fish from the lower coastal mainland of British Columbia and Oregon.

Hjort and Schreck (1982) studied electrophoretic, morphological, and life history characteristics of coho salmon in Washington, Oregon, and California. In general, they found that 1) stocks geographically close were similar; 2) stocks in large rivers were more similar to each other than to stocks from smaller stream systems, independent of geographic proximity; 3) hatchery stocks were more similar to each other than to wild stocks, and wild stocks were more similar to each other than to hatchery stocks.

Solazzi (1986) used electrophoretic data from a study at the University of California (Davis) to assist fisheries managers with decisions related to stock transfers. Solazzi identified five groups of coho salmon in Oregon and California. Columbia River fish clustered with those from the Rogue and Klamath Rivers. Two California streams also clustered with this group of large-river populations. All other Oregon coho salmon populations were contained in the other four groups.

BRT Analysis of LCR Coho Salmon Populations

Several problems became evident during the BRT's literature review of genetic studies on coho salmon. First, and most significant, was the paucity of studies using naturally spawning fish. Funding and research priorities in the Columbia River Basin have emphasized hatchery production to the exclusion of naturally spawning stocks (VTDF 1991a). Second, in comparison to other Pacific salmon, coho salmon showed less genetic variability at protein coding loci (Allendorf and Utter 1979, Utter et al. 1980) and in restriction fragment analysis of mitochondrial DNA (Moran 1987). Thus, without genetic baselines for historical native coho salmon, and hampered by the genetic peculiarities of coho salmon, it is difficult to determine the evolutionary heritage of any present-day naturally spawning populations.

Therefore, to help evaluate the genetic status of LCR coho salmon, the NMFS Northwest Fisheries Center collected fish samples from LCR streams and hatcheries for allozyme analysis. These new data were analyzed and compared with published and unpublished genetic data from a variety of sources[2].

Materials and methods--Sixteen samples of juvenile salmon were collected in January and February 1991 from populations of both naturally spawning and hatchery fish from the LCR (Fig. 7 and Table 23), including whole body collections from nine hatcheries and from presumably natural spawning parents (wild fish) at seven locations recommended by biologists from ODFW and WDF. Fish from the Lewis and Clark River (n = 6) and Grays River (n = 10) were processed electrophoretically but were not used in the analyses because of the small numbers. The collections were made by staff from NMFS, ODFW, and WDF under the coordination of William Waknitz (NMFS; Manchester, Washington), Richard

[2] This study will be described in the NOAA Technical Memorandum series.

Ledgerwood (NMFS; Hammond, Oregon), and Robert Jones (NMFS; Portland, Oregon).

In the field, whole blood was withdrawn from the dorsal aorta after caudal amputation. Blood was held on ice until the plasma was separated by centrifugation (3-6 hours later). The plasma was then frozen with the whole fish (on dry ice) and transported to the NMFS Montlake Laboratory, Seattle, Washington, where the samples were held at -85°C until processing.

Electrophoretic analyses followed Aebersold et al. (1987). Thirty-seven enzymes encoded by 80 loci were screened for each fish (Table 24). In addition, transferrin was resolved on a modified Ridgway et al. (1970) starch gel using a general stain for proteins. Comparisons among samples were made using Nei's (1972) measure of genetic similarity and the log likelihood ratio test (g-test) (Sokal and Rohlf 1969).

Dendrograms were constructed from the matrices of genetic similarities using an unweighted average linkage method (Sneath and Sokal 1973). Data also were analyzed from the literature (Utter et al. 1970, 1973, 1979; May 1975; Hjort and Schreck 1982; Olin 1984; Bartley 1987; Reisenbichler and Phelps 1987), from unpublished data, and from results of electrophoresis on new samples collected specifically for the ESA status review. The unpublished studies were from 17 NMFS samples and 20 University of California (Davis) (Gall 1991) samples.

Transferrin data were treated separately because these polymorphic loci may be maintained by a selective mechanism. The rest of the electrophoretic loci of this survey were assumed to be selectively neutral. The allozyme data from the various sources were collated into a master set consisting of 68 samples having, as a minimum requirement, data at the 18 polymorphic loci (Table 25). This minimally sufficient set of loci was used as a starting point to examine as broad a geographic range as possible. In addition to the master set itself, two of its subsets were 26 analyzed. One subset included 31 populations with data for 38 polymorphic loci (Table 26). This subset, chosen for maximum genetic resolution, included samples from British Columbia (4), Puget Sound (8), LCR (15), Washington and Oregon coasts (3), and California (1). The second subset, chosen to examine genetic relationships among samples within the LCR, consisted of the 14 samples collected in 1991 and analyzed using 19 polymorphic loci (Table 27).

Results--The distribution of transferrin allele frequencies in samples from the LCR were different from all other geographic regions (Fig. 8). Lower Columbia River samples typically showed higher frequencies of the A allele and lower frequencies of the B and C alleles than found in samples from the other geographical regions. The difference was even more striking if only the data for brood years prior to 1980 were considered: B allele frequency prior to 1980 was 0.003 compared to a frequency of 0.035 after 1980. However, even after this tenfold increase in frequency, the LCR frequency was about half that of other regions.

Cluster analysis of transferrin similarities showed that the LCR samples were most similar to those from California and very different from Oregon coastal samples (Fig. 9). The first three clusters from the top contained all of the LCR (n = 22) and California (n = 14) samples. Only 3 of 29 Oregon coastal samples group with the LCR and California samples. In comparison, the lower four clusters contained most of the Oregon coastal samples (26 of 29) and the only sample from Puget Sound.

Little structuring either geographically or temporally of genetic similarities based on transferrin areles within the LCR was apparent from cluster analysis (Fig. 10). The upper cluster included 25 of 33 samples and contained 5 of 6 wild samples. The middle cluster (7 samples) included the other wild sample along with 4 lower

LCR, 1 Willamette, and 1 upper LCR hatchery samples. The lower cluster was represented by 1 of 2 samples from Eagle Creek National Fish Hatchery. Very low frequencies of both the transferrin B and C allele characterized the upper cluster. Low transferrin B and high (around 0.20) transferrin C allele frequencies were typical of the middle cluster. High frequencies of transferrin B and C alleles (about 0.20) described the monotypic lower cluster.

In most cases, samples replicated over time fell into the same cluster of the transferrin dendrogram. However, there were three exceptions. The 1991 Eagle Creek sample was the sole representative of the lower cluster, but the samples from the late 1970s or early 1980s fell into the middle cluster. Also, early 1980s samples from Bonneville Hatchery[3] were located in the middle cluster, but the 1991 samples (Cascade) were found in the upper cluster. Finally, the 1991 sample of naturally spawning Clackamas River coho salmon fell into the upper cluster, whereas the early 1980s samples were found in the middle cluster.

Samples from the LCR were not electrophoretically differentiated from most of the other samples in a cluster analysis of genetic similarities for 68 samples using the minimally acceptable set of 18 polymorphic loci (Fig. 11). Fifteen of 18 LCR samples occurred in the second cluster along with 14 of 27 Oregon coastal, 3 of 9 California, and 8 of 9 Puget Sound samples. One LCR sample in the first cluster was in company with 1 California and 9 Oregon coastal samples. The other 2 LCR samples fell into the sixth cluster along with at least 1 sample from all of the regions represented in the 68-sample set. The mix of Oregon coastal samples occurring in clusters with LCR was 50% from both northern and southern drainages (dividing line was Florence, Oregon).

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[3] Cascade, Oxbow, and Bonneville Hatcheries form the Bonneville Hatchery complex.

Results of a cluster analysis of a 31-sample subset of the 68-sample set using 38 polymorphic loci are shown in the dendrogram of Figure 12. Nine clusters are apparent. LCR samples were distinct from British Columbia and Puget Sound samples with the exception of 1 Puget Sound sample from Green River Hatchery. The only California sample formed a cluster of its own. Although the I Oregon and 2 Washington coastal samples showed genetic similarities to some LCR samples, these were statistically distinct ($P < 0.0005$) from their nearest LCR neighbors in the dendrogram.

Finally, results of a cluster analysis of 14 samples (a subset of the 31-sample set) using 19 polymorphic loci are shown in Figure 13. These samples were presmolts collected in 1991. There was no apparent geographical or temporal structuring or separation between hatchery and wild stocks among the eight clusters.

An interesting observation was the high genetic similarity between the coho salmon samples from the Clackamas River and two other samples, the Cowlitz Hatchery late-run stock and the Cascade Hatchery stock. Unsmolted fish of the Cowlitz and Bonneville Hatchery stocks were outplanted into the Clackamas River in 1984 and 1987, respectively (Table 18). These fish would have been the correct brood years (1983 and 1986) to represent the grandparents and parents of the 1989 brood fish from the Clackamas River sampled in 1991. This information may explain why Clackamas River samples showed the highest genetic similarity to the Cascade Hatchery sample and the next highest genetic similarity to the Cowlitz Hatchery late-run sample.

Discussion--Genetic differences between the LCR and Washington or Oregon coastal coho salmon were seen in the analyses of the transferrin and the 38 polymorphic loci data sets. Transferrin allele frequencies in the LCR were different from the Oregon coast prior to the 1980s. This might suggest reproductive isolation and/or unique selection pressure. Although the degree of LCR-Oregon coast differentiation decreased after early 1980, mostly due to an increase in transferrin B frequencies, LCR samples still remained distinct from Oregon coastal samples.

The reason for the increase in the frequency of transferrin B in the LCR is unclear. The increase could indicate introgression of coastal alleles through straying or transplanting of Oregon coastal stocks, or perhaps this allele was present at low frequencies in populations of the LCR prior to the 1980s and has increased in response to changing selection pressures. Note that only two of the pre-1980s samples were nonhatchery, and one of these harbored the B allele at low frequency (May 1975).

The reason for the high degree of similarity observed between many California and LCR samples based on the transferrin locus is also unclear. There may be similar selective regimes acting on transferrin genotypes, or there may have been stock transplants. Straying would not be very likely over such distances. Very little evidence of reproductive isolation was apparent from the analysis of the 68-sample data set. Although all except 3 of the LCR samples fell into one cluster, this cluster also included about 50% of the Oregon coastal (27), 33% of the California (9), and 89% of the Puget Sound (8) samples. It is possible that the set of 18 loci used to analyze this set of samples was not adequate to define any existing genetic structuring.

Genetic differences as well as similarities between populations can be generated much more quickly by introductions of new genetic material than by 30 reproductive isolation. The introduction of new genetic material from Cascade Hatchery might explain the higher genetic similarity of the 1991 Clackamas sample with the Cascade Hatchery stock than with an earlier sample from the Clackamas. This suggests that there was gene flow between this hatchery transplant and naturally spawning Clackamas River coho salmon. Similar studies on the relationship between genetic similarities in LCR coho salmon and stocking histories might provide further insight into the evolutionary legacy of petitioned coho salmon populations.

Effects of Parasitism

Ceratomyxa shasta is a protozoan parasite of chinook and coho salmon and occurs in locations associated with lakes or reservoirs (Amos 1985). The parasite has caused large losses of adult fish in several LCR hatcheries (Wood 1979). In a survey of coho salmon in Oregon, Sanders et al. (1970) found that the parasite was present only in populations within the Columbia River or near its mouth. Ching and Munday (1984) reported *C. shasta* in the Fraser River, a large river system in British Columbia.

Hemmingsen et al. (1986) demonstrated that resistance to *C. shasta* in coho salmon is a heritable trait. When progeny of pure Big Creek (LCR), pure Soleduck and Smith Rivers (coastal), and hybrid crosses between the Columbia River and coastal river stocks were exposed to *C. shasta* in the laboratory, the Big Creek fish showed the highest resistance. The hybrid cross showed intermediate resistance, and the pure coastal fish had the lowest resistance. Based on this information, the investigators suggested that the prevalence of *C. shasta* within the LCR may exert strong selective pressure against introgression from fish that lack resistance to the parasite. This pressure could reduce gene flow between the LCR and coastal river populations.

LCR coho salmon may also exhibit an inherited resistance to other parasites or diseases (Suzumoto et al. 1977, Pratschner 1978) which might act to reduce gene flow between this region and other areas.

