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# Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California

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*"Among these fishermen one occasionally hears more or less protracted discussions as to whether the fish are trout or steelheads, whether they belong to the same species as the larger steelheads which enter the river, whether they differ from the smaller stream trout, whether they differ from the steelheads of other rivers, what is a steelhead anyway..." (Snyder 1925, p. 50).*

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## EXECUTIVE SUMMARY

In February 1994, the National Marine Fisheries Service (NMFS) received a petition seeking protection under the Endangered Species Act (ESA) for 178 populations of steelhead (anadromous *Oncorhynchus mykiss*) in Washington, Idaho, Oregon, and California. At the time, NMFS was conducting a status review of coastal steelhead populations (*O. m. irideus*) in Washington, Oregon, and California. In response to the broader petition, NMFS expanded the ongoing status review to include inland steelhead (*O. m. gairdneri*) occurring east of the Cascade Mountains in Washington, Idaho, and Oregon. This report summarizes biological and environmental information considered by the Biological Review Team (BRT) that conducted the West Coast Steelhead Status Review.

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

### West Coast Steelhead ESUs

After considering available information on steelhead genetics, phylogeny and life history, freshwater ichthyogeography, and environmental features that may affect steelhead, the BRT identified 15 ESUs—12 for coastal steelhead and 3 for the inland form. The BRT reviewed population abundance data and other risk factors for these steelhead ESUs and concluded that five (Central California Coast, South-Central California Coast, Southern California, Central Valley, and Upper Columbia River) are presently in danger of extinction, five (Lower Columbia River, Oregon Coast, Klamath Mountains Province, Northern California, and Snake River Basin) are likely to become endangered in the foreseeable future, and four steelhead ESUs (Puget Sound, Olympic Peninsula, Southwest Washington, and Upper Willamette River) are not presently in significant danger of becoming extinct or endangered, although some individual stocks within these ESUs may be at risk. The BRT concluded that the remaining steelhead ESU (Middle Columbia River) is not presently in danger of extinction but was unable to reach a conclusion as to its risk of becoming endangered in the foreseeable future.

The BRT concluded that, in general, the ESUs described below include resident *O. mykiss* in cases where they have the opportunity to interbreed with anadromous fish. Resident populations above long-standing natural barriers, and those that have resulted from the introduction of non-native rainbow trout, would not be considered part of the ESUs. Resident populations that inhabit areas upstream from human-caused migration barriers (e.g., Grand Coulee Dam, the Hells Canyon Dam complex, and numerous smaller barriers in California) may contain genetic resources similar to those of anadromous fish in the ESU, but little information is available on these fish or the role they might play in conserving natural populations of steelhead. The status, with respect to steelhead ESUs, of resident fish upstream from human-caused migration barriers must be evaluated on a case-by-case basis as more information becomes available.

**Coastal Steelhead ESUs**

**1) Puget Sound**—This ESU occupies river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington. Included are river basins as far west as the Elwha River and as far north as the Nooksack River. This ESU is primarily composed of winter steelhead but includes several populations of summer steelhead. The steelhead in this ESU generally smolt at age 2 years, whereas most steelhead in British Columbia smolt at age 3. Steelhead from this area are genetically distinct from those in other areas of Washington, both chromosomally and electrophoretically. Habitat in the Puget Sound region is dominated by glacial effects, including extensive alluvial floodplains, and the fjord-like structure of Puget Sound itself may promote distinctive steelhead migration patterns. Recent population trends within the Puget Sound ESU are predominantly downward; however, trends in the two largest stocks (Skagit and Snohomish Rivers) have been upward. The BRT was concerned about the large proportion of hatchery steelhead in Puget Sound and their origination primarily from a single stock; however, most hatchery fish appear to have advanced run timing and to be harvested prior to spawning, thus limiting their interactions with naturally spawning steelhead. Another concern of the BRT was the lack of information on the abundance and status of summer steelhead in this ESU.

**2) Olympic Peninsula**—This ESU occupies river basins of the Olympic Peninsula, Washington, west of the Elwha River and south to, but not including, the rivers that flow into Grays Harbor on the Washington coast. The Olympic Peninsula ESU is primarily composed of winter steelhead but includes several populations of summer steelhead in the larger rivers. Olympic Peninsula steelhead are genetically distinct from other steelhead ESUs; this isolation is also supported by zoogeographic patterns of other species of fish and amphibians, indicating a faunal shift in the vicinity of the Chehalis River Basin. Population trends within this ESU are generally upward, with some stocks declining. As was the case with the Puget Sound ESU, there is very little information regarding the abundance and status of summer steelhead in this region, and there is also uncertainty regarding the degree of interaction between hatchery and natural stocks.

**3) Southwest Washington**—This ESU occupies the tributaries to Grays Harbor, Willapa Bay, and the Columbia River below the Cowlitz River in Washington and below the Willamette River in Oregon. This ESU is primarily composed of winter steelhead but includes summer steelhead in the Humptulips and Chehalis River Basins. Genetic data show differentiation between steelhead of this ESU and those of adjacent regions. The ecological connectivity of the region occupied by the Southwest Washington ESU is demonstrated by similarities in riverine and estuarine ichthyofauna and current-driven sediment transfer from the Columbia River to Grays Harbor and Willapa Bay. Most population trends within this

ESU have been declining in the recent past. There is very little information regarding the abundance and status of summer steelhead in this region, and there is also uncertainty regarding the degree of interaction between hatchery and natural stocks.

4) **Lower Columbia River**—This ESU occupies tributaries to the Columbia River between the Cowlitz and Wind Rivers in Washington and the Willamette and Hood Rivers in Oregon, inclusive. Excluded are steelhead in the upper Willamette River Basin above Willamette Falls (see ESU 5-Upper Willamette River), and steelhead from the Little and Big White Salmon Rivers, Washington (see ESU 13-Middle Columbia River ESU). This ESU is composed of both winter and summer steelhead. Genetic data show distinction between steelhead of this ESU and adjacent regions, with a particularly strong difference between coastal and inland steelhead in the vicinity of the Cascade Crest. The majority of stocks for which we have data within this ESU have been declining in the recent past, but some have been increasing strongly. However, the strongest upward trends are either non-native stocks (Lower Willamette River and Clackamas River summer steelhead) or stocks that are recovering from major habitat disruption and are still at low abundance (mainstem and North Fork Toutle River). The data series for most stocks is quite short, so the preponderance of downward trends may reflect the general coastwide decline in steelhead in recent years.

5) **Upper Willamette River**—This ESU occupies the Willamette River and its tributaries upstream from Willamette Falls. The native steelhead of this basin are late-migrating winter steelhead, entering fresh water primarily in March and April. This unusual run timing appears to be an adaptation for ascending Willamette Falls, which function as an isolating mechanism for upper Willamette River steelhead. Early migrating winter steelhead and summer steelhead have been introduced to the Upper Willamette River Basin; however, these non-native populations are not components of this ESU. Native winter steelhead within this ESU have been declining on average since 1971 and have exhibited large fluctuations in abundance. The main production of native (late-run) winter steelhead is in the North Fork Santiam River, where estimates of hatchery proportion in natural spawning range from 14% to 54%.

6) **Oregon Coast**—This ESU occupies river basins on the Oregon coast north of Cape Blanco; excluded are rivers and streams that are tributaries of the Columbia River (see ESU 3-Southwest Washington). Native Oregon Coast steelhead are primarily winter steelhead; native summer steelhead occur only in the Siletz and Umpqua River Basins. Recent genetic data for steelhead in this ESU show a level of differentiation from populations from Washington, the Columbia River Basin, and coastal areas south of Cape Blanco. Ocean migration patterns also suggest a distinction between steelhead populations north and south of Cape Blanco. Steelhead, as well as chinook (*O. tshawytscha*) and coho (*O. kisutch*) salmon, from streams south of Cape Blanco tend to be south-migrating rather than north-migrating. Most steelhead populations within this ESU have been declining in the recent past, with increasing trends restricted to the southernmost portion (south of Siuslaw Bay). There is widespread production of hatchery steelhead within this ESU, largely based on out-of-basin stocks, and approximately half of the streams (including the majority of those with upward trends) are estimated to have more than 50% hatchery fish in natural spawning escapements. Given the substantial contribution of hatchery fish to natural spawning

throughout the ESU and the generally declining or slightly increasing trends, it is likely that natural stocks are not replacing themselves throughout the ESU.

**7) Klamath Mountains Province**—This ESU occupies river basins from the Elk River in Oregon to the Klamath and Trinity Rivers in California, inclusive. This ESU includes both winter and summer steelhead. Steelhead from this region are genetically distinct from populations to the north and south. The "half-pounder" life history is reported only from this region. The Klamath Mountains Province is a unique geographical area with unusual geology and plant communities. While absolute abundance of steelhead within the ESU remains fairly high, since about 1970 trends in abundance have been downward in most steelhead populations for which we have data, and a number of populations are considered by various agencies and groups to be at some risk of extinction. Declines in summer steelhead populations are of particular concern. This ESU was previously studied under a separate status review that was completed in December 1994 (Busby et al. 1994).

**8) Northern California**—This ESU occupies river basins from Redwood Creek in Humboldt County, California south to the Gualala River, inclusive, and includes winter and summer steelhead. Allozyme and mitochondrial DNA data indicate genetic discontinuities between steelhead of this region and those to the north and south. Freshwater fish species assemblages in this region are derived from the Sacramento River Basin, whereas streams to the north include fishes representative of the Klamath-Rogue ichthyofaunal province. Population abundances are very low relative to historical estimates, and recent trends are downward in stocks for which we have data, except for two small summer steelhead stocks. Summer steelhead abundance is very low. Risk factors identified for this ESU include freshwater habitat deterioration due to sedimentation and flooding related to land management practices and introduced Sacramento squawfish as a predator in the Eel River. For certain rivers (particularly the Mad River), the BRT is concerned about the influence of hatchery stocks, both in terms of genetic introgression and potential ecological interactions between introduced stocks and native stocks.

**9) Central California Coast**—This ESU occupies river basins from the Russian River to Soquel Creek, Santa Cruz County (inclusive) and the drainages of San Francisco and San Pablo Bays; excluded is the Sacramento-San Joaquin River Basin of the Central Valley of California. Mitochondrial DNA and allozyme data indicate genetic differences between the steelhead from this region and those from adjacent areas. Environmental features (e.g., precipitation patterns, vegetation, and soils) show a transition in this region from the northern redwood forest ecosystem to the more xeric southern chaparral and coastal scrub ecosystems. Steelhead populations within the major streams occupied by this ESU appear to be greatly reduced from historical levels; for example, steelhead abundance in the Russian River has been reduced roughly sevenfold since the mid-1960s, but abundance in smaller streams appears to be stable at low levels. The primary risk factor for this ESU is deteriorated habitat due to sedimentation and flooding related to land management practices. Uncertainty regarding the genetic heritage of the natural populations in tributaries to San Francisco and San Pablo Bays makes it difficult to determine which of these populations should be considered part of the ESU.

**10) South-Central California Coast**—This ESU occupies rivers from the Pajaro River, Santa Cruz County to (but not including) the Santa Maria River. Mitochondrial DNA data provide evidence for a genetic transition in the vicinity of Monterey Bay. Both mtDNA and allozyme data show large genetic differences between populations in this area, but do not provide a clear picture of population structure. The climate in this region is drier and warmer than it is to the north, resulting in chaparral and coastal scrub vegetation and stream mouths that are closed seasonally by sand berms. In addition to vegetation transitions, the northern end of this region is the southern limit of the distribution of coho salmon. The southern boundary of this ESU is near Point Conception, a well-recognized transition area for the distribution and abundance of marine flora and fauna. Total abundance of steelhead in this ESU is extremely low and declining. Risk factors for this ESU are habitat deterioration due to sedimentation and flooding related to land management practices and potential genetic interaction with hatchery rainbow trout.

**11) Southern California**—This ESU occupies rivers from the Santa Maria River to the southern extent of the species range. Steelhead occur at least as far south as Malibu Creek, Los Angeles County, and may have historically occurred as far south as the U.S.-Mexico border. Genetic data show large differences between steelhead populations within this ESU as well as between these and populations to the north. Average rainfall is substantially lower and more variable in southern California than in regions to the north, resulting in increased duration of sand berms across the mouths of streams and rivers and, in some cases, complete dewatering of the lower reaches of these streams from late spring through fall. This affects steelhead migration patterns, as well as the ability to residualize and survive elevated water temperatures. Steelhead have already been extirpated from much of their historical range in this region. The BRT had a strong concern about the widespread degradation, destruction, and blockage of freshwater habitats within the region, and the potential results of continuing habitat destruction and water allocation problems. There was also concern about the genetic effects of widespread stocking of rainbow trout.

**12) Central Valley**—This ESU occupies the Sacramento and San Joaquin Rivers and their tributaries. Recent allozyme data show that samples of steelhead from Deer and Mill Creeks and Coleman National Fish Hatchery on the Sacramento River are well differentiated from all other samples of steelhead from California. The Sacramento and San Joaquin Rivers offer the only migration route to the drainages of the Sierra Nevada and southern Cascade mountain ranges for anadromous fish. The distance from the ocean to spawning streams can exceed 300 km, providing unique potential for reproductive isolation among steelhead in California. Steelhead have already been extirpated from most of their historical range in this region. Habitat concerns in this ESU focus on the widespread degradation, destruction, and blockage of freshwater habitats within the region, and the potential results of continuing habitat destruction and water allocation problems. The BRT also had a strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU, and a strong concern for potential ecological interactions between introduced stocks and native stocks.

**Inland Steelhead ESUs**

**13) Middle Columbia River**—This ESU occupies the Columbia River Basin from above the Wind River in Washington and the Hood River in Oregon upstream to include the Yakima River, Washington. Steelhead of the Snake River Basin are not included. This ESU includes the only populations of winter inland steelhead in the United States, in the Klickitat River and Fifteenmile Creek. Some uncertainty exists about the exact boundary between coastal and inland steelhead, and the western margin of this ESU reflects currently available genetic data. There is good genetic and meristic evidence to separate this ESU from steelhead of the Snake River Basin. The boundary upstream of the Yakima River is based on limited genetic information and environmental differences including physiographic regions, climate, topography, and vegetation. All BRT members felt special concern for the status of this ESU, particularly Yakima River and winter steelhead stocks. Total steelhead abundance in the ESU appears to have been increasing recently, but the majority of natural stocks for which we have data within this ESU have been declining, including those in the John Day River, which is the largest producer of wild, natural steelhead. There is widespread production of hatchery steelhead within this ESU, but it is largely based on within-basin stocks. Habitat degradation due to grazing and water diversions has been documented throughout the range of the ESU.

**14) Upper Columbia River**—This ESU occupies the Columbia River Basin upstream from the Yakima River. All upper Columbia River steelhead are summer steelhead. The streams of this region that are utilized by steelhead primarily drain the northern Cascade Mountains of Washington State. Streamflow is supplied by snowmelt, groundwater, and glacial runoff, often resulting in extremely cold water temperatures that retard the growth and maturation of steelhead juveniles, causing some of the oldest smolt ages reported for steelhead and residualization of juvenile steelhead that fail to smolt. All anadromous fish in this region were affected by the Grand Coulee Fish Maintenance Project (1939 through 1943), wherein anadromous fish returning to spawn in the upper Columbia River were trapped at Rock Island Dam, downstream of the Wenatchee River. Some of these fish were then released to spawn in river basins above Rock Island Dam, while others were spawned in hatcheries and the offspring were released into various upper Columbia River tributaries; in both cases, no attempt was made to return these fish to their natal streams, resulting in an undetermined level of stock mixing within the upper Columbia River fish. While total abundance of populations within this ESU has been relatively stable or increasing, this appears to be true only because of major hatchery supplementation programs. Estimates of the proportion of hatchery fish in spawning escapement are 65% (Wenatchee River) and 81% (Methow and Okanogan Rivers). The major concern for this ESU is the clear failure of natural stocks to replace themselves. The BRT also had a strong concern about problems of genetic homogenization due to hatchery supplementation within the ESU. There was also concern about the apparent high harvest rates on steelhead smolts in rainbow trout fisheries and the degradation of freshwater habitats within the region, especially the effects of grazing, irrigation diversions, and hydroelectric dams.

**15) Snake River Basin**—This ESU occupies the Snake River Basin of southeast Washington, northeast Oregon, and Idaho. This region is ecologically complex and supports a diversity of steelhead populations; however, genetic and meristic data suggest that these populations are more similar to each other than they are to steelhead populations occurring outside of the Snake River Basin. Snake River Basin steelhead spawning areas are well isolated from other populations and include the highest elevations for spawning (up to 2,000 m) as well as the longest migration distance from the ocean (up to 1,500 km). Snake River steelhead are often classified into two groups, A- and B-run, based on migration timing, ocean age, and adult size. While total (hatchery + natural) run size for Snake River steelhead has increased since the mid-1970s, the increase has resulted from increased production of hatchery fish, and there has been a severe recent decline in natural run size. The majority of natural stocks for which we have data within this ESU have been declining. Parr densities in natural production areas have been substantially below estimated capacity in recent years. Downward trends and low parr densities indicate a particularly severe problem for B-run steelhead, the loss of which would substantially reduce life history diversity within this ESU. The BRT had a strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU. There was also concern about the degradation of freshwater habitats within the region, especially the effects of grazing, irrigation diversions, and hydroelectric dams.

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# INTRODUCTION

The U.S. Endangered Species Act (ESA) is intended to conserve threatened and endangered species in their native habitats. Under the ESA, vertebrate populations are considered "species" if they are "distinct." According to National Marine Fisheries Service (NMFS) policy, a salmon population or group of populations is considered "distinct" and hence a "species" under the ESA if it represents an evolutionarily significant unit (ESU) of the biological species.

The NMFS has received three petitions to list populations of steelhead (anadromous *Oncorhynchus mykiss*) as threatened or endangered "species" under the ESA. The ESA stipulates that, if a petition is found to present substantial information that a listing may be warranted, NMFS must conduct a status review and issue a determination on its findings within 1 year. On 6 May 1992, NMFS was petitioned by the Oregon Natural Resources Council and 10 co-petitioners to list Oregon's Illinois River winter steelhead (ONRC et al. 1992). NMFS concluded that Illinois River winter steelhead by themselves did not constitute an ESA "species" (Busby et al. 1993, NMFS 1993a). At the same time, however, NMFS initiated a status review of coastal steelhead populations to identify the ESU that includes Illinois River winter steelhead. This status review has been completed and resulted in the identification of a Klamath Mountains Province ESU that includes steelhead from the Illinois River (Busby et al. 1994); NMFS has proposed listing this ESU as threatened (NMFS 1995).

Washington Trout (1993) petitioned NMFS on 21 September 1993 for ESA listing of Washington's Deer Creek summer steelhead. As was the case with Illinois River winter steelhead, NMFS determined that Deer Creek summer steelhead did not by themselves constitute an ESU (NMFS 1994b).

On 16 February 1994, Oregon Natural Resources Council and 15 co-petitioners asked NMFS to list all steelhead in Washington, Idaho, Oregon, and California as threatened or endangered under the ESA (ONRC et al. 1994). The petitioners identified 178 stocks of steelhead of special concern and included information on stock origin, stock status, and factors affecting their abundance.

## Scope and Intent of the Present Document

This document addresses the ONRC et al. (1994) petition and presents environmental and biological information concerning steelhead populations in Washington, Idaho, Oregon, and California (Fig. 1). These will be collectively referred to in this document as *west coast steelhead*. The Klamath Mountains Province ESU of southwest Oregon and northwest California has been reviewed in detail elsewhere (Busby et al. 1994) and, therefore, will only be summarized in the present document.

Because the ESA stipulates that listing determinations should be made on the basis of the best scientific information available, NMFS formed a team of scientists with diverse


Figure 1. Map of the region occupied by west coast steelhead from the states of Washington, Idaho, Oregon, and California.

backgrounds in salmon biology to conduct this status review. This Biological Review Team (BRT) discussed and evaluated scientific information contained in an extensive public record developed for west coast steelhead. This document reports conclusions reached by the BRT for west coast steelhead. These conclusions are subject to revision should important new information arise in the future.

## Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" threatened or endangered?

These two questions are addressed in separate sections of this report. If it is determined that a listing(s) is warranted, then NMFS is required by law (1973 ESA Sec. 4(a)(1)) to identify one or more of the following factors responsible for the species' threatened or endangered status: 1) destruction or modification of habitat; 2) overutilization by humans; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or human factors. This status review does not formally address factors for decline, except insofar as they provide information about the degree of risk faced by the species in the future. A separate document (NMFS in press a) identifies factors for decline of west coast steelhead.

### The "Species" Question

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

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

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

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

**The "Extinction Risk" Question**

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

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

**Artificial Propagation**

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

Nevertheless, artificial propagation is important to consider in ESA evaluations of anadromous Pacific salmonids for several reasons. First, although natural fish are the focus of ESU determinations, possible effects of artificial propagation on natural populations must also be evaluated. For example, stock transfers might change the genetic or life history characteristics of a natural population in such a way that the population might seem either less or more distinctive than it was historically. Artificial propagation can also alter life history characteristics such as smolt age and migration and spawn timing. Second, artificial propagation poses a number of risks to natural populations that may affect their risk of extinction or endangerment. These risks are discussed below in the "Assessment of Extinction Risk" section. In contrast to most other types of risk for salmon populations, those arising from artificial propagation are often not reflected in traditional indices of population abundance. For example, to the extent that habitat degradation, overharvest, or hydropower development have contributed to a population's decline, these factors will already be reflected in population abundance data and accounted for in the risk analysis. The same is not true of artificial propagation. Hatchery production may mask declines in natural populations that will be missed if only raw population abundance data are considered. Therefore, a true assessment of the viability of natural populations cannot be attained without information about the contribution of naturally spawning hatchery fish. Furthermore, even if such data are available, they will not in themselves provide direct information about possibly deleterious effects of fish culture. Such an evaluation requires consideration of the genetic and demographic risks of artificial propagation for natural populations. The sections on artificial propagation in this report are intended to address these concerns.

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

## Summary of the West Coast Steelhead Petition

The petition of February 1994 was filed by Oregon Natural Resources Council, California Sport Fishing Protection Alliance, Coast Range Association, Fish in Northwest Streams, Greater Ecosystem Alliance, National Wildlife Federation, Oregon Wildlife Federation, Pilchuck Audubon Society, Quilcene Ancient Forest Coalition, Rivers Council of Washington, Save the West, Siskiyou Audubon Society, Siskiyou Regional Educational Project, Trout Unlimited of Oregon, University of Oregon Survival Center, and Western Ancient Forest Campaign. The petition called upon the Secretary of Commerce to list "anadromous steelhead trout (*Oncorhynchus mykiss*)" in Washington, Idaho, Oregon, and California according to one of four alternatives presented: 1) all steelhead, 2) summer and winter "races," 3) each steelhead ESU, or 4) each of 178 individual stocks described in the petition.

### Petitioners' "Definition of Species and Application to Steelhead Trout"

The petitioners focus on the anadromous form of *O. mykiss*, stating that "the common fish culture practice of keeping separate brood stock for steelhead and resident rainbow trout during captive breeding is the most obvious empirical proof for a genetic basis of anadromy" (ONRC et al. 1994, p. 7). Among anadromous steelhead, homing is seen as an effective mechanism for developing "distinct fish stocks" and "maintaining their genetic integrity" (ONRC et al. 1994, p. 7).

**Summer steelhead**—The petition states that summer steelhead are reproductively isolated from other steelhead temporally by migration and spawn timing and spatially through spawning "in small tributaries generally not used by winter run steelhead" (ONRC et al. 1994, p. 8). The petition states that "summer steelhead are evolutionarily significant because of time of migration, state of gonadal maturity at migration, and location of spawning" (ONRC et al. 1994, p. 8).

**A- and B-run steelhead**—The petition states that B-run summer steelhead from the Clearwater and Salmon Rivers, Idaho differ from A-run steelhead based on "greater body size at a given ocean age," ... "late run timing, older average ocean age, and long river migration," and, therefore are evolutionarily significant (ONRC et al. 1994, p. 8).

**Half-pounders**—The petition states that the half-pounder life history[1] of steelhead from the Rogue, Klamath, Mad, and Eel Rivers is evolutionarily significant.

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[1] The *half-pounder* (Snyder 1925) is a life-history trait of steelhead that is found only in the Rogue, Klamath, Mad, and Eel Rivers of southern Oregon and northern California. Following smoltification, half-pounders spend only 2-4 months in the ocean, then return to fresh water. They overwinter in fresh water and emigrate to salt water again the following spring. This is often termed a false spawning migration, as few half-pounders are sexually mature.

**Southern steelhead**—The petition states that southern steelhead[1] comprise an ESU based on the following: 1) "they are the southernmost distribution of native steelhead in North America," 2) they utilize seasonally warm rivers and streams that frequently have dewatered reaches, 3) they occupy habitat that is different from that north of San Francisco, 4) they have lower smolt age and older ocean age, and 5) "southern steelhead may breed as metapopulations that allow for recolonization of streams after prolonged drought" (ONRC et al. 1994, p. 9).

## INFORMATION RELATING TO THE SPECIES QUESTION

In this section, we summarize biological and environmental information that is relevant to determining the nature and extent of west coast steelhead ESUs. Again, in this document, *west coast steelhead* refers to steelhead in the states of Washington, Idaho, Oregon, and California. We considered information on steelhead from other locations, such as Alaska and British Columbia, in addressing the species question. However, they are not included in the phrase west coast steelhead and, when discussed in this document, they are specifically mentioned.

### Groupings of *Oncorhynchus mykiss*

The biological species *Oncorhynchus mykiss* is phylogenetically and ecologically complex. The diversity of morphology and life history within this presently recognized species has led to many classification schemes, including that of David Starr Jordan that included "32 full species, which are presently referable to the diversity within rainbow and cutthroat trout [*O. clarki*]" (Behnke 1992, p. 6). The volumes of work on this species have resulted in the recognition of several groups within the species and the development of terminology unique to *O. mykiss*. As these terms will be used extensively in this document, they are introduced here.

#### Phylogenetic Groups

Two major genetic groups of *O. mykiss* are presently recognized in North America: the *inland* and *coastal* groups, generally separated in the Fraser and Columbia River Basins in the vicinity of the Cascade crest (Huzyk and Tsuyuki 1974, Allendorf 1975, Utter and Allendorf 1977, Okazaki 1984, Parkinson 1984, Schreck et al. 1986, Reisenbichler et al. 1992). Both inland and coastal steelhead occur in British Columbia, Washington, and Oregon; Idaho has only inland steelhead; California is thought to have only coastal steelhead. These genetic groups apply to both anadromous and nonanadromous forms of *O. mykiss*; that

[2] A precise definition for southern steelhead does not exist. As described in the petition, these are steelhead from the southern limit of the species range to as far north as San Luis Obispo County or Monterey County, or south of San Francisco Bay.

is, rainbow (redband) trout east of the Cascades are genetically more similar to steelhead from east of the Cascades than they are to rainbow trout west of the Cascades. Behnke (1992) has proposed that the two forms should be considered subspecies and suggested the names *O. mykiss irideus* and *O. m. gairdneri* for the coastal and inland forms, respectively. Other subgroups of the species *O. mykiss* that may be involved in a discussion of west coast steelhead are the redband trout of the upper Klamath and upper Sacramento River Basins (*O. m. newberrii* and *O. m. stonei*, Behnke 1992), see Table 1.

**Life History Variations**

*Oncorhynchus mykiss* is considered by many to have the greatest diversity of life history patterns of any Pacific salmonid species (Shapovalov and Taft 1954, Barnhart 1986), including varying degrees of anadromy, differences in reproductive biology, and plasticity of life history between generations.

**Reproductive ecotypes**—Within the range of west coast steelhead, spawning migrations occur throughout the year, with seasonal peaks of activity. In a given river basin there may be one or more peaks in migration activity; since these *runs* are usually named for the season in which the peak occurs, some rivers may have runs known as winter, spring, summer, or fall steelhead. For example, large rivers, such as the Columbia, Rogue, and Klamath Rivers, have migrating adult steelhead at all times of the year. Through time, the names of seasonal runs have generally been simplified, especially in the Pacific Northwest[3], to two: winter and summer steelhead. There are local variations in the names used to identify the seasonal runs of steelhead; in northern California, some biologists have retained the use of the terms spring and fall steelhead to describe what others would call summer steelhead.

Biologically, steelhead can be divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration (Burgner et al. 1992). The *stream-maturing* type (commonly known as fall steelhead in Alaska, summer steelhead in the Pacific Northwest and northern California) enters fresh water in a sexually immature condition and requires several months to mature and spawn. The *ocean-maturing* type (spring steelhead in Alaska, winter steelhead elsewhere) enters fresh water with well-developed gonads and spawns shortly thereafter. This document generally uses the terms summer steelhead to refer to the stream-maturing type and winter steelhead to refer to the ocean-maturing type.

In the Pacific Northwest, steelhead that enter fresh water between May and October are considered summer steelhead, and steelhead that enter fresh water between November and April are considered winter steelhead. Variations in migration timing exist between populations, although there is considerable overlap. Some river basins have both summer and winter steelhead; others have only one type. It appears that the summer, or stream-maturing, steelhead occur where habitat is not fully utilized by winter steelhead; summer steelhead usually spawn farther upstream than winter steelhead (Withler 1966,

[3] The Pacific Northwest includes the states of Washington, Idaho, and Oregon.

Table 1. Proposed taxonomy of various forms (subspecies) of *Oncorhynchus mykiss* (Behnke 1992).

| Scientific name | Common name and comments |
|---|---|
| Rainbow trout of coastal basins | |
| *O. mykiss irideus* | Coastal rainbow trout from Alaska to California (anadromous form is called steelhead) |
| *O. mykiss mykiss* | Kamchatka rainbow trout or mikizha (anadromous form is called steelhead) |
| Redband trout of northern inland basins | |
| *O. mykiss gairdneri* | Columbia redband trout of the Columbia and Fraser River Basins east of the Cascades, including Kamloops trout (anadromous form is called steelhead) |
| Redband trout of eastern Oregon basins | |
| *O. mykiss newberrii* | Upper Klamath redband trout (including Upper Klamath Lake) |
| (no name given) | Oregon desert basin redband trout (other than Upper Klamath Lake) |
| Redband trout of the Sacramento Basin | |
| *O. mykiss aguabonita* | California golden trout |
| *O. mykiss gilberti* | Kern and Little Kern River golden trout |
| *O. mykiss stonei* | Sacramento redband trout (McCloud River subspecies) |

Roelofs 1983, Behnke 1992). In rivers where the two types co-occur, they are often separated by a seasonal hydrologic barrier, such as a waterfall. Coastal streams are dominated by winter steelhead, whereas inland steelhead of the Columbia River Basin are almost exclusively summer steelhead. Winter steelhead may have been excluded from inland areas of the Columbia River Basin by Celilo Falls, or by the great migration distance from the ocean. The Sacramento-San Joaquin River Basin historically may have had multiple runs of steelhead that probably included both ocean-maturing and stream-maturing stocks (CDFG 1995, McEwan and Jackson 1996, McEwan[4]). Currently, the steelhead of this region are referred to as winter steelhead by the California Department of Fish and Game (CDFG); however, some biologists call them fall steelhead (Cramer et. al 1995). It is thought that hatchery practices and modifications in the hydrology of the basin caused by large-scale water diversions may have altered the migration timing of steelhead in this basin (McEwan footnote 4).

**A- and B-run steelhead**—Inland steelhead of the Columbia River Basin, especially the Snake River Subbasin, are commonly referred to as either *A-run* or *B-run*. These designations are based on the observation of a bimodal migration of adult steelhead at Bonneville Dam (Columbia River river kilometer (RKm) 235) and differences in age (1- versus 2-ocean) and adult size observed among Snake River steelhead. Adult A-run steelhead enter fresh water from June to August; as defined, the A-run passes Bonneville Dam before 25 August (CBFWA 1990, IDFG 1994). Adult B-run steelhead enter fresh water from late August to October, passing Bonneville Dam after 25 August (CBFWA 1990, IDFG 1994). Above Bonneville Dam (e.g., at Lower Granite Dam on the Snake River, 695 km from the mouth of the Columbia River), run-timing separation is not observed, and the groups are separated based on ocean age and body size (IDFG 1994). A-run steelhead are defined as predominately age-1-ocean, while B-run steelhead are defined as age-2-ocean (IDFG 1994). Adult B-run steelhead are also thought to be on average 75-100 mm larger than A-run steelhead of the same age; this is attributed to their longer average residence in salt water (Bjornn 1978, CBFWA 1990, CRFMP TAC, 1991). It is unclear, however, if the life history and body size differences observed upstream have been correlated back to the groups forming the bimodal migration observed at Bonneville Dam. Furthermore, the relationship between patterns observed at the dams and the distribution of adults in spawning areas throughout the Snake River Basin is not well understood. A-run steelhead are believed to occur throughout the steelhead-bearing streams of the Snake River Basin; additionally, inland Columbia River steelhead outside of the Snake River Basin are also considered A-run (IDFG 1994). B-run steelhead are thought to be produced only in the Clearwater, Middle Fork Salmon, and South Fork Salmon Rivers (IDFG 1994).

**Half-pounders**—The *half-pounder* (terminology of Snyder 1925) is an immature steelhead that returns to fresh water after only 2 to 4 months in the ocean, generally overwinters in fresh water, then outmigrates again the following spring. Half-pounders are generally less than 400 mm (Kesner and Barnhart 1972, Everest 1973). Half-pounders are only reported from the Rogue, Klamath, Mad, and Eel Rivers of southern Oregon and

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[4] D. McEwan, California Department of Fish and Game, Inland Fisheries Division, 1416 9th Street, Sacramento, CA 95814. Pers. commun., May 1995.

northern California (Snyder 1925, Kesner and Barnhart 1972, Everest 1973, Barnhart 1986); however, it has been suggested that as mature steelhead, these fish may only spawn in the Rogue and Klamath River Basins (Cramer et al. 1995). Various explanations for this unusual life history have been proposed, but there is still no consensus as to what, if any, advantage this life history affords to the steelhead of these rivers.

**Rainbow and redband trout**—As mentioned earlier, the species *O. mykiss* exhibits varying degrees of anadromy. Nonanadromous forms of the species are usually called rainbow trout; however, nonanadromous *O. mykiss* of the inland type are often called Columbia River redband trout. Another form occurs in the upper Sacramento River and is called Sacramento redband trout. Although the anadromous and nonanadromous forms have long been taxonomically classified within the same species, the exact relationship between the forms in any given area is not well understood. In coastal populations, it is unusual for the two forms to co-occur; they are usually separated by a migration barrier, be it natural or manmade. In inland populations, co-occurrence of the two forms appears to be more frequent. Where the two forms co-occur, "it is possible that offspring of resident fish may migrate to the sea, and offspring of steelhead may remain in streams as resident fish" (Burgner et al. 1992, p. 6; see also Shapovalov and Taft 1954, p. 18). Mullan et al. (1992, p. K-427) found evidence that in very cold streams, juvenile steelhead had difficulty attaining "mean threshold size for smoltification" and concluded that "Most fish here [Methow River, Washington] that do not emigrate downstream early in life are thermally-fated to a resident life history regardless of whether they were the progeny of anadromous or resident parents." Additionally, Shapovalov and Taft (1954) reported evidence of *O. mykiss* maturing in fresh water and spawning prior to their first ocean migration; this life history variation has also been found in cutthroat trout (*O. clarki*) and some male chinook salmon (*O. tshawytscha*).

## Environmental Features

West coast steelhead are presently distributed across 15 degrees of latitude, from approximately 49°N at the U.S.-Canada border south to 34°N at the mouth of Malibu Creek, California. In some years steelhead may be found as far south as the Santa Margarita River in San Diego County. Climate and geological features vary greatly across this area, resulting in a variety of landforms and diverse patterns of vegetation, weather, soils, and water quality parameters that affect the distribution and ecology of plant and animal species, including fish.

### West Coast Ichthyogeography

**Geological events**—Western North America, part of the Pacific Ring of Fire, is a geologically active region that experiences large-scale volcanic, tectonic, and glacial events. These events affect landforms, soil types, and, therefore, drainage patterns. Headwater transfer and stream capture events have provided dispersal opportunities for several species of freshwater fish in various drainages; Minckley et al. (1986) summarized several examples of these events in Oregon and California streams.

Landforms and aquatic species distribution in the Pacific Northwest were greatly affected by glaciation and flooding that occurred during the Wisconsin glacial age between 70,000 and 10,000 years ago (Porter 1983, Allen et al. 1986, Briggs 1986). In the late Wisconsin glacial age, the Cordilleran ice sheet covered parts of present-day British Columbia, Alberta, Washington, Idaho, and Montana. Although the Cordilleran ice sheet extended only to the Puget Sound region, it affected sea level and climatic conditions much farther south (Porter 1983). Thus, much of present-day patterns of landform and zoogeography in western North America evolved in the last 10,000 years.

**Ecoregions**—Omernik (1987) delineated 13 ecoregions within the freshwater distribution of west coast steelhead based on soils, land use, land surface form, and potential natural vegetation (Table 2). The ecoregions occupied by west coast steelhead can be grouped by climatic regions.

The north coastal region includes rivers and streams draining the Coast Ranges of Washington, Oregon, and northern California. Climate in this area is under maritime influence and, therefore, includes abundant precipitation (primarily in the form of rain), summer fog, and moderate temperatures (Jackson 1993). Vegetation in this region is dominated by conifers, Sitka spruce (*Picea sitchensis*) in the north and coast redwood (*Sequoia sempervirens*) in the south (Donley et al. 1979, Jackson 1993).

In the south coastal region, south of Point Piedras Blancas, coastal rivers and streams drain directly from the South Coast Range, and from the Transverse and Peninsular Ranges of southern California to the coastal plain. This area is much drier than the north coastal strip. Vegetation is dominated by chaparral, coastal scrub, and grassland (Donley et al. 1979).

The western lowlands include the Puget Lowland in Washington and the Willamette Valley in Oregon. These areas include the rain shadows of the Coast and Olympic Mountain Ranges and the foothills of the taller Cascade Range; they receive a moderate amount of precipitation compared to regions east and west of them. Vegetation within these valleys is primarily grassland, with oak woodlands occurring in the foothills and coniferous forest dominant at higher elevations.

The Central Valley of California is positioned between the Coast Range and the Cascade and Sierra Nevada Ranges. It is warmer and drier than the western lowlands. Native vegetation in the Central Valley was bunchgrass prairie (Donley et al. 1979). The intermountain valleys of the western lowlands and Central Valley of California are now productive agricultural areas.

The rivers and streams of the Columbia Basin ecoregion (Omernik 1987) are in the rain shadow of the Cascade Mountain Range. The vegetation in this zone includes pine, juniper, and sagebrush. Streamflow is provided by snowmelt and springs. Many rivers in this region experience extreme ranges in water temperature.

The northern Rockies zone includes the high elevation Clearwater and Salmon River Basins of arid north-central Idaho. The region is dominated geologically by the Idaho

Table 2. Ecoregions (Omernik 1987) within the distribution of west coast steelhead.

| Ecoregion | Washington | Idaho | Oregon | California |
|---|---|---|---|---|
| Coast Range | ✓ | | ✓ | ✓ |
| Puget Lowland | ✓ | | | |
| Willamette Valley | ✓ | | ✓ | |
| Cascades | ✓ | | ✓ | |
| Sierra Nevada | | | ✓ | ✓ |
| Southern and Central California Plains and Hills | | | | ✓ |
| Central California Valley | | | | ✓ |
| Southern California Mountains | | | | ✓ |
| Eastern Cascades Slopes and Foothills | ✓ | | ✓ | ✓ |
| Columbia Basin | ✓ | ✓ | ✓ | |
| Blue Mountains | ✓ | ✓ | ✓ | |
| Snake River Basin/High Desert | | ✓ | ✓ | |
| Northern Rockies | ✓ | ✓ | | |

Batholith, which is composed of highly erosive granitic soils (see Matthews and Waples 1991 for a discussion on the effects on water quality and productivity).

**Ichthyogeographical classification**—Several authors have published ichthyogeographical studies for western North America (e.g., Snyder 1907, Moyle 1976, McPhail and Lindsey 1986, Swift et al. 1993). Within the range of west coast steelhead, five major freshwater ichthyogeographic regions have been described (Snyder 1907, Moyle 1976, McPhail and Lindsey 1986): Chehalis, Columbia, Klamath, Sacramento-San Joaquin, and South Coastal Drainages. Although anadromy provides steelhead with distribution opportunities not available to freshwater species, it is instructive to consider the distribution of freshwater species for evidence of potential mechanisms of reproductive isolation between steelhead populations, and for evidence of environmental parameters that address the question of ecological diversity of the species.

**Marine and estuarine ichthyogeography**—Along the U.S. Pacific Coast, there are two points where marine fish distribution and abundance markedly change: Cape Mendocino (Allen and Smith 1988) and Point Conception (Briggs 1974); both are in California. Environmental conditions that differ north and south of these points (e.g., ocean currents, upwelling, temperature, productivity) may affect anadromous fish as well as marine species.

Monaco et al. (1992) grouped west coast U.S. estuaries that have similar species assemblages. Their findings were largely consistent with ichthyofaunal distribution changes in the vicinity of Cape Mendocino and Point Conception. Monaco et al. (1992) also identified an assemblage within the inland estuaries of Puget Sound and Hood Canal in Washington (Fjord Group). Other estuary groupings are less clear geographically and seem to depend more on estuarine characteristics rather than on location.

## Hydrology

Streamflow patterns show several geographic trends. Month of peak flow is delayed with decreasing latitude, shifting from December in Washington and northern Oregon to January from the Alsea River, Oregon south to Point Arena, California, to February from Point Arena south to Big Sur, and to March in southern California (Hydrosphere 1993). In northern Washington there are often two peaks in streamflow, the larger December peak caused by precipitation (often a rain-on-snow event) and a smaller peak in spring caused by snowmelt. Rivers in Oregon and California usually have one peak streamflow month (Hydrosphere 1993). Additionally, northern streams have greater discharge per watershed area, longer periods of peak flow, and more consistent base flow than southern streams. Many coastal streams from southern Oregon to southern California experience seasonal intermittent flows, including physical isolation from the ocean through formation of sand berms. When a sand berm forms, through a combination of low streamflow and ocean transport of sand, it functions as a dam, creating a lagoon in the lower stream reach. In periods of drought, these closures may persist for extended periods of time—even years (Snider 1983, Titus et al. in press). This affects access to salt water by juvenile steelhead and access to freshwater spawning areas by adult steelhead.

## Steelhead Life History and Ecology

*Oncorhynchus mykiss* exhibit perhaps the most complex suite of life history traits of any species of Pacific salmonid. They can be anadromous or freshwater resident (and under some circumstances, apparently yield offspring of the opposite form). Resident forms are usually called rainbow, or redband, trout. Those that are anadromous can spend up to 7 years in fresh water prior to smoltification, and then spend up to 3 years in salt water prior to first spawning. The half-pounder life history type in southern Oregon and northern California spends only 2 to 4 months in salt water after smoltification, then returns to fresh water and outmigrates to sea again the following spring without spawning. Another life history variation is the ability of this species to spawn more than once (iteroparity), whereas all other species of *Oncorhynchus*, except *O. clarki*, spawn once and then die (semelparity).

### Migration and Spawn Timing

The most widespread run type of steelhead is the winter (ocean-maturing) steelhead. Winter steelhead occur in essentially all coastal rivers of Washington, Oregon, and California, south to Malibu Creek. Summer (stream-maturing) steelhead, including spring and fall steelhead in southern Oregon and northern California, are less common; for example, on the Oregon coast only the Rogue, Umpqua, and Siletz Rivers have natural populations of summer steelhead. Inland steelhead of the Columbia River Basin, however, are essentially all stream-maturing steelhead; as discussed earlier, these inland steelhead are referred to in terms of A-run and B-run.

Available information for natural populations of steelhead (Table 3) reveals considerable overlap in migration and spawn timing between populations of the same run type. Moreover, there is a high degree of overlap in spawn timing between populations regardless of run type. California steelhead generally spawn earlier than those in areas to the north; both summer and winter steelhead in California generally begin spawning in December, whereas most populations in Washington begin spawning in February or March. Relatively little information on spawn timing is available for Oregon and Idaho steelhead populations. Among inland steelhead, Columbia River populations from tributaries upstream of the Yakima River spawn later than most downstream populations.

### Ageing

Steelhead exhibit great variation in smolt age and ocean age both within and between populations, but there are some trends.

**Smolt age**—Smolt age discussed here is based on scale and otolith data from adult steelhead. The emphasis on adult steelhead is based on the assumption that fish surviving to spawning age are expressing the successful and adaptive life history strategy for steelhead in a given geographical location. Steelhead from British Columbia and Alaska most frequently smolt after 3 years in fresh water (Withler 1966, Narver 1969, Sanders 1985). In most other populations for which there are data, the modal smolt age is 2 years (Table 4). Hatchery conditions usually allow steelhead to smolt in 1 year; this difference is often used by

Table 3. Migration (shaded), spawn (s), and peak spawn (P) timing for selected populations of steelhead. Run types of steelhead are indicated by (O) = ocean-maturing and (S) = stream-maturing.

| Location<br>Population (run type) | Months: F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alaska** | | | | | | | | | | | | | | | | | | |
| Karluk River (S) | | | | | | | | | | | | | | | | | | |
| Anchor River (S) | | | | | | | | | | | | | | | | | | |
| Situk River (S) | | | | | | | | | | | P | P | | | | | | |
| Situk River (O) | | | | | | | | | | | | | | | | | | |
| Sitkoh Crek (O) | | | | | | | | | | | | | | | | | | |
| Karta River (O) | | | | | | | | | | | | | | | | | | |
| **Washington (Puget Sound)** | | | | | | | | | | | | | | | | | | |
| Nooksack River (O) | | | | | | | | | | | | | s | s | s | P | s | |
| Samish River (O) | | | | | | | | | | | | | s | s | P | s | | |
| SKAGIT RIVER BASIN | | | | | | | | | | | | | | | | | | |
| Skagit River (O) | | | | | | | | | | | | | | s | s | P | s | |
| Sauk River (S) | | | | | | | | | | | | | | | s | s | | |
| Cascade River (S) | | | | | | | | | | | | s | s | s | s | | | |
| STILLAGUAMISH RIVER BASIN | | | | | | | | | | | | | | | | | | |
| Stillaguamish River (O) | | | | | | | | | | | | | | s | s | P | s | |
| Deer Creek (S) | | | | | | | | | | | | | | | s | s | | |
| S. Fork Stillaguamish River (S) | | | | | | | | | | | | s | s | s | s | | | |

Table 3. Migration and spawn timing for selected steelhead populations. Continued.

| Location / Population (run type) — Months: | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SNOHOMISH RIVER BASIN | | | | | | | | | | | | | | | | | | |
| Snohomish River (O) | | | | | | | | | | | | | | s | P | s | s | |
| N. Fork Skykomish River (S) | | | | | | | | | | | | | | | | | | |
| Lake Washington (O) | | | | | | | | | | | | | | | | | | |
| Green River (O) | | | | | | | | | | | | | | s | P | P | s | |
| Puyallup River (O) | | | | | | | | | | | | | | s | P | P | s | |
| Nisqually River (O) | | | | | | | | | | | | | | s | P | P | s | |
| Deschutes River (O) | | | | | | | | | | | | s | P | s | s | | | |
| South Sound Inlets (O) | | | | | | | | | | | | | s | P | P | | | |
| Tahuya River (O) | | | | | | | | | | | | | s | s | P | s | | |
| Skokomish River (O) | | | | | | | | | | | | | s | s | P | s | s | |
| Dewatto River (O) | | | | | | | | | | | | | s | s | P | s | | |
| Discovery Bay (O) | | | | | | | | | | | | | s | s | P | s | s | |
| Dungeness River (O) | | | | | | | | | | | | | | s | s | P | s | |
| Morse Creek (O) | | | | | | | | | | | | | s | s | P | s | s | |
| Pysht River (O) | | | | | | | | | | | | | s | s | P | s | s | |
| Hoko River (O) | | | | | | | | | | | | | s | s | P | s | s | |

Table 3. Migration and spawn timing for selected steelhead populations. Continued.

| Location<br>Population (run type) | Months: | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Washington (coastal)** | | | | | | | | | | | | | | | | | | | |
| Quillayute River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Quillayute River (S) | | | | | | | | | | | | | | | | | | | |
| Hoh River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Hoh River (S) | | | | | | | | | | | | | | | | | | | |
| Queets River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Queets River (S) | | | | | | | | | | | | | | | | | | | |
| Quinault River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Quinault River (S) | | | | | | | | | | | | | | | | | | | |
| Moclips River (O) | | | | | | | | | | | | | s | s | s | P | P | s | |
| Copalis River (O) | | | | | | | | | | | | | | s | s | s | s | s | |
| Humptulips River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Humptulips River (S) | | | | | | | | | | | | | | | | | | | |
| Hoquiam River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Wishkah River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Wynoochee River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Satsop River (O) | | | | | | | | | | | | | | s | s | P | P | s | |
| Chehalis River (O) | | | | | | | | | | | | | | s | s | P | P | s | |

Table 3. Migration and spawn timing for selected steelhead populations. Continued.

| **Location** / Population (run type) — **Months:** | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Skookumchuck River (O) | | | | | | | | | | | | | s | s | P | P | s | |
| Willapa Bay (O) | | | | | | | | | | | | | s | s | P | P | | |
| **Columbia River Basin** | | | | | | | | | | | | | | | | | | |
| FRESHWATER ENTRY (S) | | | | | | | | | | | | | | | | | | |
| Grays River, Washington (O) | | | | | | | | | | | | | | s | s | s | s | |
| Elochoman River, Washington (O) | | | | | | | | | | | | | | s | P | P | s | |
| Mill Creek, Washington (O) | | | | | | | | | | | | | | s | P | P | s | |
| Abernathy Creek, Washington (O) | | | | | | | | | | | | | | s | P | P | s | |
| Germany Creek, Washington (O) | | | | | | | | | | | | | | s | P | P | s | |
| Cowlitz River, Washington (O) | | | | | | | | | | | | | | s | s | s | s | |
| Toutle River, Washington (O) | | | | | | | | | | | | | | s | P | P | s | |
| Coweeman River, Washington (O) | | | | | | | | | | | | | | s | s | s | s | |
| Kalama River, Washington (O) | | | | | | | | | | | | | | s | P | P | s | |
| Kalama River, Washington (S) | | | | | | | | | | | | s | s | s | s | | | |
| Lewis River, Washington (S) | | | | | | | | | | | | | | s | s | s | s | |
| Willamette River, Oregon (O) | | | | | | | | | | | | | | | s | P | s | |
| Clackamas River, Oregon (O) | | | | | | | | | | | | | | | s | P | P | |
| Washougal River, Washington (S) | | | | | | | | | | | | | | s | s | s | s | |
| Wind River, Washington (S) | | | | | | | | | | | | | | s | s | s | | |

Table 3. Migration and spawn timing for selected steelhead populations. Continued.

| Location / Population (run type) — Months: | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| White Salmon River, Washington (S) | | | | | | | | | | | | | | s | s | s | | |
| Klickitat River, Washington (S) | | | | | | | | | | | | | | s | s | s | | |
| Fifteenmile Creek, Oregon (O) | | | | | | | | | | | | | | s | s | | | |
| Deschutes River, Oregon (S) | | | | | | | | | | | | | s | s | s | s | | |
| John Day River, Oregon (S) | | | | | | | | | | | | | | s | s | s | | |
| Rock Creek, Oregon (S) | | | | | | | | | | | | | | s | s | s | | |
| Walla Walla River, Washington (S) | | | | | | | | | | | | | | s | s | s | | |
| Touchet River, Washington (S) | | | | | | | | | | | | | | s | P | P | | |
| Yakima River, Washington (S) | | | | | | | | | | | | | s | s | P | s | | |
| Wenatchee River, Washington (S) | | | | | | | | | | | | | | s | s | P | s | s |
| Entiat River, Washington (S) | | | | | | | | | | | | | | s | s | P | s | s |
| Methow River, Washington (S) | | | | | | | | | | | | | | s | s | s | s | s |
| Okanogan River, Washington (S) | | | | | | | | | | | | | | s | s | s | s | s |
| **Snake River Basin** | | | | | | | | | | | | | | | | | | |
| "A"-run freshwater entry (S) | | | | | | | | | | | | | | | | | | |
| "B"-run freshwater entry (S) | | | | | | | | | | | | | | | | | | |
| Tucannon River (S) | | | | | | | | | | | | | | s | P | P | | |
| Asotin Creek (S) | | | | | | | | | | | | | | s | P | P | | |
| Grande Ronde River (S) | | | | | | | | | | | | | | s | s | s | | |

Table 3. Migration and spawn timing for selected steelhead populations. Continued.

| Location / Population (run type) | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Oregon (coastal)** | | | | | | | | | | | | | | | | | | |
| Yaquina River (O) | | | | | | | | | | | s | s | s | s | s | | | |
| Rogue River (S) | | | | | | | | | | | | P | P | s | s | | | |
| **California** | | | | | | | | | | | | | | | | | | |
| Smith River (O) | | | | | | | | | | | | s | P | s | s | | | |
| Smith River (S) | | | | | | | | | | | s | P | s | | | | | |
| Klamath River (O) | | | | | | | | | | | s | s | s | P | s | s | | |
| Klamath River (S) | | | | | | | | | | | s | P | s | | | | | |
| Trinity River (O) | | | | | | | | | | s | P | P | P | P | s | | | |
| Trinity River (S) | | | | | | | | | | | s | P | s | | | | | |
| Redwood Creek (O) | | | | | | | | | | | s | P | s | s | | | | |
| Redwood Creek (S) | | | | | | | | | | | | | | | | | | |
| Mad River (O) | | | | | | | | | | | | s | P | P | s | | | |
| Mad River (S) | | | | | | | | | | | | | | | | | | |
| Jacoby Creek (O) | | | | | | | | | | | s | s | P | P | s | | | |
| Freshwater Creek (O) | | | | | | | | | | | s | s | P | P | s | | | |
| Eel River (O) | | | | | | | | | | s | s | P | P | s | s | | | |
| Eel River (S) | | | | | | | | | | | s | P | s | s | | | | |
| Pudding Creek (O) | | | | | | | | | | | s | P | P | s | | | | |

Table 3. Migration and spawn timing for selected steelhead populations. Continued.

| Location / Population (run type) — Months: | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Casper Creek (O) | | | | | | | | | | | | | s | P | s | | | |
| Gualala River (O) | | | | | | | | | | | | s | P | s | | | | |
| Russian River (O) | | | | | | | | | | | s | P | P | P | s | s | | |
| SACRAMENTO RIVER BASIN | | | | | | | | | | | | | | | | | | |
| early run (O) | | | | | | | | | | | s | s | P | | | | | |
| late run (O) | | | | | | | | | | | | s | P | P | s | s | | |
| American River (O) | | | | | | | | | | | s | P | P | s | s | s | | |
| Feather River (O) | | | | | | | | | | s | s | P | P | s | s | s | s | |
| Mokelumne River (O) | | | | | | | | | | | s | s | P | s | s | | | |
| San Gregorio Creek (O) | | | | | | | | | | | s | s | P | s | | | | |
| Waddell Creek (O) | | | | | | | | | | | s | P | P | P | s | s | | |
| Scott Creek (O) | | | | | | | | | | | s | P | P | P | s | s | | |
| San Lorenzo River (O) | | | | | | | | | | | s | s | P | s | | | | |
| Carmel River (O) | | | | | | | | | | | | s | P | P | s | | | |
| Santa Ynez River (O) | | | | | | | | | | | s | s | P | P | s | s | s | |
| Ventura River (O) | | | | | | | | | | | | s | P | P | s | s | s | |
| Santa Clara River (O) | | | | | | | | | | | s | s | P | P | s | s | s | |
| Malibu Creek (O) | | | | | | | | | | | | s | P | P | s | | | |

Table 4. Smolt age frequency for selected steelhead populations (modal values are presented in bold). Data are from adult steelhead, except where noted otherwise. Populations are generally arranged from north to south.

| Population | Run type[a] | Freshwater age 1 | 2 | 3 | 4 | 5 | 7 | Sample size | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **Alaska** | | | | | | | | | |
| Karluk River | S | -- | 0.36 | **0.63** | 0.01 | -- | -- | 101 | Sanders 1985 |
| Anchor River | S | -- | 0.12 | **0.85** | 0.03 | -- | -- | 90 | Sanders 1985 |
| Copper River | S | -- | 0.08 | **0.89** | 0.03 | -- | -- | 35 | Sanders 1985 |
| Situk River | S/O | -- | 0.13 | **0.71** | 0.16 | -- | -- | 284 | Sanders 1985 |
| Sitkoh Creek | O | -- | 0.04 | **0.66** | 0.30 | -- | -- | 656 | Sanders 1985 |
| Karta River | O | -- | 0.18 | **0.69** | 0.13 | -- | -- | 808 | Sanders 1985 |
| **British Columbia (mainland)** | | | | | | | | | |
| Babine River | S | -- | 0.02 | **0.82** | 0.15 | 0.01 | -- | 100 | Narver 1969 |
| Cheakamus River | O | -- | 0.45 | **0.53** | 0.02 | -- | -- | 64 | Withler 1966 |
| Capilano River | O | -- | 0.46 | **0.53** | 0.01 | -- | -- | 70 | Withler 1966 |
| Capilano River | S | 0.01 | 0.16 | **0.83** | -- | -- | -- | 86 | Withler 1966 |
| Seymour River | O | -- | 0.33 | **0.66** | 0.02 | -- | -- | 58 | Withler 1966 |
| Seymour River | S | -- | 0.40 | **0.60** | -- | -- | -- | 25 | Withler 1966 |
| **British Columbia (Fraser River Basin)** | | | | | | | | | |
| Coquitlam River | O | -- | 0.34 | **0.66** | <0.01 | -- | -- | 146 | Withler 1966 |
| Alouette River | O | 0.08 | **0.66** | 0.25 | <0.01 | -- | -- | 131 | Withler 1966 |
| Chilliwack River | O | 0.02 | **0.62** | 0.36 | <0.01 | -- | -- | 770 | Maher and Larkin 1955 |
| Chehalis River | O | -- | 0.19 | **0.68** | 0.13 | -- | -- | 111 | Withler 1966 |
| Coquihalla River | O | -- | 0.28 | **0.67** | 0.05 | -- | -- | 39 | Withler 1966 |
| Coquihalla River | S | <0.01 | 0.18 | **0.75** | 0.06 | -- | -- | 150 | Withler 1966 |
| **British Columbia (Vancouver Island)** | | | | | | | | | |
| Keogh River | O? | -- | 0.30 | **0.60** | 0.10 | -- | -- | 1391 | Ward and Slaney 1988 |
| Nanaimo River | ? | -- | **0.64** | 0.35 | 0.01 | -- | -- | 228 | Narver and Withler 1974 |
| Nahmint River | S | -- | 0.21 | **0.78** | 0.02 | -- | -- | 58 | Narver 1974 |

Table 4. Smolt age frequency. Continued.

| Population | Run type[a] | Freshwater age 1 | 2 | 3 | 4 | 5 | 7 | Sample size | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **Washington** | | | | | | | | | |
| Skagit River | O | <0.01 | **0.82** | 0.18 | <0.01 | -- | -- | n/a[b] | WDFW 1994b |
| Deer Creek | S | -- | **0.95** | 0.05 | -- | -- | -- | n/a | WDF et al. 1993 |
| Snohomish River | O | 0.01 | **0.84** | 0.15 | <0.01 | -- | -- | n/a | WDFW 1994b |
| Green River | O | 0.16 | **0.75** | 0.09 | -- | -- | -- | 100 | Pautzke and Meigs 1941 |
| Puyallup River | O | 0.05 | **0.89** | 0.06 | -- | -- | -- | n/a | WDFW 1994b |
| Nisqually River | O | 0.19 | **0.80** | 0.01 | -- | -- | -- | n/a | WDFW 1994b |
| Hoh River | O | 0.03 | **0.91** | 0.06 | -- | -- | -- | n/a | Larson and Ward 1954 |
| Quillayute River | O | 0.03 | **0.87** | 0.10 | <0.01 | -- | -- | n/a | WDFW 1994b |
| Chehalis River | O | 0.10 | **0.88** | 0.02 | -- | -- | -- | n/a | Larson and Ward 1954 |
| **Columbia River Basin** | | | | | | | | | |
| Toutle River | O | -- | **0.86** | 0.14 | -- | -- | -- | 37 | Howell et al. 1985 |
| Cowlitz River | O | -- | **0.91** | 0.09 | -- | -- | -- | 56 | Howell et al. 1985 |
| Kalama River | O | -- | **0.87** | 0.13 | <0.01 | -- | -- | 1363 | Howell et al. 1985 |
| Kalama River | S | -- | **0.89** | 0.11 | -- | -- | -- | 909 | Howell et al. 1985 |
| Willamette River | O | -- | **0.92** | 0.08 | -- | -- | -- | 141 | Howell et al. 1985 |
| Washougal River | S | -- | **1.00** | -- | -- | -- | -- | 7 | Howell et al. 1985 |
| Wind River | S | 0.05 | **0.90** | 0.05 | -- | -- | -- | 19 | Howell et al. 1985 |
| Klickitat River | S | -- | **0.94** | 0.06 | -- | -- | -- | 148 | Howell et al. 1985 |
| Deschutes River | S | 0.29 | **0.55** | 0.14 | 0.02 | -- | -- | 100 | Howell et al. 1985 |
| John Day River | S | -- | **0.62** | 0.38 | -- | -- | -- | 112 | Howell et al. 1985 |
| Yakima River | S | 0.04 | **0.91** | 0.04 | 0.01 | -- | -- | 64 | BPA 1992 |
| Wenatchee River | S | -- | **0.76** | 0.24 | -- | -- | -- | 17 | Howell et al. 1985 |
| Entiat River | S | -- | **1.00** | -- | -- | -- | -- | 8 | Howell et al. 1985 |
| above Wells Dam | S | -- | **0.57** | 0.33 | 0.08 | <0.01 | <0.01 | 349 | Mullan et al. 1992 |

Table 4. Smolt age frequency. Continued.

| Population | Run type[a] | Freshwater age 1 | 2 | 3 | 4 | 5 | 7 | Sample size | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **Snake River Basin** | | | | | | | | | |
| Lower Granite Dam | S | 0.04 | **0.62** | 0.34 | -- | -- | -- | 100 | Hassemer 1992 |
| Clearwater River | S | 0.27 | **0.59** | 0.14 | -- | -- | -- | 510 | Whitt 1954 |
| S. F. Salmon River | S | -- | 0.31 | **0.69** | -- | -- | -- | 65 | BPA 1992 |
| Lemhi River | S | -- | **1.00** | -- | -- | -- | -- | 353 | BPA 1992 |
| **Oregon** | | | | | | | | | |
| Nehalem River | O | 0.05 | **0.88** | 0.07 | -- | -- | -- | 310 | Weber and Knispel 1977 |
| Alsea River | O | 0.01 | **0.80** | 0.18 | <0.01 | -- | -- | 978 | Chapman 1958 |
| Siuslaw River | O | -- | **0.83** | 0.17 | -- | -- | -- | 125 | Lindsay et al. 1991 |
| Rogue River | O | 0.09 | **0.66** | 0.23 | 0.02 | -- | -- | 547 | ODFW 1990 |
| **California** | | | | | | | | | |
| Klamath River | S | 0.27 | **0.65** | 0.08 | -- | -- | -- | 391 | Kesner and Barnhart 1972 |
| N. F. Trinity River | S | 0.02 | **0.95** | 0.02 | -- | -- | -- | 41 | Freese 1982 |
| Mad River | O | -- | **0.97** | 0.03 | -- | -- | -- | 35 | Forsgren 1979 |
| Jacoby Creek | O | 0.11 | **0.78** | 0.11 | -- | -- | -- | 109 | Harper 1980 |
| Van Duzen River | S | **1.00** | -- | -- | -- | -- | -- | 58 | Puckett 1975 |
| M. F. Eel River | S | 0.04 | **0.79** | 0.17 | -- | -- | -- | 82 | Puckett 1975 |
| Sacramento River | O? | 0.32 | **0.69** | -- | -- | -- | -- | 83 | Hallock 1989 |
| Waddell Creek | O | 0.10 | **0.69** | 0.19 | 0.02 | -- | -- | 3,888 | Shapovalov and Taft 1954 |

[a]O = Ocean maturing; S = Stream maturing.
[b]Sample size not indicated in reference.

biologists to distinguish hatchery and wild steelhead. There appears to be an increase in the frequency of naturally produced 1-year-old smolts in the southern portion of the steelhead range (Table 4). Withler (1966) suggested that there may be a latitudinal cline in steelhead smolt age; however, Titus et al. (in press) found no statistical evidence for a latitudinal cline in steelhead smolt age from California to British Columbia.

**Ocean age**—North American steelhead most commonly spend 2 years (*2-ocean*) in the ocean before entering fresh water to spawn (Table 5). Populations in Oregon and California have higher frequencies of age-1-ocean steelhead than populations to the north, but age-2-ocean steelhead generally remains dominant. Withler (1966) and Titus et al. (in press) found that ocean age at spawning (and mean adult length) increased with increasing latitude.

**Total age**—For most steelhead populations, total age at maturity can be estimated by adding the smolt age and saltwater age. However, summer steelhead (especially in the Columbia River Basin) enter fresh water up to a year prior to spawning, and that year is generally not accounted for in the saltwater age designation; for example, a 2-ocean steelhead from the Yakima River may actually have 3 years between smolting and spawning. Table 6 shows the most common life history patterns expressed by North American steelhead from several river basins. Most steelhead in Alaska and British Columbia are 3/2 (smolt age/ocean age) and have a total age of 5 years at first spawning. For coastal steelhead in Washington, Oregon, and northern California, the modal total age at maturity is 4 years (2/2). Central and southern California steelhead appear to spend less time in the ocean, and they are dominated by 3-year-old (2/1) spawners. Complete life history data for southern California steelhead are lacking; however, it appears that it is common for these fish to smolt in 1 year (CDFG 1995). If they only have one ocean year, as neighboring populations to the north do, then adults may be spawning as 2-year-olds (1/1) in this region.

Determining total age at maturity for inland steelhead of the Columbia River Basin is complicated by variations in reporting methods. Generally, these fish spend a year in fresh water prior to spawning and this is not included in the age designation. Therefore, by adding 1 year after freshwater entry (indicated here as $^{+1}$), most Columbia River inland steelhead are 4 years old at maturity ($2/1^{+1}$). An exception is the Klickitat River; if these steelhead also spend a year in fresh water before spawning, they are dominated by 5-year-old spawners ($2/2^{+1}$). Most of the available age data for Snake River steelhead are based on length frequency; smolt age is often assumed or not reported. The data that are available from scales show a high degree of variability in age structure, from 4-year-old spawners ($2/1^{+1}$) in the Clearwater River (Whitt 1954) to 7 year-old spawners ($3/3^{+1}$) in the South Fork Salmon River (BPA 1992).

**Repeat Spawning**

As noted above, most species of *Oncorhynchus* die after spawning, whereas *O. mykiss* may spawn more than once. The frequency of multiple spawnings is variable both within and among populations (Table 7). For North American steelhead populations north of Oregon, repeat spawning is relatively uncommon, and more than two spawning migrations is

Table 5. Ocean age frequency for selected steelhead populations (modal values are presented in bold). Data are from adult steelhead and indicate age at the first spawning migration. Populations are generally arranged from north to south. Stream-maturing (summer) steelhead spend up to a year in fresh water prior to spawning; this period has generally been excluded from the ages shown on this table. Therefore, an age-2-ocean stream-maturing steelhead is actually up to one year older at spawning than an age-2-ocean ocean-maturing steelhead.

| Population | Run type[a] | Ocean age at first spawning migration | | | | | | Sample | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | size | |
| **Alaska** | | | | | | | | | |
| Karluk River | S | -- | 0.18 | **0.79** | 0.03 | -- | -- | 62 | Sanders 1985 |
| Anchor River | S | -- | 0.26 | **0.74** | -- | -- | -- | 80 | Sanders 1985 |
| Upper Copper River | S | -- | 0.17 | **0.77** | 0.06 | -- | -- | 30 | Sanders 1985 |
| Situk River | S/O | -- | -- | **0.57** | 0.43 | -- | -- | 211 | Sanders 1985 |
| Sitkoh Creek | O | -- | -- | **0.59** | 0.41 | -- | -- | 497 | Sanders 1985 |
| Karta River | O | -- | <0.01 | **0.72** | 0.27 | -- | -- | 542 | Sanders 1985 |
| **British Columbia (mainland)** | | | | | | | | | |
| Babine River | S | -- | 0.10 | **0.72** | 0.18 | -- | -- | 100 | Narver 1969 |
| Cheakamus River | O | -- | -- | **0.52** | 0.40 | 0.08 | -- | 64 | Withler 1966 |
| Capilano River | O | -- | -- | **0.67** | 0.33 | -- | -- | 70 | Withler 1966 |
| Capilano River | S | -- | 0.01 | **0.56** | 0.42 | 0.01 | -- | 86 | Withler 1966 |
| Seymour River | O | -- | 0.07 | **0.57** | 0.34 | 0.02 | -- | 58 | Withler 1966 |
| Seymour River | S | -- | -- | **0.64** | 0.36 | -- | -- | 25 | Withler 1966 |
| **British Columbia (Fraser River Basin)** | | | | | | | | | |
| Coquitlam River | O | -- | 0.01 | **0.73** | 0.23 | 0.03 | -- | 146 | Withler 1966 |
| Alouette River | O | -- | -- | **0.50** | 0.46 | 0.04 | -- | 131 | Withler 1966 |
| Chilliwack River | O | -- | <0.01 | **0.50** | 0.49 | <0.01 | -- | 770 | Maher and Larkin 1955 |
| Chehalis River | O | -- | -- | **0.50** | 0.50 | <0.01 | -- | 111 | Withler 1966 |
| Coquihalla River | O | -- | 0.05 | **0.64** | 0.31 | -- | -- | 39 | Withler 1966 |
| Coquihalla River | S | -- | 0.12 | **0.83** | 0.05 | -- | -- | 150 | Withler 1966 |

Table 5. Ocean age frequency. Continued.

| Population | Run type[a] | Ocean age at first spawning migration | | | | | | Sample | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | size | |
| **British Columbia (Vancouver Island)** | | | | | | | | | |
| Keough River | O? | -- | 0.01 | **0.65** | 0.34 | <0.01 | -- | 1391 | Ward and Slaney 1988 |
| Nanaimo River | ? | 0.01 | **0.68** | 0.31 | -- | -- | -- | 228 | Narver and Withler 1974 |
| Nahmint River | S | -- | 0.05 | **0.91** | 0.03 | -- | -- | 58 | Narver 1974 |
| **Washington** | | | | | | | | | |
| Skagit River | O | -- | -- | **0.57** | 0.42 | 0.01 | -- | n/a[b] | WDFW 1994b |
| Deer Creek | S | -- | **1.00** | -- | -- | -- | -- | n/a | WDF et al. 1993 |
| Snohomish River | O | -- | -- | **0.57** | 0.42 | 0.01 | -- | n/a | WDF et al. 1993 |
| Green River | O | 0.02 | 0.07 | **0.66** | 0.25 | -- | -- | 100 | Pautzke and Meigs 1941 |
| Puyallup River | O | -- | -- | **0.70** | 0.30 | -- | -- | n/a | WDFW 1994b |
| Nisqually River | O | -- | -- | **0.63** | 0.36 | 0.01 | -- | n/a | WDFW 1994b |
| Hoh River | O | -- | 0.02 | **0.81** | 0.17 | -- | -- | n/a | Larson and Ward 1954 |
| Quillayute River | O | -- | -- | **0.53** | 0.45 | 0.02 | -- | n/a | WDFW 1994b |
| Chehalis River | O | -- | 0.07 | **0.72** | 0.20 | 0.01 | -- | n/a | Larson and Ward 1954 |
| **Columbia River Basin** | | | | | | | | | |
| Toutle River | O | -- | 0.08 | **0.81** | 0.11 | -- | -- | 37 | Howell et al. 1985 |
| Cowlitz River | O | -- | -- | **0.64** | 0.34 | 0.02 | -- | 56 | Howell et al. 1985 |
| Kalama River | O | -- | 0.04 | **0.76** | 0.20 | -- | -- | 1363 | Howell et al. 1985 |
| Kalama River | S | -- | 0.20 | **0.74** | 0.06 | -- | -- | 909 | Howell et al. 1985 |
| Willamette River | O | -- | -- | **1.00** | -- | -- | -- | 141 | Howell et al. 1985 |
| Washougal River | S | -- | 0.14 | **0.71** | 0.14 | -- | -- | 7 | Howell et al. 1985 |
| Wind River | S | -- | 0.05 | **0.68** | 0.26 | -- | -- | 19 | Howell et al. 1985 |
| Klickitat River | S | -- | 0.16 | **0.79** | 0.05 | -- | -- | 148 | Howell et al. 1985 |
| Deschutes River | S | -- | **0.53** | 0.47 | -- | -- | -- | 100 | Howell et al. 1985 |
| John Day River | S | -- | **0.51** | 0.44 | 0.04 | -- | -- | 115 | Howell et al. 1985 |
| Yakima River | S | -- | **0.51** | 0.47 | 0.02 | -- | -- | 64 | BPA 1992 |

Table 5. Ocean age frequency. Continued.

| Population | Run type[a] | Ocean age at first spawning migration 0 | 1 | 2 | 3 | 4 | 5 | Sample size | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Wenatchee River | S | -- | **0.76** | 0.18 | 0.06 | -- | -- | 17 | Howell et al. 1985 |
| Entiat River | S | -- | **0.88** | 0.12 | -- | -- | -- | 8 | Howell et al. 1985 |
| above Wells Dam | S | -- | 0.30 | **0.70** | -- | -- | -- | 349 | Mullan et al. 1992 |
| **Snake River Basin** | | | | | | | | | |
| Lower Granite Dam | S | -- | 0.29 | **0.55** | 0.16 | -- | -- | 100 | Hassemer 1992 |
| Clearwater River | S | -- | **0.61** | 0.38 | 0.01 | -- | -- | 510 | Whitt 1954 |
| S.F. Salmon River | S | -- | -- | 0.20 | **0.80** | -- | -- | 65 | BPA 1992 |
| Lemhi River | S | -- | 0.09 | **0.86** | 0.05 | -- | -- | 353 | BPA 1992 |
| **Oregon** | | | | | | | | | |
| Nehalem River | O | -- | 0.07 | **0.84** | 0.08 | -- | -- | 310 | Weber and Knispel 1977 |
| Alsea River | O | -- | 0.05 | **0.66** | 0.26 | 0.03 | -- | 978 | Chapman 1958 |
| Siuslaw River | O | -- | -- | **0.82** | 0.17 | 0.01 | -- | 125 | Lindsay et al. 1991 |
| Rogue River[c] | O | -- | 0.14 | **0.86** | -- | -- | -- | 547 | ODFW 1990 |
| **California** | | | | | | | | | |
| Klamath River | S | -- | **0.78** | 0.22 | <0.01 | -- | -- | 391 | Kesner and Barnhart 1972 |
| Mad River | O | -- | 0.28 | **0.69** | 0.03 | -- | -- | 35 | Forsgren 1979 |
| Jacoby Creek | O | -- | 0.35 | **0.63** | 0.02 | -- | -- | 109 | Harper 1980 |
| Van Duzen River | S | -- | 0.09 | **0.62** | 0.29 | -- | -- | 58 | Puckett 1975 |
| M. F. Eel River | S | -- | **0.56** | 0.42 | 0.02 | -- | -- | 82 | Puckett 1975 |
| Sacramento River | O? | -- | **0.57** | 0.43 | -- | -- | -- | 83 | Hallock 1989 |
| Waddell Creek | O | -- | **0.60** | 0.40 | <0.01 | -- | -- | 3,888 | Shapovalov and Taft 1954 |

[a]O = Ocean maturing; S = Stream maturing.
[b]Sample size not indicated in reference.
[c]Adults with half-pounder life history (*spawning migrants*, ODFW 1990) are included as age-2-ocean; these comprise 26% of the sample size.