CONCLUSIONS

In keeping with the guidelines established by NMFS (Waples 1991) for species determination under ESA, the BRT evaluated whether LCR coho salmon represent a “distinct population segment” that is reproductively isolated and “represents an important component in the evolutionary legacy of the species.” During the status review of LCR coho salmon, the BRT considered the following information on reproductive isolation particularly significant:

1) Few studies of distinct populations of naturally spawning fish in the LCR were identified. No recent studies concerning the genetics, morphology, behavior, or other aspects of LCR wild fish populations were identified which would delineate reproductively isolated groups.
2) Hatcheries in the LCR rear coho salmon that are products of multitudes of stocks from throughout the region, including the coast. In recent years, the emphasis in hatchery production has focused on fish derived from the LCR, but the lineage of even these stocks involves interhatchery transfers.
3) The LCR has been managed for hatchery production, not wild salmon, for over 30 years. Hatcheries have released fish in virtually every major tributary throughout the LCR. In these releases, the carrying capacities of tributaries were often exceeded by hundreds of thousands of hatchery fry or smolts. The extent and duration of the releases suggest that naturally spawning populations in these streams are mixtures of the native and introduced hatchery stocks.

4) Numerous studies have determined that fidelity of homing in coho salmon (one of the most important factors necessary for reproductive isolation) occurs at a rate similar to that found in other anadromous salmon (usually well over 90%). However, coho salmon stray at a high rate when access to natal streams is blocked or imprinting is inadequate. Within the LCR, extensive blockage of natal spawning areas has occurred and many fish released from hatcheries have not been properly imprinted.
5) Differential resistance to the parasite *Ceratomyxa shasta*, prevalent in the Columbia River, may reduce gene flow between coho salmon populations in the LCR and other regions.
6) Time of return to the LCR is different between early and late spawners. Hatchery fish have been selected for early- to mid-season spawning. It has been proposed that coho salmon spawning from mid-December to March may represent native nonhatchery populations. However, the BRT found no published studies on genetic, morphological, behavioral, or other characteristics of these fish which would indicate whether these late-spawning stocks are feral-hatchery fish or isolated remnants of historical populations.
7) Numerous studies indicate that naturally spawning populations of coho salmon have a complex stock structure that could survive a series of natural or manmade disruptions. Whether the extent of hatchery releases, overharvest, and extensive habitat destruction on the Columbia River is beyond the capability of these populations to survive is unknown.
8) Electrophoretic surveys of naturally spawning coho salmon in the LCR have been extremely limited, and available information is inconclusive.
9) Hatchery releases and outplants have been extensive and of over 30 years duration. It is unlikely that any naturally spawning populations e2dst in the LCR

that do not have some introgression from hatchery stocks. The extent of this introgression is unknown.

10) There has been little attempt to maintain habitat in the LCR; consequently, many streams can no longer maintain sizeable spawning populations or successfully rear juveniles.

11) For decades, harvest of LCR coho salmon has often exceeded 90%. It is likely populations of naturally spawning fish were depleted below levels necessary for survival, especially when these same populations were spawning in poorly maintained habitat and mixed with extensive hatchery releases and/or outplants.

12) There is at least one well-documented naturally spawning coho salmon population--the late, post-December run in the Clackamas River. However, only a preliminary investigation was carried out on this stock as it was not part of the initial ESA petition. This run has a complex history of human disruption and requires further investigation.

13) Observations of naturally spawning coho salmon in the Columbia River are in the ESA record (e.g., Sandy River, Lewis and Clark River, Washougal River, and Hood River). However, the BRT was unable to find any published genetic, morphological, or other specific studies on these stocks.

From the information developed during the status review, the BRT concluded that at one time, coho salmon spawning in the LCR were probably reproductively isolated from other coho salmon populations. However, human intervention during the last century has lessened this isolation; the evidence evaluated by the BRT was insufficient to determine the extent or significance of this reduction.

The BRT concluded that the available data fail to identify an existing evolutionarily significant unit in the lower Columbia River. If one or more coho salmon ESUs are present in the Columbia River, fishery management actions and research studies have inadequately documented these populations.

Table 1.--Coho salmon counts over North Fork Dam, Clackamas River, from August to March 1958-89, in percent of run per month per 3-year period.

Years	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1958-60			4.7	47.6	23.8	13.8	9.9	0.2
1968-70	0.1	4.4	25.1	38.2	23.2	5.9	3.0	0.2
1978-80	0.1	14.0	9.8	20.5	30.2	17.9	7.5	0.1
1987-89	5.1	30.4	16.2	8.0	9.6	24.0	10.4	8.9

Table 2.--Columbia River coho salmon abundance, 1925-90.

			Population estimate[a]				
Year	No. (10^3)	Year	No. (10^3)	Year	No. (10^3)	Year	No. (10^3)
1925	1,145.3	1945	226.5	1965	519.0	1985	365.3
1926	953.2	1946	156.6	1966	785.9	1986	1,521.2
1927	751.7	1947	225.4	1967	694.2	1987	302.7
1928	537.2	1948	173.4	1968	423.9	1988	655.6
1929	967.0	1949	130.5	1969	463.4	1989	683.5
1930	1,116.5	1950	160.4	1970	1,057.1	1990	182.8
1931	391.6	1951	120.5	1971	528.4		
1932	591.2	1952	139.4	1972	268.7		
1933	389.9	1953	65.5	1973	283.8		
1934	689.0	1954	41.4	1974	448.3		
1935	387.3	1955	74.9	1975	282.5		
1936	250.9	1956	66.0	1976	326.2		
1937	265.8	1957	57.0	1977	87.8		
1938	348.5	1958	27.6	1978	298.3		
1939	234.9	1959	21.1	1979	263.6		
1940	210.0	1960	47.7	1980	288.7		
1941	165.4	1961	112.4	1981	162.5		
1942	105.1	1962	184.7	1982	435.6		
1943	104.4	1963	161.9	1983	100.5		
1944	224.9	1964	453.9	1984	407.9		

[a] Population estimates:

1925 to 1938: Total inriver catch/average fish weight x 1/harvest rate. Catch data from Beiningen (1976). Assumes estimated annual harvest of 77% as suggested by Chapman (1986) and estimated average fish weight of 4.08 kg as suggested by Oregon Fish Commission (1975).

1938 to 1959: (Zone 1-5 inriver catch/average fish weight x 1/harvest rate) + yearly total count of coho salmon passing Bonneville Dam. Catch data from Oregon Fish Commission (1975). Assumes estimated annual harvest of 77% as suggested by Chapman (1986) for 1938 to 1950 and actual yearly harvest rates as described by ODFW (1991a) for 1951 to 1959. Assumes average fish weight of 4.08 kg as suggested by Oregon Fish Commission (1975). Bonneville Dam counts from COE (1990).

1960 to 1990: Zone 1-5 inriver catch + lower river sport catch + hatchery returns + tributary dam counts + Bonneville Dam counts. Data from PFMC (1991).

Table 3.--Results of population dynamics computer modeling* for select groups of Columbia River coho salmon.

Group	Mean	Var	N^q	N^e	N^t	P^1 (100)	P^e (10)
Columbia River run:							
1925 to 1943	-0.12308	0.02462	374.9K	2.7x10_6	1.0x10_7	0.392	n/a
1944 to 1959	-0.12358	0.01966	105.7K	2.2x10_6	8.1x10_6	0.733	n/a
1960 to 1990	0.07223	0.10373	1.5x10_6	8	12	<0.001	<0.001
Washington index streams, October to December:							
1951 to 1990	0.10352	0.53897	153	1,359	4,074	0.129	n/a
Washington index streams, post-December:							
1951 to 1990	-0.06729	0.50688	18	1.8x10_8	1.2x10_9	0.896	n/a
Oregon index streams, post-December:							
1951 to 1990	-0.10015	0.17580	1	2.4x10_7	1.1x10_8	1.000	n/a
Clackamas River, post-December:							
1951 to 1990	0.05266	0.10389	2,055	17	27	<0.001	<0.001

*Dennis et al. 1991. This model estimates the probability of extinction assuming continuation of population abundance trends from the period modeled to the future.

Legend

Mean = infinitesimal mean.
Var. = infinitesimal variance.
N^q = most recent index (abundance) value.
N^e = "endangered" threshold (the index value giving a 5% probability of reaching N = 1 within the next 10 years).
N^t = "Threatened" threshold (the index value giving a 50% probability of reaching N = N^e within the next 10 years).
P^1(100) = probability of reaching N = 1 within the next 100 years.
P^e(10) = probability of reaching N = N^e within the next 10 years.

Table 4.--Columbia River coho salmon production (Washington-side, below Bonneville Dam).

Stream	Natural spawners[b] ISP[c]	Natural spawners[b] NMFS[d]	WDF hatchery[a] Average returns[e]	WDF hatchery[a] Upstream release[f]	WDF outplants[a] Yearly average 1980s[g]
Chinook River	--	50	--	--	115,000
Chinook to Grays River	--	50	--	--	23,000
Grays River	2,500	1,500	3,387	300	1,489,000
Jim Crow Creek.	--	50	--	--	116,000
Deep River	--	--	--	--	121,000
Skamokawa River	--	250	--	--	410,000
Elokomin River	--	1,800	6,362	2,124	2,774,000
Mill Creek	--	350	--	--	127,000
Abernathy Creek	--	250	--	--	304,000
Germany Creek	--	300	--	--	203,000
Coal Creek	--	50	--	--	211,000
Cowlitz River	7,700	4,750	33,152	8,290	9,635,000
Kalama River	2,600	1,500	5,678	2,012	2,182,000
Lewis River	9,700	--	40,558	2,844	1,497,000
-N. Fork.	--	4,500	--	--	5,339,000
-E. Fork.	--	2,000	--	--	1,001,000
Salmon Creek	--	325	--	--	236,000
Washougal River	--	500	4,573	500	2,784,000
Lawton, St. Cloud, & Duncan Creek	--	100	--	--	128,000
Woodard, Hardy, & Hamilton Creek	--	200	--	--	61,000
TOTAL (below Bonneville Dam)	22,500	18,525	93,710	16,070	28,756,000
1977 to 1989 average			70,528[a]		

Data from:

[a] Washington Department of Fisheries (WDF 1991a) submission to ESA record.
[b] Includes instream spawning for fish of natural and hatchery origin.
[c] Northwest Power Planning Council Integrated System Plan (ISP) (CBFWA 1990).
[d] National Marine Fisheries Service Technical Memorandum F/NWC-122 (Wahle and Pearson 1987).
[e] Average 1988-89 adult returns.
[f] Maximum 1988-89 upstream release from adult capture.
[g] Two- to 10-year average, depending on data set.

Table 5.--Columbia River coho salmon production (Washington-side, above Bonneville Dam).

Stream	Natural spawners[a] ISP[b] 1988-89	Natural spawners[a] NMFS[c] 1984-85
Wind River	--	100
Little White Salmon River	--	0
Spring Creek	15,000	0
Big White Salmon River	700	50
Klickitat River	5,100	500
Yakima River	100	50
Wenatchee River	--	50
Entiat River	--	0
Methow River	--	0
Okanogan River	--	0
Columbia River	--	0
Snake River (below Lower Granite Dam)	--	0
Walla Walla River	--	0
Tucannon River	--	0
Asotin Creek	--	0
TOTAL (above Bonneville Dam)	20,900	750

[a] Includes instream spawning for fish of natural and hatchery origin.

Data from:
[b] NWPPC Integrated System Plan (ISP) (CBFWA 1990) information on recent escapement.
[c] National Marine Fisheries Service Technical Memorandum (Wahle and Pearson 1987).

Table 6.--Columbia River coho salmon production (Oregon-side, below Bonneville Dam).

Stream	Natural spawners[a]	
	ISP[b] 1988-89	NMFS[c] 1984-85
Lewis & Clark River	--	300
Youngs River	--	25
Klaskanine River	--	500
Bear Creek	--	25
Big Creek	--	300
Gnat Creek	--	30
Plympton Creek	--	0
Clatskanie River	--	300
Milton Creek	--	100
Scappoose Creek	--	150
Sandy River	15,000	1,000
Wahkeena Creek	--	0
Tanner Creek	--	0
TOTAL (below Bonneville Dam)	15,000	2,730

[a] Includes instream spawning for fish of natural and hatchery origin.