Table 6. Most common life history patterns reported for selected steelhead populations; frequency of occurrence in sample is shown in parentheses. Format used is freshwater age/ocean age at first spawning migration. Populations are generally arranged from north to south.

| Population | Run type[a] | Life history (frequency) | | | | Sample size | Reference |
|---|---|---|---|---|---|---|---|
| | | Primary | | Secondary | | | |
| **Alaska** | | | | | | | |
| Karluk River | S | 3/2 | (0.42) | 2/2 | (0.36) | 62 | Sanders 1985 |
| Anchor River | S | 3/2 | (0.61) | 3/1 | (0.23) | 80 | Sanders 1985 |
| Copper River | S | 3/2 | (0.73) | 3/1 | (0.10) | 30 | Sanders 1985 |
| Situk River | S/O | 3/2 | (0.43) | 3/3 | (0.32) | 211 | Sanders 1985 |
| Sitkoh Creek | O | 3/2 | (0.38) | 3/3 | (0.27) | 497 | Sanders 1985 |
| Karta River | O | 3/2 | (0.46) | 3/3 | (0.20) | 542 | Sanders 1985 |
| **British Columbia (mainland)** | | | | | | | |
| Babine River | S | 3/2 | (0.62) | 3/3 | (0.17) | 100 | Narver 1969 |
| Cheakamus River | O | 3/2 | (0.34) | 2/3 | (0.25) | 64 | Withler 1966 |
| Capilano River | O | 3/2 | (0.40) | 2/2 | (0.26) | 70 | Withler 1966 |
| Capilano River | S | 3/2 | (0.49) | 3/3 | (0.31) | 86 | Withler 1966 |
| Seymour River | O | 3/2 | (0.38) | 3/3 | (0.22) | 58 | Withler 1966 |
| Seymour River | S | 3/2 | (0.48) | 2/3 | (0.24) | 25 | Withler 1966 |
| **British Columbia (Fraser River Basin)** | | | | | | | |
| Coquitlam River | O | 3/2 | (0.49) | 2/2 | (0.23) | 146 | Withler 1966 |
| Alouette River | O | 2/2 | (0.32) | 2/3 | (0.32) | 131 | Withler 1966 |
| Chilliwack River | O | 2/2 | (0.31) | 2/3 | (0.31) | 770 | Maher and Larkin 1955 |
| Chehalis River | O | 3/3 | (0.34) | 3/2 | (0.33) | 111 | Withler 1966 |
| Coquihalla River | O | 3/2 | (0.49) | 3/3 | (0.18) | 39 | Withler 1966 |
| Coquihalla River | S | 3/2 | (0.63) | 2/2 | (0.15) | 150 | Withler 1966 |
| **British Columbia (Vancouver Island)** | | | | | | | |
| Keogh River | O? | 3/2 | (0.40) | 3/3 | (0.19) | 1391 | Ward and Slaney 1988 |
| Nanaimo River | ? | 2/1 | (0.41) | 3/1 | (0.26) | 228 | Narver and Withler 1974 |
| Nahmint River | S | 3/2 | (0.71) | 2.2 | (0.19) | 58 | Narver 1974 |

Table 6. Most common life history patterns. Continued.

| Population | Run type[a] | Life history (frequency) Primary | | Secondary | | Sample size | Reference |
|---|---|---|---|---|---|---|---|
| **Washington** | | | | | | | |
| Skagit River | O | 2/2 | (0.48) | 2/3 | (0.33) | n/a[b] | WDFW 1994b |
| Deer Creek | S | 2/1 | (0.95) | 3/1 | (0.05) | n/a | WDFW 1994b |
| Snohomish River | O | 2/2 | (0.47) | 2/3 | (0.36) | n/a | WDFW 1994b |
| Green River | O | 2/2 | (0.52) | 2/3 | (0.17) | 100 | Larson and Ward 1954 |
| Puyallup River | O | 2/2 | (0.61) | 2/3 | (0.28) | n/a | WDFW 1994b |
| Nisqually River | O | 2/2 | (0.51) | 2/3 | (0.28) | n/a | WDFW 1994b |
| Hoh River | O | 2/2 | (0.74) | 2/3 | (0.14) | n/a | WDFW 1994b |
| Quillayute River | O | 2/2 | (0.46) | 2/3 | (0.40) | n/a | WDFW 1994b |
| Chehalis River | O | 2/2 | (0.66) | 2/3 | (0.15) | 100 | Larson and Ward 1954 |
| **Columbia River Basin** | | | | | | | |
| Toutle River | O | 2/2 | (0.73) | 2/3 | (0.11) | 37 | Howell et al. 1985 |
| Cowlitz River | O | 2/2 | (0.55) | 2/3 | (0.34) | 56 | Howell et al. 1985 |
| Kalama River | O | 2/2 | (0.65) | 2/3 | (0.18) | 1363 | Howell et al. 1985 |
| Kalama River | S | 2/2 | (0.67) | 2/1 | (0.17) | 909 | Howell et al. 1985 |
| Willamette River | O | 2/2 | (0.92) | 3/2 | (0.08) | 141 | Howell et al. 1985 |
| Washougal River | S | 2/2 | (0.71) | 2/1 & 2/3 | (0.14) | 7 | Howell et al. 1985 |
| Wind River | S | 2/2 | (0.58) | 2/3 | (0.26) | 19 | Howell et al. 1985 |
| Klickitat River | S | 2/2 | (0.75) | 2/1 | (0.14) | 148 | Howell et al. 1985 |
| Deschutes River | S | 2/1 | (0.35) | 1/2 | (0.22) | 100 | Howell et al. 1985 |
| Yakima River | S | 2/1 | (0.47) | 2/1 | (0.42) | 64 | BPA 1992 |
| Wenatchee River | S | 2/1 | (0.65) | 3/1 & 3/2 | (0.12) | 17 | Howell et al. 1985 |
| Entiat River | S | 2/1 | (0.88) | 2/2 | (0.12) | 8 | Howell et al. 1985 |
| above Wells Dam | S | 2/2 | (0.41) | 3/2 | (0.24) | 349 | Mullan et al. 1992 |

Table 6. Most common life history patterns. Continued.

| Population | Run type[a] | Life history (frequency) | | | | Sample size | Reference |
|---|---|---|---|---|---|---|---|
| | | Primary | | Secondary | | | |
| **Snake River Basin** | | | | | | | |
| Clearwater River | S | 2/1 | (0.34) | 2/2 | (0.25) | 510 | Whitt 1954 |
| S.F. Salmon River | S | 3/3 | (0.49) | 2/3 | (0.31) | 65 | BPA 1992 |
| Lemhi River | S | 2/2 | (0.86) | 2/1 | (0.09) | 353 | BPA 1992 |
| **Oregon** | | | | | | | |
| Nehalem River | O | 2/2 | (0.73) | 2/3 | (0.08) | 310 | Weber and Knispel 1977 |
| Alsea River | O | 2/2 | (0.52) | 2/3 | (0.22) | 978 | Chapman 1958 |
| Siuslaw River | O | 2/2 | (0.67) | 2/3 | (0.16) | 125 | Lindsay et al. 1991 |
| Rogue River[c] | O | 2/2 | (0.60) | 3/2 | (0.17) | 547 | ODFW 1990 |
| **California** | | | | | | | |
| Klamath River | S | 2/1 | (0.52) | 1/1 | (0.19) | 391 | Kesner and Barnhart 1972 |
| Mad River | O | 2/2 | (0.69) | 2/1 | (0.26) | 35 | Forsgren 1979 |
| Jacoby Creek | O | 2/2 | (0.50) | 2/1 | (0.26) | 109 | Harper 1980 |
| Van Duzen River | S | 1/2 | (0.62) | 1/3 | (0.29) | 58 | Puckett 1975 |
| M.F. Eel River | S | 2/1 | (0.45) | 2/2 | (0.33) | 82 | Puckett 1975 |
| Sacramento River | O? | 2/1 | (0.36) | 2/2 | (0.31) | 83 | Hallock 1989 |
| Waddell Creek | O | 2/1 | (0.39) | 2/2 | (0.30) | 3,888 | Shapovalov and Taft 1954 |

[a]O = Ocean maturing; S = Stream maturing.
[b]Sample size not indicated in reference.
[c]Adults with half-pounder life history (*spawning migrants*, ODFW 1990) are included as age-2-ocean; these comprise 26% of the sample size, but had no effect on the ranking of most common life history patterns.

Table 7. Repeat spawning frequency for selected steelhead populations. Data were collected from scale samples. Numbers indicate the proportion of steelhead collected in each study during a given spawning migration; for example,89% of the steelhead collected by Chapman (1958) in the Alsea River were on their first spawning migration. Populations are generally arranged from north to south.

| | | Spawning migration | | | | | Sample | |
|---|---|---|---|---|---|---|---|---|
| Population | Run type[a] | 1 | 2 | 3 | 4 | 5 | size | Reference |
| **British Columbia (mainland)** | | | | | | | | |
| Babine River | S | **0.97** | 0.03 | -- | -- | -- | 121 | Narver 1969 |
| Cheakamus River | O | **0.69** | 0.26 | 0.05 | -- | -- | 64 | Withler 1966 |
| Capilano River | S | **0.94** | 0.06 | -- | -- | -- | 99 | Withler 1966 |
| Seymour River | O | **0.95** | 0.05 | -- | -- | -- | 41 | Withler 1966 |
| Seymour River | S | **0.96** | 0.04 | -- | -- | -- | 45 | Withler 1966 |
| **British Columbia (Fraser River Basin)** | | | | | | | | |
| Coquitlam River | O | **0.95** | 0.03 | 0.02 | -- | -- | 148 | Withler 1966 |
| Coquihalla River | O | **0.94** | 0.03 | 0.03 | -- | -- | 31 | Withler 1966 |
| Coquihalla River | S | **0.94** | 0.06 | <0.01 | -- | -- | 158 | Withler 1966 |
| **Washington** | | | | | | | | |
| Skagit River | O | **0.92** | 0.07 | 0.01 | -- | -- | n/a[b] | WDFW 1994b |
| Snohomish River | O | **0.92** | 0.06 | 0.01 | -- | -- | n/a | WDFW 1994b |
| Green River | O | **0.93** | 0.07 | <0.01 | -- | -- | n/a | WDFW 1994b |
| Puyallup River | O | **0.89** | 0.10 | <0.01 | -- | -- | n/a | WDFW 1994b |
| Nisqually River | O | **0.93** | 0.06 | 0.01 | -- | -- | n/a | WDFW 1994b |
| Quillayute River | O | **0.91** | 0.07 | 0.01 | -- | -- | n/a | WDFW 1994b |
| **Columbia River Basin** | | | | | | | | |
| Cowlitz River | O | **0.96** | 0.04 | -- | -- | -- | 56 | Howell et al. 1985 |
| Toutle River | O | **0.89** | 0.05 | 0.05 | -- | -- | 37 | Howell et al. 1985 |
| Kalama River | O | **0.93** | 0.06 | <0.01 | <0.01 | -- | 1,363 | Howell et al. 1985 |
| Kalama River | S | **0.94** | 0.06 | <0.01 | -- | -- | 909 | Howell et al. 1985 |
| Klickitat River | S | **0.97** | 0.02 | 0.01 | -- | -- | 148 | Howell et al. 1985 |

Table 7. Repeat spawning frequency. Continued.

| Population | Run type[a] | Spawning migration 1 | 2 | 3 | 4 | 5 | Sample size | Reference |
|---|---|---|---|---|---|---|---|---|
| **Oregon** | | | | | | | | |
| Alsea River | O | **0.89** | 0.09 | 0.02 | -- | -- | 1,223 | Chapman 1958 |
| Siuslaw River | O | **0.86** | 0.11 | 0.02 | -- | 0.01 | 125 | Lindsay et al. 1991 |
| Rogue River | S | **0.79** | 0.17 | 0.04 | -- | -- | 4,058 | ODFW 1994d |
| **California** | | | | | | | | |
| Mad River | O | **0.77** | 0.17 | 0.06 | -- | -- | 35 | Forsgren 1979 |
| Jacoby Creek | O | **0.83** | 0.17 | -- | -- | -- | 109 | Harper 1980 |
| Sacramento River | O | **0.83** | 0.14 | 0.02 | 0.01 | -- | n/a | Hallock 1989 |
| Waddell Creek | O | **0.83** | 0.15 | 0.02 | <0.01 | -- | 3,888 | Shapovalov and Taft 1954 |

[a]O = Ocean-maturing; S = Stream-maturing.
[b]Sample size not indicated in reference.

rare. In Oregon and California, the frequency of two spawning migrations is higher, but more than two spawning migrations is still unusual. The largest number of spawning migrations for which we found data was five, from the Siuslaw River, Oregon (Bali 1959). Iteroparous steelhead are predominately female.

### Resident Fish

Although we have defined steelhead as anadromous *O. mykiss*, there are areas where the separation between rainbow or redband trout and steelhead is obscured. In areas where anthropogenic barriers have isolated populations of *O. mykiss*, these landlocked populations could conceivably residualize[5] and, therefore, continue to exist in the nonanadromous form. Similarly, the mouths of some rivers in Oregon and California close seasonally, forming lagoons (during droughts, these rivers may remain closed for extended periods of time—even years). Again, landlocked *O. mykiss* in these systems could residualize. In some inland populations, growth rate can cause *O. mykiss* to residualize (Mullan et al. 1992); this apparently involves both fish that grow too quickly and those that grow too slowly.

## Steelhead Genetics

### Previous Studies of Population Genetic Structure

**Protein electrophoresis**—Allendorf (1975) first distinguished two major groups of *O. mykiss* in Washington, Oregon, and Idaho, separated geographically by the Cascade Crest; he termed these groups inland and coastal. These two groups have large and consistent differences in allele frequency that apply to both anadromous and resident forms. Subsequent studies have supported this finding (Utter and Allendorf 1977, Okazaki 1984, Schreck et al. 1986, Reisenbichler et al. 1992), and similar differences have been identified between *O. mykiss* from the interior and coastal regions of British Columbia (Huzyk and Tsuyuki 1974, Parkinson 1984).

Several genetic studies since the mid-1970s have used protein electrophoresis to examine population structure in coastal or inland *O. mykiss*. Allozyme studies of coastal Oregon steelhead have been reported by Hatch (1990) and Reisenbichler et al. (1992). Hatch (1990) surveyed 13 protein-coding loci in steelhead from 12 hatcheries and 26 coastal rivers or tributaries in Oregon. He found evidence for a north-south cline in allele frequencies in 5 of the 13 enzyme systems analyzed, but only in river basins larger than 350 km$^2$. Hatch also reported that "the area south of the Coos River was marked by sharp transition in four enzymes..." (p. 17) and that "the pattern of several alleles ending their detectable Oregon

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[5] Residual *O. mykiss* are those that have an anadromous lineage but are themelves nonanadromous; the term was first proposed by Ricker (1938) in describing life-history variations in *O. nerka*. The change in life history may be the result of a physical or physiological barrier to migration (e.g., a dam, or slow growth that precludes smoltification).

presence just north of Cape Blanco suggests that there is a less than average amount of straying between the populations north and south of this feature" (p. 33).

Reisenbichler et al. (1992) examined 10 polymorphic gene loci in steelhead from 37 natural and hatchery populations in the Pacific Northwest, including 24 from the Oregon coast and two in northern California (Trinity River summer-run and Mad River Hatchery winter-run). They did not discuss clines in allele frequencies; instead, they found evidence for genetic differentiation between some clusters of populations. For example, steelhead north of the Umpqua River formed a separate cluster from steelhead in southern Oregon. The Trinity River sample was genetically similar to most of the Rogue River samples, but steelhead from the Mad River Hatchery were genetically distinct from other hatchery and natural populations in California and Oregon.

As part of previous ESA status reviews, NMFS biologists analyzed genetic variability at 39 polymorphic gene loci in 20 samples of coastal steelhead from the Nehalem River in northern Oregon to the Eel River in northern California (Busby et al. 1993, 1994). These studies found evidence for three genetic groups of populations in the area sampled: Oregon coast north of Cape Blanco (3 samples), Cape Blanco to the Klamath River Basin, inclusive (13 samples), and south of the Klamath River Basin (4 samples). Little geographic pattern was evident for samples from the area between Cape Blanco and the Klamath River. Redwood Creek, the first major stream south of the Klamath River, appears to be in a transitional zone; the sample from this stream is similar to the southern group but also has some genetic affinity with samples from the Klamath River and areas to the north. The sharp transition in allele frequencies for steelhead populations in this area is apparent in Figure 4 of Busby et al. (1994).

Berg and Gall (1988) examined genetic variability at 24 polymorphic loci in 31 California populations "known to have been inhabited by anadromous rainbow trout prior to the major water projects of the twentieth century" (p. 123). Twenty-three of their samples were from the upper Sacramento River Basin, three were from the upper Klamath River Basin, and the remaining five were from coastal streams from Eel River to San Diego County. Sample sizes averaged about 30 fish per population and ranged from a high of 57 to a low of 7. Berg and Gall (1988) found relatively high levels of genetic variability but no clear geographic patterns in the genetic relationships among populations.

Reisenbichler and Phelps (1989) found variation at 19 gene loci in steelhead from 9 drainages in northwestern Washington (primarily the Olympic Peninsula). However, they found genetic differences between drainages to be much smaller than had been reported by Parkinson (1984) for steelhead populations from adjacent drainages in British Columbia. Reisenbichler and Phelps (1989) and Reisenbichler et al. (1992) suggested that since both Washington and Oregon had far more extensive hatchery steelhead programs in the 1970s and early 1980s than did British Columbia, the relative homogeneity among populations in these states may be due to introgression of hatchery fish into naturally spawning populations. Furthermore, during that period, hatcheries in both Oregon and Washington predominately used steelhead that had originated from one or two within-state sources (the Alsea River stock in Oregon and the Chambers Creek and Skamania stocks in Washington). However, Hatch (1990) pointed out that the geographic area covered by the Reisenbichler and Phelps (1989) study (natural populations collected primarily from a 70 km stretch of coastline) might be too small to allow a direct comparison with the British Columbia study.

As part of a comprehensive effort to inventory wild stocks of anadromous salmonids, the Washington Department of Fish and Wildlife (WDFW) recently published a report of the first year of genetic analyses for steelhead populations. Phelps et al. (1994) reported new data for 56 variable gene loci for 12 natural and 8 hatchery populations, primarily in Puget Sound and the lower Columbia River. Furthermore, WDFW data for additional samples allowed the investigators to conduct analyses on 30 different populations. With few exceptions, usually involving hatchery stocks, Phelps et al. found statistically significant differences between all pairs of populations. This contrasts with results of Reisenbichler and Phelps (1989), who generally failed to find significant differences between populations on the Washington coast.

Phelps et al. (1994) used several different methods to examine population structure. One consistent result was a high degree of genetic similarity among samples from winter-run steelhead hatcheries, including those from Puget Sound (Skykomish River, Chambers Creek, Tokul Creek), Olympic Peninsula (Bogachiel River), and the Columbia River (Skamania, Beaver Creek). Relationships among the remaining Puget Sound samples were less clear. For example, the summer-run sample from Deer Creek showed affinities to winter-run fish from the North Fork Stillaguamish River (to which Deer Creek is a tributary), to summer-run fish from the Skykomish River Hatchery, or to no populations in particular, depending on the analysis.

Phelps et al. (1994) also considered data for 14 samples of steelhead from the Columbia River in their study. Summer-run samples from the Wind and Washougal Rivers in the lower Columbia River were outliers in the analyses. The Wind River sample contained an allele at a frequency of 15% that was not found in steelhead in any other sample analyzed by Phelps et al. (1994), and this presumably is responsible for the distinctiveness of the Wind River sample. As expected, Phelps et al. (1994) found that inland steelhead were genetically distinct from the samples of coastal steelhead examined. The inland group was represented primarily by six samples from the Klickitat River, with additional samples from Big White Salmon River, Satus Creek in the Yakima River Basin, and Wells Hatchery in the middle Columbia River. The relationships among these samples are difficult to determine from the results presented by Phelps et al. because the patterns of genetic affinity differed among the various analyses they used.

Phelps et al. (1994) examined their genetic data for evidence of the effects of hatchery fish on natural populations. The presence, in most cases, of statistically significant differences between the hatchery and natural samples of steelhead suggests that at least some native population structure remains. In addition, Phelps et al. found eight loci that had alleles at relatively uniform frequencies among the winter-run hatchery steelhead populations that could be used as indicators of the degree of introgression into natural populations. Based on this analysis, they concluded that the Cedar River, Deer Creek, North Fork Skykomish, North Fork Stillaguamish River, Wind River, Washougal River, and Big White Salmon River populations had limited amounts of hatchery introgression and that the Green River, Skykomish River main stem, Tolt River, Raging River, and Pilchuck River had moderate to large amounts of hatchery introgression. Because the "marker" alleles only occurred at frequencies of a few percent even in the hatchery steelhead stocks, these conclusions should be regarded as tentative.

Phelps et al. (1994) also found large genetic distances (about three times as large as the distance between inland and coastal steelhead) between four widely used rainbow trout hatchery stocks from Washington and all steelhead populations examined. They concluded that there has been little, if any, permanent genetic effect on the sampled steelhead populations from the widespread stocking of rainbow trout over the past century. Campton and Johnston (1985) found a different result for some *O. mykiss* populations in the Yakima River Basin, where they found evidence for introgression of non-native rainbow trout into wild populations. However, the affected populations were believed to be nonanadromous, and Campton and Johnston (1985) found no evidence for introgression of hatchery rainbow trout (or steelhead from Skamania Hatchery) into natural steelhead populations in the Yakima River.

Leider et al. (1995) reported preliminary results for an additional 55 samples of steelhead and wild resident rainbow trout from Washington. These samples considerably extended the geographic coverage in the WDFW data set for the Olympic Peninsula and southwest Washington coast. The most important result of the new samples is that they revealed considerably more geographic coherence to the population genetic structure of coastal steelhead in Washington than had been evident in previous studies. In the analyses of Leider et al. (1995), the patterns of genetic affinity among populations differed somewhat depending on the distance metric used, and some samples were outliers with no clear affinity to any group. In general, however, samples from the following geographic areas tended to be more similar to one another than they were to samples from other areas: north Puget Sound (including the Stillaguamish River and drainages to the north), south Puget Sound, Olympic Peninsula, southwest Washington, and lower Columbia River (Kalama, Wind, and Washougal Rivers). Notable genetic outliers included the Nooksack River and the Tahuya River. The genetic relationships among these geographic areas do not appear to be well resolved because the pattern of affinities differed substantially among analyses.

Inland *O. mykiss* were represented by 48 samples in the Leider et al. (1995) study. Analyses based on Nei's (1978) and Cavalli-Sforza and Edward's (1967) distances both found consistent differences between samples from the Yakima and Klickitat River Basins, and both analyses also showed that samples from Wells Hatchery were outliers within the inland group. No samples from natural populations in the upper Columbia River were included in the Leider et al. (1995) study. Leider et al. acknowledged some uncertainty in identifying the boundary between inland and coastal forms, but on the basis of genetic data tentatively placed it between the Wind and Big White Salmon Rivers.

Several other genetic studies have included steelhead from the Columbia River Basin. Reisenbichler et al. (1992) focussed on steelhead from coastal streams but also included 10 samples from the Columbia River Basin. Within their study, they found the greatest degree of genetic differentiation between the inland and coastal forms. Within the inland group, four samples from the Snake River and three from the Deschutes River formed separate genetic clusters. The three samples Reisenbichler et al. (1992) examined from the upper Willamette River formed the most distinctive subgroup within the coastal group.

The study of Schreck et al. (1986), which examined life history and morphological features as well as biochemical genetics, included the greatest number and geographic range of steelhead samples from the Columbia River of any study to date. Again, they found the largest differences between steelhead from east and west of the Cascades. Coastal forms from west of the Cascades could be further partitioned into a subgroup from the upper Willamette River, a subgroup from the lower Columbia River, and a subgroup containing samples from both the lower Columbia and Willamette Rivers. East of the Cascades, Schreck et al. also found evidence for differentiation among populations but only a weak geographic pattern to the observed structure.

Hershberger and Dole (1987) examined samples from nine populations of inland steelhead from tributaries of the Columbia River between Rock Island and Chief Joseph Dams. They found 20 polymorphic gene loci but relatively little genetic differentiation among populations from the Wenatchee, Methow, Entiat, and Okanogan Rivers. In contrast, they found relatively large allele frequency differences between these samples and a sample of coastal steelhead from the Skamania River.

Currens and Schreck (1993) examined genetic and meristic variation in adult steelhead used for broodstock in the Umatilla River and in samples from 13 populations of *O. mykiss* in the Umatilla River Basin. They found significant allele frequency differences among populations but no strong geographic patterns. Results suggested that steelhead from one population (McKay Creek) were the offspring of native and introduced rainbow trout. Currens and Schreck (1993) did not compare genetic data for the Umatilla River samples to data for other populations in the Columbia River Basin, but they did cite unpublished meristic data that distinguished Snake River steelhead from those in the middle and upper Columbia River.

Milner and Teel (1985) examined steelhead from 13 localities in the Snake River and found three major genetic clusters: one including four Salmon River samples, another including three samples from the Lochsa and Selway Rivers in the Clearwater River Basin, and a third including Dworshak National Fish Hatchery (NFH), several samples from the lower Clearwater River, and one sample each from the Grande Ronde and Imnaha River Basins.

Waples et al. (1993) summarized genetic data based on 50 polymorphic gene loci for 2 years of samples of steelhead from the Snake River. Results included the following: 1) The two samples from Dworshak NFH were the most distinctive genetically and have substantial allele frequency differences compared to all other natural and hatchery samples. 2) Natural samples from the Clearwater River differed somewhat from those from other drainages, and there was weaker evidence for differentiation between steelhead from the Grande Ronde, Imnaha, and Tucannon Rivers (Salmon River populations were not included in the experimental design). 3) In general, differences between temporal samples from the same stream were smaller than differences between geographic populations.

The steelhead population in Dworshak NFH is derived from native fish from the North Fork Clearwater River that were brought into the hatchery in 1969 when Dworshak Dam blocked access to their native habitat. To evaluate whether the distinctive genetic characteristics of Dworshak NFH steelhead might be the result of genetic changes in the hatchery (for example, spawn timing has been shifted in the hatchery, and there may have been selection for large fish, at least in the early years of the program), we examined genetic profiles for a limited number of gene loci scored in samples from the hatchery dating back to 1972 (Milner 1977 and Teel[6]). These data show some variation over time but do not show a trend toward greater divergence from natural populations in more recent samples. Broodstock data[7], which show that over 1,000 adults were spawned at the hatchery each year since 1969, also fail to provide evidence for a population bottleneck that might have caused substantial allele frequency changes due to drift. In the future, we hope to compare genetic profiles of Dworshak NFH fish with populations of resident *O. mykiss* in the North Fork Clearwater River, provided that native populations that have been largely unaffected by releases of hatchery rainbow trout into Dworshak Reservoir can be identified.

**DNA**—In recent years, genetic methods that analyze DNA variation directly have seen increasing use in salmonid studies, and we are aware of two studies of mitochondrial DNA (mtDNA) that assess population structure in steelhead. In a study that remains unpublished, Buroker[8] examined restriction-fragment-length polymorphisms in mtDNA from 120 individuals from 23 major river systems from Alaska to California. He found no evidence for strong geographic structuring of populations, as most of the common clonal types were widely dispersed. However, Buroker also found that steelhead from southern Oregon were highly diverse in mtDNA. In the 120 fish analyzed, 18 different mtDNA clonal types were observed. These clones were clustered into four lineages, all of which overlap in southern Oregon. The 12 fish examined from the Rogue River had 6 of the 18 mtDNA clonal types observed in the study.

In another study, Nielsen (1994; see also Nielsen et al. 1994) sequenced part of the D-loop section of mtDNA in 37 samples of steelhead and rainbow trout in California and found that a different mtDNA clonal type was the most common in each of three geographic regions: north coast (Humboldt Bay to Gualala Point), central coast (Russian River to Point Sur), and south coast (San Simeon Point to Santa Monica Bay). These regions were defined through a combination of genetic and ecological (primarily ocean upwelling and plankton

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[6] D. Teel, unpubl. data. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.

[7] R. Roseburg, USFWS, P.O. Box 18, Ahsahka, ID 83520. Pers. commun., November 1994.

[8] N. Buroker, 21617 88th Ave. West, Edmonds, WA 98026. Pers. commun., March 1993.

distribution) information (Nielsen[9]). Nielsen also found significant differences between the regions in allele frequencies at a nuclear DNA microsatellite locus.

Neeley (1995) performed some additional statistical analyses on Nielsen's data and some new mtDNA data collected specifically for the status review (Cramer et al. 1995). Neeley used principal components analysis to summarize variation at all 13 mtDNA alleles reported by Nielsen. The first two principal components together explained 70% of the total variation, and Neeley compared scores for each population on these two principal components to a ranked indicator of their latitude. Simple and multiple regression analyses suggested a partitioning of the populations into three groups based on latitude, with the boundary between the northern and central groups occurring just north of the Russian River, and the boundary for the central and southern groups occurring just south of the San Lorenzo River. Additional variation exists in the mtDNA data that is not explained by the first two principal components or the three-group partition, but no clear geographic patterns to this variation could be detected.

**Chromosomal studies**—Chromosomal karyotypes in steelhead and rainbow trout have also been extensively studied (see review in Thorgaard 1983). In a survey of steelhead from Alaska to central California, Thorgaard (1983) found that although chromosome numbers ranging from 58 to 64 were observed, a 58-chromosome karyotype was the most common in most samples. In contrast to results for studies of morphological and allozyme characters, Thorgaard did not find chromosomal differences between interior and coastal *O. mykiss* populations. All interior/redband trout populations had predominately 58 chromosomes, as did most coastal rainbow trout and steelhead populations.

The exceptions to the 58-chromosome pattern, however, provide insight into population genetic structuring in *O. mykiss*. Two geographic regions were characterized by steelhead with 59 or 60 chromosomes: the Puget Sound/Strait of Georgia region and the Rogue River/northern California region. However, the karyotypes of fish from these two regions were different; northern fish with 59 or 60 chromosomes had a different number of subtelocentric and acrocentric chromosomes than did southern fish (Thorgaard 1977). Farther south, winter steelhead in the Mad and Gualala Rivers from northern California and resident trout from the San Luis Rey River in southern California had 61-64 chromosomes (Thorgaard 1983).

Although Thorgaard's (1983) study showed that an unusual 60-chromosome karyotype exists in the Puget Sound region, sampling in that study was limited to a very few populations. Ostberg and Thorgaard (1994) examined additional populations in the area and found the 60-chromosome karyotype in presumed native steelhead from the Nooksack, Cedar, and Stillaguamish Rivers.

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[9] J. Nielsen, Hopkins Marine Laboratory, Ocean View Boulevard, Pacific Grove, CA 93950. Pers. commun., November-December 1994, and January 1995.

**Comparison of Steelhead and Rainbow Trout**

Allendorf (1975) found that the genetic distinction between coastal and inland *O. mykiss* applies to both life history forms; that is, rainbow trout east of the Cascades are genetically more similar to steelhead from east of the Cascades than they are to rainbow trout west of the Cascades. Many recent studies of *O. mykiss* have focussed on either rainbow trout or steelhead and thus provide no direct information about the relationship between the forms on a finer geographic scale. However, Leider et al. (1995) included several new samples of rainbow trout from the Elwha and Cedar Rivers in their study of steelhead populations in Washington and found that their results "support the hypothesis that the two forms were not reproductively isolated from each other." Leider et al. also concluded that, based on preliminary analysis of data collected previously for the Yakima and Big White Salmon Rivers (Pearsons et al. 1994, Phelps et al. 1990), wild resident rainbow trout in those streams would be indistinguishable from steelhead. In addition, some protein electrophoretic studies that have reported data only for rainbow trout probably also included samples of steelhead (K. Currens[10]). For example, in the John Day River, an Oregon tributary of the Columbia River, genetic differences between *O. mykiss* from the North and South Forks were larger than differences between presumed steelhead and rainbow trout in the South Fork (Currens et al. 1987). In the Deschutes River, another Oregon tributary of the Columbia River, Currens et al. (1990) found much larger genetic differences between *O. mykiss* from above and below a barrier falls, but relatively modest differences between presumed steelhead and rainbow trout from below the falls.

In a study of mtDNA in *O. mykiss*, Wilson et al. (1985) compared 19 steelhead from 4 locations in British Columbia with 19 rainbow trout from British Columbia, Alberta, and California. No genetic differences were detected between steelhead and rainbow trout from one British Columbia location (the lower Fraser River), but steelhead from the other three populations showed a greater genetic affinity to each other than to rainbow trout from any of the populations sampled. However, this result is difficult to interpret because of the small sample sizes and the fact that there were only two localities at which both steelhead and rainbow trout were collected. Furthermore, Buroker (footnote 8) found that the mtDNA marker Wilson et al. (1985) used to distinguish rainbow trout was the most common type found in his study of North American steelhead.

Gall et al. (1990) examined allozyme variation in resident *O. mykiss* from the San Leandro Creek watershed, which drains into the east side of the San Francisco Bay. These fish are believed to be descended from steelhead, which have not had access to this area since the construction of Chabot Reservoir in 1875. Gall et al. (1990) found that samples from two creeks upstream of the reservoir are genetically more similar to coastal *O. mykiss* than they are to inland forms or to hatchery rainbow trout. Nielsen (footnote 9) compared mtDNA haplotypes in southern steelhead with those in several California populations of resident *O. mykiss* and in several stocks of hatchery rainbow trout that have been stocked in coastal

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[10] K. Currens, Oregon Cooperative Fishery Research Unit, Oregon State University, Corvallis, OR 97331. Pers. commun., May 1994.

California streams. She found that some resident populations resemble nearby anadromous populations in their mtDNA profiles, but others show evidence of introgression from hatchery rainbow trout.

**Run Timing**

Differentiation based on timing of upstream migration in steelhead has also been investigated by genetic methods. Allendorf (1975) and Utter and Allendorf (1977) found that summer and winter steelhead of a particular coastal stream tended to resemble one another genetically more than they resembled populations of adjacent drainages with similar run timing. Later allozyme studies have supported these conclusions in a variety of geographical areas (Chilcote et al. 1980, Schreck et al. 1986, Reisenbichler and Phelps 1989), including the Rogue River (Reisenbichler et al. 1992). However, in each of these more recent studies, the summer-run stocks have had some extent of hatchery introgression and therefore may not represent the indigenous population. Furthermore, in at least some cases, interpretation of the results may be complicated by difficulties in determining run timing of the fish sampled.

Thorgaard (1983) analyzed chromosomal variability in winter- and summer-run steelhead from two rivers that had little history of hatchery introductions: the Quinault River in Washington and the Rogue River in Oregon. Chromosome number differed between the two river systems but was similar in summer and winter steelhead within each river system.

**New Studies**

For this status review, two types of new studies were undertaken by NMFS to enhance our understanding of population genetic structure in west coast steelhead. First, new samples from Idaho and California were collected for allozyme analysis. Second, recent data collected by NMFS and WDFW were combined into a single data set to facilitate comparisons among individual studies (Appendix A).

In 1994, the U.S. Fish and Wildlife Service (USFWS) and Idaho Department of Fish and Game (IDFG) collected samples of steelhead from a number of natural populations in the Clearwater and Salmon River Basins in an attempt to determine whether releases of hatchery fish had affected the genetic structure of natural populations. Genetic analysis of these samples performed by NMFS (Waples 1995) indicated that none of the populations in the lower Clearwater River show evidence of substantial genetic introgression by steelhead from Dworshak NFH, in spite of widespread outplanting in the area. The samples from the Salmon River provided little clear insight into population structure. Two factors may have contributed to this latter result: 1) Some of the Salmon River samples were small (about 25 fish), thus limiting power to detect population structure, and 2) the populations sampled were among those believed most likely to have shown the effects of artificial propagation, so they may not be a good indication of native population structure.

In order to obtain a more complete picture of genetic structure of steelhead in California, NMFS worked with the California Department of Fish and Game to identify natural populations of *O. mykiss* that could be sampled without placing local populations at undue risk. Through these efforts, 10 samples (generally of 40-60 juvenile fish per sample) were collected and analyzed by NMFS for allozyme variation. Tissue samples from these collections are also being provided to J. Nielsen for use in her continuing studies of DNA variation in California *O. mykiss*. In addition, we analyzed four samples of steelhead from southern Oregon and northern California that were collected (but not analyzed) in 1992 as part of the status review for Illinois River winter steelhead. Important results from these new allozyme analyses can be summarized as follows.

1) The California samples show levels of population differentiation that are unprecedented for the species. At one locus (*FBALD-3**; Fig. 2), a sample from the Klamath River was fixed for one allele and a sample from Gaviota Creek (near Santa Barbara) was fixed for another allele. A fixed allelic difference between populations is a rare occurrence for any Pacific salmon species, being generally encountered, if at all, only between populations at extreme ends of a geographic range. Previously, Busby et al. (1994) found a sharp transition in allelic frequencies at *FBALD-3** in populations south of the Klamath River drainage, but their study did not include samples from south of the Eel River.

2) More detail about population structure of California steelhead can be obtained by examining Figures 3 and 4, which are different ways of summarizing patterns of genetic relationships based on Nei's (1978) unbiased genetic distance values between each pair of populations. Figure 3 is a dendrogram constructed using the unweighted pair-group method analysis (UPGMA) with arithmetic averaging, and Figure 4 is a different representation of the same data using multidimensional scaling (MDS). Multidimensional scaling plots allow one to view in two or three dimensions the pattern of relationships among populations; in contrast, a dendrogram is essentially a one-dimensional representation of the data. In general, two-dimensional MDS plots result in less distortion of the relationships among populations than do dendrograms, and three-dimensional plots have less distortion than two-dimensional plots. However, complex three-dimensional analyses are often difficult to represent in two-dimensional figures, so two-dimensional MDS plots are sometimes preferred for data sets that involve a large number of samples.

The new samples from the Chetco River and the Trinity River Hatchery and Cole Rivers Hatchery (Rogue River) cluster with samples previously analyzed from the Klamath Mountains Province, but the sample from Iron Gate Hatchery (Klamath River) is somewhat of an outlier. A new sample from the Middle Fork of the Eel River showed an affinity to the Mad River/Eel River/Redwood Creek group identified by Busby et al. (1994). The other new California samples were all quite different from any samples of coastal or inland steelhead previously examined. The sample from Coleman NFH and those from Mill and Deer Creeks (the two natural populations in the Sacramento River Basin believed to contain the most likely remnants of native steelhead) form a small, coherent group that is quite distinct from all other California steelhead. The remaining California samples (from Ten Mile River in Mendocino County to Gaviota Creek and Arroyo Hondo in Santa Barbara County) formed a cluster that diverged from the other samples at a genetic distance (Nei's D $\approx$ 0.03) higher than that previously found between coastal and inland races of steelhead (e.g., Busby et al. 1993).

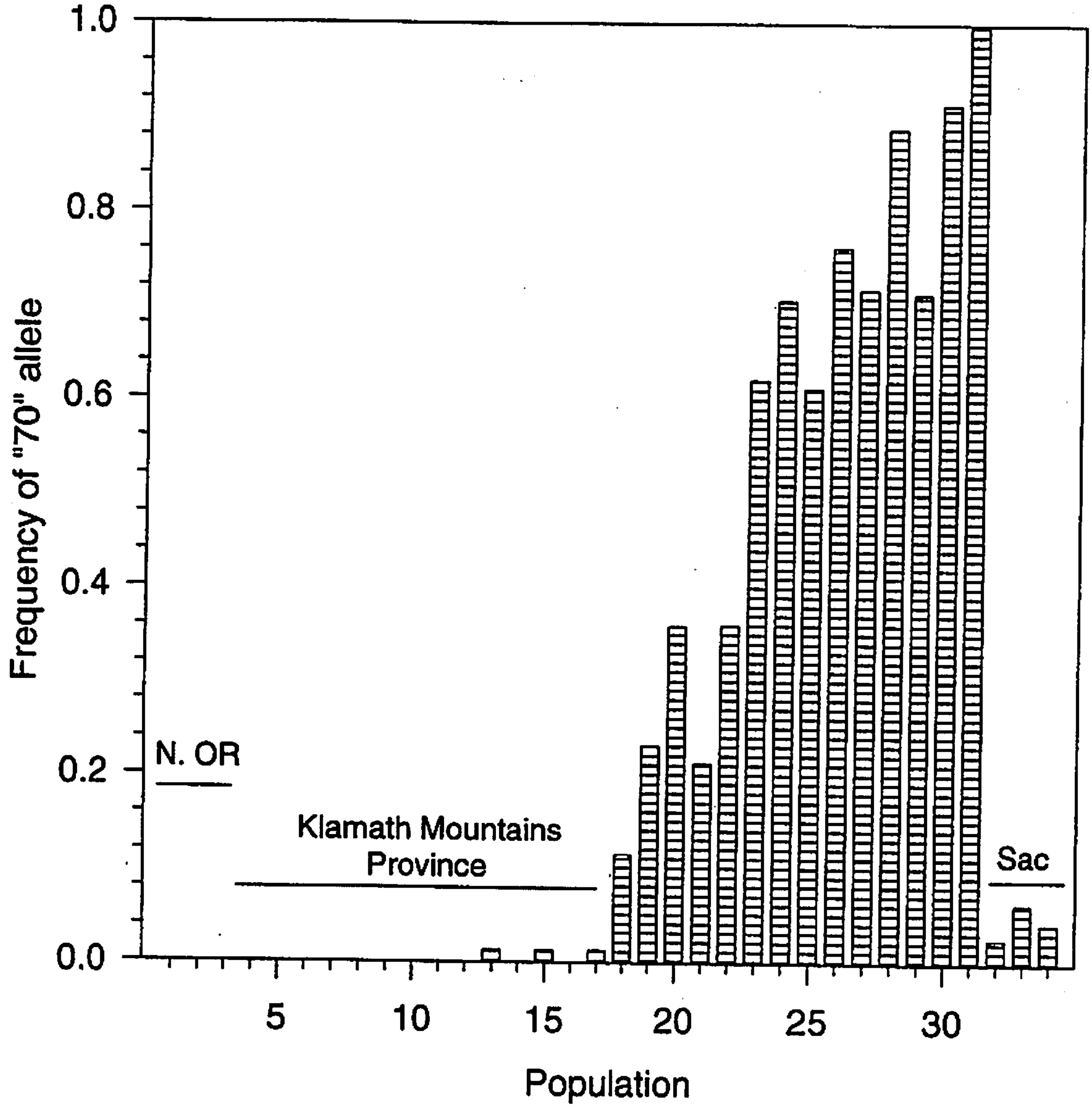


Figure 2. Variation in frequency of the "70" allele at the gene locus *FBALD-3** in 34 samples of steelhead from southern Oregon to southern California analyzed by NMFS. 1 = Nehalem R.; 2 = Yaquina R.; 3 = Bandon Hatchery; 4 = Elk R.; 5 = Lobster Cr.; 6 = upper Butte Cr.; 7 = Cole Rivers Hatchery; 8 = Grayback Cr.; 9 = Secret Cr.; 10 = Lawson Cr.; 11 = Indigo Cr.; 12 = Pistol R.; 13 = Winchuck R.; 14 = Chetco R.; 15 = Smith R.; 16 = Klamath R.; 17 = Trinity R.; 18 = Redwood Cr.; 19 = Mad River Hatchery; 20 = Mad R.; 21 = Eel R.; 22 = Middle Fork Eel R.; 23 = Ten Mile R.; 24 = Lagunitas Cr.; 25 = Alameda Cr.; 26 = Carmel R.; 27 = San Lorenzo R.; 28 = Scott Cr.; 29 = Whale Rock Hatchery; 30= Arroyo Hondo Cr.; 31 = Gaviota Cr.; 32 = Coleman Hatchery; 33 = Deer Cr.; 34 = Mill Cr. Coastal populations 1-31 are numbered from north to south; populations 32-34 are from the Sacramento River Basin (Sac).

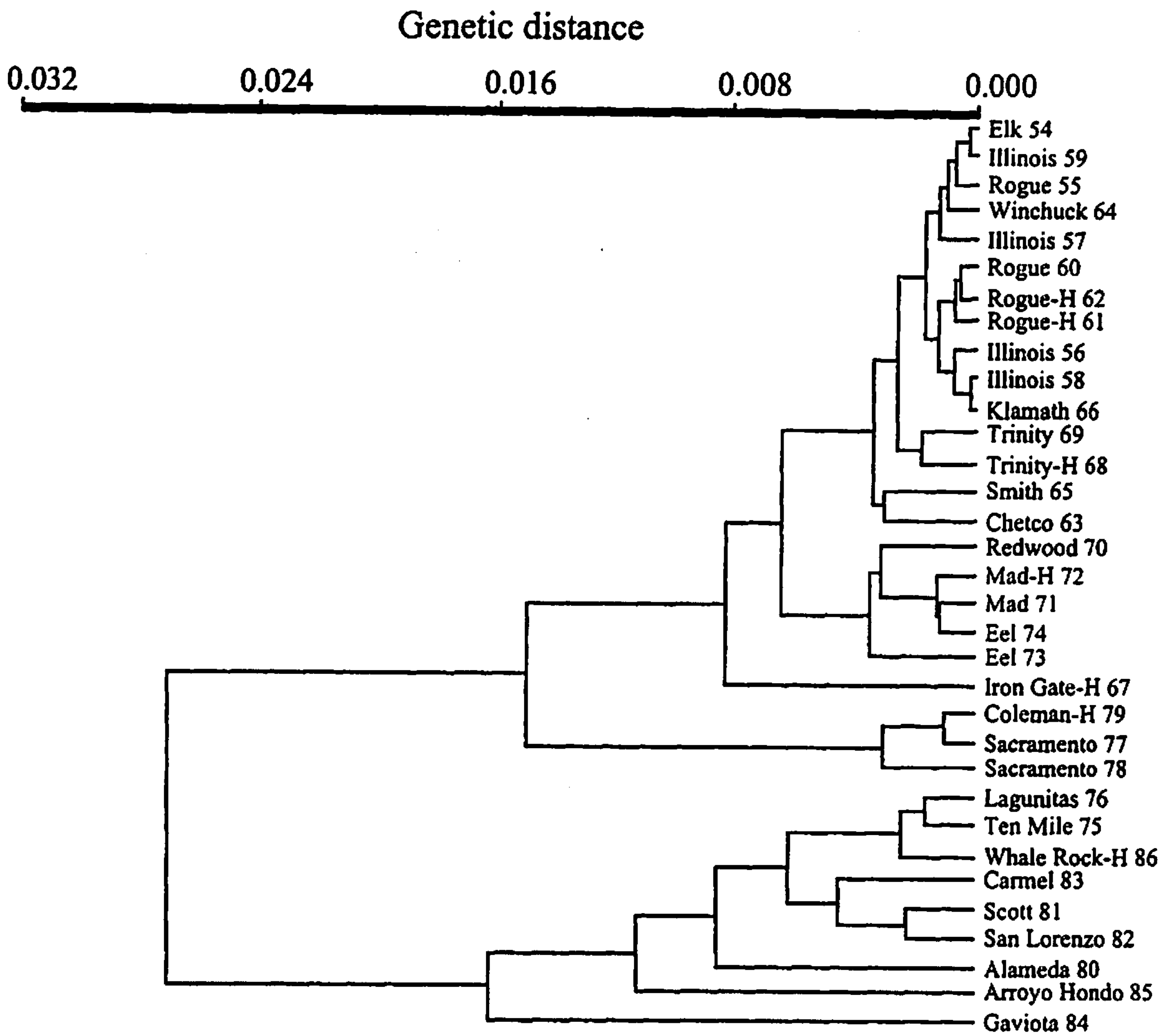


Figure 3. Dendrogram based on unweighted pair-group method analysis (UPGMA) clustering of pairwise genetic distance values (Nei 1978) among 33 hatchery (-H) and natural steelhead populations from southern Oregon to southern California. Analysis was based on data for 51 polymorphic gene loci scored in samples analyzed by NMFS. Sample names and numeric codes correspond to those in Appendix A.

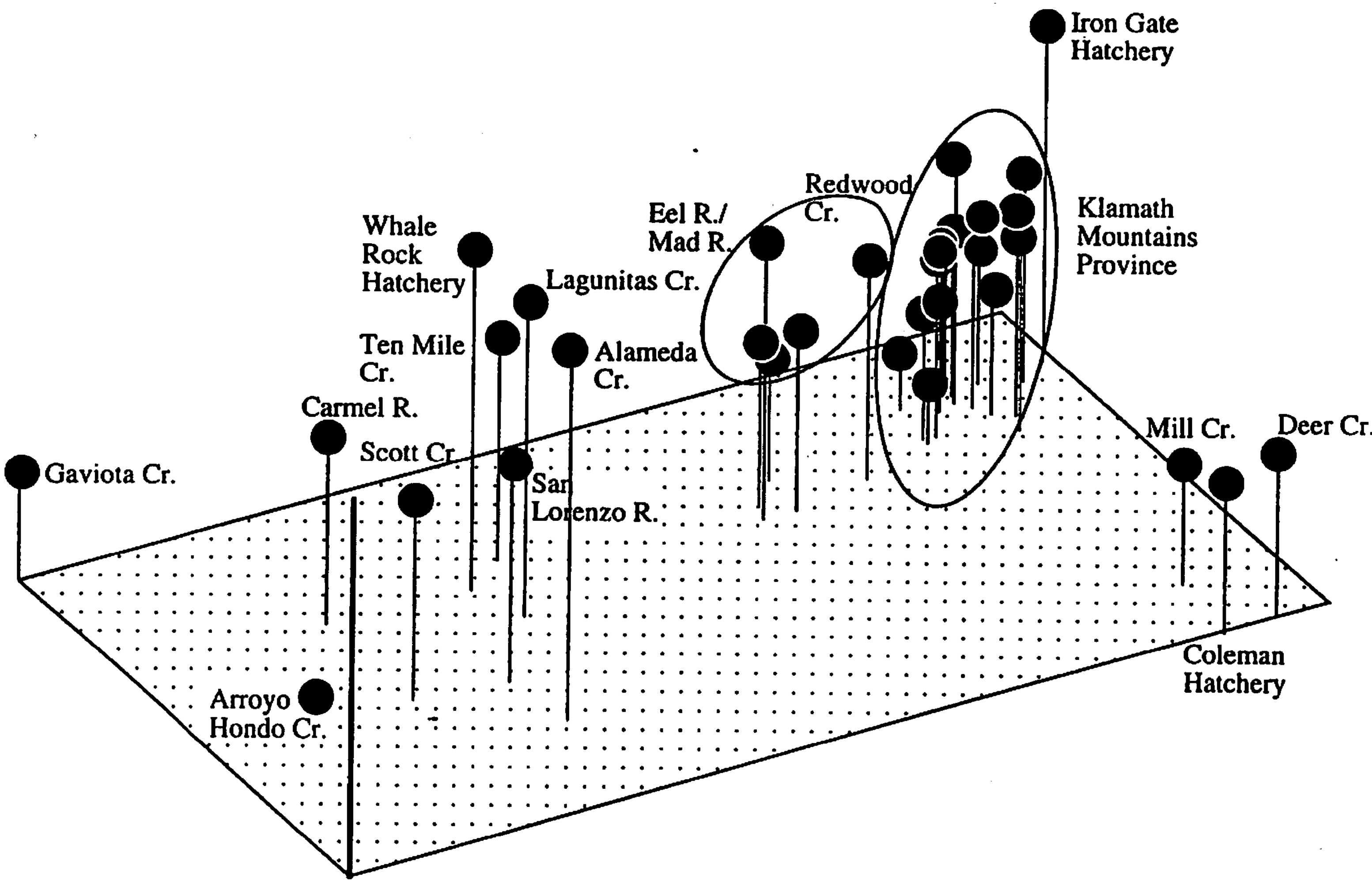


Figure 4. Multidimensional scaling plot (MDS) of genetic distance values used in Figure 3.

In spite of the large interpopulational genetic differences, the pattern of population structure south of the Eel River is not entirely clear from the allozyme data. The MDS plot (Fig. 4) shows the magnitude of the diversity but also illustrates the difficulty in drawing inferences about geographic population structure. For example, the two samples from Santa Barbara County are genetically quite divergent but are not similar to each other. In the allozyme analysis, we found only modest genetic differences between the samples from Ten Mile River and Lagunitas Creek (a tributary of Tomales Bay), both of which are north of San Francisco, but we also found that these samples were more similar to the sample from Whale Rock Hatchery (near San Luis Obispo) than they were to the geographically closer samples from the San Francisco-Monterey area (Scott Creek, Carmel River, and San Lorenzo River).

3) Our allozyme analysis is consistent with Nielsen's (1994) mtDNA study in finding a high degree of interpopulational differentiation within California. The allozyme data also support Nielsen's finding of large genetic differences among samples from southern California. One notable difference in the two analyses is that, whereas Nielsen found substantial differences in the frequencies of some mtDNA alleles between samples from Mendocino and Marin Counties, we did not (as evidenced by the relative similarity between the Ten Mile River and Lagunitas Creek allozyme samples).

4) To examine possible explanations for the distinctive genetic characteristics of the samples from the Sacramento River, we performed another analysis that included data for five rainbow trout samples provided by WDFW, including the four that Phelps et al. (1994) used in their comparisons with Washington state steelhead. This new analysis (Figs. 5 and 6) showed that steelhead from the Sacramento River are genetically more similar to these rainbow trout populations than they are to coastal steelhead populations from California. This could be the result of integration of rainbow trout into the steelhead broodstock at Coleman NFH and subsequent effects of Coleman NFH strays or outplants on natural populations in the Sacramento River; the difficulty of distinguishing between nonanadromous and anadromous *O. mykiss* during broodstock collection in the upper Sacramento River has been described by several authors (e.g., Hallock et al. 1961, Behnke 1992, Cramer et al. 1995). On the other hand, this genetic similarity could simply reflect ancestral relationships, since the origins of most of the present-day rainbow trout stocks can be traced to collections of anadromous and nonanadromous *O. mykiss* from the McCloud River in the Sacramento River Basin made early in the century (Behnke 1992).

To facilitate direct comparisons among recent collections by WDFW (whose samples are all from within Washington state) and NMFS (whose new data are primarily from the Snake River, Oregon, and California), the two agencies collaborated to integrate their genetic data for steelhead into a single data set. Lead scientists for this collaboration were Stevan Phelps from WDFW and Paul Aebersold from NMFS. Extensive inter-laboratory communication that included exchange of recipes and procedures and detailed review of photographic records indicated a high degree of consistency in data for the two agencies.

To reduce the number of samples in the analysis, collections from different years within locations were combined to form single pooled samples for each location. This combined data set includes information for samples from 100 natural populations of

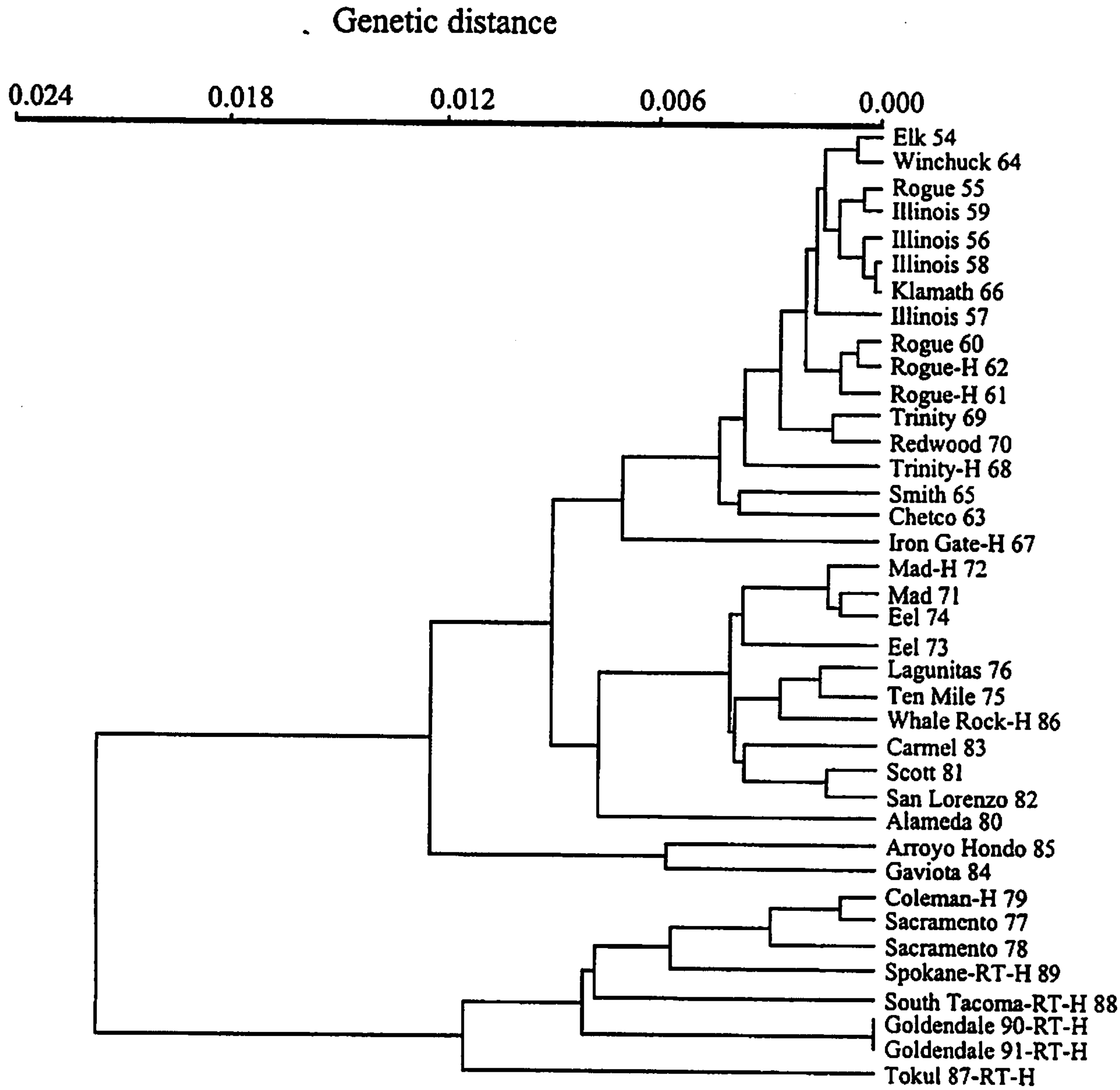


Figure 5. Dendrogram based on unweighted pair-group method analysis (UPGMA) clustering of pairwise genetic distance values (Nei 1978) among 33 hatchery (H) and natural steelhead populations from southern Oregon to southern California and 5 hatchery stocks of rainbow trout (RT) from Washington. Analysis was based on data for 40 polymorphic gene loci scored in samples analyzed by NMFS (steelhead) and WDFW (rainbow trout). Sample names and numeric codes correspond to those in Appendix A.

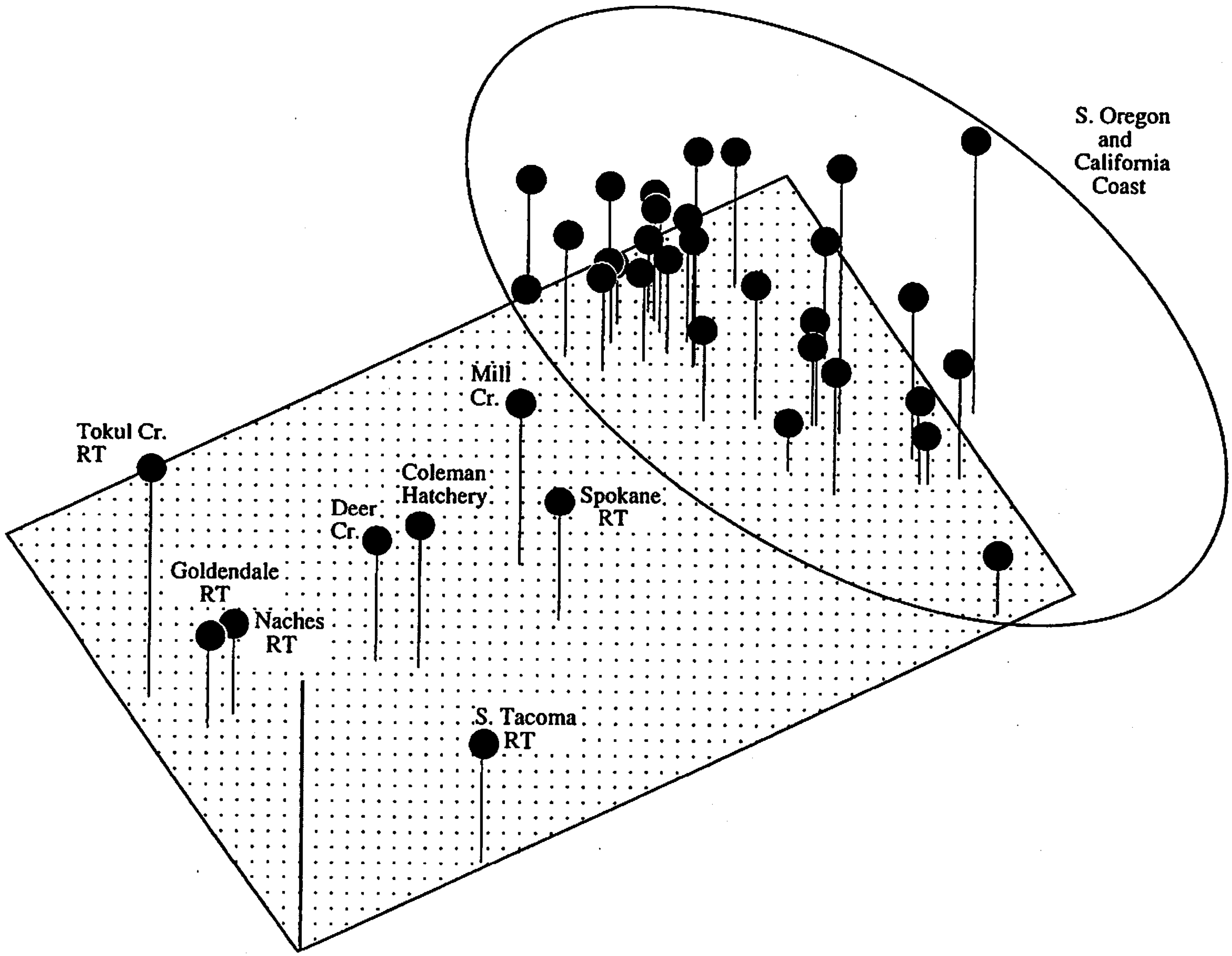


Figure 6. Multidimensional scaling plot of genetic distance values used in Figure 5 (RT = rainbow trout).

steelhead and rainbow trout and 3 steelhead hatcheries. To account for some differences between laboratories in the suite of gene loci examined, the number of polymorphic gene loci used in this combined data set (42) was slightly less than the full complement used by either NMFS or WDFW in their individual analyses. Therefore, those individual studies provide more detailed information about genetic relationships within particular geographic areas. Nevertheless, the combined data set provides the broadest geographic coverage to date for a data set that takes advantage of significant advances in recent years in the number of genetic markers for *O. mykiss*. Results of analyses of this data set are shown in Figures 7 and 8.

These figures show clearly the major difference between coastal and inland forms. The position of one of the Klickitat River samples, #94 (Bowman Creek), which is not clearly aligned with either the inland or coastal groups in Figure 8, may reflect the genetic influence of hatchery coastal rainbow trout overlaid upon a native inland steelhead population (Phelps[11]). Within the inland group, samples from the middle Columbia River form a separate subgroup from those in the Snake River, with one Yakima River Basin sample (Toppenish Creek) being an outlier. No recent genetic data are available for populations in Columbia River tributaries upstream from the Yakima River. Dworshak NFH was included in these figures to provide an indication of the relative distinctiveness of this population.

Within the coastal group, the geographic differences among Washington populations detected by Leider et al. (1995) are modest in comparison to the overall pattern of diversity from Puget Sound to southern California. However, there are a number of coastal steelhead samples from Washington that do not show a strong genetic affinity to any other populations. The most notable outliers in the combined analysis were samples from the Upper Chehalis, Washougal, Nooksack, and Tahuya Rivers. With the benefit of this combined data set, it is apparent that populations south of Cape Blanco are genetically distinct from all northern populations. Previous analyses that considered steelhead from the Klamath Mountains Province (Busby et al. 1993, 1994) did not include samples from Washington, so this was the first time a direct comparison of the two groups has been possible.

The relative magnitude of genetic diversity among steelhead populations from California is readily apparent from these figures. In the dendrogram, California samples from south of the Eel River form a genetically diverse cluster that joins the other west coast steelhead populations external to the inland-coastal break in Washington and Oregon. Although California steelhead, including those in the Sacramento River, are more similar genetically to other coastal steelhead populations than they are to inland steelhead from the Columbia River Basin (see Fig. 8), the genetic diversity within the coastal steelhead lineage is considerable.

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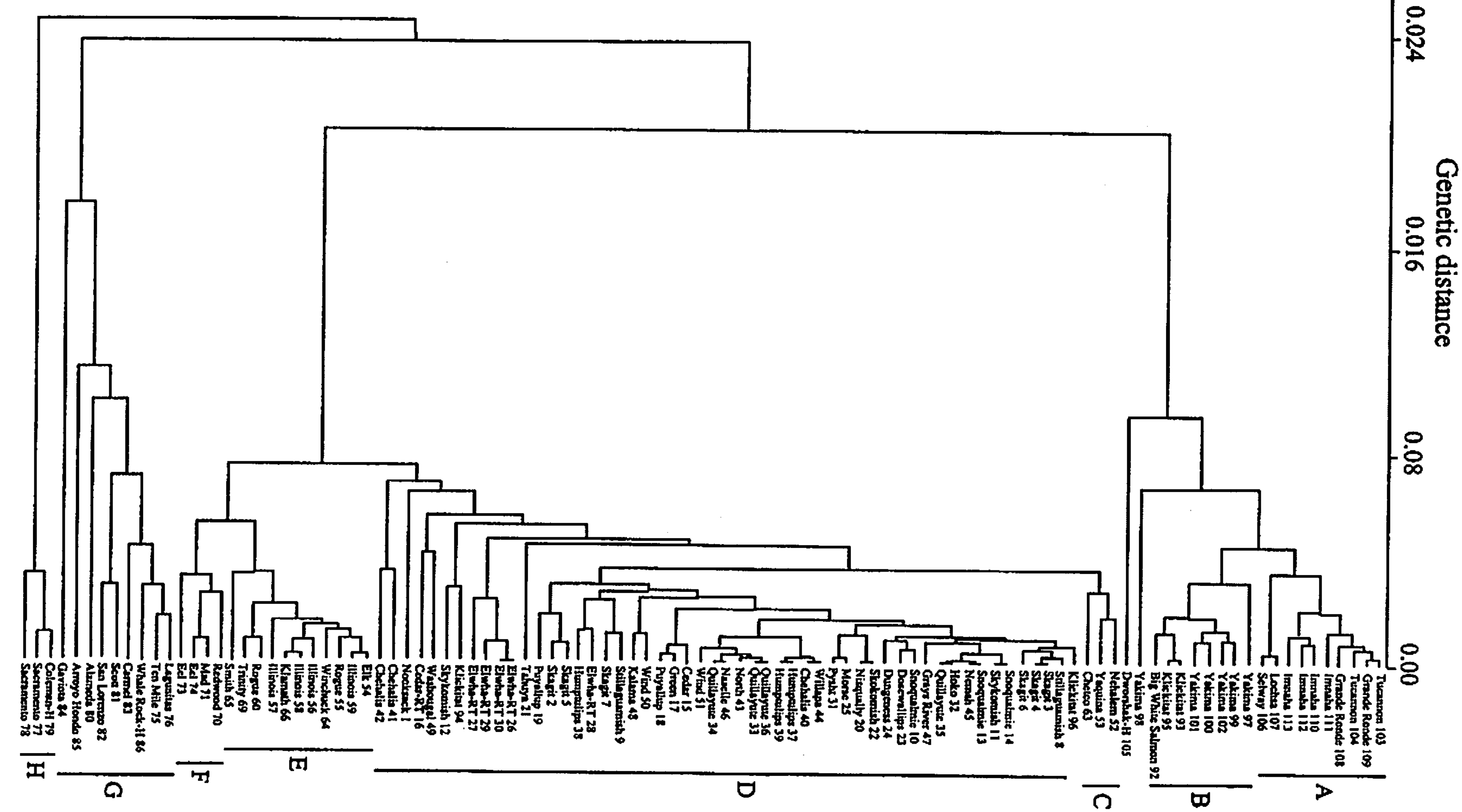
[11] S. Phelps, Washington Department of Fish and Wildlife, Olympia, WA. Pers. commun., November 1994.

Figure 7. Dendrogram based on unweighted pair-group method analysis (UPGMA) clustering of pairwise genetic distance values (Nei 1978) among 103 natural and hatchery (-H) steelhead and rainbow trout (-RT) populations from Puget Sound, Washington to southern California. Analysis was based on data for 42 polymorphic gene loci scored in samples analyzed by NMFS and WDFW. Sample names and numeric codes correspond to those in Appendix A. Geographic clusters (A and B = inland subspecies; C through H = coastal subspecies): A = Snake River; B = middle Columbia River; C = Oregon coast; D = Puget Sound, Washington coast, and lower Columbia River; E = Klamath Mountains Province; F = northern California; G = central and southern California; and H = central valley of California.



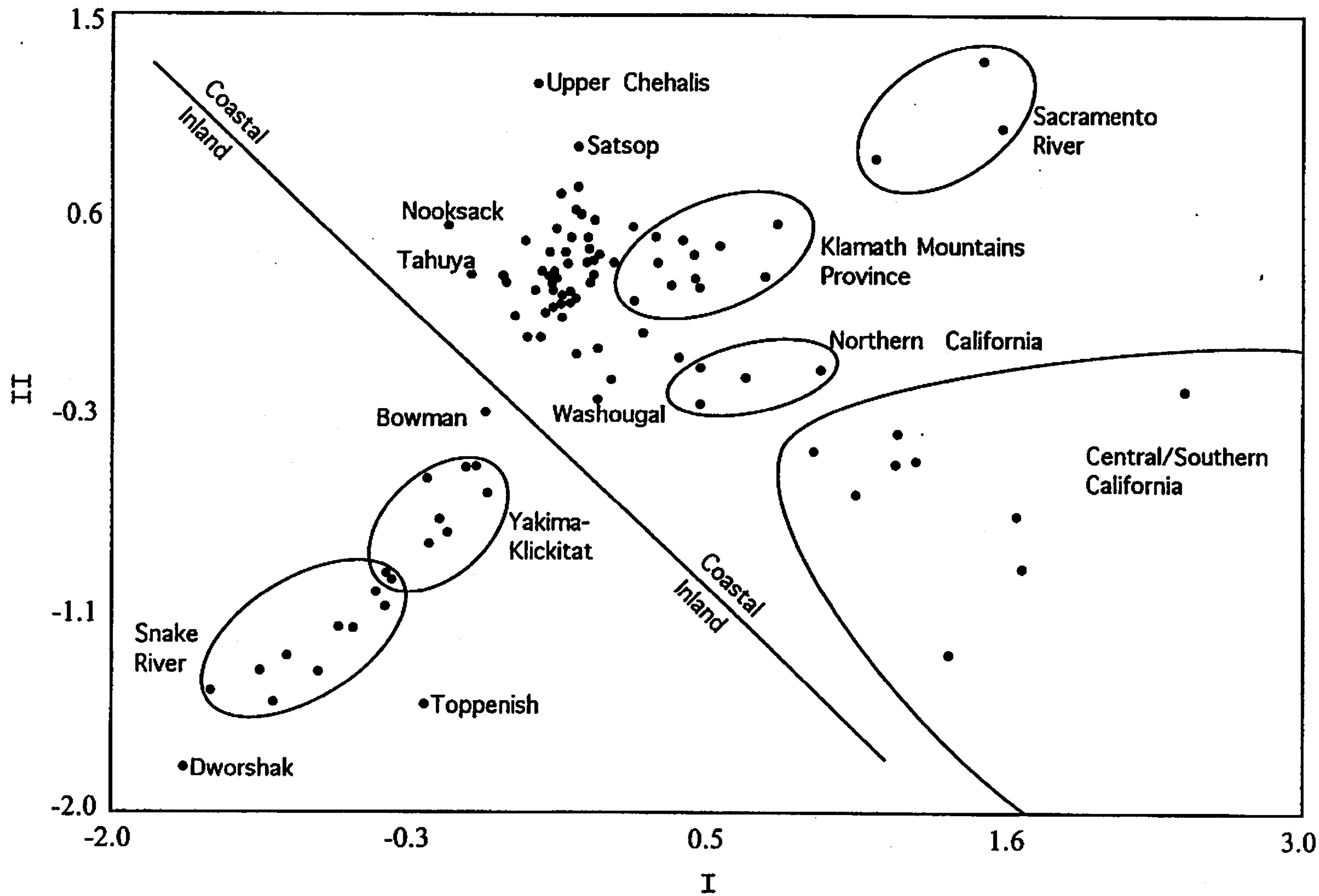



Figure 8. Multidimensional scaling plot of genetic distance values used in Figure 7.

**Synthesis and Discussion**

The old and new genetic data from allozyme, DNA, and chromosomal studies can be synthesized and summarized as follows:

1) All studies that have addressed the question have found large genetic differences between coastal and inland forms (both anadromous and nonanadromous) of *O. mykiss*. In the Columbia River Basin, the boundary between the two forms occurs at approximately the Cascade Crest. However, available data are not sufficient to determine with certainty whether there is a transitional (perhaps intergrade) zone between the forms or whether they remain discrete. If the two forms are discrete even in this area of closest contact, the exact boundaries are unclear.

2) Genetic data do not support the hypothesis that winter- and summer-run steelhead are separate monophyletic units, as appears to be the case with inland and coastal forms. Rather, steelhead with different run timing in the same geographic area may be genetically more similar than either is to fish from another area with a similar run timing. This result, however, does not mean that there cannot be genetic differences between summer and winter steelhead in any given drainage.

3) The inland steelhead lineage is represented only by populations in the Columbia and Fraser River Basins. Within the inland group, consistent differences are found between populations from the Snake and Columbia Rivers, and there is also evidence for a modest level of population differentiation between major drainages within each of these two rivers. Steelhead from Dworshak NFH are genetically the most distinctive population within the inland lineage.

4) Within the geographic area covered by this status review, coastal steelhead occur in a diverse array of populations. A large group showing consistent geographic structure but relatively modest genetic differences between populations includes most samples from Puget Sound, coastal Washington, and the lower Columbia River. The few recent samples from coastal Oregon north of Cape Blanco show some differences from this larger group, and populations from the Klamath Mountains Province are genetically different from those to the north or south. South of the Klamath River, large differences are found between coastal populations, both for allozymes and DNA markers, but the geographic structure to the variation is not fully resolved. Samples from the Sacramento River are quite distinct from all other coastal and inland populations that have been sampled but show some affinity to hatchery rainbow trout.

Any of several factors might explain the much higher diversity among coastal steelhead populations in California than in Washington. First, it is possible that diversity among populations in Washington was greater historically but has been eroded by human influence. There is a long history of widespread releases of a few hatchery stocks in Washington (see Reisenbichler and Phelps 1989). Phelps et al. (1994) found evidence for substantial effects of hatchery stocks on several winter steelhead populations. The occurrence of a number of quite distinct natural populations of coastal steelhead (e.g., upper

Chehalis, Washougal, Wind, Nooksack, and Tahuya Rivers) might be explained if they represent remnants of more complex population structure that occurred historically.

Two factors, either individually or in combination, likely contributed to the high level of genetic variation in California steelhead. First, environmental conditions in most streams in central and southern California are extreme for anadromous salmonids, with low flows and summer water temperatures that may reach or exceed typical thermal limits for *O. mykiss*. These environmental conditions may promote strong local adaptations and inhibit gene flow among populations. In addition, sand berms at the mouth of streams may completely block migration of juveniles or adults in some years, and it is likely that this phenomenon fosters flexible life history patterns, a greater importance of resident fish, and increased opportunities for isolation. Second, it is possible that these factors, which historically would be likely to promote isolation and differentiation, have been intensified by human-mediated events of the past century. Major water projects in California have reduced stream flows and increased the frequency and duration of stream blockages. South of San Francisco Bay, a high proportion of native steelhead populations are declining or already extinct (Titus et al. in press), indicating reduced opportunities for genetic contact between populations. In addition, declines in abundance in the populations that do remain facilitate more rapid differentiation among populations due to genetic drift.

## Discussion and Conclusions on ESU Determinations

Based on a review of the biology and ecology of west coast steelhead, the Biological Review Team (BRT) identified 15 ESUs, 12 of which include coastal forms and 3 of which include inland forms (Fig. 9, Appendix B). Genetic data (from protein electrophoresis, DNA markers, and chromosomal analysis) were the primary evidence considered for the reproductive isolation criterion, supplemented by inferences about barriers to migration created by natural geographic features. A number of factors were considered to be important in evaluations of ecological/genetic diversity, with data for migration and spawn timing, life history, ichthyogeography, hydrology, and other environmental features of the habitat being particularly informative. In the following summaries, we describe only those factors that were valuable in making individual ESU determinations.

Each of the ESUs includes multiple spawning populations of *O. mykiss*, and most ESUs also extend over a considerable geographic area. This result is consistent with NMFS' species definition paper, which states that, in general, "ESUs should correspond to more comprehensive units unless there is clear evidence that evolutionarily important differences exist between smaller population segments" (Waples 1991b, p. 20). However, considerable diversity in genetic or life history traits or habitat features may exist within a single complex ESU, and the descriptions below briefly summarize some of the notable types of diversity within each ESU. This diversity is considered in the next section in evaluating risk to the ESU as a whole.

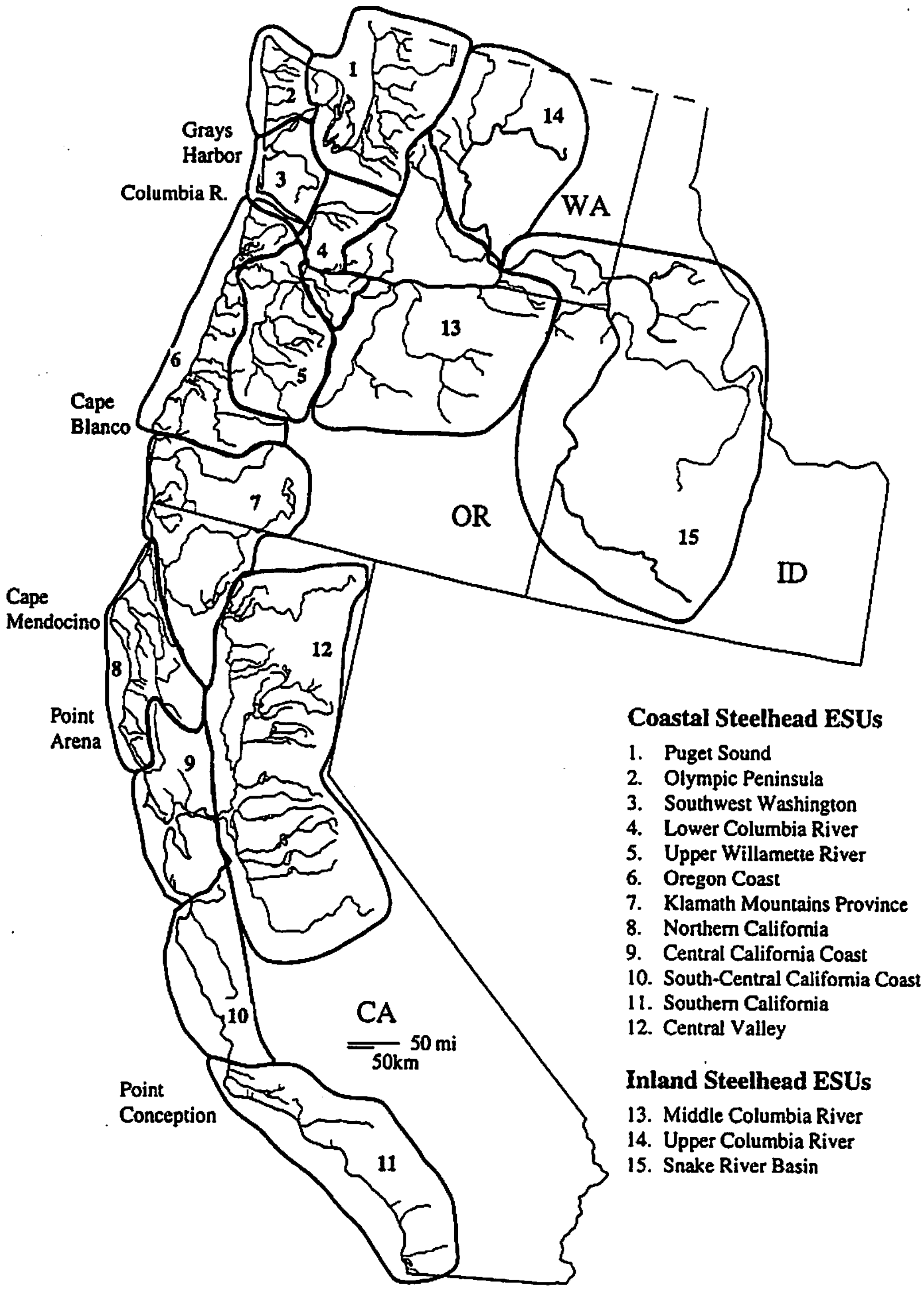



Figure 9. Map of the approximate historic geographic ranges of proposed evolutionarily significant units (ESUs) for west coast steelhead (present distribution may be less). See text for more detail.