Data from:
[b] NWPPC Integrated System Plan (ISP) (CBFWA 1990).
[c] National Marine Fisheries Service Technical Memorandum (Wahle and Pearson 1987).

Table 7.--Columbia River coho salmon production (Oregon-side, above Bonneville Dam).

Stream	Natural spawners[a] NMFS[b] 1984-85
Eagle Creek	0
Herman Creek	0
Lindsey Creek	35
Viento Creek	30
Hood River	50
Mosier Creek	30
Chenowith Creek	20
Mill Creek	30
Deschutes River	40
John Day River	0
Umatilla River	0
Grande Ronde River	300
Imnaha River	0
TOTAL (above Bonneville Dam)	535

[a] Includes instream spawning for fish of natural and hatchery origin.

Data from:
[b] National Marine Fisheries Service Technical Memorandum (Wahle and Pearson 1987).

Table 8.--Columbia River coho salmon production (Oregon-side, Willamette River).

Stream	Natural spawners[a] ISP[b] 1988-89	Natural spawners[a] NMFS[c] 1984-85
Willamette River - main-stem	14,300	0
Clackamas River		
-early	--	--
-late	600	2,000
Molalla River	--	100
Pudding River	--	50
Mill Creek	--	0
Santiam River	--	200
Calapooya River	--	0
McKenzie River	--	100
Middle Fork	--	0
Coast Fork	--	0
Marys River	--	25
Luckiamute River	--	100
Rickreall Creek	--	25
Yamhill River	--	400
Tualatin River	--	200
TOTAL -- (Willamette River system)	14,900	3,200

[a] Includes instream spawning for fish of natural and hatchery origin.

Data from:
[b] NWPPC Integrated System Plan (ISP) (CBFWA 1990).
[c] National Marine Fisheries Service Technical Memorandum (Wahle and Pearson 1987).

Table 9.--NMFS calculation of 1990-91 coho salmon spawners/km in Oregon Department of Fish and Wildlife lower Columbia River standard index areas. Data from ODFW (1991a).

Stream	Kilometers surveyed	Total count	Peak count	Peak spawners/km
Youngs River	0.5	13	10	20.8
Little Creek	2.0	22	7	3.5
Willard Unit	1.1	0	0	0.0
Carcus Creek	2.4	3	3	1.3
Milton Creek	0.8	0	0	0.0
Salmon Creek	0.6	0	0	0.0
Sierkes Creek	0.8	0	0	0.0
Raymond Creek	1.6	1	1	0.6
Deep Creek	3.4	4	3	0.9
Tickle Creek	2.3	1	1	0.4
Average				2.8

Table 10.--Hatcheries rearing coho salmon in the lower Columbia River.

Washington Department of Fisheries hatcheries
Grays
Elokomin
Cowlitz
Toutle
Lower Kalama
Kalama Falls
Lewis
Speelyai
Washougal
Oregon Department of Fish and Wildlife hatcheries
Klaskanine
Big Creek
Sandy
Bonneville
Oxbow
Cascade
U.S. Fish and Wildlife Service hatchery
Eagle Creek

Table 11.--Washington hatchery outplants of coho salmon (in thousands) into the lower Columbia River below Bonneville Dam, 1980-88. Data compiled from Washington Department of Fisheries (WDF) outplanting records (Coleman and Rasch 1981; Castoldi and Rasch 1982; Castoldi 1983; Hill 1984; Kirby 1985; Abrahamson 1986, 1987, 1988; WDF 1991d; personal communication William Hopley, WDF).

	Pre-smolt			Smolt		
Location	Total fish outplanted (10^3)	Average 1980-88 (10^3)	Average (*) (10^3)	Total fish outplanted (10^3)	Average 1980-88 (10^3)	Average (*) (10^3)
Chinook River	925	102	115(8)			
Chinook River to Grays River	47	5	23(2)			
Grays River	5,936	659	989(6)	4,500	500	500(9)
Jim Crow Creek	581	65	116(5)			
Deep River	606	67	121(5)			
Skamokawa Creek	1,643	182	410(4)			
Elokomin River	3,660	406	457(8)	20,860	2,317	2,317(9)
Mill Creek	127	14	127(1)			
Abernathy Creek	1,218	135	304(4)			
Germany Creek	610	67	203(3)			
Coal Creek	105	117	211(5)			
Cowlitz River	50,419	5,602	5,602(9)	36,304	4,033	4,033(9)
Kalama River	6,741	749	842(8)	12,063	1,340	1,340(9)
Lewis River	5,485	609	609(9)	8,000	888	888(9)
N. Fork Lewis River	1,599	177	799(2)	36,324	4,036	4,540(8)
E. Fork Lewis River	5,007	556	1,001(5)			
Salmon Creek	2,129	236	236(9)			
Washougal River	4,704	522	522(9)	20,364	2,262	2,262(9)
Lawton Creek to Duncan Creek	899	99	128(9)			
Woodland Creek to Greenleaf Creek	122	13	61(2)			
TOTAL	92,563	10,382		138,415	15,376	

(*) Number of years outplants were made.

Table 12.--Oregon hatchery off-station outplants of coho salmon (in thousands) in the lower Columbia River below Bonneville Dam, 1980-88. Data compiled from ODFW (1991a).

	Presmolt			Smolt		
Location	Total fish outplanted (10^3)	Average 1980-88 (10^3)	Average (*) (10^3)	Total fish outplanted (10^3)	Average 1980-88 (10^3)	Average (*) (10^3)
Lewis & Clark River	1,329	133	221(6)			
Youngs River	2,318	232	289(8)			
Klaskanine River	2,518	252	419(6)	1,875	188	375(5)
Bear Creek	324	32	81(4)			
Big Creek				844	84	84(1)
Gnat Creek						
Plympton Creek	97	10	10(1)			
Clatskanie River	4,108	411	513(8)			
Milton Creek	449	45	74(6)			
Scappoose Creek	551	55	91(6)			
Clackamas River	4,870	487	487(10)	164	16	55(3)
Sandy River	2,219	222	317(7)			
TOTAL	18,783	1,879		2,883	288	

(*) Number of years outplants were made.

Table 13.--Oregon hatchery on-station outplants of coho salmon (in thousands) into the lower Columbia River below Bonneville Dam, from date hatchery began operation to the present. Data compiled from ODFW (1991a).

	Years outplanted		Total number outplanted	
Hatchery	From	To	Smolts (10^3)	Presmolts (10^3)
Klaskanine	1911	1990	57,512	42,639
Big Creek	1938	1990	28,572	28,324
Eagle Creek	1960	1990	25,772	7,285
Sandy	1951	1990	26,422	3,581
Bonneville	1911	1990	70,758	24,673
Cascade	1958	1980	6,639	1,174
Oxbow	1938	1969	1,320	6,981
Total released			216,995	114,657

Table 14.--Transfers of coho salmon into hatcheries in Oregon. Data compiled from ODFW (1991a).

Hatchery	Stock transferred	Number of transfers	Years
Bonneville	Trask	2	1911-W,1957
	Alsea	1	1922-W
	Coos Bay	1	1925
	Tenmile Lake	5	1930-1943-W
	Yaquina	1	1939-W
	Lewis (Washington)	1	1933
	Klaskanine	6	1941-1949
	Big Creek	6	1942-1971
	Sandy	5	1945-1970
	Toutle (Washington)	2	1955,1956
	Eagle Creek	1	1970
	Oxbow	2	1942,1968
	Cascade	1	1970
Oxbow	Bonneville	4	1937-1959
	Sandy	1	1956
	Cascade	1	1964
	Big Creek	1	1961
	Eagle Creek	1	1959
	Tenmile Lake	1	1937-W
Cascade	Oxbow	1	1959
	Bonneville	2	1962,1966
	Big Creek	1	1961
	Eagle Creek	1	1959
Klaskanine	Big Creek	7	1926-1989
	Trask	6	1926-1955
	Alsea	3	1927(W)-1955
	Nestucca	1	1930-W
	Siletz	1	1939-W
	Tenmile Lake	4	1934-1937-W
	Lewis (Washington)	1	1933
	Cascade	2	1981,1982
	Sandy	2	1983,1987
	Bonneville	5	1981-1987

W = Wild stock transfer.

Table 14.--Continued.

Hatchery	Stock transferred	Number of transfers	Years
Eagle Creek	Sandy	4	1956-1990
	Toutle (Washington)	2	1956,1966
	Grays (Washington)	1	1966
	Elokomin (Washington)	1	1966
	Kalama (Washington)	1	1990
	Klaskanine	1	1990
	Big Creek	2	1958,1990
Sandy	Bonneville	3	1951-1965
	Big Creek	1	1961
Big Creek	Klaskanine	3	1944-1968

Table 15.--Transfers of presmolt and smolt coho salmon from hatcheries into watersheds in Oregon. Most transfers of fish ranged from 20,000 to 100,000, with some as high as 999,000 for presmolts and 750,000 for smolts. Data compiled from ODFW (1991a).

Watershed	Stock transferred	Number of transfers	Year
Lewis & Clark River	Klaskanine	6	1948-1971
	Big Creek	3	1977-1985
	Sandy	4	1980-1983
	Oxbow	1	1981
Youngs River	Klaskanine	7	1951-1982
	Big Creek	4	1953-1987
	Trask	1	1979
	Sandy	2	1983,1989
	Cowlitz (Washington)	1	1984
	Bonneville	1	1987
	Eagle Creek	3	1988-1990
Klaskanine River	Big Creek	3	1952-1985
	Sandy	2	1981,1990
	Cascade	2	1981,1982
	Cowlitz (Washington)	1	1984
	Bonneville	1	1987
	Eagle Creek	3	1988-1990
Bear Creek	Sandy	1	1981
	Big Creek	3	1981-1985
	Bonneville	1	1987
	Klaskanine	3	1944-1968
Big Creek	Bonneville	1	1986
Gnat Creek	Big Creek	3	1952-1961
Plympton Creek	Sandy	1	1981
	Klaskanine	1	1963
	Cascade	1	1978
Clatskanie River	Big Creek	10	1949-1985
	Sandy	5	1980-1988
	Cascade	1	1981
	Cowlitz (Washington)	1	1984
	Bonneville	1	1987
	Oxbow	1	1981
	Klaskanine	3	1963-1972

Table 15.--Continued.

Watershed	Stock transferred	Number of transfers	Years
Milton Creek	Sandy	4	1980-1983
	Cowlitz (Washington)	1	1984
	Bonneville	1	1987
Scappoose Creek	Big Creek	8	1951-1959
	Sandy	4	1980-1983
	Bonneville	2	1952,1987
	Cowlitz (Washington)	1	1984
Clackamas River	Cascade	2	1981,1983
	Bonneville	10	1919-1988
	Oxbow	2	1981,1987
	Sandy	14	1964-1987
	Eagle Creek	13	1962-1989
	Gnat Creek	1	1983
	Cowlitz (Washington)	1	1984
	S. Santiam	2	1987,1988
Sandy River	Bonneville	9	1919-1987
	Oxbow	3	1981-1985
	Cowlitz (Wash)	1	1984
	Cascade	2	1963,1983
	Big Creek	4	1951-1956

Table 16.--Transfers of adult coho salmon from hatcheries into watersheds in Oregon. Most transfers consisted of 100-200 fish. Data compiled from ODFW (1991a).

Watershed	Stock transferred	Number of transfers	Years
Lewis & Clark River	Klaskanine	10	1964-1984
	Big Creek	2	1968,1972
Youngs River	Klaskanine	12	1964-1984
	Big Creek	4	1968-1980
Klaskanine River	Big Creek	1	1972
Bear Creek	Klaskanine	1	1984
Big Creek	none		
Gnat Creek	Klaskanine	1	1965
Plympton Creek	none		
Clatskanie River	Klaskanine	1	1965
Milton Creek	Big Creek	1	1964
	Sandy	1	1984
Scappoose Creek	Klaskanine	1	1964
	Big Creek	2	1964-1966
	Sandy	1	1984
Clackamas River	Sandy	8	1966-1986
	Bonneville	5	1967-1972
	Cascade	1	1971
	Big Creek	1	1971
Sandy River	none		

Table 17.--Outplanting histories during the 1980s of streams in Oregon which are managed for "wild" or "naturally spawning" fish. Data compiled from ODFW (1991a).