## Evolutionary Significance of Phylogenetic and Life History Forms

In defining ESUs for west coast steelhead, it is necessary to consider the significance of the various phylogenetic and life history forms that have been described (see page 7). Of these, only the coastal or inland groups are considered monophyletic, the others apparently being adaptive expressions of the life history plasticity that is characteristic of *O. mykiss*. Genetic analyses show large and consistent differentiation between coastal and inland steelhead. Also, these groups have not been found to co-occur in nature, although some degree of overlap in the Columbia River Basin in the vicinity of the Cascade Crest cannot be ruled out.

Unlike the coastal/inland groups, summer and winter steelhead co-occur in several river basins, primarily within the range of the coastal steelhead group. The few genetic analyses that have considered this issue indicate that summer and winter steelhead from the same river basin are more genetically similar to each other than to the same run type in another river basin. This indicates that all summer steelhead, for example, are not descended and distributed from one ancestral source and, therefore, are not a monophyletic unit.

Genetic assessments within and between river basins have not specifically been conducted on A- and B-run steelhead. One reason for this is that most genetic analyses in the Snake River Basin have been conducted on juvenile steelhead, while the characteristics of A- and B-run are manifested in the adults. We do know that there is geographic structure to the genetic data that does not appear to strictly follow the distribution of the A- and B-runs within the Columbia and Snake River Basins.

Half-pounders are only reported in the literature from a small geographic region in southern Oregon and northern California. However, genetic data do not show a particularly strong affinity among rivers having half-pounders; rather, the affinities are geographic, including streams both with and without half-pounders. Additionally, winter steelhead broodstock for Cole Rivers Hatchery on the Rogue River in Oregon were initially selected for fish without evidence of the half-pounder life history, yet there is evidence that among winter steelhead subsequently returning to the hatchery, approximately 30% underwent a half-pounder migration (Evenson[12]), suggesting that this is not strictly a genetic trait.

**Resident fish**—Few detailed studies have been done on the relationship between resident and anadromous *O. mykiss* in the same location. Genetic studies generally show that the two forms from the same area are more similar to each other than either is to the same form from a different geographic area. Thus, rainbow trout and steelhead from the same area may share a common gene pool, at least over evolutionary time periods. It is also generally believed (although definitive information on this topic is scarce) that progeny of nonanadromous *O. mykiss* can be anadromous, and that anadromous O. mykiss can produce nonanadromous progeny. It was the consensus of fishery biologists we consulted throughout

[12] M. Evenson, District Fish Biologist, Oregon Department of Fish and Wildlife, 1495 East Gregory Road, Central Point, OR 97502. Pers. commun., January 1993 and May 1994.

the region that resident fish should generally be considered part of the steelhead ESUs. On the other hand, there is also evidence for substantial genetic divergence between resident and anadromous fish in areas where resident populations have been isolated by long-standing natural barriers. In addition, hatchery rainbow trout derived from a few mixed strains have been widely planted throughout the range of west coast steelhead, and resident populations established as a result of such transplants would not be native to the area.

Based on these considerations, the BRT concluded that, in general, the ESUs described below include resident *O. mykiss* in cases where they have the opportunity to interbreed with anadromous fish. Geographic areas in which the role of resident fish may be particularly important include southern California and the upper Columbia River; in both of these areas, extreme environmental conditions may promote increased flexibility in life history strategies for native populations of *O. mykiss*. Resident populations above long-standing natural barriers, and those that have resulted from the introduction of non-native rainbow trout, would not be considered part of the ESUs. Resident populations that inhabit areas upstream from human-caused migration barriers (e.g., Grand Coulee Dam, the Hells Canyon Dam complex, and numerous smaller barriers in California) may contain genetic resources similar to those of anadromous fish in the ESU, but little information is available on these fish or the role they might play in conserving natural populations of steelhead. The status with respect to steelhead ESUs of resident fish upstream from human-caused migration barriers must be evaluated on a case-by-case basis as more information becomes available.

**Coastal Steelhead ESUs**

**1) Puget Sound**—This coastal steelhead ESU occupies river basins of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, Washington. Included are river basins as far west as the Elwha River and as far north as the Nooksack River.

No recent genetic comparisons have been made of steelhead populations from Washington and British Columbia, but samples from the Nooksack River differ from other Puget Sound populations, and this may reflect a genetic transition zone or discontinuity in northern Puget Sound. In life history traits, there appears to be a sharp transition between steelhead populations from Washington, which smolt primarily at age 2, and those in British Columbia, which most commonly smolt at age 3. This pattern holds for comparisons across the Strait of Juan de Fuca as well as for comparisons of Puget Sound and Strait of Georgia populations. At the present time, therefore, evidence suggests that the northern boundary for this ESU coincides approximately with the U.S.-Canada border.

Recent genetic data provided by WDFW show that samples from the Puget Sound area generally form a coherent group, distinct from populations elsewhere in Washington. There is also evidence for some genetic differentiation between populations from northern and southern Puget Sound, but the BRT did not consider that ecological or life history differences were sufficient to warrant subdividing this ESU. Chromosomal studies show that steelhead from the Puget Sound area have a distinctive karyotype not found in other regions.

The Puget Sound region is in the rain shadow of the Olympic Mountains and therefore is drier than the Olympic Peninsula; most of the Puget Sound region averages less than 160 cm of precipitation annually, while most areas of the Olympic Peninsula exceed 240 cm (Jackson 1993). Climate and river hydrology change west of the Elwha River (see Weitkamp et al. 1995). The rivers in Puget Sound generally have high relief in the headwaters and extensive alluvial floodplains in the lowlands. Geology and topography are dominated by the effects of the Cordilleran Ice Sheet as evidenced by glacial deposits and the regional geomorphology.

Puget Sound's fjord-like structure may affect steelhead migration patterns; for example, some populations of coho and chinook salmon, at least historically, remained within Puget Sound and did not migrate to the Pacific Ocean itself (Wright 1968, Williams et al. 1975, Healey 1980). Even when Puget Sound steelhead migrate to the high seas, they may spend considerable time as juveniles or adults in the protected marine environment of Puget Sound, a feature not readily accessible to steelhead from other ESUs.

Most of the life history information for this ESU is from winter-run fish. Apart from the difference with Canadian populations noted above, life history attributes of steelhead within this ESU (migration and spawn timing, smolt age, ocean age, and total age at first spawning) appear to be similar to those of other west coast steelhead. Ocean age for Puget Sound summer steelhead varies among populations; for example, summer steelhead in Deer Creek (North Fork Stillaguamish River Basin) are predominately age-1-ocean, while those in the Tolt River (Snoqualmie River Basin) are most commonly age-3-ocean (WDF et al. 1993).

The Puget Sound ESU includes two stocks that have attracted considerable public attention recently: Deer Creek summer steelhead (North Fork Stillaguamish River Basin) and Lake Washington winter steelhead. Deer Creek summer steelhead were petitioned for listing under the ESA (Washington Trout 1993), but NMFS determined that this population did not by itself represent an ESU (NMFS 1994b). Adult Lake Washington winter steelhead have experienced a high rate of predation by California sea lions (*Zalophus californianus*) below the fish ladder at Hiram M. Chittenden Locks (also known as the Ballard Locks), the artificial outlet of Lake Washington. Deer Creek summer steelhead and Lake Washington winter steelhead were 2 of the 178 stocks identified in the west coast steelhead petition (ONRC et al. 1994).

This ESU is primarily composed of winter steelhead but includes several stocks of summer steelhead, usually in subbasins of large river systems and above seasonal hydrologic barriers. Nonanadromous *O. mykiss* co-occur with the anadromous form in the Puget Sound region; however, the relationship between these forms in this geographic area is unclear.

**2) Olympic Peninsula**—This coastal steelhead ESU occupies river basins of the Olympic Peninsula, Washington west of the Elwha River and south to, but not including, the rivers that flow into Grays Harbor.

Genetic data collected by WDFW support the hypothesis that, as a group, steelhead populations from the Olympic Peninsula are substantially isolated from those in other regions of western Washington. The Olympic Peninsula ESU is further characterized by habitat, climatic, and zoogeographical differences between it and adjacent ESUs. The Olympic Peninsula includes coastal basins that receive more precipitation than any other area in the range of west coast steelhead. Topography on the Olympic Peninsula is characterized by much greater relief than that to the south; the Olympic Mountains range from 1,200 to 2,400 m above sea level. This affects precipitation quantity and river-basin hydrography. The result is "copious amounts of rain and over 100 inches of snow during the winter months" as well as substantial summer precipitation (Jackson 1993, p. 50-51). One manifestation of the ecological difference between Puget Sound and the Olympic Peninsula is the shift in vegetation zone, respectively, from western hemlock (*Tsuga heterophylla*) to Sitka spruce (*Picea sitchensis*) (Frenkel 1993).

Zoogeographic patterns also support ecological separation of the Olympic Peninsula from adjacent areas. According to McPhail and Lindsey (1986, p. 631), west of the Cascades pygmy whitefish (*Prosopium coulteri*) and longnose sucker (*Catostomus catostomus*) are only known from previously glaciated areas to the north of the Chehalis River. The distribution of several amphibian species also appears to change at the Chehalis River Basin (Stebbins 1966, Cook 1984, Leonard et al. 1993).

Limited life history information is available for Olympic Peninsula steelhead, and the information that does exist is primarily from winter-run fish. As with the Puget Sound ESU, known life history attributes of Olympic Peninsula steelhead are similar to those of other west coast steelhead, the notable exception being the difference between U.S. and Canadian populations in age at smolting.

The Olympic Peninsula ESU is primarily composed of winter steelhead but includes several stocks of summer steelhead in the larger rivers. Nonanadromous *O. mykiss* co-occur with the anadromous form in Olympic Peninsula rivers; however, the relationship between these forms in this geographic area is unclear.

**3) Southwest Washington**—This coastal steelhead ESU occupies the tributaries to Grays Harbor, Willapa Bay, and the Columbia River below the Cowlitz River in Washington and below the Willamette River in Oregon.

This ESU is delineated primarily by genetics and habitat features. Recent genetic data (Leider et al. 1995) show consistent differences between steelhead populations from the southwest Washington coast and those from coastal areas to the north, as well as those from Columbia River drainages east of the Cowlitz River. However, existing data do not clearly define the genetic relationship between steelhead from the southwest Washington coast and those from Columbia River tributaries below the Cowlitz River.

The geographic location of this ESU corresponds to the Chehalis and Columbia River glacial refugia during the Wisconsin Glaciation. Although there are morphological differences between populations of fish species common to the Chehalis and Columbia Rivers, both share a common Columbia River ichthyofauna (McPhail and Lindsey 1986). The two river basins are physically separated at present, but transport of sediments of

Columbia River origin to both Grays Harbor and Willapa Bay (Landry and Hickey 1989) provides an ecological link. Furthermore, Monaco et al. (1992) found similarities in the estuarine ichthyofauna of Grays Harbor, Willapa Bay, and the Columbia River.

This ESU is primarily composed of winter steelhead but includes summer steelhead in the Humptulips and Chehalis River Basins. Nonanadromous *O. mykiss* co-occur with the anadromous form in southwest Washington rivers; however, the relationship between these forms in this geographic area is unclear. Life history attributes for steelhead within this ESU appear to be similar to those of other west coast steelhead.

**4) Lower Columbia River**—This coastal steelhead ESU occupies tributaries to the Columbia River between the Cowlitz and Wind Rivers in Washington and the Willamette and Hood Rivers in Oregon, inclusive. Excluded are steelhead in the upper Willamette River Basin above Willamette Falls (see ESU 5-Upper Willamette River), and steelhead from the Little and Big White Salmon Rivers, Washington, which are in the Middle Columbia River ESU.

This ESU is delineated primarily by genetics and habitat features. Steelhead populations in this ESU are of the coastal genetic group (Schreck et al. 1986, Reisenbichler et al. 1992, Chapman et al. 1994), and a number of genetic studies have shown that they are part of a different ancestral lineage than inland steelhead from the Columbia River Basin. Genetic data also show steelhead from this ESU to be distinct from steelhead from the upper Willamette River and from coastal streams in Oregon and Washington. Recent genetic data from WDFW also show clear differences between samples from the Wind, Washougal, and Big White Salmon Rivers and those from the coast of southwest Washington.

Steelhead-bearing rivers within this geographical region drain the Cascade Mountains from Mount Ranier to Mount Hood, including the Toutle River that was greatly impacted by the eruptions of Mount St. Helens in the 1980s.

Much consideration has been given to the interface between coastal and inland steelhead, both in the current review and in other studies. The boundary presented here represents the best understanding of steelhead genetics, biology, and ecology to date and is consistent with the findings of WDFW and Oregon Department of Fish and Wildlife (ODFW). Clearly, additional genetic analysis of steelhead in this region is desirable.

This ESU is composed of winter steelhead and summer steelhead. Nonanadromous *O. mykiss* co-occur with the anadromous form in Lower Columbia River tributaries; however, the relationship between these forms in this geographic area is unclear. Life history attributes for steelhead within this ESU appear to be similar to those of other west coast steelhead.

**5) Upper Willamette River**—This coastal steelhead ESU occupies the Willamette River, and its tributaries, upstream from Willamette Falls.

Steelhead from the upper Willamette River are genetically distinct from those in the lower river. Reproductive isolation from lower river populations may have been facilitated by Willamette Falls (RKm 77), which is known to be a migration barrier to some anadromous salmonids. For example, winter steelhead and spring chinook salmon occurred historically above the falls, but summer steelhead, fall chinook salmon, and coho salmon did not.

The native steelhead of this basin are late-migrating winter steelhead, entering fresh water primarily in March and April (Howell et al. 1985), whereas most other populations of west coast winter steelhead enter fresh water beginning in November or December. As early as 1885, fish ladders were constructed at Willamette Falls to aid the passage of anadromous fish; the ladders have been modified and rebuilt, most recently in 1971, as technology has improved (Bennett 1987, PGE 1994). These fishways facilitated successful introduction of Skamania stock summer steelhead and early migrating Big Creek stock winter steelhead to the upper basin. Another effort to expand steelhead production in the upper Willamette River was the stocking of native steelhead in tributaries not historically utilized by that species. Native steelhead primarily used tributaries on the east side of the basin, with cutthroat trout predominating in streams draining the west side of the basin.

The Willamette River Basin is zoogeographically complex. In addition to the obvious connection with the Columbia River, the Willamette River Basin has historically had connections with coastal basins through stream capture and headwater transfer events (Minckley et al. 1986).

The relationship between anadromous and nonanadromous *O. mykiss* in this geographic area is unclear. Nonanadromous *O. mykiss* are known to occupy the Upper Willamette River Basin; however, most of these nonanadromous populations occur above natural and manmade barriers (Kostow 1995). Historically, spawning by Upper Willamette River steelhead was concentrated in the North and Middle Santiam River Basins (Fulton 1970). These areas are now largely blocked to fish passage by dams, and steelhead spawning is now distributed throughout more of the Upper Willamette River Basin than in the past (Fulton 1970). Due to introductions of non-native steelhead stocks and transplantation of native stocks within the basin, it is difficult to formulate a clear picture of the present distribution of native Upper Willamette River Basin steelhead, and their relationship to nonanadromous and possibly residualized (footnote 5) *O. mykiss* within the basin.

**6) Oregon Coast**—This coastal steelhead ESU occupies river basins on the Oregon coast north of Cape Blanco; excluded are rivers and streams that are tributaries of the Columbia River (see ESU 3-Southwest Washington).

Recent genetic data from steelhead in this ESU are limited, but they show a level of differentiation from populations from Washington, the Columbia River Basin, and coastal areas south of Cape Blanco. Ocean migration patterns also suggest a distinction between steelhead populations north and south of Cape Blanco. Steelhead, as well as chinook and coho salmon, from streams south of Cape Blanco tend to be south-migrating rather than north-migrating (Everest 1973, Nicholas and Hankin 1988, Pearcy et al. 1990, Pearcy 1992).

We have little information on migration and spawn timing of natural steelhead populations within this ESU. Age structure appears to be similar to other west coast steelhead, dominated by 4-year-old spawners. Iteroparity is more common among Oregon coast steelhead than populations to the north.

The Oregon Coast ESU primarily contains winter steelhead. There are only two native stocks of summer steelhead in this ESU; one occurs in the Siletz River above a waterfall that is a barrier to winter steelhead, and the other occurs in the Umpqua River Basin. Summer steelhead from the Siletz River have been used in attempts by ODFW to establish fisheries in other basins with little success, primarily due to susceptibility to *Ceratomyxa shasta*. Alsea River winter steelhead have been widely used for steelhead broodstock in coastal rivers.

Populations of nonanadromous *O. mykiss* (rainbow trout) are relatively uncommon on the Oregon coast, as compared with other areas, occurring primarily above migration barriers and in the Umpqua River Basin (Kostow 1995). The lack of life history diversity within the Oregon Coast ESU may reflect habitat availability in this region. Summer steelhead appear to occupy habitat not fully utilized by the winter steelhead (i.e., above seasonal barriers or in very long rivers where distance may serve as a migration barrier to ocean-maturing winter steelhead). Rainbow trout appear to occur primarily in habitat that is unavailable to steelhead, but it also occurs in rivers where temperature regimes or artificial barriers interfere with the smoltification process, therefore facilitating nonanadromy. Most rivers on the Oregon coast are comparatively short, draining the Coast Range, and their accessible steelhead habitat may be fully utilized by winter steelhead. The Umpqua River, which supports winter steelhead, summer steelhead, and rainbow trout is the longest river in this region; it is the only river within the range of the Oregon Coast ESU that arises in the Cascade Mountains and penetrates the Coast Range. Migration distance and thermal regimes may prevent full utilization of habitat by winter steelhead, allowing summer steelhead and rainbow trout to occur in the Umpqua River Basin.

**7) Klamath Mountains Province**—This coastal steelhead ESU occupies river basins from the Elk River in Oregon to the Klamath and Trinity Rivers in California, inclusive.

This ESU has been more fully described by Busby et al. (1994). The location of this ESU is dominated by a prominent geological feature known as the Klamath Mountains Province; this region includes diverse and unique floral communities. Similarities in ichthyofauna between the Rogue and Klamath Rivers have been described by Snyder (1907) and Moyle (1976). Protein electrophoretic analyses of coastal steelhead have indicated genetic discontinuities between the steelhead of this region and those to the north and south (Hatch 1990; Busby et al. 1993, 1994). Chromosomal studies have also identified a distinctive karyotype that has only been reported from populations within this ESU. Steelhead within this ESU include both winter and summer steelhead as well as the unusual *half-pounder* life history. Nonanadromous *O. mykiss* may co-occur with the anadromous form; however, the relationship between the two forms in this geographic area is unclear.

Among the remaining questions regarding this ESU is the relationship between *O. mykiss* below and above Klamath Falls, Oregon. Behnke (1992) has proposed that the two groups are in different subspecies, and that the upper group, a redband trout (*O. m. newberrii*), utilized anadromy until blocked by the Copco dams in the early 1900s.

However, Moyle (1976) stated that Klamath Falls was the upstream barrier to anadromous fish prior to construction of the dams.

**8) Northern California**—This coastal steelhead ESU occupies river basins from Redwood Creek in Humboldt County, California to the Gualala River, inclusive.

The geographic boundaries of this ESU coincide closely with the northern California region of steelhead populations identified by Nielsen (1994) on the basis of genetic and biogeographic data. Allozyme data indicate a discontinuity between steelhead populations of this region and those to the north, and mitochondrial DNA data suggest a genetic transition in the area between Point Arena and San Francisco Bay. Thorgaard (1983) found unusually high numbers of chromosomes in steelhead from south of the Klamath River. Freshwater fishes in this geographic area are derived from the Sacramento River Basin (Snyder 1907, Moyle 1976), whereas streams to the north include fishes derived from the Klamath-Rogue ichthyofaunal province.

Precipitation is generally higher in this geographic area than in regions to the south, averaging 100 to 200 cm of rainfall annually (Donley et al. 1979). This area includes the extreme southern end of the contiguous portion of the Coast Range Ecoregion (Omernik 1987).

There are life history similarities between steelhead of the Northern California ESU and those of the Klamath Mountains Province ESU. Steelhead within this ESU include winter and summer steelhead, including what is presently considered to be the southernmost population of summer steelhead, in the Middle Fork Eel River. Half-pounder juveniles occur in this geographic area, specifically in the Mad and Eel Rivers; indeed, Snyder (1925) first described the half-pounder from the Eel River. However, Cramer et al. (1995) suggest that adults with the half-pounder juvenile life history may not spawn south of the Klamath River Basin. As with the Rogue and Klamath Rivers, some of the larger rivers in this area have migrating steelhead year-round, and seasonal runs have been named. Nonanadromous *O. mykiss* may co-occur with the anadromous form; however, the relationship between these forms in this geographic area is unclear.

**9) Central California Coast**—This coastal steelhead ESU occupies river basins from the Russian River to Soquel Creek, Santa Cruz County (inclusive), and the drainages of San Francisco and San Pablo Bays; excluded is the Sacramento-San Joaquin River Basin of the Central Valley of California.

Analysis of mtDNA data suggests that genetic transitions occur just north of the Russian River and just north of Monterey. Allozyme data show large genetic differences between steelhead populations from the Eel and Mad Rivers and those to the south.

Environmental characteristics differ between the central California coast and areas to the north and south. Landforms in this area are characterized by very erosive soils. The coastal climate is relatively moist and cool throughout the year, but inland regions (e.g., upper Russian River Basin) are warmer and drier. Annual precipitation is markedly less and month of peak flow is later for streams south of Point Arena than those to the north. Minimum winter water temperatures are higher in this area than in streams to the north. The central California coast area includes the southern limit of the redwood forest, and within this area there is a transition to the more xeric vegetation of the south coast and interior.

Only winter steelhead are found in this ESU and those to the south. Migration and spawn timing are similar to adjacent steelhead populations. We have little other life history information for steelhead in this ESU. The relationship between anadromous and nonanadromous *O. mykiss*, including possibly residualized (footnote 5) fish upstream from dams, is unclear.

**10) South-Central California Coast**—This coastal steelhead ESU occupies rivers from the Pajaro River, Santa Cruz County to (but not including) the Santa Maria River.

Mitochondrial DNA data provide evidence for a genetic transition in the vicinity of Monterey Bay. Both mtDNA and allozyme data show large genetic differences between populations in this area, but the data do not provide a clear picture of population structure.

Most rivers of this region drain the Santa Lucia Range, the southernmost unit of the California Coast Ranges. The climate is drier and warmer than in the north, which is reflected in the vegetational change from coniferous forest to chaparral and coastal scrub. Another biological transition at the north of this area is the southern limit of the distribution of coho salmon (*O. kisutch*). The mouths of many rivers and streams in this area are seasonally closed by sand berms that form during periods of low flow in the summer. The southern boundary of this ESU is near Point Conception, a well-recognized transition area for the distribution and abundance of marine flora and fauna.

Only winter steelhead are found in this ESU. Migration and spawn timing are similar to adjacent steelhead populations. We have little other life history information for steelhead in this ESU. The relationship between anadromous and nonanadromous *O. mykiss*, including possibly residualized (footnote 5) fish upstream from dams, is unclear but likely to be important.

**11) Southern California**—This coastal steelhead ESU occupies rivers from the Santa Maria River to the southern extent of the species range. Historically, *O. mykiss* occurred at least as far south as Rio del Presidio in Mexico (Behnke 1992, Burgner et al. 1992). Spawning populations of steelhead did not occur that far south but may have extended to the Santo Domingo River in Mexico (Barnhart 1986); however, some reports state that steelhead may not have existed south of the U.S.-Mexico border (Behnke 1992, Burgner et al. 1992). The present southernmost stream used by steelhead for spawning is generally thought to be Malibu Creek, California (Behnke 1992, Burgner et al. 1992); however, in years of substantial rainfall, spawning steelhead can be found as far south as the Santa Margarita River, San Diego County (Barnhart 1986, Higgins 1991).

Genetic data show large differences between steelhead populations within this ESU as well as between these and populations to the north. Steelhead populations between the Santa

Ynez River and Malibu Creek show a predominance of a mitochondrial DNA type (ST8) that is rare in populations to the north. Allozyme data indicate that two samples from Santa Barbara County are genetically among the most distinctive of any natural populations of coastal steelhead yet examined.

Migration and life history patterns of southern California steelhead depend more strongly on rainfall and streamflow than is the case for steelhead populations farther north (Moore 1980, Titus et al. in press). Average rainfall is substantially lower and more variable in southern California than in regions to the north, resulting in increased duration of sand berms across the mouths of streams and rivers and, in some cases, complete dewatering of the lower reaches of these streams from late spring through fall. Environmental conditions in marginal habitats may be extreme (e.g., elevated water temperatures, droughts, floods, and fires) and presumably impose selective pressures on steelhead populations. Their utilization of southern California streams and rivers with elevated temperatures (in some cases much higher than the preferred range for steelhead) suggests that steelhead within this ESU are able to withstand higher temperatures than populations to the north. The relatively warm and productive waters of the Ventura River have resulted in more rapid growth of juvenile steelhead than occurs in more northerly populations (Moore 1980, Titus et al. in press, McEwan and Jackson 1996). However, we have relatively little life history information for steelhead from this ESU. Additionally, the relationship between anadromous and nonanadromous *O. mykiss*, including possibly residualized (footnote 5) fish upstream from dams, is unclear.

**12) Central Valley**—This steelhead ESU occupies the Sacramento and San Joaquin Rivers and their tributaries.

Recent allozyme data show that samples of steelhead from Deer and Mill Creeks and Coleman NFH on the Sacramento River are well differentiated from all other samples of steelhead from California.

The Sacramento and San Joaquin Rivers offer the only migration route to the drainages of the Sierra Nevada and southern Cascade mountain ranges for anadromous fish. The distance from the ocean to spawning streams can exceed 300 km, providing unique potential for reproductive isolation among steelhead in California. The Central Valley is much drier than the coastal regions to the west, receiving on average only 10-50 cm of rainfall per year. The valley is characterized by alluvial soils, and native vegetation was dominated by prairie grasses prior to agricultural development.

Currently, all steelhead in the Central Valley are considered winter steelhead by the California Department of Fish and Game (CDFG), although "three distinct runs," including summer steelhead, may have occurred there as recently as 1947 (CDFG 1995, McEwan and Jackson 1996). Steelhead within this ESU have the longest freshwater migration of any population of winter steelhead. There is essentially a single continuous run of steelhead in the upper Sacramento River. River entry ranges from July through May, with peaks in September and February; spawning begins in late December and can extend into April (McEwan and Jackson 1996).

There are two recognized taxonomic forms of native *O. mykiss* within the Sacramento River Basin: coastal steelhead/rainbow trout (*O. m. irideus*, Behnke 1992) and Sacramento redband trout (*O. m. stonei*, Behnke 1992). Sacramento redband trout from the McCloud River are presently on the Fish and Wildlife Service's Candidate List, category 1, for proposed listing under the ESA. How the coastal and Sacramento redband forms of *O. mykiss* interacted in the Sacramento River prior to construction of Shasta Dam in the 1940s, which blocked anadromous fish passage, is not clear. In describing the McCloud River egg-taking station (1879-1888), Behnke (1992) said that coastal steelhead and resident redband trout were spawned together. Therefore, it appears the two forms historically co-occurred at spawning time but may have maintained reproductive isolation. In addition to the relationship between coastal steelhead and Sacramento redband forms, the relationship between anadromous and nonanadromous forms of coastal *O. mykiss*, including possible residualized (footnote 5) fish upstream from dams, is unclear.

**Inland Steelhead ESUs**

**13) Middle Columbia River**—This ESU occupies the Columbia River Basin from above the Wind River in Washington and the Hood River in Oregon upstream to include the Yakima River, Washington. Steelhead of the Snake River Basin are not included.

Genetic differences between inland and coastal steelhead are well established, although some uncertainty remains about the exact geographic boundaries of the two forms in the Columbia River (see discussion above for ESU 4-Lower Columbia River). Electrophoretic and meristic data show consistent differences between steelhead from the middle Columbia River and the Snake River Basin. No recent genetic data exist for natural steelhead populations in the upper Columbia River, but recent WDFW data show that the Wells Hatchery stock from the upper Columbia River does not have a close genetic affinity to sampled populations from the middle Columbia River.

All steelhead in the Columbia River Basin upstream from The Dalles Dam are summer-run, inland steelhead (Schreck et al. 1986, Reisenbichler et al. 1992, Chapman et al. 1994). Steelhead in Fifteenmile Creek, Oregon are genetically allied with inland *O. mykiss*, but are winter-run. Winter steelhead are also found in the Klickitat and White Salmon Rivers, Washington.

Franklin and Dyrness (1973) place the Yakima River Basin in the Columbia Basin Physiographic Province (along with the Deschutes, John Day, Walla Walla, and lower Snake River Basins); rivers upstream from the Yakima River are in other physiographic provinces. Geology within this province is dominated by the Columbia River basalt formation, formed from lava deposition in the miocene epoch, which is overlain by plio-Pleistocene deposits of glaciolacustrine origin (Franklin and Dyrness 1973). This intermontane region includes some of the driest areas of the Pacific Northwest, generally receiving less than 40 cm of precipitation annually (Jackson 1993). Indeed, Deschutes River steelhead are occasionally referred to by anglers as "the desert steelhead." Vegetation in this region is of the shrub-steppe province, reflecting the xeric climate and harsh temperature extremes.

Life history information for steelhead of this region indicates that most middle Columbia River steelhead smolt at 2 years and spend 1 to 2 years in salt water prior to re-entering fresh water, where they may remain up to a year prior to spawning (Howell et al. 1985, BPA 1992). Within this ESU, the Klickitat River is unusual in that it produces both summer and winter steelhead, and the summer steelhead are dominated by age-2-ocean steelhead, whereas most other rivers in this region produce about equal numbers of both age-1- and 2-ocean steelhead. Nonanadromous *O. mykiss* (Columbia River redband trout) co-occur with the anadromous form within this ESU; information suggests that the two forms may not be reproductively isolated, except where barriers are involved. Questions remain regarding the degree of reproductive interaction between the forms, as well as the frequency of residualization of steelhead within this ESU, both below and above migration barriers. Some populations of Columbia River redband trout are presently on the Fish and Wildlife Service's Candidate List, category 2, for proposed listing under the ESA.

The BRT considered different scenarios for the composition of the Middle Columbia River ESU with respect to the downstream and upstream boundaries. Life history information for Klickitat River steelhead is more similar to Lower Columbia River steelhead than to other populations within the Middle Columbia River ESU; additionally, Schreck et al. (1986) placed Klickitat River steelhead in the coastal steelhead group based on genetic, morphometric, meristic and life history characteristics. However, recent genetic analyses (Phelps et al. 1994, Leider et al. 1995) suggest a closer affinity for Klickitat River steelhead with the inland steelhead group. Similarly, there was much consideration of whether Yakima River steelhead are within the Middle or Upper Columbia River ESU. The conclusion that Yakima River steelhead are part of the Middle Columbia River ESU was based on life history and habitat characteristics, as well as genetic evidence of some affinity between steelhead of the Yakima and Klickitat River Basins (Phelps et al. 1994).

**14) Upper Columbia River**—This inland steelhead ESU occupies the Columbia River Basin upstream from the Yakima River.

The rivers in this area primarily drain the east slope of the northern Cascade Mountains and include the Wenatchee, Entiat, Methow, and Okanogan River Basins. Some of these upper Columbia River subbasins, including the Okanogan River and the upper Columbia River proper, extend into British Columbia. The status of steelhead in British Columbia is, therefore, applicable to this ESU. The general consensus from discussions at the Pacific Salmon Biological and Technical Meeting on steelhead, Lewiston, Idaho (18 October 1994) and with the B.C. Ministry of the Environment[13] is that steelhead never occurred in large numbers in British Columbia in the upper Columbia River Basin. Therefore, it is considered that this ESU includes only U.S. populations.

The geographic area occupied by this ESU forms part of the larger Columbia Basin Ecoregion (Omernik 1987). The Wenatchee and Entiat Rivers are in the Northern Cascades

[13] B. Shepherd, Fisheries Section Head, B.C. Ministry of the Environment, 3547 Skaha Lake Road, Penticton, B.C., Canada V2AZK2. Pers. commun., November 1994.

Physiographic Province and the Okanogan and Methow Rivers are in the Okanogan Highlands Physiographic Province (Franklin and Dyrness 1973). The geology of these provinces is somewhat similar and very complex, having developed from marine invasions (beginning in the Paleozoic Era and continuing to the Cretaceous Period), volcanic deposits (Pleistocene Epoch), and glaciation (late Pleistocene) (Franklin and Dyrness 1973). Franklin and Dyrness (1973, p. 17) described the North Cascades as "a topographically mature area of great relief." The river valleys are deeply dissected and maintain low gradients except for the extreme headwaters (Franklin and Dyrness 1973).

Climate in this area includes extremes in temperatures and precipitation; most precipitation falls in the mountains as snow (Mullan et al. 1992). Streamflow in this area is provided by melting snowpack, groundwater, and runoff from alpine glaciers (Mullan et al. 1992). Mullan et al. (1992, p. iv) described this area as a harsh environment for fish and stated that it "should not be confused with the more studied, benign, coastal streams of the Pacific Northwest."

Life history characteristics for Upper Columbia River Basin steelhead are similar to those of other inland steelhead ESUs; however, some of the oldest smolt ages for steelhead, up to 7 years, are reported from this ESU. This may be associated with the cold stream temperatures discussed by Mullan et al. (1992), who stated (p. v) that the cold water in some of the streams of this area may cause some fish to be "thermally-fated to a resident (rainbow trout) life history regardless of whether they were the progeny of anadromous or resident parents." The relationship between anadromous and nonanadromous *O. mykiss* in this geographic area is unclear. Based on limited data available from adult fish, smolt age in this ESU is dominated by 2-year-olds. Again based on limited data, steelhead from the Wenatchee and Entiat Rivers return to fresh water after 1 year in salt water, whereas Methow River steelhead are primarily age-2-ocean (Howell et al. 1985). As with other inland steelhead, these remain in fresh water up to a year prior to spawning.

**15) Snake River Basin**—This inland steelhead ESU occupies the Snake River Basin of southeast Washington, northeast Oregon, and Idaho.

Most Snake River tributaries supporting steelhead populations are well isolated from steelhead streams outside of the Snake River Basin. Recent genetic data from NMFS and WDFW show that samples from the Snake River are more similar genetically to other Snake River samples than they are to samples from outside the Snake River, and meristic data support this finding. Ecologically, steelhead spawning habitat in the Snake River is distinctive in having large areas of open, low-relief streams at high elevation. In many Snake River tributaries, spawning occurs at a higher elevation (up to 2,000 m) than is found for steelhead in any other geographic region. Snake River Basin steelhead also migrate farther from the ocean (up to 1,500 km) than most (perhaps all) other steelhead populations in the world.

The Snake River flows through terrain that is warmer and drier on an annual basis than the upper Columbia River Basin or other drainages farther north. Geologically, the landforms are older and much more eroded than most other steelhead habitat. The eastern portion of the basin flows out of the granitic geological unit known as the Idaho Batholith; the western Snake River Basin drains sedimentary and volcanic soils of the Blue Mountains complex (Rosenfeld 1993). Collectively, the environmental factors of the Snake River Basin result in a river that is warmer and more turbid, with higher pH and alkalinity, than most others in the species' range.

Snake River Basin steelhead are summer steelhead, as are most inland steelhead, and comprise two groups, A- and B-run, based on migration timing, ocean-age, and adult size (see page 10 for more information). Snake River Basin steelhead enter fresh water from June to October and spawn during the following spring from March to May. A-run steelhead are thought to be predominately age-1-ocean, while B-run steelhead are thought to be age-2-ocean (IDFG 1994). Snake River Basin steelhead usually smolt as 2- or 3-year-olds (Whitt 1954, BPA 1992, Hassemer 1992).

The steelhead population from Dworshak NFH is the most divergent single population of inland steelhead based on genetic traits determined by protein electrophoresis. Additionally, steelhead returning to Dworshak NFH are considered to have a distinctive appearance, and are the one steelhead population that is consistently referred to as B-run. We considered the possibility that Dworshak NFH steelhead should be in their own ESU. However, we have little specific information about characteristics of this population's native habitat in the North Fork Clearwater River, which is currently unavailable to anadromous fish because Dworshak Dam has no fish passage facilities. At present, the Dworshak NFH population is considered to be part of the Snake River ESU.

Nonanadromous *O. mykiss* (Columbia River redband trout) may co-occur with the anadromous form within this ESU, but the relationship between anadromous and nonanadromous forms of inland *O. mykiss*, including possibly residualized (footnote 5) fish upstream from dams, is unclear. Some populations of Columbia River redband trout are presently on the Fish and Wildlife Service's Candidate List, category 2, for proposed listing under the ESA.

**Relationship of Steelhead ESUs to State Conservation Management Units**

Both Washington and Oregon have recently completed a preliminary inventory of conservation management units for steelhead populations (Leider et al. 1994, 1995; Kostow 1995). Washington Department of Fish and Wildlife's Genetic Conservation Management Units (GCMUs) for steelhead are intended to be comparable to ESUs and consider many of the same factors (genetics, environment, life history), while ODFW's Gene Conservation Groups (GCGs) are based primarily on genetics. In contrast to ESUs, which may transcend political boundaries, both GCMUs and GCGs consider only populations within their respective state boundaries. Neither Idaho nor California has identified conservation units for steelhead.

For the most part, the ESUs identified here for steelhead are congruent with the conservation units identified by the states. The Oregon coastal and upper Willamette River ESUs as proposed here are identical in geographic coverage to GCGs identified by ODFW, and the Oregon part of the Lower Columbia River and Southwest Washington ESUs are similar to one of Oregon's GCGs. The Klamath Mountains Province ESU includes two GCGs that ODFW has delineated on the Oregon coast south of Cape Blanco. In the Columbia River Basin, ODFW places the coastal/inland break between the Hood River (coastal) and Mosier Creek (inland), which is downstream of Fifteenmile Creek. We are proposing the same location for our coastal/inland break, yet recognize that this could be modified. Other boundaries of ODFW's GCGs for inland steelhead are consistent with the ESUs we have described.

WDFW initially proposed seven GCMUs of steelhead in Washington state (Leider et al. 1994), and later revised the number to nine (Leider et al. 1995). Whereas the earlier determination considered life history and habitat characteristics as well as genetics, the two new GCMUs were identified entirely on the basis of new genetic information. WDFW has emphasized that all GCMU designations should be considered provisional and subject to revision as warranted by new information. In their revised formulation, WDFW recognizes two GCMUs (North Puget Sound and South Puget Sound) within the geographic area occupied by the Puget Sound ESU. WDFW also has split the geographic area occupied by the Middle Columbia River ESU into two GCMUs, Mid-Columbia and Yakima River. The remaining five GCMUs in the revised WDFW scheme are consistent with steelhead ESUs 2, 3, 4, 14, and 15.

**Relationship of Steelhead ESUs to Boundaries for Coho Salmon ESUs**

In its coastwide status review for coho salmon, NMFS identified 6 ESUs in Washington, Oregon, and California (NMFS 1994a), whereas 15 ESUs have been identified for west coast steelhead. The additional nine steelhead ESUs are largely from areas not currently, or in some cases historically, inhabited by coho salmon (upper Columbia and Snake Rivers, upper Willamette River, Central Valley of California, and southern California). The six coho salmon ESUs are very similar in geographic coverage to six of the proposed ESUs for steelhead (Puget Sound, Olympic Peninsula, Southwest Washington, Lower Columbia River, Oregon Coast, Klamath Mountains Province, and Northern California ESUs). Principal differences are that the Puget Sound ESU for steelhead does not include Canadian populations, whereas the coho salmon ESU does; genetic data supported the separation of the Southwest Washington and Lower Columbia River steelhead ESUs, whereas genetic data for coho salmon indicated that these areas form one ESU for that species; the southern boundary for the Klamath Mountains Province ESU for steelhead is at the Klamath River, whereas the boundary for the comparable ESU for coho salmon is further south, at Punta Gorda; and the southernmost ESU for coho salmon includes rivers occupied by the Northern California and Central California Coast steelhead ESUs.

## Artificial Propagation

The remainder of this section is intended to provide a summary of the nature and scope of artificial propagation activities for west coast steelhead.

Artificial propagation of *O. mykiss* began in the 1870s in the San Francisco Bay area (Behnke 1992). These fish were presumably rainbow trout. From 1877 to 1888, egg taking stations were established on the lower McCloud River (upper Sacramento River Basin) for propagation of redband trout and coastal steelhead, with no apparent effort to separate the two forms (Behnke 1992). From that time, *O. mykiss* has been widely propagated, and stocks have been transported literally around the globe. Behnke (1992, p. 174) stated that "the overwhelming majority of brood stocks of rainbow trout maintained around the world originated mainly from various mixtures of coastal steelhead." Therefore, in evaluating artificial propagation of steelhead, it is also important to consider the propagation of rainbow trout.

The popularity of *O. mykiss* as a cultured species makes it infeasible to discuss each propagation facility on the west coast in this document. Behnke (1992, p. 174) noted that, "in California alone, 169 hatcheries and egg-taking stations drew on diverse populations of rainbow trout from 1870 to 1960." A list of major steelhead propagation facilities currently in operation is provided in Appendix C. Annual hatchery production of steelhead on the west coast of North America increased from about 3 million juvenile steelhead in 1960 to over 30 million in 1985 (Light 1989). The majority of hatchery produced steelhead are from the Pacific Northwest states of Idaho, Washington, and Oregon (Table 8, Appendix D), predominately in the Columbia River Basin (Light 1989).

Below we summarize some of the major artificial propagation programs for west coast steelhead.

### Grand Coulee Fish Maintenance Project

In 1939, the construction of Grand Coulee Dam on the Columbia River (RKm 956) blocked over 1,800 km of river from access by anadromous fish (Mullan et al. 1992). In an effort to preserve fish runs affected by Grand Coulee Dam, all anadromous fish migrating upstream were trapped at Rock Island Dam (RKm 729) from 1939 through 1943 and either released to spawn in tributaries between Rock Island and Grand Coulee Dams or spawned in hatcheries and the offspring released in that area (Peven 1990, Mullan et al. 1992, Chapman et al. 1994). Through this process, stocks of all anadromous salmonids, including steelhead, which historically were native to several separate subbasins above Rock Island Dam, were randomly redistributed among tributaries in the Rock Island-Grand Coulee reach. Exactly how this has affected stock composition of steelhead is unknown.

### Widespread Steelhead Broodstocks

Several steelhead broodstocks have been widely used in steelhead propagation. These broodstocks have had the greatest potential to affect native steelhead populations due

Table 8. Steelhead smolt production by hatcheries, listed from north to south (Light 1989*).

| Location (number of hatcheries) | Average annual smolt production, 1978-87 | Percent of coastwide total |
|---|---|---|
| Alaska (4) | 62,000 | 0.2 |
| British Columbia (22) | 616,000 | 2.5 |
| Washington (44) | 6,782,000 | 27.6 |
| Idaho (4)* | 10,320,000 | 41.9 |
| Oregon (26) | 4,537,000 | 18.4 |
| California (9) | 2,304,000 | 9.4 |
| Total (109) | 24,621,000 | 100.0 |
| *Revised below to include new data (IDFG 1995)** | | |
| Alaska (4) | 62,000 | *0.3* |
| British Columbia (22) | 616,000 | *3.1* |
| Washington (44) | 6,782,000 | *34.5* |
| *Idaho (4)** | *5,372,000* | *27.3* |
| Oregon (26) | 4,537,000 | *23.1* |
| California (9) | 2,304,000 | *11.7* |
| Total (109) | *19,673,000* | *100.0* |

*Data from IDFG (1995) are inconsistent with those in Light (1989); we were unable to resolve this inconsistency. As Light's (1989) data have been presented in previous documents (Busby et al. 1993, 1994), IDFG's (1995) modified data are presented in the bottom half of the current table, including adjusted percentage of total production. Revised numbers are *italicized.*

to their broad distribution and extensive incorporation into various steelhead propagation programs throughout the west coast.

**Chambers Creek winter steelhead**—This stock of winter steelhead comes from Chambers Creek, Tacoma, Washington and was first cultured in the 1920s (Crawford 1979). Chambers Creek steelhead have been introduced throughout western Washington, including the Puget Sound region, and in tributaries of the lower Columbia River. As much as 90% of steelhead harvested from some western Washington streams can be attributed to Chambers Creek winter steelhead, through artificial and established natural production (Crawford 1979, WDF et al. 1993). Concerns over genetic introgression into native stocks by Chambers Creek steelhead led to attempts to establish native brood stocks in Washington (Crawford 1979); however, the Chambers Creek steelhead stock is still considered essential to most of Washington winter steelhead hatchery operations (Huew et al. 1990, WDF et al. 1993).

**Skamania summer steelhead**—Skamania summer steelhead were developed from Washougal and Klickitat River summer steelhead in the late 1950s at the Skamania Hatchery, Washington (Crawford 1979). This stock has been widely used in Washington, Idaho, Oregon, California, Indiana, Rhode Island, and North Carolina (Crawford 1979, CDFG 1994). In many cases, Skamania stock have been introduced where summer steelhead did not naturally exist, to provide recreational angling opportunities, for example, the Willamette River. Additionally, Skamania stock have been introduced in river basins having endemic summer steelhead populations, such as the Stillaguamish and Columbia River tributaries.

**Alsea River winter steelhead**—This stock is originally from the Alsea River, Oregon and has been cultured since the 1930s (ODFW 1986). Historically introduced into most coastal Oregon streams since the 1980s, Alsea stock have primarily been used on the central Oregon coast (Salmon River south to Coquille River) and occasionally in the lower Columbia River Basin (ODFW 1986, CBFWA 1990).

**Big Creek and Cowlitz River winter steelhead**—These two stocks dominate the production of hatchery winter steelhead in the lower Columbia River Basin—the Big Creek stock on the Oregon side, and the Cowlitz stock on the Washington side (CBFWA 1990). The Big Creek stock was developed in the 1960s from the earliest maturing steelhead native to Big Creek (Howell et al. 1985). The initial source for the Cowlitz Hatchery stock was a 1:1 mix of Chambers Creek and native Cowlitz River fish (Crawford 1979). The Big Creek and Cowlitz Hatcheries produce about 700,000 and 650,000 smolts per year, respectively, which are released into most major river basins tributary to the Columbia River below Bonneville Dam (Howell et al. 1985). Cowlitz stock steelhead eggs have been used in hatchery programs of other states, including California (Howell et al. 1985, CDFG 1994). Big Creek winter steelhead have established naturally reproducing populations in the upper Willamette River Basin (Howell et al. 1985).

**Eel River winter steelhead**—Eggs collected from Eel River winter steelhead were used in establishing several CDFG steelhead hatchery programs, for example. Mad River and Nimbus Hatcheries, until steelhead returns to these hatcheries supplied sufficient eggs for the hatcheries' production goals without such supplementation (CDFG 1994,1995; Will[14]). Eel River winter steelhead eggs are collected at an egg-taking station located at Cape Horn Dam, northeast of Ukiah, California. This facility, originally named Snow Mountain Station, was established by Snow Mountain Light and Power Company in 1907; since the 1960s the egg taking station has been operated by the California Department of Fish and Game under the name Van Arsdale Fisheries Station[15]. Incorporation of Eel River steelhead into hatchery programs generally occurred prior to 1975; most eggs collected since then have been reared off-site, usually at Mad River Hatchery, then returned to the Eel River (CDFG 1994, Will footnote 14).

**Wells Hatchery summer steelhead**—Summer steelhead from the Wells Hatchery are the primary stock used in the Columbia River Basin above Rock Island Dam (Chapman et al. 1994). The stock was developed in the early 1960s from naturally spawning populations intercepted at fish passage facilities above Priest Rapids Dam (see page 72, Grand Coulee Fish Maintenance Project). Since 1970, the Wells stock has been distributed in the Columbia River Basin from the Big White Salmon River upstream to the Grand Ronde River in the Snake River Basin, and the Similkameen River, a tributary of the Okanogan River (Howell et al. 1985). About 1 million Wells summer steelhead are released annually (Howell et al. 1985).

**Lyons Ferry summer steelhead**—Lyons Ferry Hatchery was constructed in the early 1980s to provide summer steelhead for streams in southeast Washington, including both the Snake and Walla Walla River Basins (Delarm and Smith 1990d). The Lyons Ferry stock was derived from eggs obtained from ODFW's Wallowa Hatchery on the Grande Ronde River, augmented with occasional transfers of Wells Hatchery stock (Delarm and Smith 1990d). About 1 million fish per year are produced at the Lyons Ferry Hatchery (Delarm and Smith 1990d).

**Dworshak summer steelhead**—This stock was developed from native B-run North Fork Clearwater River summer steelhead in 1969 (Howell et al. 1985). As many as 3 million fish are released from Dworshak NFH every year, mostly into the Clearwater River Basin, although limited introductions have occurred in the Salmon and Snake Rivers as well (Howell et al. 1985).

**Summary of Artificial Propagation by ESU**

In general, hatchery stocks of steelhead have been widely introduced throughout the west coast of the United States, so that today there are few native steelhead stocks that have not had some influence from hatchery operations (Crawford 1979, Howell et al 1985, Light

[14] B. Will, Manager, Rowdy Creek Fish Hatchery, P.O. Box 328, Smith River, CA 95567. Pers. commun., May 1995.

[15] In the present document, we will use the contemporary name, Van Arsdale Fisheries Station, when referring to this propagation facility.

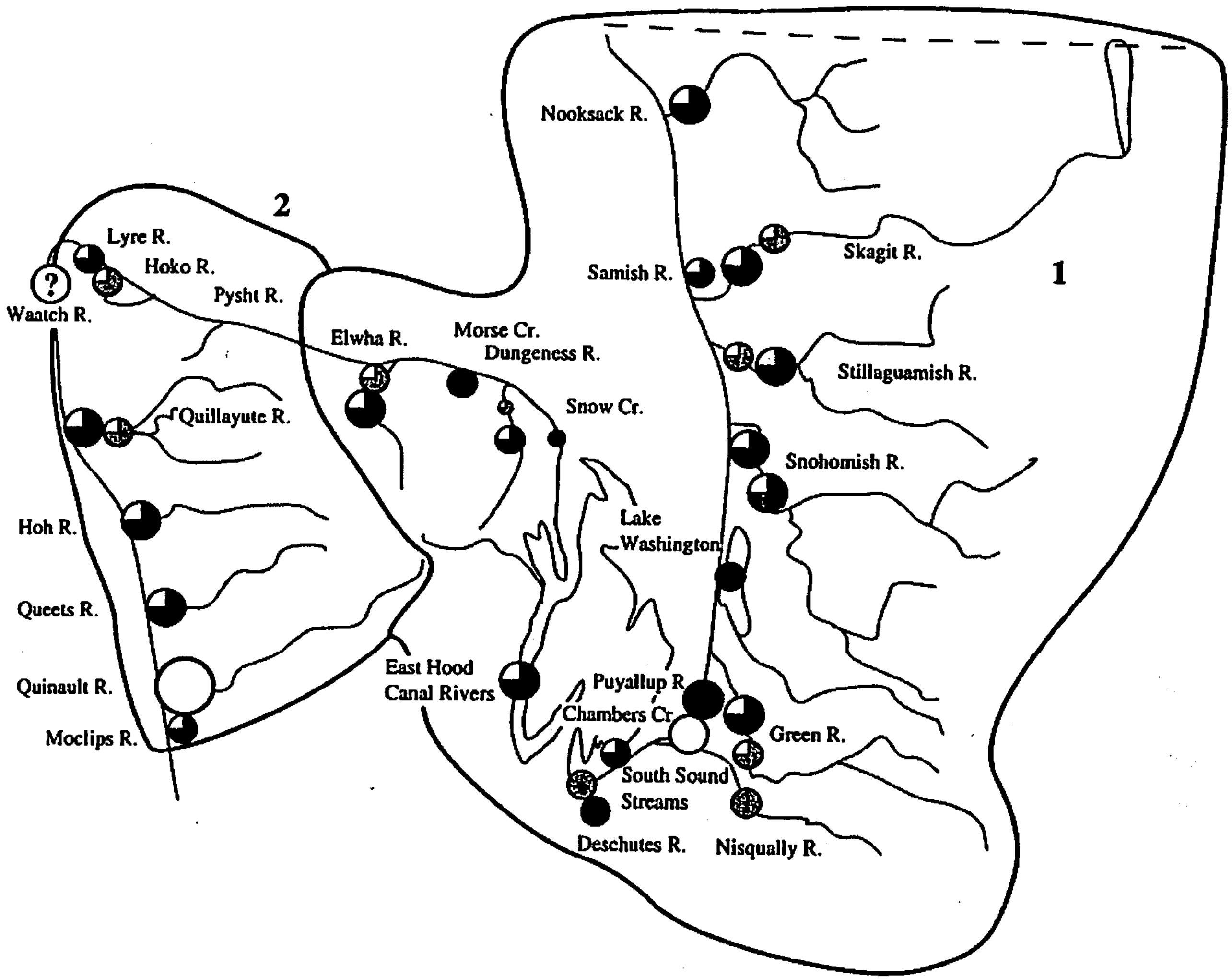
1989, Cramer et al 1995, ODFW 1994a-c). In this section, we present a brief overview of the artificial propagation activities within the geographic ranges of the 15 west coast steelhead ESUs.

**1) Puget Sound**—Artificial propagation of steelhead in the range of the Puget Sound ESU is pronounced (Fig. 10). About 1,500,000 winter steelhead and 400,000 summer steelhead, mostly smolts, are released annually into river basins in this area (WDF et al. 1993, WDFW 1994a). Hatchery programs in the Puget Sound region largely rely on Chambers Creek winter steelhead and Skamania-stock summer steelhead (Crawford 1979, Huew et al. 1990). The abundance of hatchery winter steelhead in Puget Sound results in a target harvest rate of 90% (WDF et al. 1993). Most Skamania-stock summer steelhead are introduced into streams not previously utilized by summer steelhead, although this stock is also routinely planted in streams containing indigenous Puget Sound summer steelhead, such as the Skagit, Stillaguamish, and Snohomish River systems (Crawford 1979). The Nisqually River is the only major river in Puget Sound not receiving hatchery winter steelhead (WDF et al. 1993); however, this river is planted with about 24,000 Skamania-stock summer steelhead per year (WDFW 1994a).

**2) Olympic Peninsula**—The hatchery effort for steelhead on the Olympic Peninsula is pronounced, but not to the extent found in Puget Sound, especially for summer steelhead (Fig. 10). About 40,000 summer steelhead, primarily Skamania stock, are released annually on the Olympic Peninsula, all in the Quillayute River Basin (Crawford 1979, WDF et al. 1993). However, these fish are known to stray into many nearby river systems when returning to fresh water as adults (WDF et al. 1993). About 840,000 winter steelhead, primarily from a stock designated as "Bogachiel/Chambers Creek," are planted annually in this area (WDF et al. 1993, WDFW 1994a).

Recently, wild steelhead have been incorporated into the hatchery stocks being planted into a few streams in this area. However, based on the early spawn timing necessary for compatibility with hatchery spawning protocols (WDF et al. 1993), most of these wild fish would likely have a significant hatchery ancestry themselves. Hatchery fish derived from native winter steelhead populations are released into the Quinault River and other streams occupied by this ESU. However, because of the influence of nonindigenous stocks that are also planted in the Quinault River Basin, the naturally spawning winter steelhead are thought to be of mixed origin (WDF et al. 1993).

**3) Southwest Washington**—Southwest Washington winter steelhead hatchery stocks were originally derived from the Chambers Creek stock (Puget Sound origin) (Fig. 11), but recent hatchery efforts in southwest Washington streams have emphasized using stocks of local origin (WDF et al. 1993). Dominant winter steelhead hatchery stocks used in Columbia River tributaries occupied by this ESU are Beaver Creek Hatchery (Elochoman River/ Chambers Creek origin) in Washington, and Gnat and Big Creek steelhead stocks in Oregon (Howell et al. 1985, ODFW 1993, WDF et al. 1993). Hatchery programs for summer steelhead in this region use the Skamania stock, and the majority of all summer steelhead returning to rivers in this ESU are Skamania hatchery fish (WDF et al. 1993).



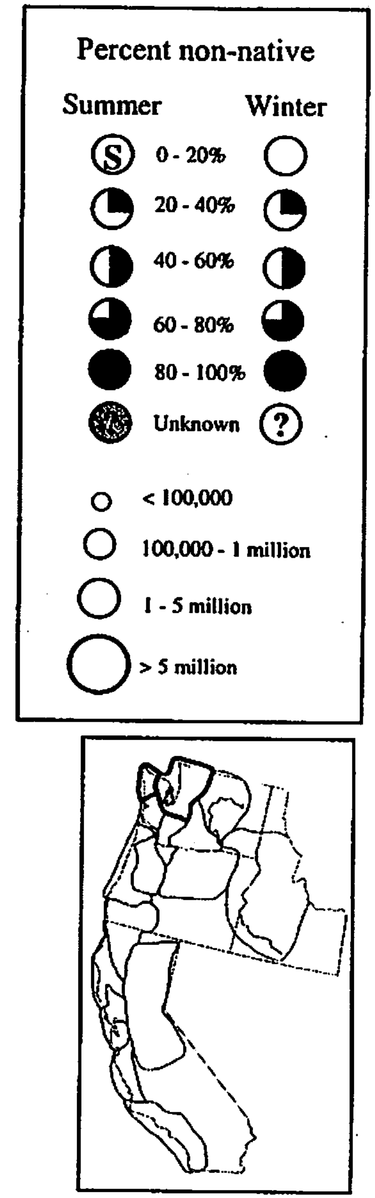




Figure 10. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 1-Puget Sound and 2-Olympic Peninsula, for the period 1980-94. Size of circles represents the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Huew et al. 1990, WDF et al. 1993, WDFW 1994a).

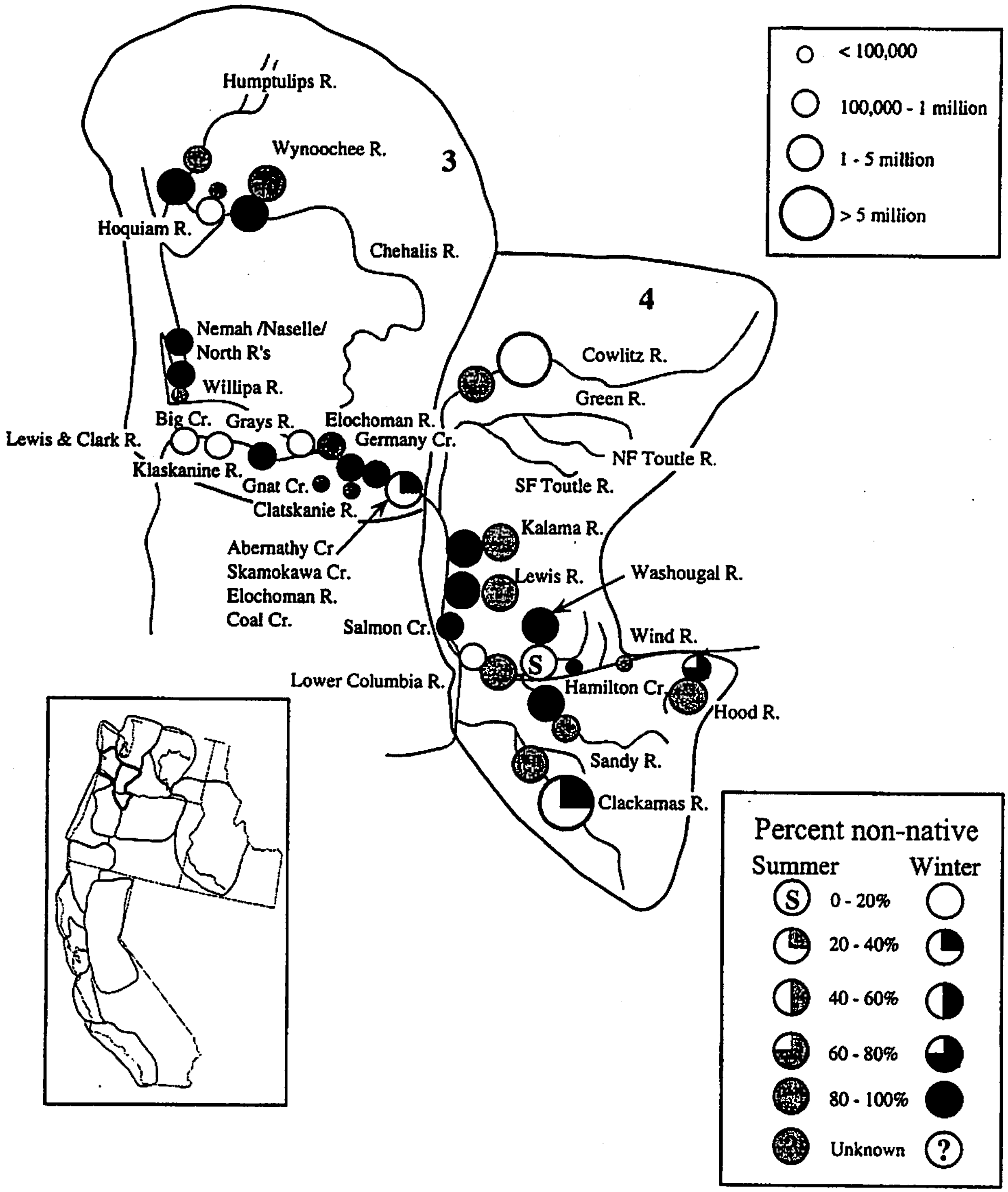



Figure 11. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 3-Southwest Washington and 4-Lower Columbia River, for the period 1980-94. Size of circles represents the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, WDF et al. 1993, ODFW 1994c, WDFW 1994a).

**4) Lower Columbia River**—More than 2 million winter steelhead and over 1 million summer steelhead smolts are released each year within the basins occupied by the Lower Columbia River ESU (Fig. 11). The primary winter steelhead stocks used in hatchery programs in the Lower Columbia River are from Eagle Creek and Gnat Creek Hatcheries in Oregon, and Beaver Creek (Elochoman River/Chambers Creek origin) and the Cowlitz River in Washington (Howell et al. 1985). Chambers Creek winter steelhead from Puget Sound are also an important component of Lower Columbia River hatchery management (Howell et al. 1985). In some cases, the influence of hatchery steelhead is pronounced: Cowlitz River "wild" winter steelhead are almost all the progeny of feral Cowlitz Hatchery steelhead (WDF et al. 1993). Skamania-stock summer steelhead are used extensively in both Washington and Oregon tributaries of the Lower Columbia River (Howell et al. 1985, ODFW 1994c, WDF et al. 1993).

**5) Upper Willamette River**—Over 175,000 winter steelhead are released annually into the region occupied by this ESU (Howell et al. 1985, ODFW 1994c) (Fig. 12). Most of these are from hatchery stocks derived from native winter steelhead from the Santiam River system. However, substantial numbers of Gnat Creek (i.e., Big Creek-stock) winter steelhead from the lower Columbia River are also introduced into the area every year (Howell et al. 1985, ODFW 1994c). The latter transplants have succeeded in establishing naturally reproducing populations of Big Creek-stock steelhead in the Upper Willamette River Basin (Howell et al. 1985). Summer steelhead are not native to the upper Willamette River, but Skamania-stock summer steelhead are planted in this area (Howell et al. 1985, ODFW 1994c). Natural production of summer steelhead appears to be low (2.5% of total run in 1981), and the population is largely maintained by releases of hatchery fish (Howell et al. 1985).

**6) Oregon Coast**—Over 1,300,000 winter steelhead and more than 350,000 summer steelhead are targeted for release in 1995 into Oregon coastal streams north of Cape Blanco (ODFW 1994b). As is the case in several other steelhead ESUs, few Oregon coastal hatchery stocks are native to the rivers receiving them (ODFW 1994a,c) (Fig. 12). However, releases of specific hatchery steelhead stocks along the Oregon coast generally occur only within certain geographic areas. For example, the Nehalem River hatchery stock is not planted in streams south of the Nehalem River; Cedar Creek hatchery steelhead are released from the Miami River south to the Little Nestucca River; Alsea Hatchery steelhead are released from the Salmon River south to the Smith River (Umpqua River Basin); the Umpqua River is planted only with its own stocks; and Coos/Coquille stock are used in rivers south of Coos Bay to Cape Blanco (ODFW 1994b). Nonetheless, the overall impact of hatchery steelhead on the Oregon coast is significant. For instance, of 19 Oregon coastal rivers examined for hatchery influence, all but 2, the Coquille and North Umpqua Rivers, receive hatchery fish that are "genetically dissimilar to wild fish" (ODFW 1994a). Furthermore, it is estimated that 54% of the total number of winter steelhead spawning in these rivers are of hatchery origin (ODFW 1994a). All summer steelhead in this ESU, apart from those in the Siletz and Umpqua River Basins, are introduced from the Siletz River. Within the Siletz River, about 90% of the naturally spawning summer steelhead are of hatchery origin (ODFW 1994a). North Umpqua River summer steelhead is the only stock of hatchery steelhead on the Oregon Coast considered by ODFW to be genetically similar to the native steelhead from the area in which it is released. This hatchery stock is derived from the native North Umpqua fish, and

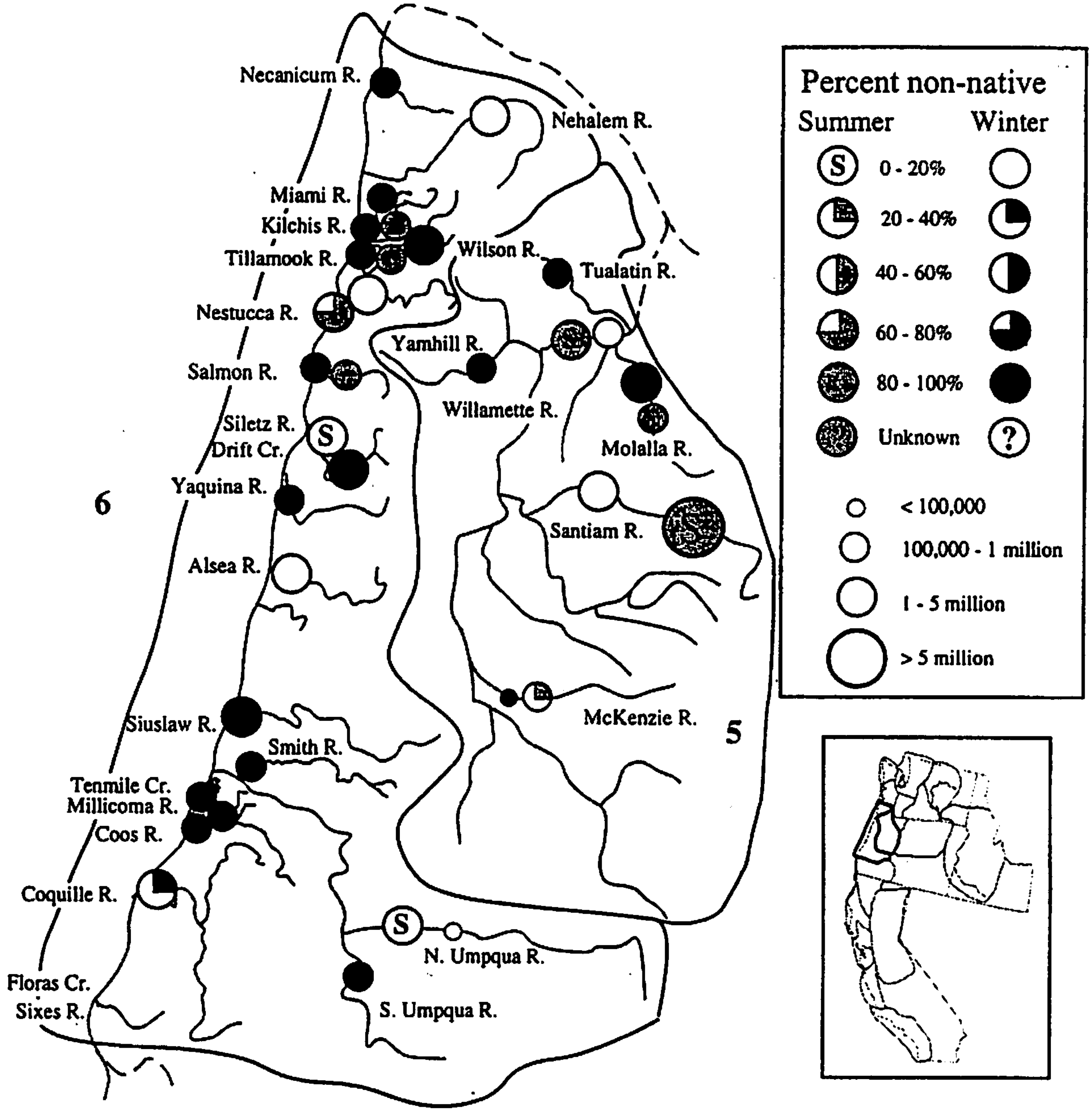



Figure 12. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, ODFW 1994c).

little attempt has been made to alter the stock's life history characteristics (e.g., migration and spawn timing) (ODFW 1994a).

**7) Klamath Mountains Province**—Total production of hatchery steelhead in the rivers occupied by this ESU is about 1,500,000 fish per year, of which about 320,000 are winter steelhead and the remainder are summer or fall steelhead (Busby et al. 1994) (Fig. 13). Steelhead released into the Chetco and Rogue River Basins are derived primarily from local stocks; however, prior to 1970 Alsea Hatchery steelhead were released into the Chetco River (ODFW 1986). Although hatchery production in the Klamath River Basin relies primarily on broodstock returns to the hatcheries, the Iron Gate or Trinity Hatcheries in the Klamath River system received transfers of stock from the Cowlitz and Washougal Hatcheries, as well as transfers from the Sacramento, Willamette, Mad, and Eel River Basins prior to 1973 (Busby et al. 1994). In general, the rivers in this area are planted with hatchery fish derived primarily from native stocks (e.g., Chetco, Rogue, and Klamath Rivers), or apparently are not stocked at all (e.g., Pistol, Winchuck, and Illinois Rivers) (ODFW 1994c).

**8) Northern California**—The primary steelhead hatchery within the range of this ESU is Mad River Hatchery, established in 1971 by CDFG for fisheries enhancement (McEwan and Jackson 1996). The Mad River Hatchery winter steelhead stock was founded with steelhead eggs from the Eel River (Van Arsdale Fisheries Station, see page 74) and the San Lorenzo River (Cramer et al. 1995; Will footnote 14). Returns of steelhead to Mad River Hatchery were sufficient to supply the hatchery's production needs by 1974 (Cramer et al. 1995). Van Arsdale Fisheries Station continues to transfer Eel River steelhead eggs to Mad River Hatchery for rearing and subsequent release into the Eel River (CDFG 1994). The migration and spawn timings of hatchery stocks in northern California have been truncated since hatchery operations began (Cramer et al. 1995). In addition, both Mad River Hatchery and Van Arsdale Fisheries Station release unsmolted steelhead (CDFG 1994), which have been shown to survive poorly to spawning age (Cramer et al. 1995).

Introduced Skamania-stock summer steelhead appear to be reproducing naturally in the Mad River (Cramer et al. 1995). An average of 96,000 juvenile steelhead of Van Arsdale Fisheries Station and Mad River Hatchery stock origins have been released annually into the Eel River Basin since 1970 (CDFG 1994). Approximately 233,000 juvenile steelhead of various stock origins are released annually into Mad River (CDFG 1994). All other basins in this area together receive about 75,000 steelhead per year (Cramer et al. 1995), for a total annual hatchery release of at least 404,000 steelhead within the range of the Northern California ESU (Fig. 13).

**9) Central California Coast**—Warm Springs Hatchery on the Russian River is currently the only major steelhead facility within the region occupied by this ESU; however, release records show that a substantial number of steelhead from Mad River Hatchery are released in this area (CDFG 1994) (Fig. 14). In the early part of the century, steelhead from the Scott Creek Hatchery, themselves a mix of various steelhead stocks from Oregon and Washington, were widely introduced throughout the smaller river basins in this area (Bryant 1994). Although few out-of-basin stocks have been transferred into Warm Springs Hatchery, Mad River Hatchery and Eel River steelhead have been introduced directly into the Russian

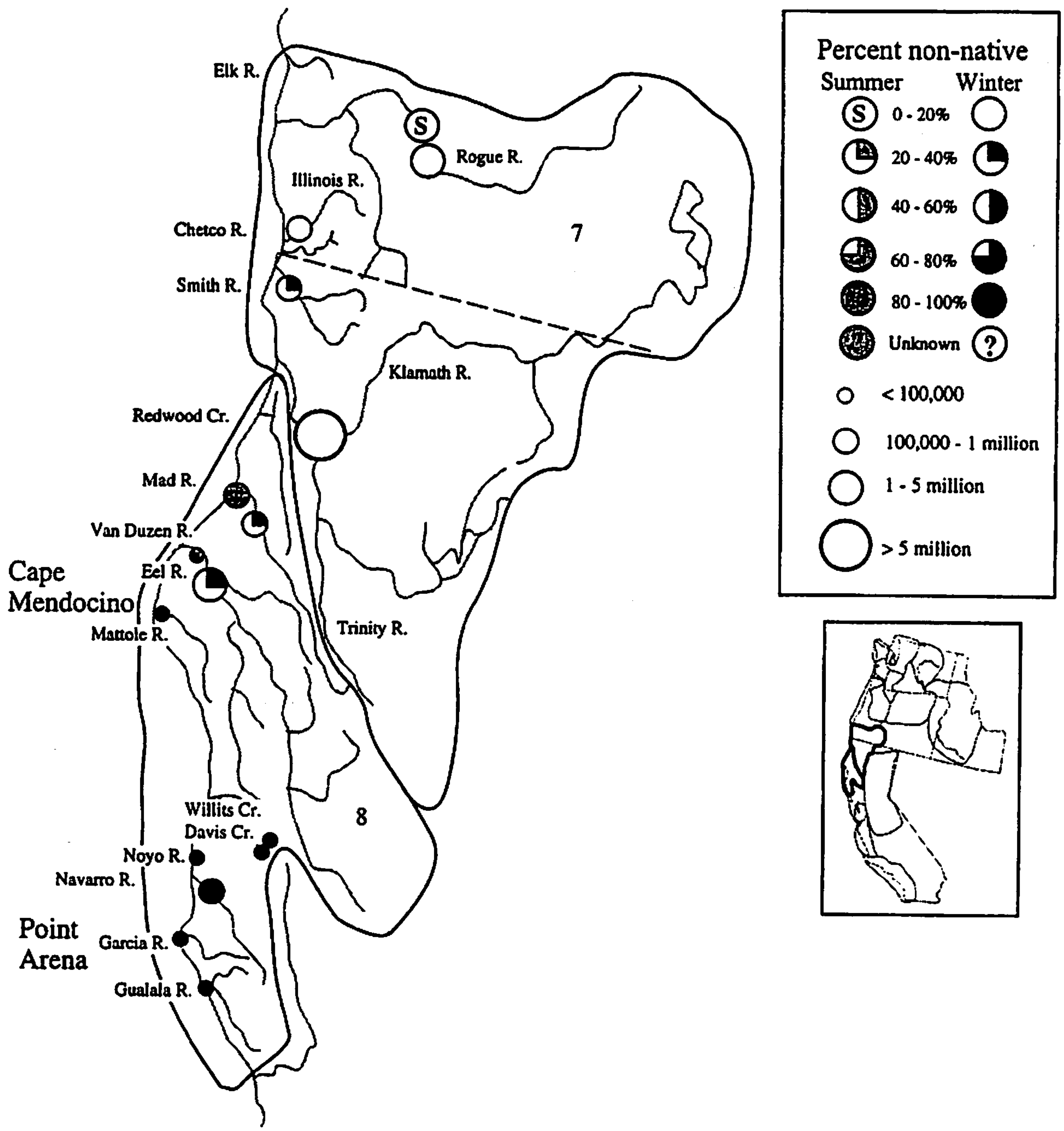



Figure 13. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 7-Klamath Mountains Province and 8-Northern California, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (CDFG 1994, ODFW 1994c, Cramer et al. 1995).

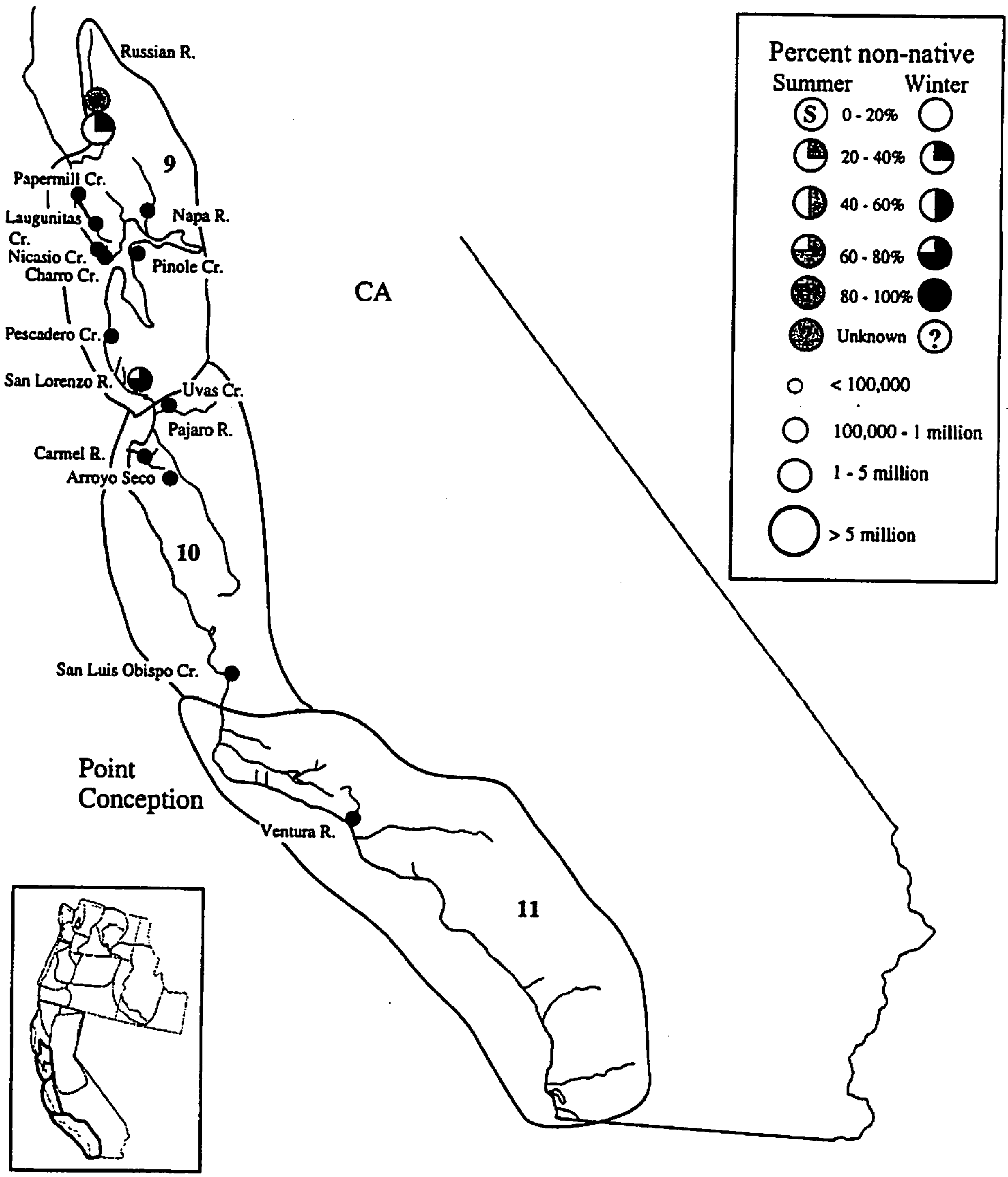



Figure 14. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California, for the period 1971-90. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (CDFG 1994, Cramer et al. 1995).