	Presmolts			Adults		
Stream	Number	Stock	Year	Number	Stock	Year
Still Creek (Sandy)	32,000	Sandy	1987	200	Sandy	1986
	30,000	Sandy	1985	200	Sandy	1985
	45,000	Oxbow	1985	400	Sandy	1984
	88,000	Cowlitz	1984	597	Sandy	1980
	81,000	Sandy	1983			
	95,000	Sandy	1982			
	82,500	Sandy	1980			
Milton Creek (Scappoose)	49,500	Bonn.	1987	200	Sandy	1984
	55,000	Cowlitz	1984			
	131,000	Sandy	1983			
	56,000	Sandy	1982			
	70,500	Sandy	1981			
	95,500	Sandy	1980			
Raymond Creek (Scappoose)	No recorded outplants					
Sierkes Creek (Scappoose)	No recorded outplants					
Carcus Creek (Clatskanie)	Not outplanted since 1952					

Table 18.--Coho salmon outplants in the Clackamas River system in 1984 and 1987. The 1983 brood Cowlitz presmolts (outplanted in 1984) could have been parents of the 1986 brood group, outplanted as pre-smolts in 1987 (smolts are 1985 brood year). The 1986 brood fish could/would be parents of 1989 juveniles sampled in Clackamas River system during January 1991. Data compiled from ODFW (1991a).

Stream	Presmolts		Smolts		1983 Cowlitz presmolts
	Number	Stock	Number	Stock	
Clackamas River			56,000	S. Santiam	
Clear Creek	49,000	Bonn.	20,000	S. Santiam	49,000
	44,000	Oxbow			
	69,000	Sandy			
L. Clear Creek	39,500	Bonn.			37,000
Mosier Creek	15,000	Bonn.			
L. Cedar Creek	35,500	Bonn.			
L. Clear II	39,500	Oxbow			
Richardson's	30,000	Bonn.			
Deep Creek	76,000	Sandy	14,500	S. Santiam	56,500
N.F. Deep Creek	39,500	Sandy			37,000
Tickle Creek	71,000	Bonn.			37,000
Goose Creek	30,000	Bonn.			
N.F.Eagle Creek	92,500	Bonn.			81,000
Bear Creek	30,000	Bonn.			
L. Eagle Creek	40,000	Bonn.			
Grabenheim	30,500	Bonn.			
Trout Creek	30,000	Bonn.			24,500
Delph Creek	68,500	Bonn.			
Wade Creek	50,000	Bonn.			
Abernathy Creek	44,500	Bonn.			
Holcomb Creek	25,000	Bonn.			

L. = lower.
N.F. = north fork.

Table 19.--Recent outplanting and adult return histories for Olequa Creek System, tributary to the Cowlitz River, Washington. Data compiled from WDF outplanting records (see Table 11).

Year*	Presmolts	Average size (g)	Smolts	Adults returned
1980/82	0	-	0	24
1981/83	0	-	0	-
1982/84	0	-	0	11
1983/85	0	-	0	-
1984/86	466,300	~0.4	0	-
1985/87	506,700	~0.8	0	-
1986/88	547,000	~0.9	0	-
1987/89	640,000	~0.9	0	-
1988/90	533,200	~0.3	0	-

* Year of presmolt release/year of adult return from that release.

Table 20.--Rates of adult spawner returns for outplantings of 1988 brood year presmolt, and 1989 brood year smolt coho salmon. Streams are outplanted with hatchery fish, but are not located near hatcheries. Data compiled from ODFW (1991a).

Stream	Pre-smolts	Smolts	Adults	Km surv.	Total km	Total coho	Return (%)
Beaver Creek	65,500	None	0	0.3	1.4	0	--
N.F. Eagle Creek	67,000	None	0	2.4	12.9	0	--
Youngs River	None	87	13	0.5	0.6	265,000	0.032
S.F. Klaskanine	None	320	13	1.9	9.5	275,000	0.12

N.F. = north fork.
S.F. = south fork.

Table 21.--Lower Columbia River streams in Washington and Oregon not outplanted with coho salmon since at least 1980.

Washington		Oregon	
Stream	Tributary to	Stream	Tributary to
Wallacut Cr.	Columbia River	Stavebolt Cr.	Lewis &
unnamed	"	Hortill Cr.	Clark River
S.F. Grays R.	Grays R.	Klickitat Cr.	"
Eggman Cr.	Skamokawa Cr.	Speelyai Cr.	"
Standard Cr.	"	Scheewash Cr.	"
Pollard Cr.	"	Johnson Cr.	Columbia R.
Clear Cr.	Elokomin R.	Camp Cr.	Johnson Cr.
Beaver Cr.	"	John Day R.	"
unnamed	Mill Cr.	Waterworks Cr.	Bear Cr.
Midway Cr.	Abernathy Cr.	Hillcrest Cr.	Columbia R.
Eriek Cr.	"	Plympton Cr.	Westport
Ordway Cr.	"	Olsen Cr.	Slough
Loper Cr.	Germany Cr.	OK Cr.	"
John Cr.	"	Tandy Cr.	"
Arkansas Cr.	Cowlitz R.	Graham Cr.	"
Tucker Cr.	"	Page Cr.	Clatskanie R.
Clark Cr.	"	Carcus Cr.	"
O'Neil Cr.	Coweman R.	Keystone Cr.	"
Baird Cr.	"	Miller Cr.	"
Jacks Cr.	Kalama R.	Adam Cr.	"
Spencer Cr.	"	Palmer Cr.	Beaver Cr.
Knoulton Cr.	"	Elk Cr.	"
Summers Cr.	"	Wilson Cr.	"
Langdon Cr.	"	Fox Cr.	Columbia R.
Bush Cr.	"	Green Cr.	"
Schoolhouse Cr.	Columbia R.	Endicott Cr.	Tide Cr.
Bybee Cr.	"	Bishop Cr.	"
Brush Cr.	Lewis R.	McBride Cr.	Columbia R.
Bitter Cr.	"	Perry Cr.	Milton Cr.
Cold Cr.	"	Raymond Cr.	"
Vogel Cr.	Washougal R.	Brush Cr.	"
Jackson Cr.	"	Sierkes Cr.	"
Hagen Cr.	"	7 streams	McKay Cr.
Wildboy Cr.	"	N. Fork	Clackamas R.
Texas Cr.	"	Clackamas R.	
8 streams	"	7 streams	S. Fork
above hatchery			Clackamas R.
		7 streams	Sandy R.

S.F. = south fork.

Table 22.--Status of adult returns in 1990-91, from lower Columbia River streams in Oregon which have little or no history of hatchery transplants. Data compiled from ODFW (1991a).

Stream	Tributary to	Outplanting record[a]	Adult activity[b]	Code[c]	Early/ late	Total count[d]
Stavebolt	Lewis &	NR	*	B	E/L	15/29
Hortill	Clark R.	NR	*	B	E/L	10/69
Klickitat	"	NR	*	A	E	1/10
Speelyai	"	NR	*	B	E/L	4/2
Scheewash	"	NR	*	R	E/L	6/6
Johnson	Johnson	'81(1)	*	R	E	3/0
Camp	"	NR	*	R	L	0/2
John Day R.	Col. R.	NR	NS			
Waterworks	Bear Cr.	NR	NS			
Hillcrest	Col. R.	NR	NS			
Plympton	Westport	'78(1)	*	R	E	9/1
Olsen	Slough	NR	NS			
OK	"	NR	NS			
Tandy	"	NR	NS			
Graham	"	NR	NS			
Page	Clatskanie	NR	*	R	L	0/1
Carcus	River	'52(1)	*	B	E/L	3/1
Keystone	"	NR	NS			
Miller	"	NR	NS			
Adam	"	NR	NS			
Palmer	Beaver Cr.	NR	NS			
Elk	"	NR	NS			
Wilson	"	NR	NS			
Fox	Col. R.	NR	NS			
Green	"	NR	NS			
Endicott	Tide Cr.	NR	NS			
Bishop	"	NR	NS			
McBride	Col. R.	NR	NS			
Perry	Milton Cr.	NR	NS			
Raymond	Scappoose	NR	*	A	E	1/0
Brush	"	NR	*	A	E	3/0
7 streams	McKay Cr.	NR	NS			
N. Fork Clackamas	N. Fork Clackamas	NR	NS			
Boyer	"	'66(2)	NS			
7 streams	S. Fork Clackamas	'64 to '70 (1 or 2)	NS			
7 streams	Sandy R.	'38 to '82 (1 or 2)	NS			

Notes continued.

Table 22.--Continued.

[a]	NR	= none recorded; for outplanted streams, year of last outplant and total years outplanted ( ) are given.
[b]	NS	= nonsurvey (adults) stream.
[c]	A	= only adults observed.
	R	= only redds observed.
	B	= both adults and redds observed.
[d]	Total Count	= Adults + redds for early (before December 15) and for late (after December 15) runs.

Table 23.--Samples of coho salmon from 16 locations on the Columbia River below Bonneville Dam in 1991.

Location	Collection date	Sample size
<u>WDF hatcheries</u>		
Grays River	11 Jan	50
Grays River	24 Jan	80
Cowlitz River		
early run	23 Jan	80
late run	23 Jan	80
Lewis River		
early run	24 Jan	80
late run	24 Jan	80
<u>USFWS hatchery</u>		
Eagle Creek, OR	25 Jan	80
<u>ODFW hatcheries</u>		
Sandy River	6 Feb	80
Cascade River	7 Feb	80
<u>Streams</u>		
Hardy Creek, WA	18 Jan	50
Still Creek, OR	22 Jan	62
Clackamas River, OR	23 Jan	60
Scappoose Creek, OR	24 Jan	44
Clatskanie River, OR	25 Jan	50
Grays River, WA	30 Jan	11
Lewis and Clark River, OR	31 Jan	6

WDF = Washington Department of Fisheries.
USFWS = U.S. Fish and Wildlife Service.
ODFW = Oregon Department of Fish and Wildlife.

Table 24.--List of enzymes surveyed, Enzyme Commission (E.C.) numbers, and locus abbreviations for each presumptive gene locus.

Enzyme	E.C. number	Locus abbreviation
Aspartate aminotransferase	2.6.1.1	*sAAT-1,2** *sAAT-3** *sAAT-4** *mAAT-1**
Acid phosphatase	3.1.3.2	*ACP-1** *ACP-2**
Adenosine deaminase	3.5.4.4	*ADA-1** *ADA-2**
Alcohol dehydrogenase	1.1.1.1	*ADH**
Aconitate hydratase	4.2.1.3	*sAH** *mAH-1** *mAH-2** *mAH-3** *mAH-4**
Adenylate kinase	2.7.4.3	*AK**
Alanine aminotransferase	2.6.1.2	*ALAT**
Creatine kinase	2.7.3.2	*CK-A1** *CK-A2** *CK-B** *CK-C1** *CK-C2**
Esterase	3.1.1.-	*EST-1**
Fructose-bisphosphate aldolase	4.2.1.13	*FBALD-3** *FBALD-4**
Fumarate hydratase	4.2.1.2	*FH**
b-N-Acetylgalactosaminidase	3.2.1.53	*βALA**
Glyceraldehyde-3-phosphate dehydrogenase	1.2.1.12	*GAPDH-2** *GAPDH-3** *GAPDH-4** *GAPDH-5**

Table 24.--Continued.