River as recently as 1991, and many river and creek basins in this area periodically receive Mad River Hatchery steelhead (CDFG 1994). Since 1971, the Russian River has received about 140,000 fish per year of various stocks (CDFG 1994, Cramer et al. 1995). Release records for hatchery steelhead in other basins occupied by the Central California Coast ESU are incomplete and are not reported here.

**10) South-Central California Coast**—Artificial propagation efforts for steelhead have not been extensive in this region (Fig. 14). For example, since 1971, about 16,000 Mad River Hatchery winter steelhead have been planted into the Carmel River and San Luis Obispo Creek (CDFG 1994).

**11) Southern California**—Compared to many other areas, the hatchery effort in southern California has not been extensive (Fig. 14). Between 1910 and 1940, sporadic introductions of steelhead into various streams within rivers occupied by this ESU were made with small lots of more northerly stocks, primarily from Scott Creek, Central California ESU (Bryant 1994). No records were found pertaining to hatchery activity in this region between 1940 and 1970. Since the early 1970s, steelhead from state hatcheries have been periodically released in this area, but not on a large scale. For example, about 50,000 Mad River Hatchery steelhead have been planted in southern California streams in the last 20 years, mainly in the Ventura River and Arroyo Seco Creek (CDFG 1994).

**12) Central Valley**—There appear to be no steelhead-bearing rivers in the Sacramento River Basin that have not received releases of multiple hatchery stocks (CDFG 1994, Cramer et al. 1995) (Fig. 15). Major steelhead production facilities within the Central Valley of California include: Coleman NFH, Feather River Hatchery, Mokelumne River Fish Installation, and Nimbus Hatchery. Each of these facilities has utilized steelhead stocks originating from within the basin as well as out-of-basin stocks; stock transfers between the Central Valley steelhead facilities have historically been commonplace (CDFG 1994).

Nimbus Hatchery, located on the American River (tributary to the Sacramento River), was founded with Eel River winter steelhead from Van Arsdale Fisheries Station and returning American River steelhead; Mad and Russian River stocks, as well as Sacramento River stocks, have been mixed into the Nimbus Hatchery population over time (CDFG 1994, Cramer et al. 1995). To mitigate the loss of steelhead in the Mokelumne River (San Joaquin River Basin) following completion of Comanche Dam in 1963, Nimbus stock, as well as fish from Coleman NFH and Feather River Hatchery, have been introduced to the Mokelumne River (CDFG 1994, Cramer et al. 1995, McEwan and Jackson 1996). Further mixing of steelhead stocks in the Sacramento River Basin may result from straying by hatchery stocks within the basin, which has been observed to be as high as 24-35% in some cases (Hallock 1989, Cramer et al. 1995). Since 1983, about 2,800,000 juvenile steelhead have been released annually into the Sacramento River Basin (CDFG 1994, Cramer et al. 1995, McEwan and Jackson 1996).

Attempts to establish a summer steelhead fishery in the Central Valley began in the late 1960s and continued intermittently into the 1980s using Skamania-stock (see page 74) summer steelhead (CDFG 1994). Despite successful returns of summer steelhead to Nimbus

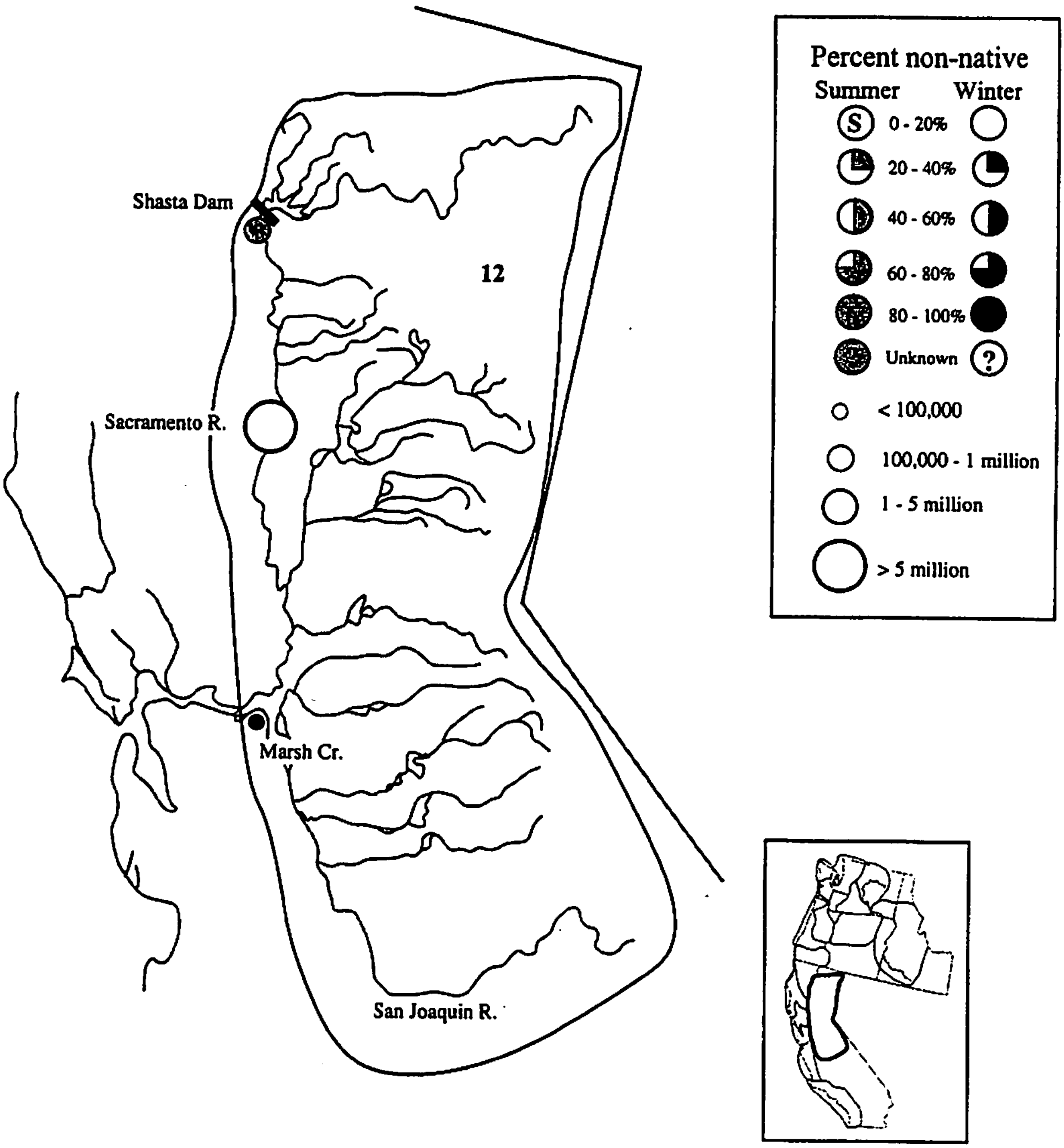



Figure 15. Total releases of hatchery steelhead into rivers occupied by steelhead ESU 12-Central Valley, for the period 1971-90. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (CDFG 1994, Cramer et al. 1995).

Hatchery, this program appears to have been discontinued; the last record of Skamania-stock releases from Nimbus hatchery occurred in fiscal year 1980-81 (CDFG 1994). Recent CDFG documents and communications (e.g., CDFG 1995, McEwan and Jackson 1996) on steelhead do not mention summer steelhead in the Central Valley.

**13) Middle Columbia River**—Over 2 million hatchery summer steelhead are released into the rivers occupied by this ESU every year (Howell et al. 1985, CBFWA 1990, Delarm and Smith 1990c,d) (Fig. 16). Hatchery steelhead in the Deschutes River are derived from native stock, as is the current hatchery stock used in the Umatilla River, although both systems received small plants of out-of-basin stocks many years ago (Howell et al. 1985). However, strays from several Columbia River Basin hatcheries are common in the Umatilla and Deschutes Rivers, where they can amount to 20% of the steelhead handled at Warm Springs Hatchery (Howell et al. 1985). Various stocks have been, or are being, introduced into other rivers in this region, with the Yakima River alone receiving Skamania, Wallowa, Wells, and Lyons Ferry steelhead stocks from other ESUs (Howell et al. 1985, ODFW 1994c, WDFW 1994a). The John Day River in this ESU is not planted with steelhead (Howell et al. 1985). In the Yakima River Basin, Satus Creek is reserved as a genetic refuge for native steelhead and is not planted (Howell et al. 1985).

**14) Upper Columbia River**—Over 1,500,000 summer steelhead are released into this ESU annually (Howell et al. 1985, CBFWA 1990, Delarm and Smith 1990d, Chapman et al. 1994, WDFW 1994a) (Fig. 16). Beginning in the early 1940s, the wild stocks of steelhead in this ESU were thoroughly mixed as a result of the Grand Coulee Fish Maintenance Project, enacted to salvage fish runs blocked by the construction of Grand Coulee Dam (Fish and Hanavan 1948, Mullan et al. 1992). All steelhead, including those destined for Canadian streams, were collected at Rock Island Dam and distributed to streams in this region. In addition, some of the mixture of returning adults were used to establish the hatchery stocks used in this region (Fish and Hanavan 1948, Mullan et al. 1992). As a result, the stocks in this ESU have essentially been homogenized since that time. The progeny of hatchery broodstock collected at a few locations in the upper Columbia River continue to be released throughout the region (Chapman et al. 1994).

**15) Snake River Basin**—Artificial propagation of steelhead within the rivers occupied by the Snake River Basin ESU produces annual releases in excess of 10 million smolts (Howell et al. 1985, CBFWA 1990, Delarm and Smith 1990a-d, ODFW 1994c, WDFW 1994a) (Fig. 17). Hatcheries in this area are operated by the states of Washington, Idaho, and Oregon, as well as the U.S. Fish and Wildlife Service. Most of the stocks used in these hatcheries are from within the ESU; however, there has been substantial mixing of these stocks among facilities. Several propagation facilities are operated to mitigate two series of dams on the Snake River.

The Lower Snake River Compensation Plan (LSRCP) was developed to mitigate fishery losses due to four dams on the lower Snake River (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams). The LSRCP steelhead facilities include Dworshak and Hagerman NFHs, and Clearwater, Sawtooth, and Magic Valley Hatcheries.

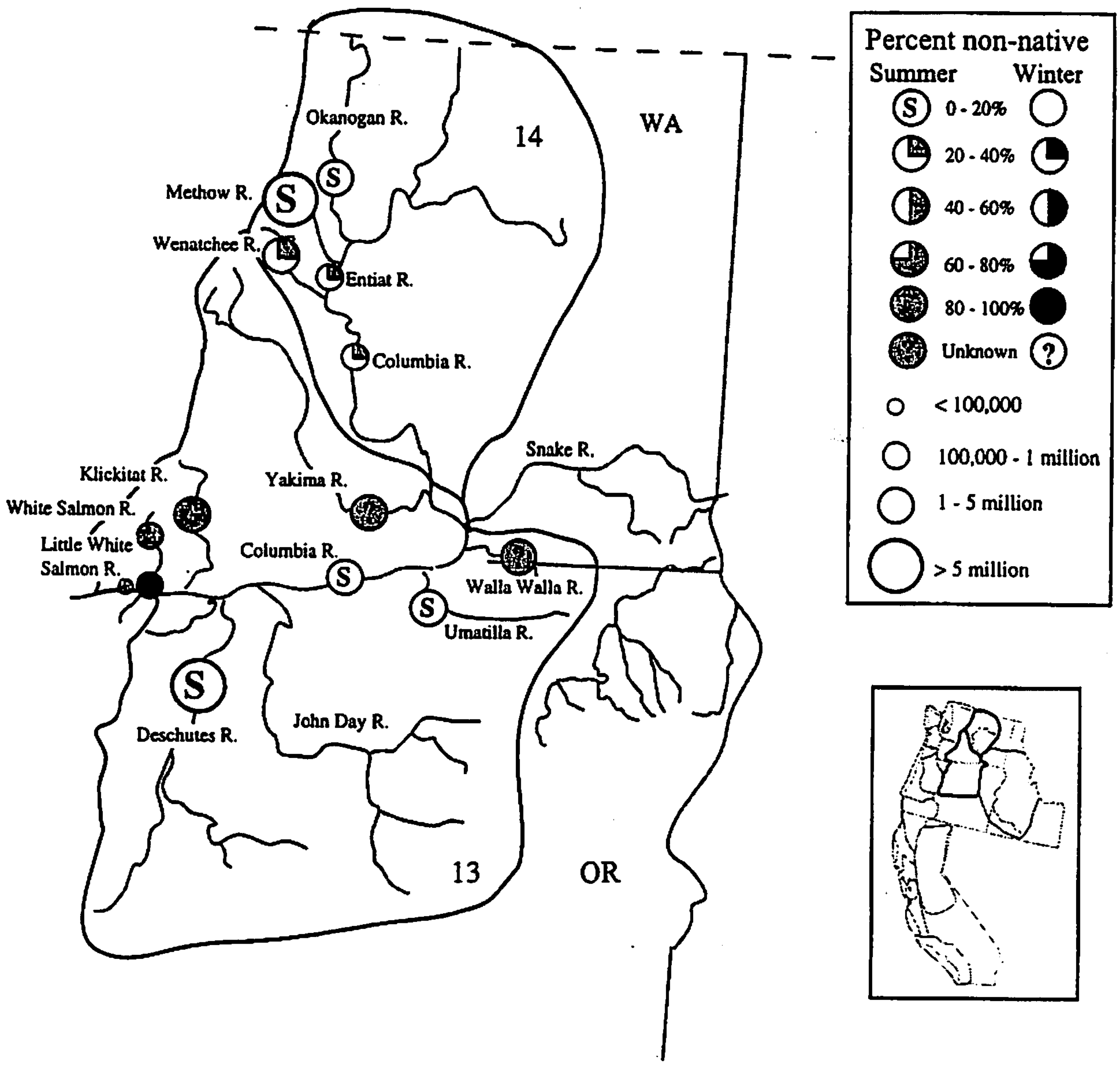



Figure 16. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 13-Middle Columbia River and 14-Upper Columbia River, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Shelldrake 1993, ODFW 1994c, WDFW 1994a).

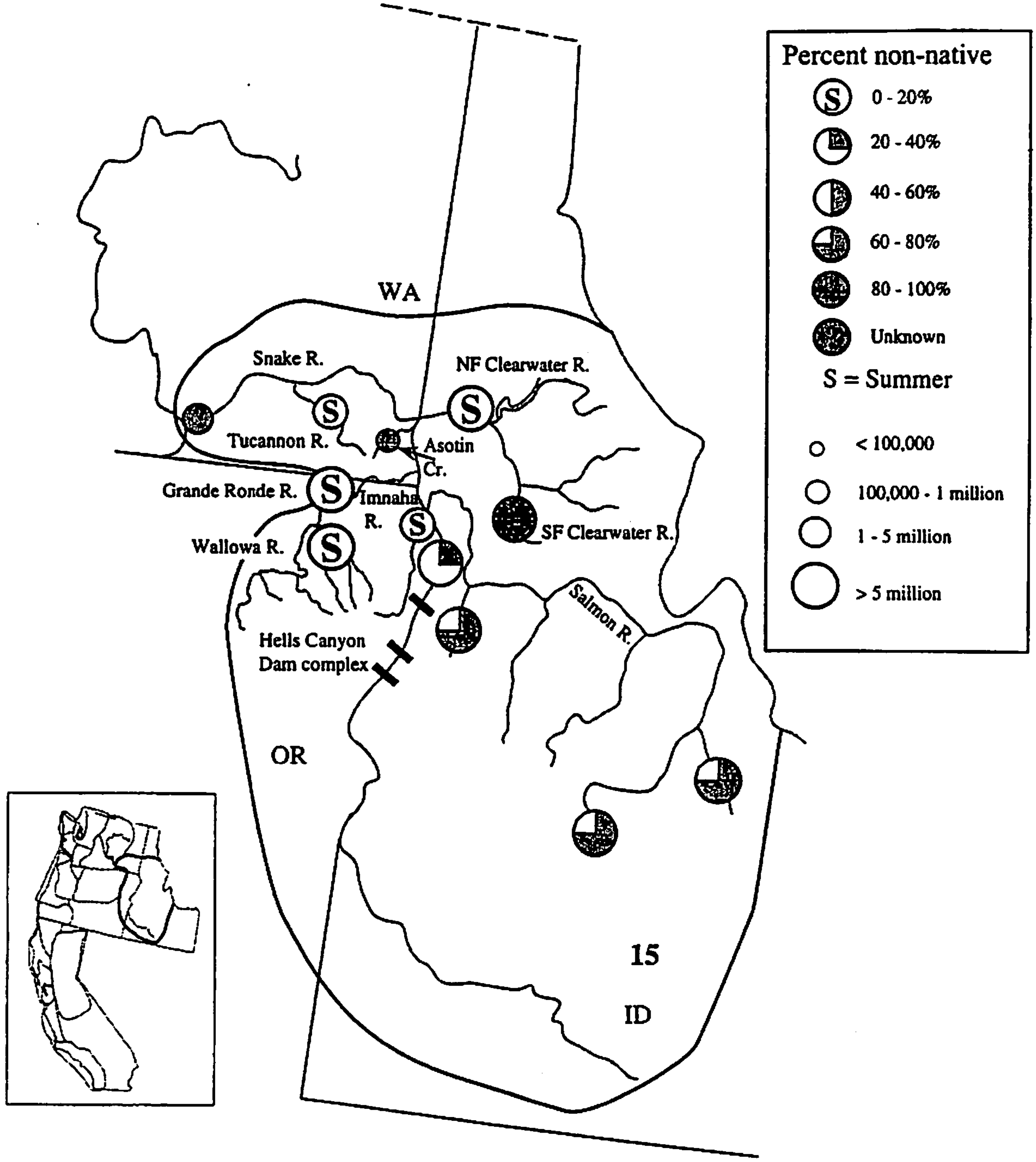



Figure 17. Total releases of hatchery steelhead into rivers occupied by steelhead ESU 15-Snake River Basin, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Hutchison 1993, Shelldrake 1993, ODFW 1994c, WDFW 1994a). All data are for summer steelhead.

The Hells Canyon Complex forms the second series of dams (Hells Canyon, Oxbow, and Brownlee Dams); these block anadromous fish passage to the upper Snake River Basin. Steelhead mitigation facilities for the Hells Canyon Complex include Oxbow, Pahsimeroi, and Niagara Springs Steelhead Hatcheries. One goal of the Hells Canyon Complex mitigation was to relocate part of the upper Snake River steelhead run to the Salmon River. To accomplish this, steelhead broodstock are collected at Hells Canyon Dam, spawned at Oxbow Hatchery, and the fertilized eggs are transferred to rearing facilities, such as Niagara Springs Steelhead Hatchery (Hutchison 1993). These steelhead are subsequently released as smolts at various locations within the Salmon River Basin, primarily near Sawtooth and Pahsimeroi Hatcheries (Hutchison 1993, Kiefer[16]). These activities resulted in the development of the "Pahsimeroi stock," which was originally composed of indigenous Salmon River Basin steelhead combined with upper Snake River steelhead. This Pahsimeroi stock was also used to start the steelhead program at Sawtooth Hatchery. In recent years, wild steelhead have been passed above Pahsimeroi and Sawtooth Hatcheries, and only hatchery-origin fish have been used for broodstock.

Within the Snake River Basin, Dworshak NFH and Clearwater Hatchery appear to be the only facilities that have not incorporated out-of-basin steelhead into their broodstock.

## ASSESSMENT OF EXTINCTION RISK

### Background

As outlined in the Introduction above, NMFS considers a variety of information in evaluating the level of risk facing an ESU. Aspects of several of these risk considerations are common to all west coast steelhead ESUs. These are discussed in general below; more specific discussion of factors for each of the 14 ESUs under consideration here can be found in the following sections. The status of the Klamath Mountains Province ESU (ESU 7), has already been considered (Busby et al. 1994), and is referred to here only for comparison.

#### Absolute Numbers

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

[16] S. Kiefer, Fisheries Staff Biologist, Idaho Department of Fish and Game, 600 South Walnut, Box 25, Boise, ID 83707-0025. Pers. commun., June 1995.

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

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

Because the ESA (and NMFS policy) mandates that we focus on viability of natural populations, we attempted to distinguish natural fish from hatchery produced fish in this review. All statistics were based on data that indicated the total number or density of adults spawning in natural habitat (i.e., "naturally spawning fish"). The total of all naturally spawning fish (i.e., "total escapement") is divided into two components (Fig. 18): "Hatchery produced" fish which are reared as juveniles in a hatchery but return as adults to spawn naturally; and "natural" fish which are progeny of naturally spawning fish.

**Historical Abundance and Carrying Capacity**

The relationship of current abundance and habitat capacity to that which existed historically is an important consideration in evaluating risk. Knowledge of historical population conditions provides a perspective of the conditions under which present stocks evolved, as well as the basis for establishing long-term trends in populations. Comparison of present and past habitat capacity can also indicate long-term population trends and problems of population fragmentation. The relationship of present abundance to present carrying capacity is important for understanding the health of populations, but the fact that a population is near its current capacity does not in itself mean that it is healthy. For a population that is near capacity, there may be limits to the effectiveness of short-term management actions in increasing abundance. For such a population, competition and other interactions between hatchery and natural fish may also be important considerations because the addition of hatchery fish may further increase population density in a limited habitat.

For steelhead, quantitative abundance estimates are rarely available for periods before the 1950s. The main exceptions are long-term counts at dams in the Columbia River Basin and northern California that extend back to the 1930s or 1940s. Quantitative assessments of habitat are quite rare, although rough estimates of carrying capacity are frequently made for setting management goals. From the evidence available, it is clear that production of natural steelhead is now substantially below historical levels for all ESUs considered here, although

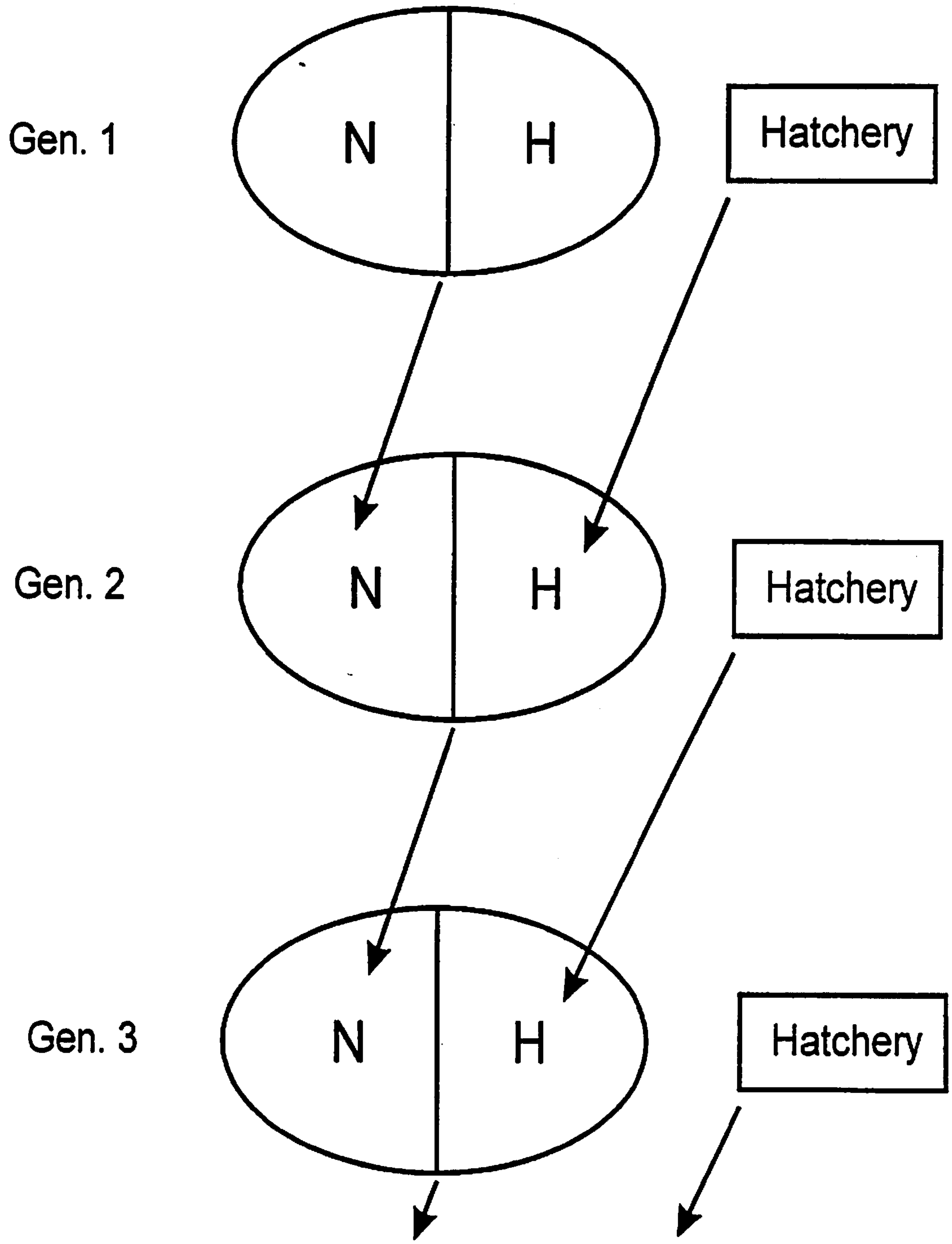



Figure 18. Schematic diagram of mixing of naturally and hatchery produced fish in natural habitat. Ovals represent the total spawning in natural habitat each generation. This total can be composed of naturally produced (N) and hatchery produced (H) offspring of individuals in the previous generation.

this decline in natural production has been offset to a variable extent by increasing hatchery production in many areas.

Although no analysis of the proportion of total habitat lost due to blockages has been attempted by us, there have been significant blockages of freshwater habitat in every ESU. Freshwater and estuarine habitats are also degraded throughout the entire region considered here, although the severity of degradation varies among ESUs and is described in the individual ESU summaries below.

**Trends in Abundance**

Short- and long-term trends in abundance are a primary indicator of risk in salmonid populations. Trends may be calculated from a variety of quantitative data, including dam or weir counts, stream surveys, and catch data. These data sources and methods are discussed in more detail below, under Approach to Risk Assessment. Regular sampling has not been conducted for many steelhead populations, and data series are quite short for most of those populations with sampling data. Where data series were lacking, we inferred general trends by comparing historical and recent abundance estimates, or by considering trends in habitat quantity or condition.

The important role of artificial propagation (in the form of hatcheries) for Pacific salmon and steelhead requires careful consideration in ESA evaluations. Artificial propagation has implications both for evaluating production trends and for evaluating the genetic integrity of populations. Waples (1991b) and Hard et al. (1992) discussed the role of artificial propagation in ESU determinations and emphasized the need to focus on natural production in a threatened or endangered status determination. To address this need, and because of the ESA's emphasis on ecosystem conservation, our analysis focused on naturally reproducing steelhead. A fundamental question in ESA risk assessments is whether natural production is sufficient to maintain the population without the continued infusion of artificially produced fish. A full answer to this question is difficult without extensive studies of relative production and interactions between hatchery and natural fish. When such information is lacking, the presence of hatchery fish in natural populations leads to substantial uncertainty in evaluating the status of a natural population.

One method of approaching this issue is to calculate the natural cohort replacement ratio, defined as the number of naturally spawning adults that are naturally produced in one generation divided by the number of naturally spawning adults (regardless of parentage) in the previous generation. Because data for steelhead are rarely sufficient for this calculation, we did not attempt to estimate this ratio in this report. However, the ratio can be approximated from the average population trend if the degree of hatchery contribution to natural spawning can be estimated (Busby et al. 1994, Appendix B). Where such estimates were available, the presence of hatchery fish among natural spawners was taken into consideration in evaluating the sustainability of natural production for individual populations within the ESUs identified.

Recent coastwide trends in steelhead abundance provided a larger perspective for this review. Between the 1890s and the 1960s, total U.S. commercial catch of steelhead declined

sevenfold, but this may reflect restrictions on the fishery more than declines in abundance. Rough estimates of total coastwide steelhead run size made in 1972 and 1987 were similar (Sheppard 1972, Light 1987). By all accounts, however, there has been significant replacement of natural production with hatchery fish. Throughout British Columbia, Washington, and Oregon, both natural and hatchery steelhead stocks have exhibited recent decreases in survival, which may be due at least in part to climate and ocean production (Cooper and Johnson 1992).

**Factors Causing Variability**

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

**Threats to Genetic Integrity**

In addition to its effect on natural replacement rates, artificial propagation can have a substantial impact on the genetic integrity of natural salmon and steelhead populations. This can occur in several ways. First, stock transfers that result in interbreeding of hatchery and natural fish can lead to loss of fitness in local populations and loss of diversity among populations. The latter is important to maintaining long-term viability of an ESU because genetic diversity among salmonid populations helps to buffer overall productivity against periodic or unpredictable changes in the environment (Riggs 1990, Fagen and Smoker 1989). Ricker (1972) and Taylor (1991) summarized some of the evidence for local adaptations in Pacific salmonids that may be at risk from stock transfers.

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

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

For smaller steelhead stocks (either natural or hatchery), small-population effects (inbreeding, genetic drift) can also be important concerns for genetic integrity. Inbreeding and genetic drift are well understood at the theoretical level, and researchers have found evidence of inbreeding depression in various fish species (Allendorf and Ryman 1987). Other studies have shown that hatchery practices commonly used with anadromous Pacific

salmonids have the potential to affect genetic integrity (e.g., Simon et al. 1986, Withler 1988, Waples and Teel 1990). However, we are not aware of empirical evidence for inbreeding depression or loss of genetic variability in any natural or hatchery populations of Pacific salmon or steelhead.

One type of genetic change in hatchery populations—advancement of run timing—is particularly relevant to west coast steelhead because it is a commonly used management strategy, particularly in Washington state. The logic behind this strategy is that displacing the run timing of hatchery fish from that of natural populations will reduce the possibility for genetic interactions between hatchery and natural fish and will allow for selective harvest of hatchery fish. For coastal steelhead in Washington, WDFW has provided information indicating substantial separation in peak run timing between hatchery and natural winter steelhead, and this pattern may occur in other coastal areas as well. However, run timing separation is seldom complete, and WDFW has found genetic evidence for substantial hatchery introgression in several winter steelhead populations (Phelps et al. 1994; see discussion under Steelhead Genetics, page 37). This issue is discussed further below under Approach to Risk Assessment (see page 103).

**Recent Events Affecting Extinction Risk**

A variety of factors, both natural and human-induced, affect the degree of risk facing salmonid populations. Because of time lags between these events and their effects, as well as variability within populations, recent changes in any of these factors may affect current risk without any apparent change in available population statistics. Thus, consideration of these effects must go beyond examination of recent abundance and trends. Unfortunately, forecasting future effects is rarely straightforward and usually involves qualitative evaluations based on informed professional judgement. Events affecting populations may include natural changes in the environment or human-induced changes, either beneficial or detrimental. Possible future effects of recent or proposed conservation measures have not been taken into account in this analysis, but we have considered documented changes in the natural environment. A key question regarding the role of recent events is, given our uncertainty regarding the future, how we evaluate the risk that a population may not persist.

Most Pacific salmonid stocks south of British Columbia have been affected by changes in ocean production that occurred during the 1970s (Pearcy 1992, Lawson 1993). Cooper and Johnson (1992) described a widespread decline in both natural and hatchery steelhead production since 1985, extending from British Columbia through Oregon. They attributed this decline largely to ocean factors but did not identify specific effects. However, climate conditions are known to have changed recently in the Pacific Northwest and much of the Pacific coast has also been experiencing drought conditions in recent years, which may have depressed freshwater production. We do not know whether these climate conditions represent a long-term shift in conditions which will continue affecting stocks into the future, or whether they indicate short-term environmental fluctuations which may be reversed in the near future.

**Other Risk Factors**

Other risk factors typically considered for salmonid populations include disease prevalence, predation, and changes in life history characteristics such as spawning age or size. We have not found evidence that any of these factors are widespread throughout any steelhead ESU. Various diseases have been reported as problems in some hatcheries, but we have found no reports of substantial disease problems in natural steelhead populations.

Bacterial kidney disease, *Ceratomyxa shasta*, and infectious hematopoietic necrosis are reported to be problems within steelhead hatcheries in northern California (Foott et al. 1994). Chapman et al. (1994) reported several diseases in Columbia River Basin steelhead hatcheries. Predation by marine mammals or introduced freshwater fishes is important for individual populations, as noted in the ESU summaries below.

## Approach to Risk Assessment

**Previous Assessments**

In considering the status of ESUs, we evaluated both qualitative and quantitative information. Qualitative evaluations included aspects of several of the risk considerations outlined above, as well as recent, published assessments by agencies or conservation groups of the status of west coast steelhead stocks (Nehlsen et al. 1991; Higgins et al. 1992; Nickelson et al. 1992; WDF et al. 1993; USFS 1993a,b; Titus et al. in press). These evaluations are summarized in Appendix E.

Nehlsen et al. (1991) considered salmonid stocks throughout Washington, Idaho, Oregon, and California and enumerated all stocks that they found to be extinct or at risk of extinction. Stocks that did not appear in their summary were excluded either because they were not at risk of extinction or there was insufficient information to classify them. They classified stocks as extinct (X), possibly extinct (A+), at high risk of extinction (A), at moderate risk of extinction (B), or of special concern (C). They considered it likely that stocks at high risk of extinction have reached the threshold for classification as endangered under the ESA. Stocks were placed in this category if they had declined from historic levels and were continuing to decline, or if they had spawning escapements less than 200. Stocks were classified as at moderate risk of extinction if they had declined from historic levels but appeared to be stable at a level above 200 spawners. They believed that stocks in this category had reached the threshold for classification as threatened under the ESA. They classified a stock as of special concern if a relatively minor disturbance could threaten it, if insufficient data were available for it, or if it were influenced by large releases of hatchery fish or possessed some unique character. For steelhead, they classified 98 stocks as follows: 23 extinct, 1 possibly extinct, 27 high risk, 17 moderate risk, and 30 special concern (Table 9).

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| | none | none | **winter steelhead**<br>Dewatto R. | **winter steelhead**<br>Lake Washington<br>Tahuya R. | **winter steelhead**<br>Nooksack R.<br>Skokomish R.<br>Samish R. |
| | | | **summer steelhead**<br>Tolt R.<br>Deer Cr. | **summer steelhead**<br>S.F. Nooksack R. | |
| 2-Olympic Peninsula | | | | | |
| | none | none | none | none | none |
| 3-Southwest Washington | | | | | |
| | none | none | none | **winter steelhead**<br>small Columbia<br>R. tributaries | **winter steelhead**<br>Grays R.<br>Elochoman R. |
| 4-Lower Columbia River | | | | | |
| | **summer steelhead**<br>Sandy R. | **summer steelhead**<br>White Salmon R. | **winter steelhead**<br>White Salmon R.<br>Wind R.<br>Hood R. | **winter steelhead**<br>Cowlitz R.<br>Washougal R.<br>Clackamas R.<br>small tributaries | **winter steelhead**<br>Coweeman R.<br>Toutle R.<br>Kalama R.<br>Lewis R. |
| | | | **summer steelhead**<br>Cowlitz R.<br>N.F. Lewis R.<br>Washougal R. | **summer steelhead**<br>Hood R.<br>Wind R. | **summer steelhead**<br>E.F. Lewis R. |
| 5-Upper Willamette River | | | | | |
| | none | none | none | none | **winter steelhead**<br>Calapooia R. |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 6-Oregon Coast | | | | | |
| | **summer steelhead**<br>S. Umpqua R. | none | none | **summer steelhead**<br>Siletz R. | **winter steelhead**<br>Tillamook R.<br>Nestucca R.<br>Salmon R.<br>Siletz R.<br>Yaquina R.<br>Alsea R.<br>Yachats R.<br>Tenmile Cr.<br>Big Cr.<br>Siuslaw R. |
| 7-Klamath Mountains Province | | | | | |
| | none | none | **summer steelhead**<br>Smith R. | **winter steelhead**<br>Illinois R.<br>**summer steelhead**<br>Rogue R.<br>Klamath R. | none |
| 8-Northern California | | | | | |
| | none | none | **summer steelhead**<br>Redwood Cr.<br>Mad R. | **summer steelhead**<br>Eel R. | none |
| 9-Central California Coast | | | | | |
| | none | none | **winter steelhead**<br>Napa R.<br>San Francisco<br>Bay tributaries | none | none |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 10-South-Central California Coast | none | none | **winter steelhead**<br>Pajaro R.<br>Carmel R. | **winter steelhead**<br>Salinas R. | **winter steelhead**<br>Big Sur R.<br>Little Sur R. |
| 11-Southern California | **winter steelhead**<br>Gaviota Cr.<br>Rincon Cr.<br>Los Angeles R.<br>San Gabriel R.<br>Santa Ana R.<br>San Diego R.<br>San Luis Rey R.<br>San Mateo Cr.<br>Santa Margarita R.<br>Sweetwater R.<br>Maria Ygnacio R. | none | **winter steelhead**<br>Santa Ynez R.<br>Santa Clara R.<br>Ventura R.<br>Malibu Cr. | none | none |
| 12-Central Valley | none | none | **winter steelhead**<br>Sacramento R. | none | none |
| 13-Middle Columbia River | none | none | **winter steelhead**<br>Klickitat R.<br>small tributaries<br>**summer steelhead**<br>small tributaries | **winter steelhead**<br>Fifteenmile Cr. | **summer steelhead**<br>Klickitat R.<br>Walla Walla R. |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 14-Upper Columbia River | | | | | |
| | **summer steelhead** | none | **summer steelhead** | none | **summer steelhead** |
| | Spokane R. | | Entiat R. | | Wenatchee R. |
| | Pend Oreille R. | | Methow R. | | |
| | | | Okanogan R. | | |
| 15-Snake River Basin | | | | | |
| | **summer steelhead** | none | none | **summer steelhead** | **summer steelhead** |
| | Powder R. | | | Asotin Cr. | Tucannon R. |
| | Burnt R. | | | | Salmon R. |
| | Weiser R. | | | | Clearwater R. |
| | Payette R. | | | | Imnaha R. |
| | Malheur R. | | | | |
| | Boise R. | | | | |
| | Owyhee R. | | | | |
| | Bruneau R. | | | | |

[a]ESU = evolutionarily significant unit.