Enzyme	E.C. number	Locus abbreviation
Guanine deaminase	3.5.4.3	*GDA-1** *GDA-2**
N-Acetyl-b-glucosaminidase	3.2.1.30	β*LUA**
Glycerol-3-phosphate dehydrogenase	1.1.1.8	*G3PDH-1** *G3PDH-2** *G3PDH-3** *G3PDH-4**
Glucose-6-phosphate isomerase	5.3.1.9	*GPI-B1** *GPI-B2** *GPI-A**
Glutathione reductase	1.6.4.2	*GR**
Hydroxyacylglutathione hydrolase	3.1.2.6	*HAGH**
L-Iditol dehydrogenase	1.1.1.14	*IDDH-1** *IDDH-2**
Isocitrate dehydrogenase	1.1.1.42	*sIDHp-1** *sIDHp-2** *mIDHp-1** *mIDHp-2**
L-Lactate dehydrogenase	1.1.1.27	*LDH-A1** *LDH-A2** *LDH-B1** *LDH-B2** *LDH-C**
a-Mannosidase	3.2.1.24	α*MAN**

Table 24.--Continued.

Enzyme	E.C. number	Locus abbreviation
Malate dehydrogenase	1.1.1.37	*sMDH-A1,2** *sMDH-B1,2** *mMDH-1** *mMDH-2** *mMDH-3**
Mannose-6-phosphate isomerase	5.3.1.8	*MPI**
Dipeptidase	3.4.-.-	*PEP-A**
Tripeptide aminopeptidase	3.4.-.-	*PEP-B1** *PEP-B2**
Peptidase-C	3.4.-.-	*PEP-C**
Proline dipeptidase	3.4.-.-	*PEP-D1** *PEP-D2**
Leucyl-tyrosine dipeptidase	3.4.-.-	*PEP-LT**
Phosphogluconate dehydrogenase	1.1.1.44	*PGDH**
Phosphoglycerate kinase	2.7.2.3	*PGK-1** *PGK-2**
Phosphoglucomutase	5.4.2.2	*PGM-1** *PGM-2**
Pyruvate kinase	2.7.1.40	*PK-2**
Purine-nucleoside phosphorylase	2.4.2.1	*PNP-1** *PNP-2**
Superoxide dismutase	1.15.1.1	*sSOD-1**
Triose-phosphate isomerase	5.3.1.1	*TPI-1.1** *TPI-1.2** *TPI-2.1** *TPI-2.2**

Table 25.--Eighteen loci used for 68 samples of coho salmon from California to British Columbia.

Locus	Number of samples polymorphic	Range of common allele frequencies	Number of alleles
sAAT-1,2*	24	1.000 - 0.745	3
ADH*	2	1.000 - 0.981	3
sAH*	46	1.000 - 0.893	3
GPI-A*	13	1.000 - 0.840	3
GPI-B1*	2	1.000 - 0.950	2
GPI-B2*	36	1.000 - 0.805	3
LDH-B1*	13	1.000 - 0.920	3
LDH-B2*	12	1.000 - 0.952	3
sMDH-B1,2*	19	1.000 - 0.937	3
MPI*	24	1.000 - 0.880	3
PEP-A*	47	1.000 - 0.856	3
PEP-B1*	7	1.000 - 0.935	3
PEP-C*	68	0.897 - 0.486	3
PEP-D2*	29	1.000 - 0.894	4
PGDH*	4	1.000 - 0.740	3
PGM-1*	45	1.000 - 0.689	4
PGM-2*	18	1.000 - 0.925	3
sSOD-1*	4	1.000 - 0.871	2

Table 26.--Thirty-eight loci used for 31 samples of coho salmon from California to British Columbia.

Locus	Number of samples polymorphic	Range of common allele frequencies	Number of alleles
sAAT-1,2*	7	1.000 - 0.987	3
ADA-1*	14	1.000 - 0.935	3
ADA-2*	1	1.000 - 0.995	2
sAH*	23	1.000 - 0.900	4
mAH-2*	10	1.000 - 0.893	3
CK-A1*	2	1.000 - 0.990	3
CK-A2*	3	1.000 - 0.974	2
CK-C2*	5	1.000 - 0.955	3
FH*	12	1.000 - 0.959	3
βGALA*	31	0.775 - 0.418	3
GAPDH-2*	24	1.000 - 0.750	4
GAPDH-3*	4	1.000 - 0.909	2
GAPDH-4*	2	1.000 - 0.975	2
GPI-A*	4	1.000 - 0.850	2
GPI-B1*	1	1.000 - 0.950	2
GPI-B2*	15	1.000 - 0.925	3
GR*	1	1.000 - 0.994	2
HAGH*	11	1.000 - 0.974	4
sIDHp-2*	5	1.000 - 0.975	3
LDH-A2*	1	1.000 - 0.975	2
LDH-B1*	10	1.000 - 0.942	3
LDH-B2*	7	1.000 - 0.970	3
αMAN*	1	1.000 - 0.990	2
sMDH-A1,2*	3	1.000 - 0.990	3
sMDH-B1,2*	9	1.000 - 0.984	3
MPI*	10	1.000 - 0.929	3
PEP-A*	27	1.000 - 0.856	2
PEP-B1*	5	1.000 - 0.969	3
PEP-C*	31	0.897 - 0.613	2
PEP-LT*	1	1.000 - 0.990	2
PGDH*	1	1.000 - 0.985	2
PGK-1*	3	1.000 - 0.913	2
PGK-2*	2	1.000 - 0.985	2
PGM-1*	20	1.000 - 0.788	4
PGM-2*	9	1.000 - 0.925	3
PNP-1*	23	1.000 - 0.475	2
sSOD-1*	1	1.000 - 0.871	2
TPI-1.2*	2	1.000 - 0.975	2

Table 27.--Nineteen loci used for 14 samples of Columbia River coho salmon.

Locus	Number of samples polymorphic	Range of common allele frequencies	Number of alleles
sAAT-4*	13	1.000 - 0.844	4
sAH*	13	1.000 - 0.900	3
mAH-2*	10	1.000 - 0.893	3
FBALD-4*	7	1.000 - 0.950	2
βGALA*	14	0.769 - 0.479	3
GAPDH-2*	12	1.000 - 0.750	2
GAPDH-3*	4	1.000 - 0.909	2
βGLUA*	3	1.000 - 0.987	2
GPI-B1*	1	1.000 - 0.950	2
GPI-B2*	7	1.000 - 0.960	4
LDH-B1*	7	1.000 - 0.942	2
MPI*	6	1.000 - 0.949	3
PEP-A*	12	1.000 - 0.927	2
PEP-C*	14	0.982 - 0.613	2
PGK-1*	2	1.000 - 0.913	2
PGM-1*	6	1.000 - 0.975	4
PGM-2*	6	1.000 - 0.950	3
PNP-1*	14	0.988 - 0.475	2
TF*	13	1.000 - 0.600	4

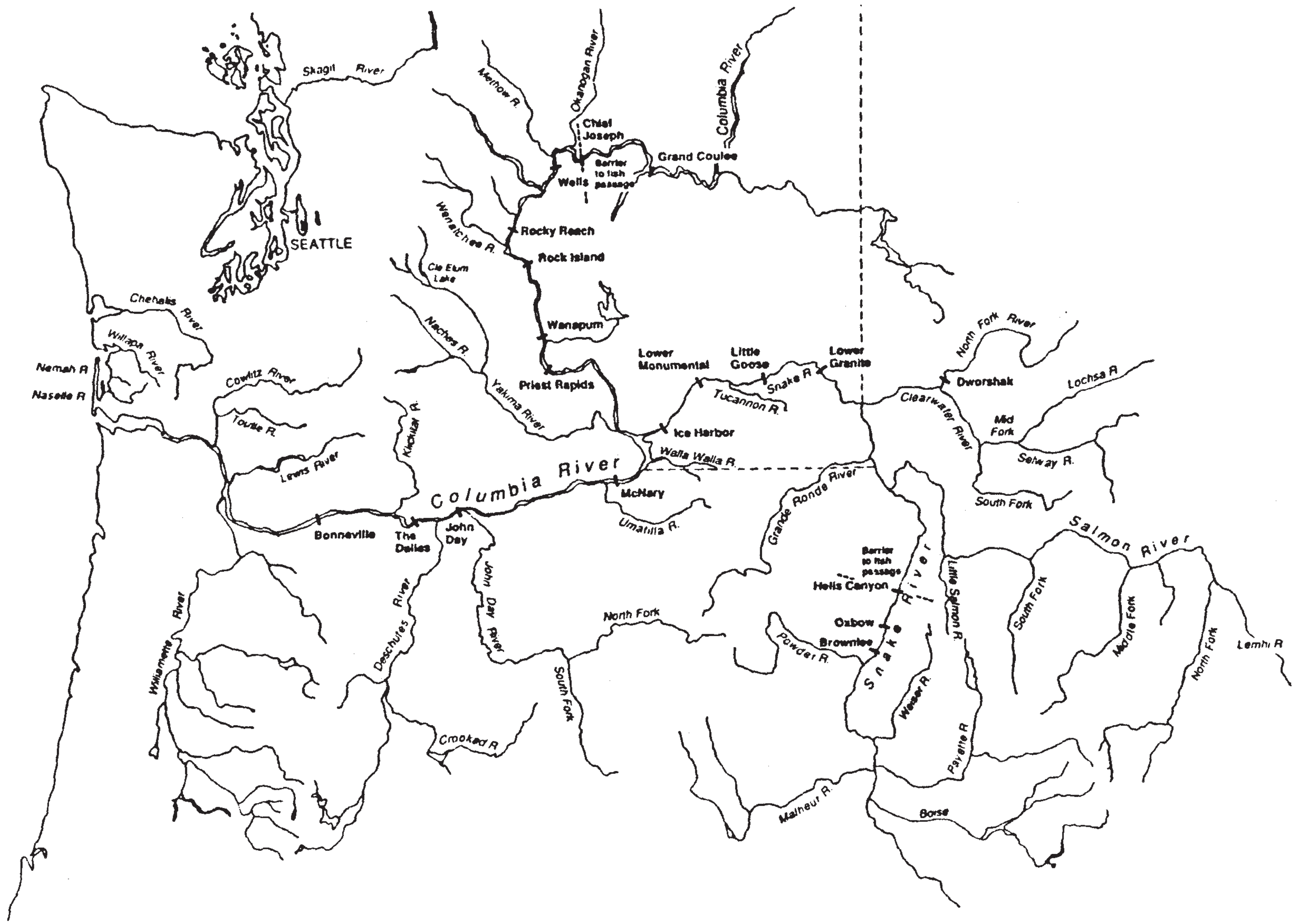


Figure 1.--Columbia and Snake River Basins with major tributaries and dams.

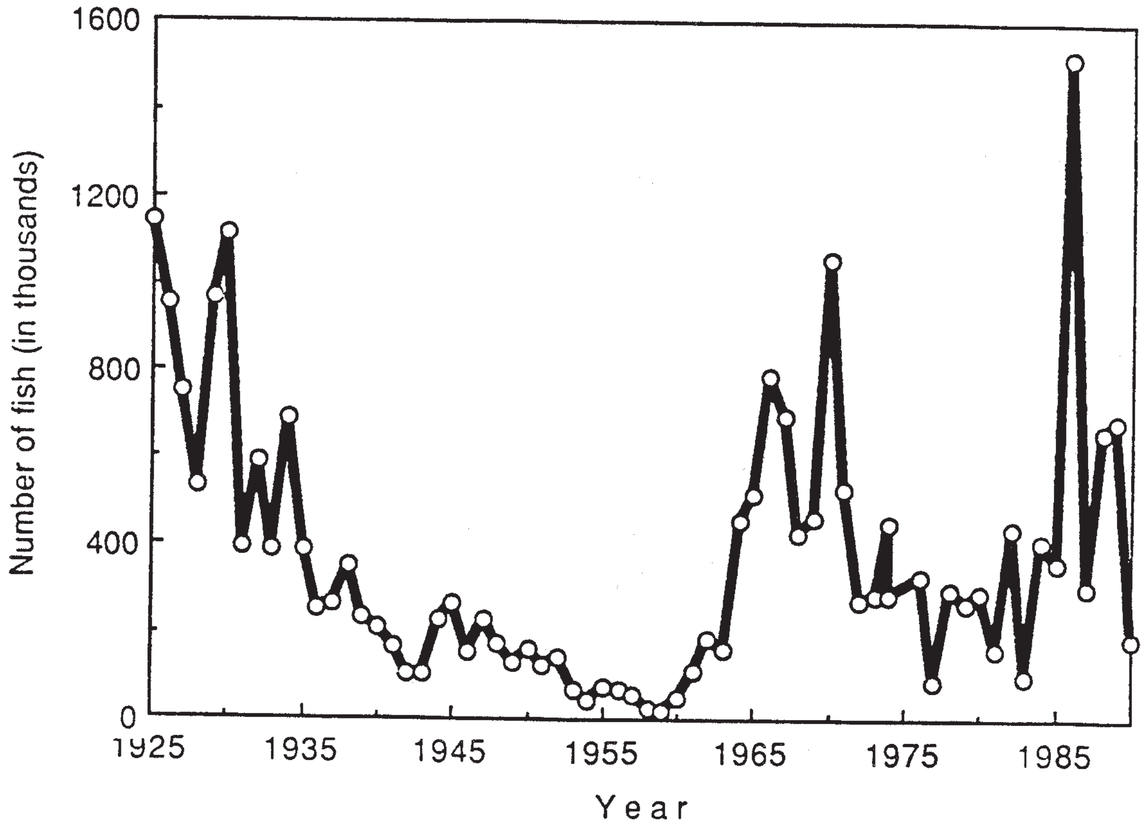


Figure 2.--Harvest of coho salmon in the Columbia River from 1925 to 1990 (Beiningen 1976, Mullan 1984, PFMC 1991).

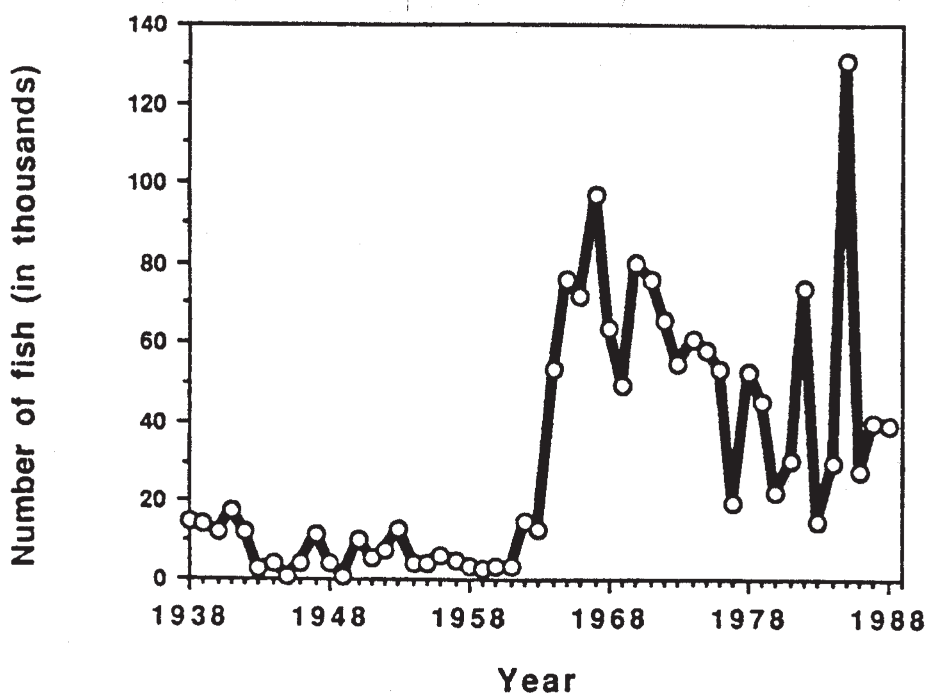


Figure 3.--Counts of adult coho salmon swimming up fish ladders at Bonneville Dam from the time of completion in 1938 to 1988 (COE 1990).

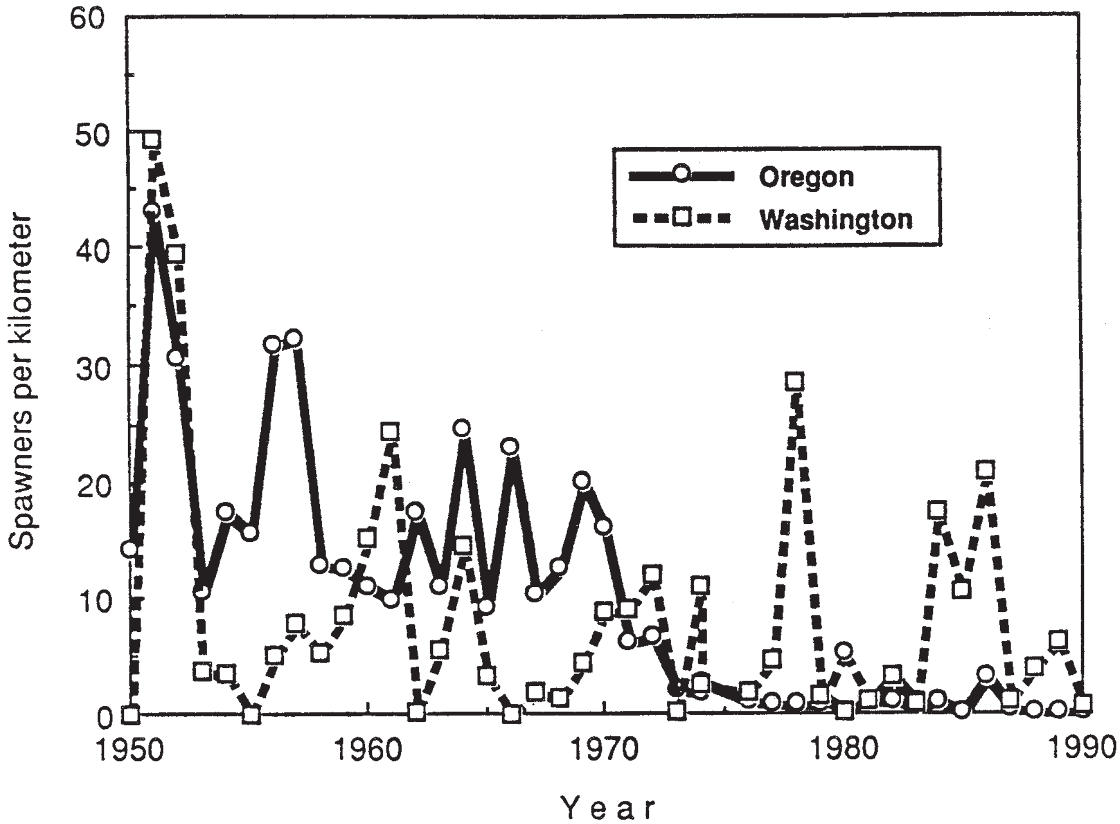


Figure 4.--Abundance of post-December coho salmon spawners observed per km of index stream in Oregon and Washington from 1950 to 1990 (ODFW 1990b, 1991a; WDF 1991b).

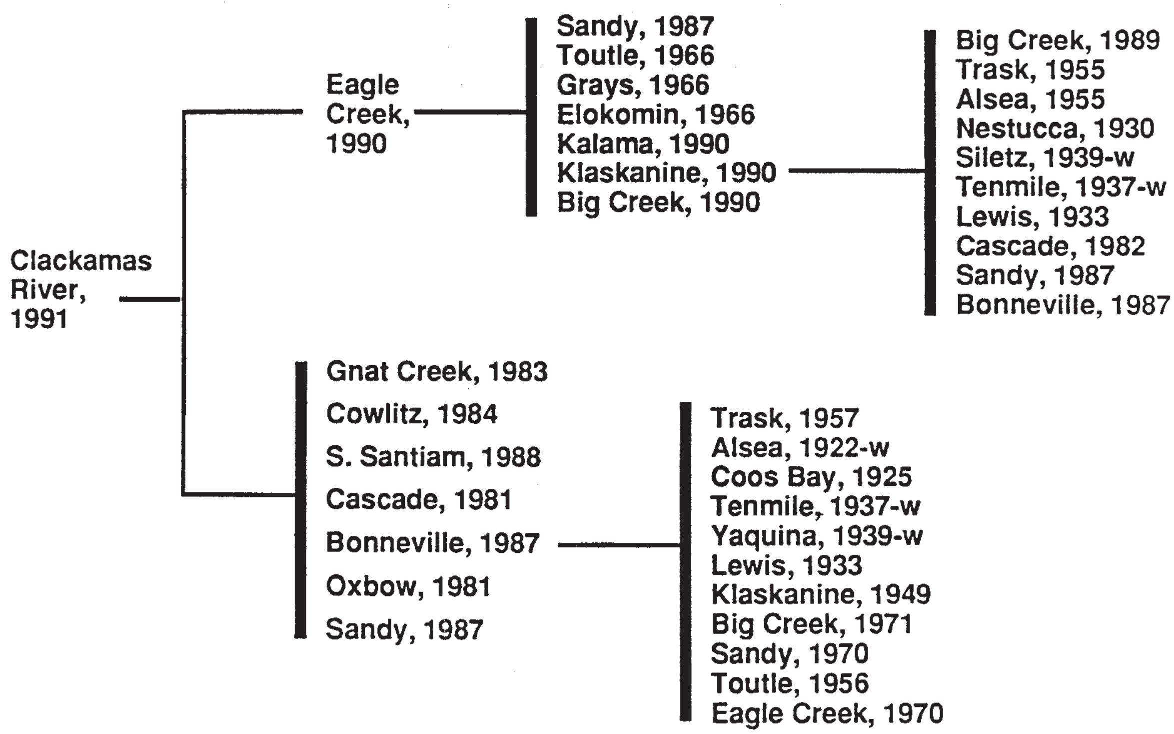


Figure 5.--Family histories, with dates of transfer, of some coho salmon stocks that have been introduced into the Clackamas River. The Clackamas River is now managed for naturally spawning coho salmon. The letter "w" indicates the stock was taken from a naturally spawning population; all others are of hatchery origin with their own family history.

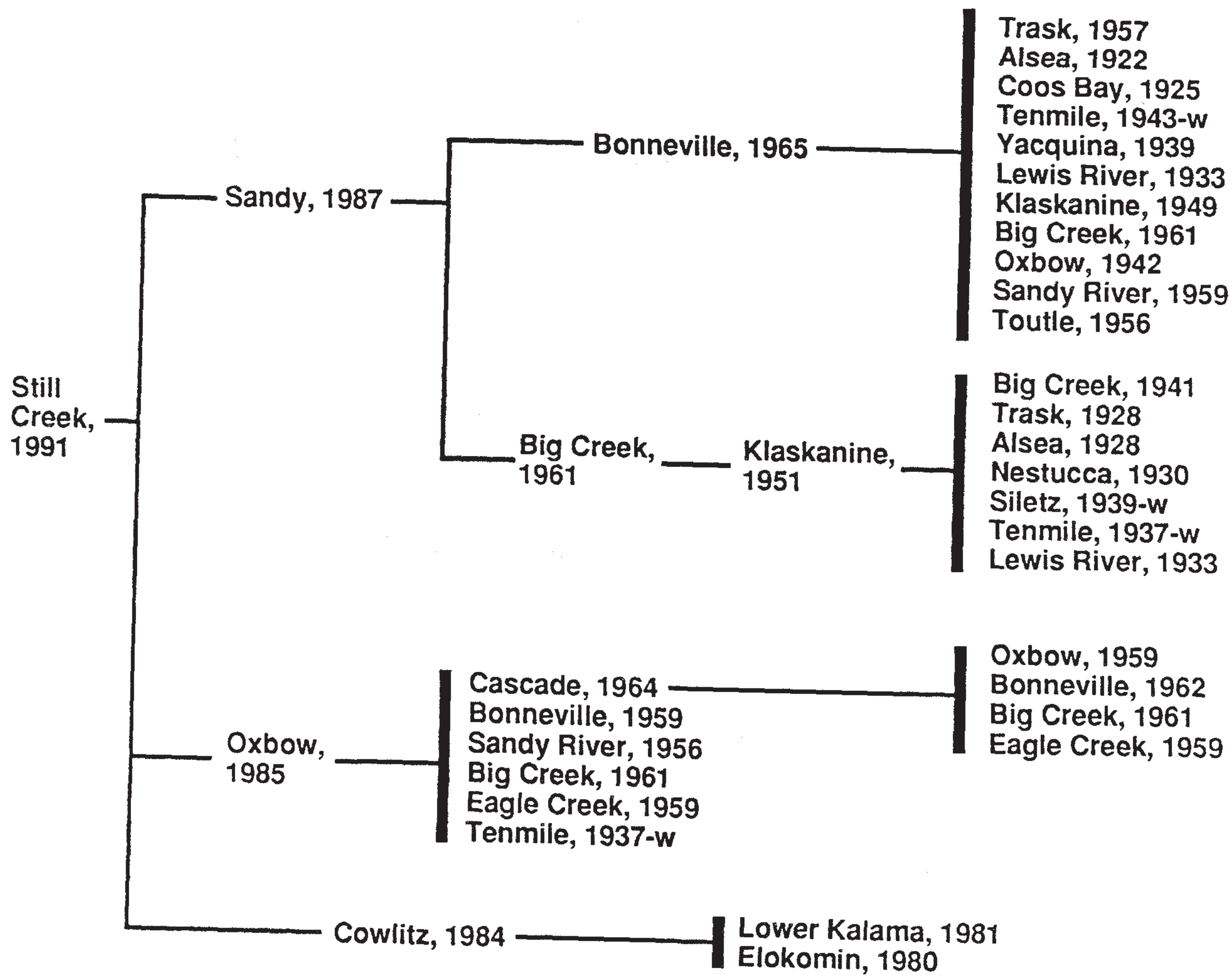


Figure 6.--Family histories, with dates of transfer, of some coho salmon stocks that have been introduced into Still Creek. Still Creek has been identified by ODFW (1991a,b) as supporting a run of post-December coho salmon, which ODFW believes may be of nonhatchery origin. All stocks transferred into Still Creek were of hatchery origin, except those marked with the letter "w," indicating that the stock was taken from a naturally spawning population.

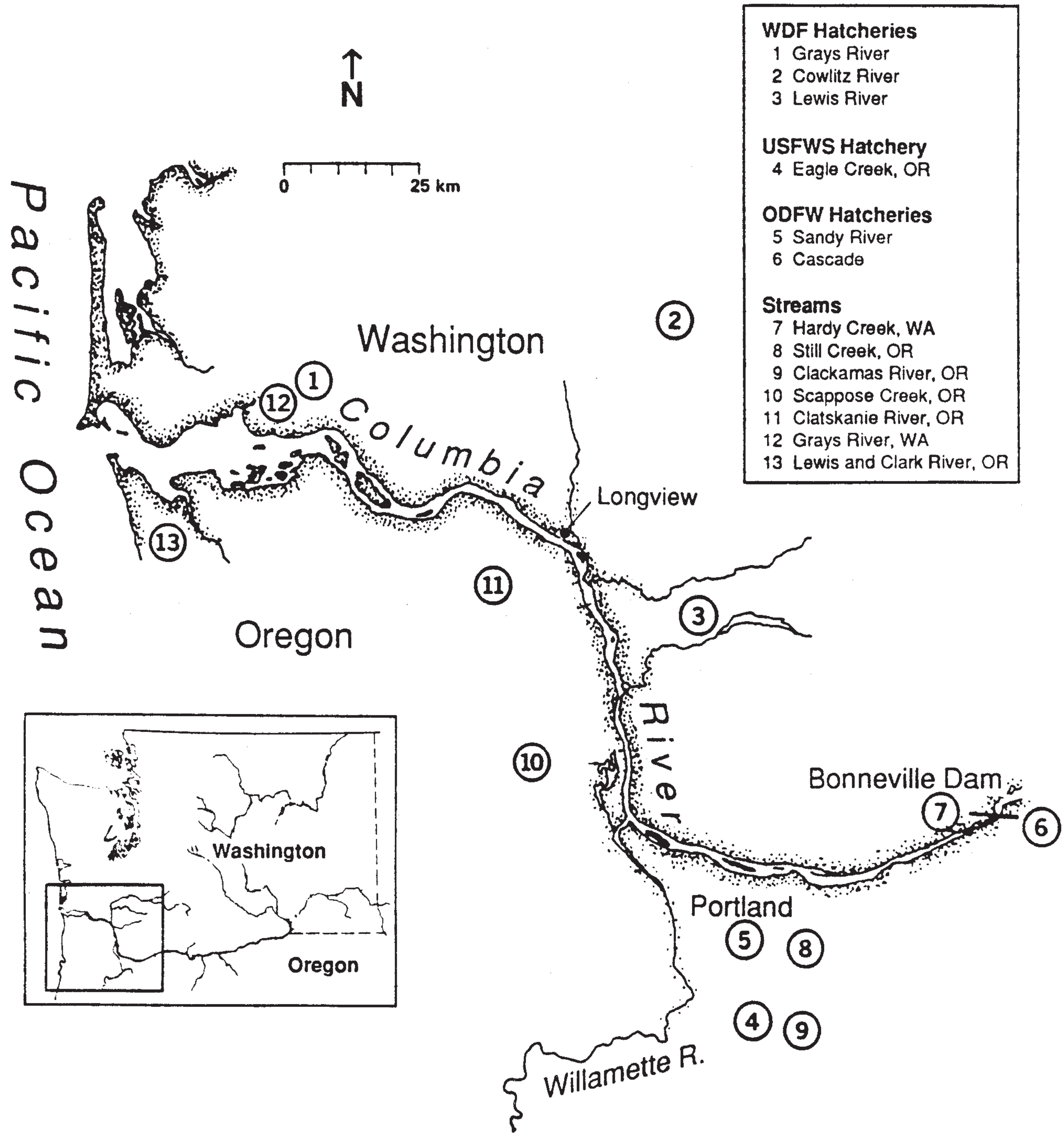


Figure 7.--Lower Columbia River Basin. Numbers correspond to collection sites for genetic samples listed in Table 23.

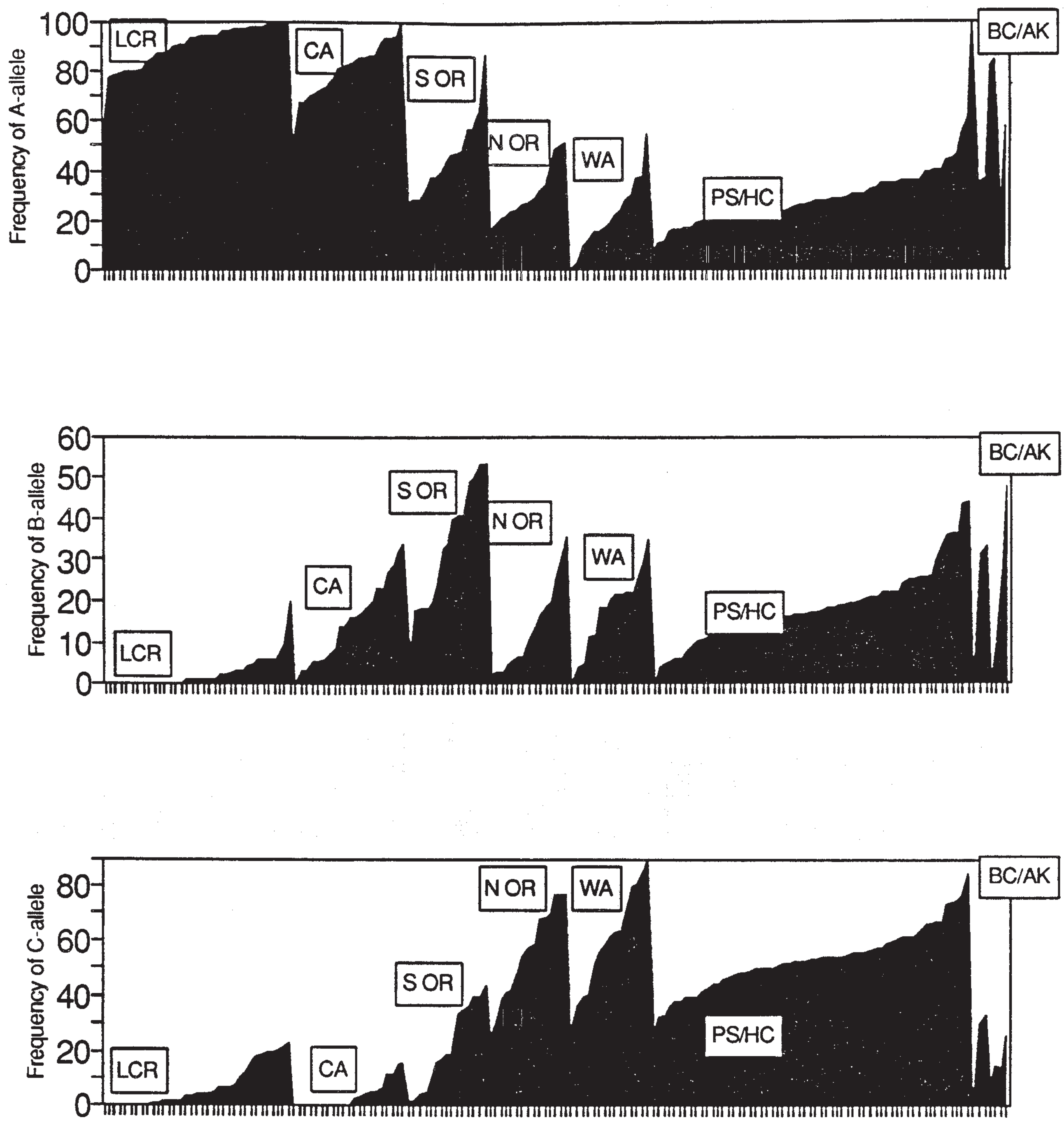


Figure 8.--Frequencies of transferrin A-, B-, and C-alleles for 167 samples of coho salmon from California to Alaska. Locations are arranged from lowest to highest allelic frequency within a geographical region. Samples were collected from lower Columbia River (LCR), California (CA), southern Oregon coast (SOR), northern Oregon coast (NOR), Washington coast (WA), Puget Sound and Hood Canal in Washington (PS/HC), and British Columbia/Alaska (BC/AK).

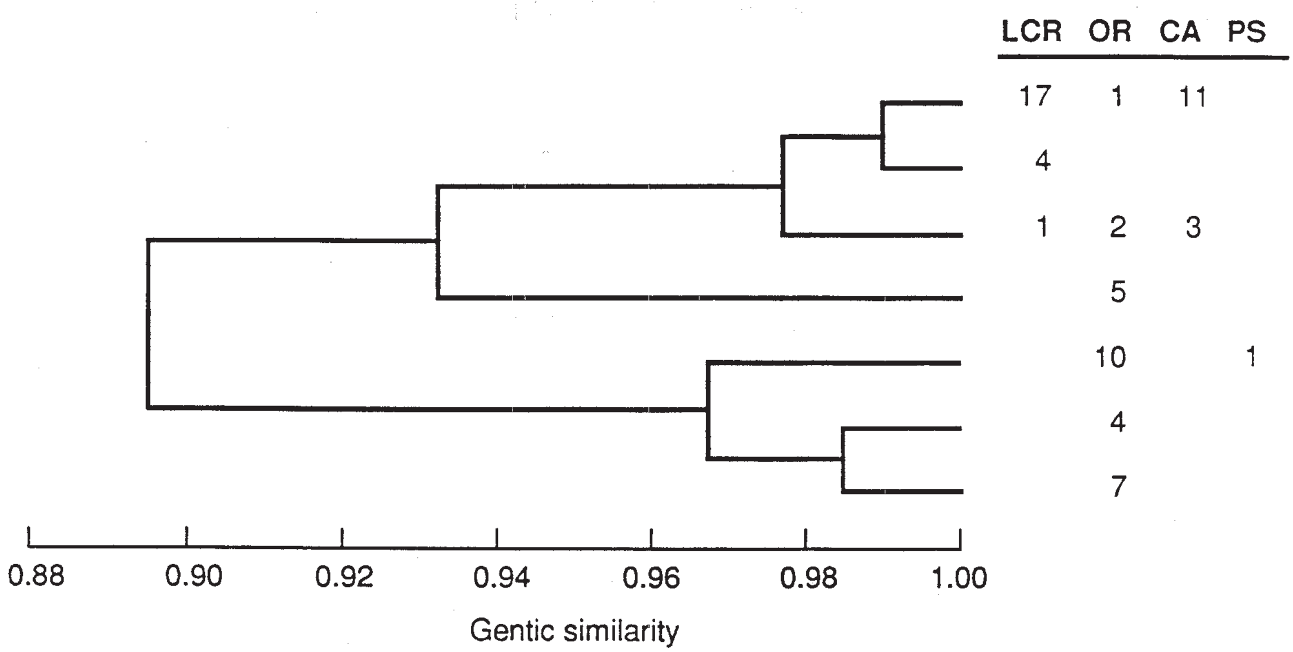


Figure 9.--Dendrogram of genetic similarities (Nei 1972) based on frequencies of transferrin alleles from 66 samples of coho salmon from the lower Columbia River (LCR), Oregon coast (OR), California coast (CA), and Puget Sound (PS). Numbers of samples from each location are indicated for each cluster.

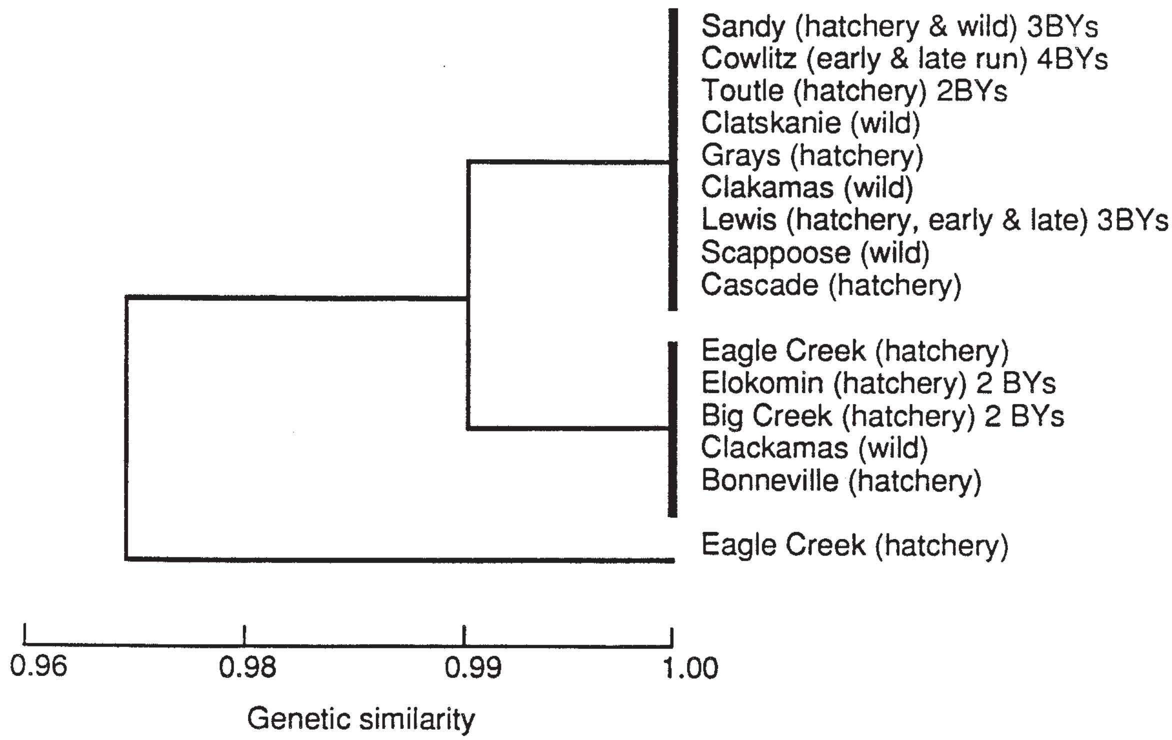
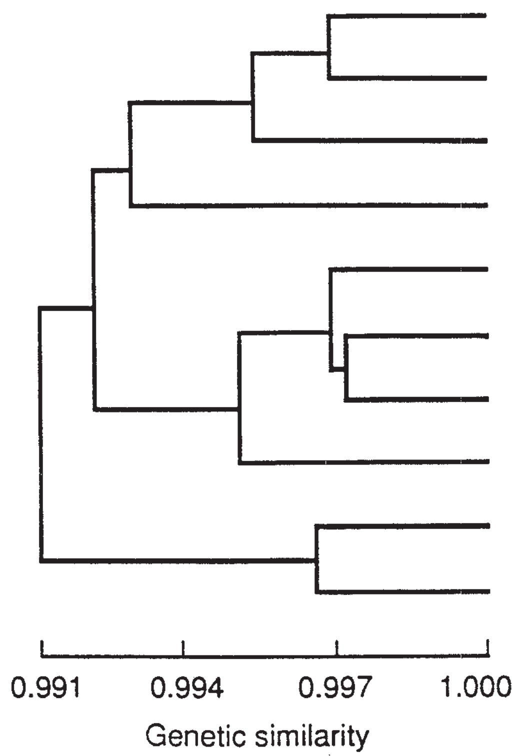


Figure 10.--Dendrogram of genetic similarities (Nei 1972) based on frequencies of transferrin alleles from 33 samples of coho salmon from the lower Columbia River. Numbers of samples from each location, if more than one, are indicated for each cluster. BY = brood year.



LCR	OR	CA	WA	PS	BC
1	9	1	0	0	0
15	14	3	0	8	0
0	1	0	0	0	0
0	1	0	0	0	0
0	0	2	0	0	0
2	1	1	2	1	1
0	0	1	0	0	0
0	0	0	0	0	2
0	1	0	0	0	0
0	0	1	0	0	0

Figure 11.--Dendrogram of genetic similarities (Nei 1972) using allozymes (excluding transferrin) analyzed for 18 polymorphic loci. Data are based on 68 samples of coho salmon from the lower Columbia River (LCR), Oregon coast (OR), California coast (CA), Washington coast (WA), Puget Sound (PS), and British Columbia (BC). Numbers of samples from each location are indicated for each cluster.

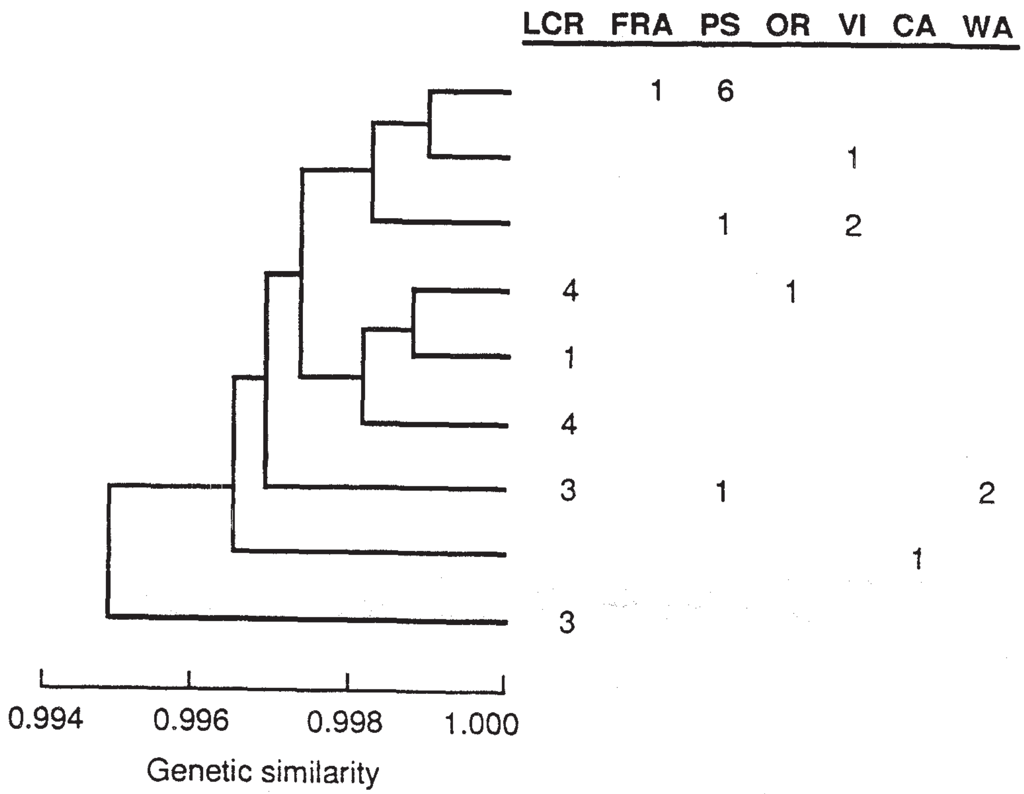


Figure 12.--Dendrogram of genetic similarities (Nei 1972) using allozymes (excluding transferrin) analyzed for 38 polymorphic loci. Data are based on 31 samples of coho salmon from the lower Columbia River (LCR), Fraser River in British Columbia (FRA), Puget Sound (PS), Oregon coast (OR), Vancouver Island, British Columbia (VI), California coast (CA), and Washington Coast (WA). Number of samples from each location are indicated for each cluster.

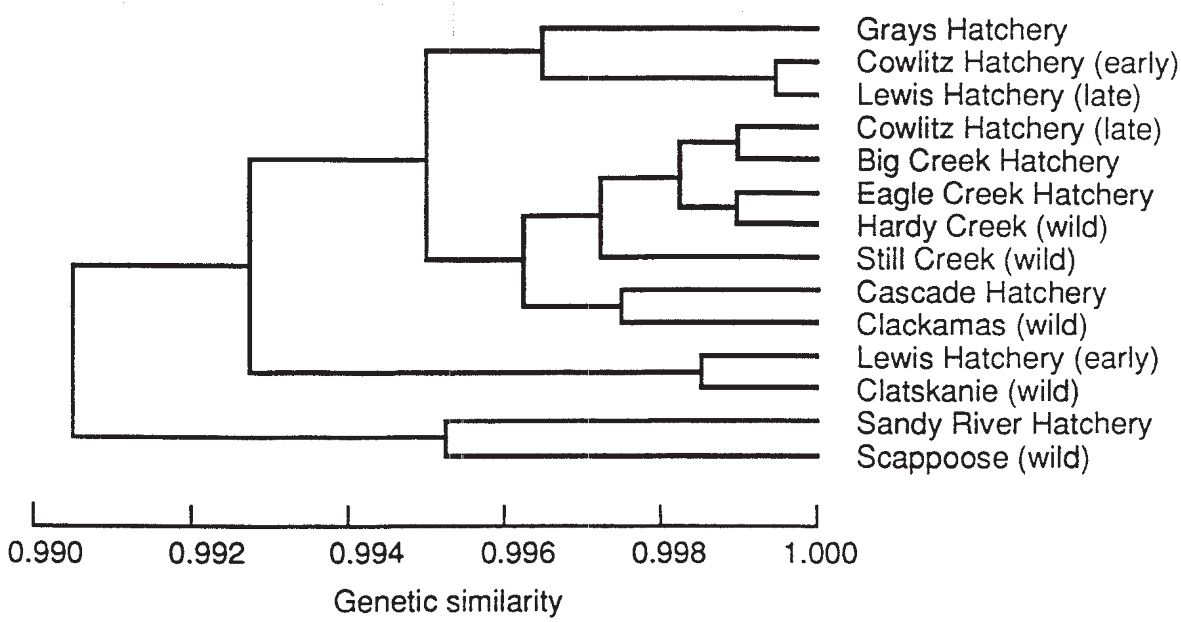


Figure 13.--Dendrogram of genetic similarities (Nei 1972) in allozymes (excluding transferrin) using 19 polymorphic loci from juvenile coho salmon from 14 locations in the lower Columbia River in 1991.

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