[b]Due to lack of information on steelhead stocks that are presumed to be extinct, the relationship of these stocks, and the relationship of any residualized, resident forms, to adjacent steelhead ESUs is uncertain. They are listed here based on geography and to give a complete presentation of the stocks identified by Nehlsen et al. (1991).

Higgins et al. (1992) used the same classification scheme as Nehlsen et al. (1991) but provided a more detailed review of some northern California salmonid stocks. In this review, their evaluation is relevant only to the northern California ESU.

Nickelson et al. (1992) rated coastal Oregon (excluding Columbia River Basin) salmon and steelhead stocks on the basis of their status over the past 20 years. They used the following classifications: *depressed* (spawning habitat underseeded, declining trends, or recent escapements below long-term average), *healthy* (spawning habitat fully seeded and stable or increasing trends), or *of special concern* (300 or fewer spawners or a problem with hatchery interbreeding). They classified 27 steelhead populations in coastal Oregon as follows: 21 depressed, 1 special concern, and 5 healthy.

WDF et al. (1993) categorized all salmon and steelhead stocks in Washington on the basis of stock origin (*native*, *non-native*, *mixed*, or *unknown*), production type (*wild*, *composite*, or *unknown*) and status (*healthy*, *depressed*, *critical*, or *unknown*). Status categories were defined as follows: *healthy*, "experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock;" *depressed*, "production is below expected levels ... but above the level where permanent damage to the stock is likely;" and *critical*, "experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred." Of the 141 steelhead stocks identified, 36 were classified as healthy, 1 as critical, 44 as depressed, and 60 as unknown. Most of those classified as unknown are small stocks without large fisheries.

USFS (1993a,b) provided verbal descriptions of the status of steelhead stocks on Forest Service lands and noted their agreement or disagreement with status designations in other reviews. In Appendix E, we have grouped their comments into status categories based on key phrases used in their descriptions: *stable* or *healthy* (S); *unknown* (U); *depressed*, *declining*, *low*, or *moderate risk of extinction* (D); *critical*, *high risk of extinction*, or *severely depressed* (C); *extinct* (X); and *not present* (N).

Titus et al. (in press) provided a detailed review of steelhead populations south of San Francisco Bay, classifying them by categories based on presence or absence of the species and general trends in abundance. They used special symbols to categorize population status, as follows: steelhead present, no discernable change from historical levels (X); production reduced from historical levels, or likely so (<); current presence or absence unknown (?); extinct (E).

We encountered several problems in applying results of these studies to ESA evaluations, with a major problem being that the definition of "stock" or "population" varied considerably in scale among studies, and sometimes among regions within a study. Identified units range in size from large river basins (e.g., "Sacramento River" in Nehlsen et al. 1991), to minor coastal streams and tributaries (Titus et al. in press).

A second problem was the definition of categories used to classify stock status. Only Nehlsen et al. (1991) and Higgins et al. (1992) used categories intended to relate to ESA "threatened" or "endangered" status, and they applied their own interpretations of these terms to individual stocks, not to ESUs as defined here. Nickelson et al. (1992) and WDF et al. (1993) used general terms describing the status of stocks that could not be directly related to the considerations important in ESA evaluations. For example, the WDF et al. (1993) definition of healthy could conceivably include a stock at substantial extinction risk due to loss of habitat, hatchery fish interactions, or environmental variation (although this does not appear to be the case for any steelhead stocks).

A third problem is the selection of stocks or populations to include in the review. Nehlsen et al. (1991) and Higgins et al. (1992) did not evaluate (or even identify) stocks not perceived to be at risk, so it is difficult to determine the proportion of stocks they considered to be at risk in any given area. For steelhead, WDF et al. (1993) included only stocks considered to be substantially wild and included data only for the wild component for streams that have both hatchery and natural fish escaping to spawn (Johnson[17]), giving an incomplete evaluation of steelhead utilizing natural habitat.

**Data Evaluations**

Quantitative evaluations of data included comparisons of current and historical abundance of steelhead and calculation of recent trends in escapement and the proportion of natural spawning attributable to hatchery fish. Historical abundance information for these ESUs is largely anecdotal. Time series data are available for many populations, but data extent and quality varied among ESUs. We compiled and analyzed this information to provide several summary statistics of natural spawning abundance, including (where available) recent total spawning run size and escapement, percent annual change in total escapement, recent naturally produced spawning run size and escapement, and average percentage of natural spawners that were of hatchery origin.

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

**Data types**—Quantitative assessments were based on historical and recent run-size estimates and time series of freshwater spawner and juvenile survey data, harvest rate estimates, and counts of adults migrating past dams. We considered this information separately for each ESU. Because of the disparity of data sources and quality for the different ESUs, data sources and analyses are described separately for each ESU. Information on stock abundance was compiled from a variety of state, federal, and tribal agency records. We believe these records to be complete in terms of existing long-term adult abundance information for steelhead in the region covered. Principal data sources were

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[17] T. Johnson, Washington Department of Fish and Wildlife, 283236 Hwy. 101, Port Townsend, WA 98368. Pers. commun., March 1995.

angler catch estimates, dam or weir counts, and stream surveys. None of these sources provided a complete measure of adult spawner abundance for any of the streams; specific problems are discussed below for each data type.

Sport harvest information was the main abundance data available for most Oregon coastal populations. In 1952, Oregon instituted a punchcard system to record all salmon and steelhead caught by species. There are a variety of problems in interpreting abundance trends from sport harvest data; these are discussed in detail in the Oregon Coast ESU section below.

Counts of adult steelhead at dams and weirs are available from several river basins along the coast. These counts are probably the most accurate estimates available of total spawning run abundance, but often represent only small portions of the total population in each river basin. As with angler catches, these counts typically represent a combination of hatchery produced and natural fish, and thus are not a direct index of natural population trends.

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

**Computed statistics**—To represent current run size or escapement where recent data were available, we computed the geometric mean of the most recent 5 years reported (or fewer years if data series is shorter than 5 years). We tried to use only estimates that reflect the total abundance for an entire river basin or tributary, avoiding index counts or dam counts that represent only a small portion of available habitat. For Oregon angler catch data for coastal streams, catch was expanded to total run size and escapement (run size minus catch) using the methods and harvest rate estimates of Kenaston (1989). For the inland streams, we had no estimates of harvest rate to do this expansion. To avoid some local bias problems in areas with few anglers, catch data were used only for streams with an average catch greater than 100 steelhead per year. Where time-series data were not available, we relied on recent estimates from state agency reports; time periods included in such estimates varied considerably.

Where adequate data were available, trends in total escapement (or run size if escapement data were not available) were calculated for all data sets with more than 5 years of data, based on total escapement or an escapement index (such as fish per mile from a stream survey). As an indication of overall steelhead population trends in individual streams, we calculated average (over the available data series) percent annual change in adult spawner indices within each river basin. Trends were calculated as the slope ($a$) of the regression of ln(abundance) against years, corresponding to the biological model $N(t) = b \cdot e^{at}$, where $b$ is abundance at time $t$=0. Slopes significantly different from zero ($P<0.05$) were noted. The regressions provided direct estimates of mean instantaneous rates of population change ($a$); these values were subsequently converted to percent annual change, calculated as $100 \cdot (e^{a} - 1)$.

No attempt was made to account for the influence of hatchery produced fish on these estimates, so the estimated trends include any supplementation effect of hatchery fish.

Percentages of hatchery fish in spawning escapements were computed from 5-year geometric means of hatchery and natural escapement data where estimates of both were available. In most cases, however, we had to rely on recent estimates from state agencies. The time span and methods used in such estimates were often not reported, so the reliability of many of these estimates is unknown. For many Washington winter steelhead populations, we were able to calculate this percentage from WDFW steelhead inventory tables (WDFW 1994b) which provided estimates of both natural (late-run) and hatchery (early-run) spawner abundance. In Oregon, the main source for hatchery percentage estimates was the ODFW 1992 Wild Fish Management Policy report (Chilcote et al. 1992). Many of the estimates in that report were based on scale analysis of fish sampled from angler catches, and thus probably overestimate the proportion of hatchery fish actually spawning because the sport fishery selects for a higher proportion of hatchery fish in many areas. ODFW (1995a,b) has provided improved estimates for several stocks, which we used where available.

**Run timing**—An issue that may play a significant role in determining the nature and extent of interactions between hatchery and wild steelhead is separation of run timing. It is common for hatchery stocks of steelhead to return and spawn several weeks or months earlier than the natural populations they were derived from. This can occur either through selection for early returning adults in broodstock collection, or through faster growth and higher survival in the hatchery of progeny from early spawning fish. Earlier spawning for hatchery steelhead has at least two advantages from a fishery management perspective. First, the longer growth period makes it easier to produce hatchery fish that smolt in 1 year. Second, separation of spawn timing for natural and hatchery fish provides an opportunity to maximize harvest of hatchery fish while minimizing impacts on natural populations. Because winter steelhead generally spawn later than summer steelhead, winter steelhead provide the greatest opportunity for advancement of run and spawn timing in the hatchery.

State agencies in Washington and Oregon have adopted somewhat different approaches to the issue of run timing in hatchery steelhead. The Washington Department of Fisheries and Wildlife has intentionally developed early spawning hatchery stocks of winter steelhead for planting into coastal and lower Columbia River drainages. The early run timing is meant to accomplish two major objectives: provide an opportunity for high harvest rates on early returning hatchery fish without undue risk to wild fish, and minimize opportunities for interbreeding between naturally spawning hatchery fish and wild fish.

In contrast, the Oregon Department of Fish and Wildlife has not vigorously promoted altered run timing in their hatchery steelhead stocks. Although steelhead from Oregon coastal hatcheries commonly return and spawn somewhat earlier than their natural counterparts, the timing difference is not generally as great as in Washington. It should be noted, however, that WDFW generally uses only a few regional donor stocks (Chambers Creek and Skamania throughout Western Washington; Elochoman, Cowlitz and Skamania in the Lower Columbia River; Wells in the Upper Columbia River), so that stock transfers from a few regional hatcheries provide advanced-run stock to a multitude of rivers. On the other hand, ODFW, although relying on some regional donor stocks, also maintains many individual hatchery populations that are indigenous to the river into which they are planted (e.g., North Umpqua, Chetco, Deschutes, Clackamas Rivers). Therefore, advanced-run fish have not been distributed throughout the Oregon state hatchery system as extensively as have those in Washington.

In reviewing the status of individual ESUs of west coast steelhead, we considered the risks posed by artificial propagation to be important, particularly in combination with other risk factors indicating declines in abundance. Information submitted to the ESA Administrative Record for West Coast Steelhead indicates that, in general, the current WDFW policy to encourage run and spawn time separation between hatchery and natural winter steelhead and to maintain very high (80-90%) harvest rates on hatchery steelhead has resulted in less overlap on the natural spawning grounds than is the case for winter steelhead in Oregon. This factor was a consideration in the BRT's conclusions that some of the ESUs for coastal steelhead in Washington state are not at risk of extinction or endangerment (see below). However, BRT conclusions on this issue should be regarded as preliminary because information about the degree of interactions that actually occur between hatchery and natural fish is still incomplete.

Furthermore, although the WDFW strategy may be effective in reducing opportunities for direct interactions between hatchery and natural steelhead adults, those genetic and ecological interactions that do occur may be more deleterious to the natural population. A considerable body of evidence indicates that run and spawn timing in salmonids can have a strong genetic component, and it is not likely that substantially altered spawn timing would be advantageous to the natural population in the long term. In the short term, juvenile progeny of early spawning hatchery fish that do survive will be larger and may outcompete their natural counterparts. In addition, high harvest rates focused on hatchery fish may eliminate early natural spawners, resulting in a selective shift in natural run timing.

## Analysis of Biological Information

### Coastal Steelhead ESUs

**1) Puget Sound**—Previous assessments of steelhead within the range of this ESU have identified several stocks as being at risk or of concern. Nehlsen et al. (1991) identified nine stocks as at some degree of risk or concern (Table 9). WDF et al. (1993) considered 53 stocks within the ESU, of which 31 were considered to be of native origin and predominantly natural production. Their assessment of these 31 stocks was 11 healthy, 3 depressed, 1 critical, and 16 unknown. Their assessment of the remaining (not native/natural) stocks was 3 healthy, 11 depressed, and 8 unknown (Appendix E).

No estimates of historical (pre-1960s) abundance specific to the Puget Sound ESU are available. Total run size for Puget Sound in the early 1980s can be calculated from estimates in Light (1987) as approximately 100,000 winter steelhead and 20,000 summer steelhead. Light provided no estimate of hatchery proportions specific to Puget Sound streams, but for

Puget Sound and coastal Washington combined, he estimated that 70% of steelhead in ocean runs were of hatchery origin. The percentage in escapement to spawning grounds would be substantially lower due to differential harvest and hatchery rack returns.

Recent 5-year average natural escapements for streams with adequate data range from less than 100 to 7,200, with corresponding total run sizes of 550-19,800 (Table 10). Total recent run size for major stocks in this ESU was greater than 45,000, with total natural escapement of about 22,000. The geographic distribution of escapement is illustrated in Figure 19.

There are substantial habitat blockages by dams in the Skagit and Elwha River Basins, and minor blockages, for example, impassable culverts, throughout the region. The Washington State salmon and steelhead stock inventory (SASSI) (WDF et al. 1993) appendices note habitat problems, including flooding, unstable soils, and poor land management practices, for most stocks in this region. In general, habitat has been degraded from its pristine condition, and this trend is likely to continue with further population growth and resultant urbanization in the Puget Sound region. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than are winter steelhead.

Of the 21 independent stocks for which we had adequate adult escapement information to compute trends (Appendix E), 17 have been declining and 4 increasing during the available data series, with a range from 18% annual decline (Lake Washington winter steelhead) to 7% annual increase (Skykomish River winter steelhead). Eleven of these trends (9 negative, 2 positive) were significantly different from zero. Note that these trends are for the late run wild component of winter steelhead populations; no adult trend data are available for summer steelhead. In addition, most of these trends are based on relatively short data series and may be influenced by recent climate conditions. The two basins producing the largest numbers of steelhead (Skagit and Snohomish Rivers) both have overall upward trends. Trends for individual river basins are summarized in Table 10 and Figure 20.

Hatchery fish are widespread, spawn naturally throughout the Puget Sound region, and are largely derived from a single stock (Chambers Creek). The proportion of spawning escapement comprised of hatchery fish ranged from less than 1% (Nisqually River) to 51% (Morse Creek). In general, hatchery proportions are higher in Hood Canal and the Strait of Juan de Fuca than in Puget Sound proper (Table 10). Most hatchery fish in this region originated from stocks indigenous to the ESU, but they are generally not native to their local river basins. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region. Given the lack of strong trends in abundance for the major stocks and the apparent limited contribution of hatchery fish to production of the late-run winter stocks, most winter steelhead stocks in the Puget Sound ESU appear to be naturally self-sustaining at this time. However, there are clearly isolated problems with sustainability of some steelhead runs in this ESU, notably with Deer Creek summer steelhead (although juvenile abundance for this stock increased in 1994) and with Lake Washington winter steelhead. Summer steelhead stocks within this ESU are all small, occupy limited habitat, and in most cases are subject to introgression by hatchery fish. While

Table 10. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Puget Sound steelhead evolutionarily significant unit, by major river basin. Where no estimate for whole basin is available, ranges for individual stocks are given (see Appendix B for details). Run size and escapement are total adult steelhead; trend is percent annual change in total escapement (or an index of total escapement). Only basins with data are included. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Nooksack River | | | | -11.6 to -7.9 | |
| Samish River | | | 850 | | |
| Skagit River | 11,100 | 7,700 | 7,200 | +2.0 | 5 |
| Stillaguamish River | | | 1,200 | -6.3 | |
| Snohomish River | 19,800 | 8,000 | 6,800 | +3.1 | 12 |
| Lake Washington | | | 300 | -17.5 | |
| Green River | 4,300 | 1,700 | 1,500 | -1.7 | 12 |
| Puyallup River | 3,300 | 2,000 | 1,900 | -5.2 | 5 |
| Nisqually River | 1,900 | 1,200 | 1,200 | -5.1 | < 1 |
| Dewatto River | | | 30 | -1.2 | |
| Tahuya River | | | 100 | -0.6 | 49 |
| Skokomish River | | | 650 | -3.5 | |
| Snow Creek | | | 30 | -8.9 | |
| Dungeness River | | | 400 | -5.5 | |
| Morse Creek | 550 | 200 | 100 | -12.3 | 51 |

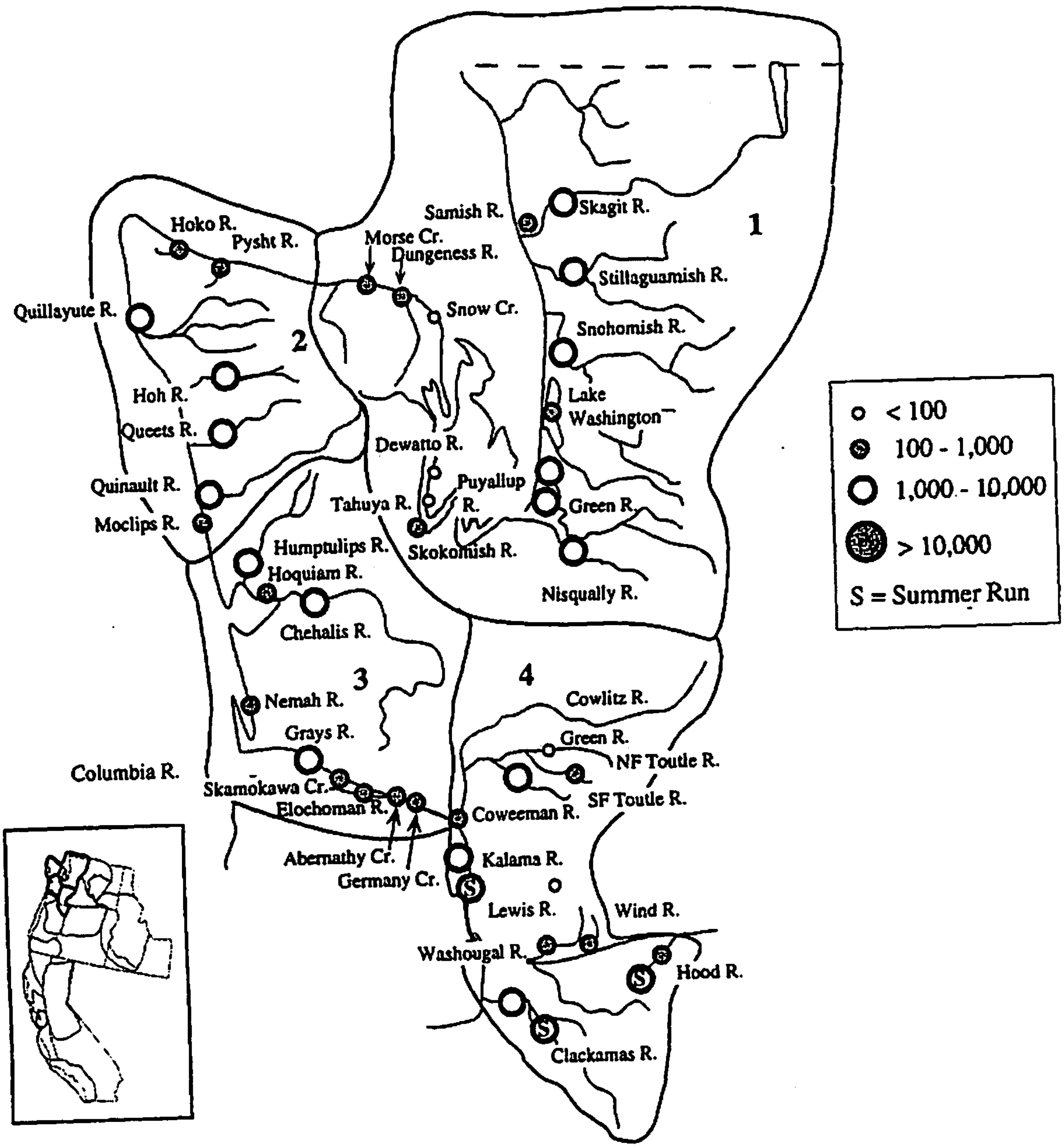


Figure 19. Recent total escapement for populations in steelhead ESUs 1-Puget Sound, 2-Olympic Peninsula, 3-Southwest Washington, and 4-Lower Columbia River. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details).

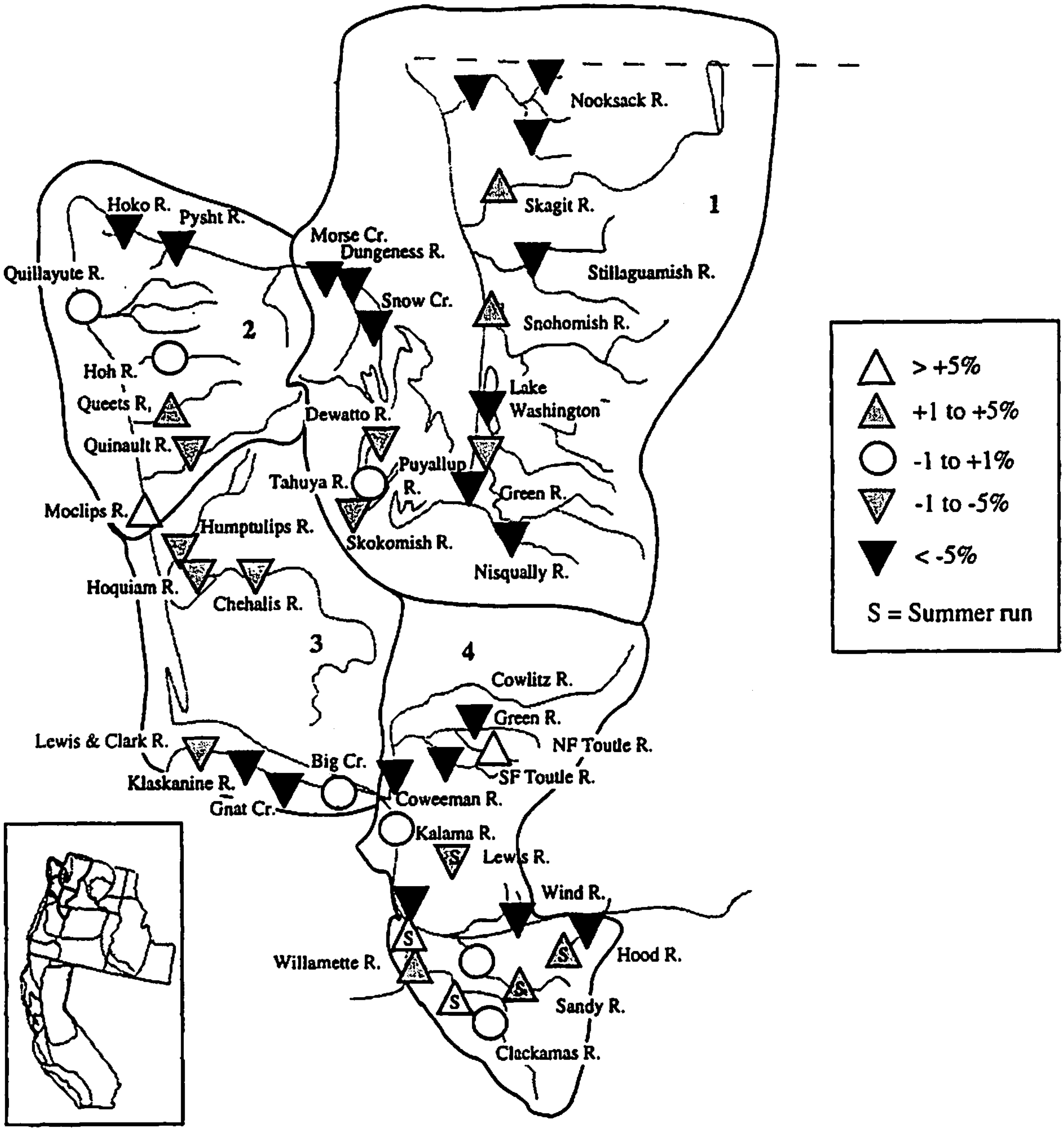


Figure 20. Trends (percent annual change) in total escapement for populations in steelhead ESUs 1-Puget Sound, 2-Olympic Peninsula, 3-Southwest Washington, and 4-Lower Columbia River. All data are for winter steelhead, except as noted (see Appendix E for details).

there are few data to assess the status of these summer runs, there is cause for concern regarding their sustainability.

At present, the major threat to genetic integrity for Puget Sound steelhead comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

**2) Olympic Peninsula**—Previous assessments of stocks within this ESU have not identified any stocks as being at risk or of special concern. Nehlsen et al. (1991) identified no stocks as at risk (Table 9). WDF et al. (1993) considered 31 stocks within the ESU, of which 23 were considered to be of native origin and predominantly natural production. The status of these 23 stocks was assessed as 11 healthy and 12 unknown, while the status of the eight remaining (not native/natural) stocks was two healthy and six unknown (Appendix E).

No estimates of historical (pre-1960s) abundance specific to the Olympic Peninsula ESU are available. Total run size for the major stocks in the Olympic Peninsula ESU during the early 1980s was calculated from estimates in Light (1987) as approximately 60,000 winter steelhead. Light provided no estimate of hatchery proportion in these streams, but for Puget Sound and coastal Washington together, he estimated that 70% of steelhead were of hatchery origin. Recent 5-year average natural escapements for streams with adequate data range from 250 to 6,900, with corresponding total run sizes of 450-19,700 (Table 11, Appendix E). Total recent (1989-93 average) run size for major streams in this ESU was approximately 54,000, with a natural escapement of 20,000 fish. The geographic distribution of this escapement is illustrated in Figure 19.

No major habitat blockages are known for these streams, but minor blockages (such as impassable culverts) are likely throughout the region. SASSI appendices (WDF et al. 1993) note freshwater habitat problems largely relating to poor land management practices, and recent poor ocean productivity affecting most stocks in this region. Clearcut logging has been extensive throughout most watersheds in this area, with the exception of the upper reaches of the larger rivers that drain Olympic National Park. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than winter steelhead.

Of the 12 independent stocks for which we had adequate adult escapement information to compute trends (Appendix E), 7 have been declining and 5 increasing during the available data series, with a range from 8% annual decline to 14% annual increase. Three of the downward trends were significantly different from zero, but three of the four river basins producing the largest numbers of natural fish have upward trends in basinwide total numbers (Table 11, Fig. 20). Note that these trends are all for winter steelhead populations; no adult trend data are available for summer steelhead.

Hatchery fish are widespread and escaping to spawn naturally throughout the region, with hatchery production largely derived from a few parent stocks. Estimated proportions of hatchery fish in natural spawning habitat range from 16% (Quillayute River) to 44% (Quinault River). However, the two largest producers of natural fish (Quillayute and Queets

Table 11. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Olympic Peninsula steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Pysht River | 650 | 400 | 250 | -5.8 | 43 |
| Hoko River | | | 550 | -7.6 | |
| Quillayute River | 19,700 | 8,300 | 6,900 | +0.6 | 16 |
| Hoh River | | | 2,300 | +0.2 | |
| Queets River | 13,400 | 7,400 | 5,900 | +4.3 | 19 |
| Quinault River | 16,400 | 6,300 | 3,400 | -1.8 | 44 |
| Moclips River | 450 | 400 | 250 | +13.6 | 37 |

Rivers) had the lowest proportions. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region. Given the lack of strong trends in abundance and the apparent limited contribution of hatchery fish to production of the late-run winter stocks, most winter steelhead stocks in the Olympic Peninsula ESU appear to be naturally sustaining at this time. However, there are clearly isolated problems with sustainability of some winter steelhead runs in this ESU, notably the Pysht/Independents stock, which has a small population with a strongly declining trend over the available data series (even though it has been exceeding harvest management goals recently), and the Quinault River stock, which has a declining trend and substantial hatchery contribution to natural spawning.

At present, the major threat to genetic integrity for Olympic Peninsula steelhead comes from past and present hatchery practices. Risk factors relating to these hatchery practices were discussed previously in the Background section.

**3) Southwest Washington**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified three stock groups as at risk or of concern: moderate risk for small Columbia River tributaries and special concern for the Grays and Elochoman Rivers (Table 9). WDF et al. (1993) considered 22 stocks within the ESU, of which 19 were considered to be of native origin and predominantly natural production. The status of these 19 stocks was 6 healthy, 6 depressed, and 7 unknown. The status of the remaining three stocks (not native/natural or unknown origin) was one healthy, one depressed, and one unknown. Most healthy stocks were in tributaries to Grays Harbor, and most depressed stocks were in lower Columbia River tributaries (Appendix E).

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Recent 5-year average natural escapements in individual tributaries with adequate data range from 150 to 2,300, with the Chehalis River and its tributaries representing the bulk of production (Appendix E). Total recent (5-year average) natural escapement for major streams in this ESU was approximately 13,000 (Table 12). The geographic distribution of escapement is illustrated in Figure 19.

No major habitat blockages are known for these streams, but minor blockages (such as impassable culverts) are likely throughout the region. Habitat problems for most stocks in this ESU are similar to those in adjacent coastal ESUs. Clearcut logging has been extensive throughout most watersheds in this area. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than are winter steelhead.

All but one (Wynoochee River) of the 12 independent stocks for which we had adequate adult escapement information to compute trends (Appendix E) have been declining during the available data series, with a range from 7% annual decline to 0.4% annual increase. Six of the downward trends were significantly different from zero. However, most of the data series used for trend calculations were short, beginning in the mid-1980s; thus, the trends may largely reflect the effects of recent climate conditions.

Table 12. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Southwest Washington steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Humptulips River | 4,100 | 2,500 | 2,300 | -3.5 | 10 |
| Hoquiam River | | | 600 | -4.2 | |
| Chehalis River | 13,600 | 8,500 | 7,700 | -1.1 | 9 |
| Nemah River | | | 650 | | |
| Grays River | | 1,200 | 900 | | 23 |
| Skamokawa Creek | | 300 | 250 | | 6 |
| Elochoman River | | 900 | 250 | | 72 |
| Abernathy Creek | | 200 | 150 | | 25 |
| Germany Creek | | 200 | 150 | | 23 |
| Lewis & Clark River | | | | -1.7 | 50 |
| Klaskanine River | | | | -5.2 | 55 |
| Big Creek | | | | -5.2 | |
| Gnat Creek | | | | -0.3 | |

For Washington streams, these trends are for the late run wild component of winter steelhead populations; Oregon data included all stock components. Most of the Oregon trends are based on angler catch data, and so may not reflect trends in underlying population abundance (see discussion for the Oregon Coast ESU). In general, stock condition appears to be healthier in southwest Washington than in the lower Columbia River Basin (Appendix E). Trends for individual river basins are summarized in Table 12 and Figure 20.

Hatchery fish, largely from parent stocks outside the ESU, are widespread and escaping to spawn naturally throughout the region. This could substantially change the genetic composition of the resource despite management efforts to minimize introgression of the hatchery gene pool into natural populations. Estimates of proportion of hatchery fish on natural spawning grounds range from 9% in the Chehalis River, the largest producer of steelhead in the ESU, to 82% in the Clatskanie River. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region. However, some Washington stocks (notably lower Columbia River tributaries—Table 12) appear to have received substantial hatchery contributions to their wild spawning components, and Nehlsen et al. (1991) identified two stocks in this ESU as of special concern due to hatchery influence (Table 9).

The preponderance of negative trends in abundance, the contribution of non-native hatchery fish to production, and the poor condition of stocks in lower Columbia River tributaries are causes for concern for the future of this ESU.

Again the major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

**4) Lower Columbia River**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 19 stocks as at risk or of concern (Table 9). WDF et al. (1993) considered 23 stocks within the ESU, of which 19 were considered to be of native origin and predominantly natural production. The status of these 19 stocks was 2 healthy, 10 depressed, and 7 unknown. All four of the remaining (not native/natural or unknown origin) stocks were classified as depressed.

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Total run size for the major stocks in the lower Columbia River (below Bonneville Dam, including the upper Willamette ESU) for the early 1980s can be calculated from the estimates of Light (1987) as approximately 150,000 winter steelhead and 80,000 summer steelhead. Light estimated that 75% of the total run (summer and winter steelhead combined) was of hatchery origin. Recent 5-year average natural escapements for streams with adequate data range from less than 100 to 1,100 (Table 13, Appendix E). Total recent (5-year average) run size for major streams in this ESU was greater than 16,000, but this total includes only the few basins for which estimates are available. The geographic distribution of escapement is illustrated in Figure 19.

Table 13. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Lower Columbia River steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Cowlitz River | W | | 100 - 1,000 | 90 - 950 | -16.5 to +47.9 | 0 - 35 |
| Kalama River | W | 2,300 | 1,400 | 900 | +0.1 | 32 |
| | S | 6,600 | 3,300 | 1,100 | -1.2 | 66 |
| Lewis River (East Fork) | | | | 90 | -15.7 | |
| Washougal River | | | | 100 | | |
| Wind River | S | | 600 | 300 | -7.8 | 53 |
| Sandy River | W | | | | -0.4 | > 30 |
| | S | | | | +3.4 | |
| Lower Willamette River | W | | | | +2.5 | |
| | S | | | | +9.3 | |
| Clackamas River | W | 1,300 | | | -0.4 | 70 |
| | S | 3,500 | | | +10.8 | |
| Hood River | W | 750 | | | -7.3 | > 40 |
| | S | 1,500 | | | +4.2 | 80 |

Significant habitat blockages resulted from dams on the Sandy River, and minor blockages (such as impassable culverts) are likely throughout the region. Habitat problems for most stocks in this ESU are similar to those in adjacent coastal ESUs. Clearcut logging has been extensive throughout most watersheds in this area, and urbanization is a substantial concern in the Portland and Vancouver areas. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than are winter steelhead.

Of the 18 stocks for which we had adequate adult escapement information to compute trends (Appendix E), 11 have been declining and 7 increasing during the available data series, with a range from 24% annual decline to 48% annual increase. Eight of these trends (five negative, three positive) were significantly different from zero. Most of the data series for this ESU are short, beginning only in the late 1970s to the mid-1980s; thus they may be heavily influenced by short-term climate effects. Some of the Washington trends (notably those for the Cowlitz and Kalama River Basins) have been influenced (positively or negatively) by the 1980 eruption of Mount St. Helens; we have not attempted to correct for this here. For Washington streams, these trends are for the late run wild component of winter steelhead populations; Oregon data included all stock components. Most of the Oregon trends are based on angler catch, and so they may not reflect trends in underlying population abundance—see discussion under the Oregon Coast ESU. Trends for individual river basins are summarized in Table 13 and Figure 20.

Hatchery fish are widespread and escaping to spawn naturally throughout the region. Most of the hatchery stocks used originated primarily from stocks within the ESU, but many are not native to local river basins. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region; however, some Washington stocks (notably Kalama River winter and summer steelhead—Appendix E) appear to have substantial hatchery contribution to wild spawning, and Nehlsen et al. (1991) identified several stocks in this ESU as of special concern due to hatchery influence (Table 9). ODFW estimates of hatchery composition indicate a range from about 30% (Sandy River and Tanner Creek winter steelhead) to 80% (Hood River summer steelhead) hatchery fish in spawning escapements. Estimates for Hood River winter steelhead range from 0% (ODFW 1995b) to greater than 40% (ODFW 1995a). Given the relatively low natural run sizes to individual streams, the preponderance of negative trends in abundance, and the apparent substantial contribution of hatchery fish to production, the BRT had substantial concern that the majority of natural steelhead populations in this ESU (both winter and summer) may not be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed under Background above.

**5) Upper Willamette River**—The only previous assessment of risk to stocks within this ESU is that of Nehlsen et al. (1991), who identified one stock (Calapooia River) as of special concern (Table 9).

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Total recent 5-year average run size for this ESU can be estimated from counts at Willamette Falls for the years 1989-93. Dam counts indicate that the late-run (native) winter steelhead average run size was approximately 4,200, while early-run winter and summer steelhead averaged 1,900 and 9,700, respectively (Table 14, Fig. 21, Appendix E). Only the late-run winter steelhead are included in this ESU; other runs are mentioned because of their possible ecological interactions with the native stock. Adequate angler catch data were available to derive approximate average winter steelhead escapement for three tributaries: Mollala River, 2,300 (predominantly non-native); North Fork Santiam River, 2,000; South Fork Santiam River, 550.

Substantial habitat blockages resulted from Detroit, Big Cliff and Green Peter Dams on the Santiam River, and flood control dams on the mainstem Willamette. Other blockages such as smaller dams or impassable culverts are likely throughout the region. Habitat problems for most stocks in this ESU are similar to those in adjacent coastal ESUs. Clearcut logging has been common throughout most watersheds in this area, and there is extensive urbanization in the Willamette Valley. Bottom et al. (1985) identified specific factors affecting salmon habitat in various areas of Oregon, including streamflow and temperature problems, riparian habitat losses, and instream habitat problems. Within the Willamette Valley, they noted that temperatures and streamflows reach critical levels for salmonids in places where there are significant water withdrawals or removal of streamside vegetation, that loss of riparian vegetation results from agricultural practices and rural and urban development, that bank erosion is severe in several areas of the basin, and that splash dams, debris removal and stream channelization have caused long-term damage to salmonid habitats.

Total basin run size or escapement estimates exhibit declines for both total winter and late winter steelhead, while summer steelhead estimates exhibit an increase (Table 14, Fig. 22). However, all of these basinwide estimates have exhibited large fluctuations (Fig. 23). Of the three tributary winter steelhead stocks for which we had adequate adult escapement information to compute trends, two have been declining and one increasing over the available data series, with a range from 4.9% annual decline to 2.4% annual increase. None of these trends were significantly different from zero (Table 14, Appendix E). Note that two of these trends, those from the North and South Forks of the Santiam River, are based on angler catch, and so may not reflect trends in underlying population abundance—see discussion for the Oregon Coast ESU.

Hatchery fish are widespread throughout the region. Both summer steelhead and early-run winter steelhead have been introduced to the basin and escape to spawn naturally in substantial numbers. Indigenous late-run winter steelhead are also produced in the Santiam River Basin. Estimates of hatchery composition for winter steelhead escapements are available only for the North Fork Santiam River and the Mollala River. These estimates are variable, ranging from 14% (ODFW 1995b) to 54% (ODFW 1995a) on the North Fork Santiam River alone. There is probably some temporal and spatial separation in spawning between the early and late winter stocks. While we have little information on the actual contribution of hatchery fish to natural production, given the generally low numbers of fish escaping to tributaries and the general declines in winter steelhead abundance in the basin,

Table 14. Summary of estimated total run size and trends in total escapement for the Upper Willamette River steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Willamette River | W - Early | 1,900 | | | -4.5 | |
| | W - Late | 4,200 | | | -3.5 | |
| | S | 9,700 | | | +13.5 | |

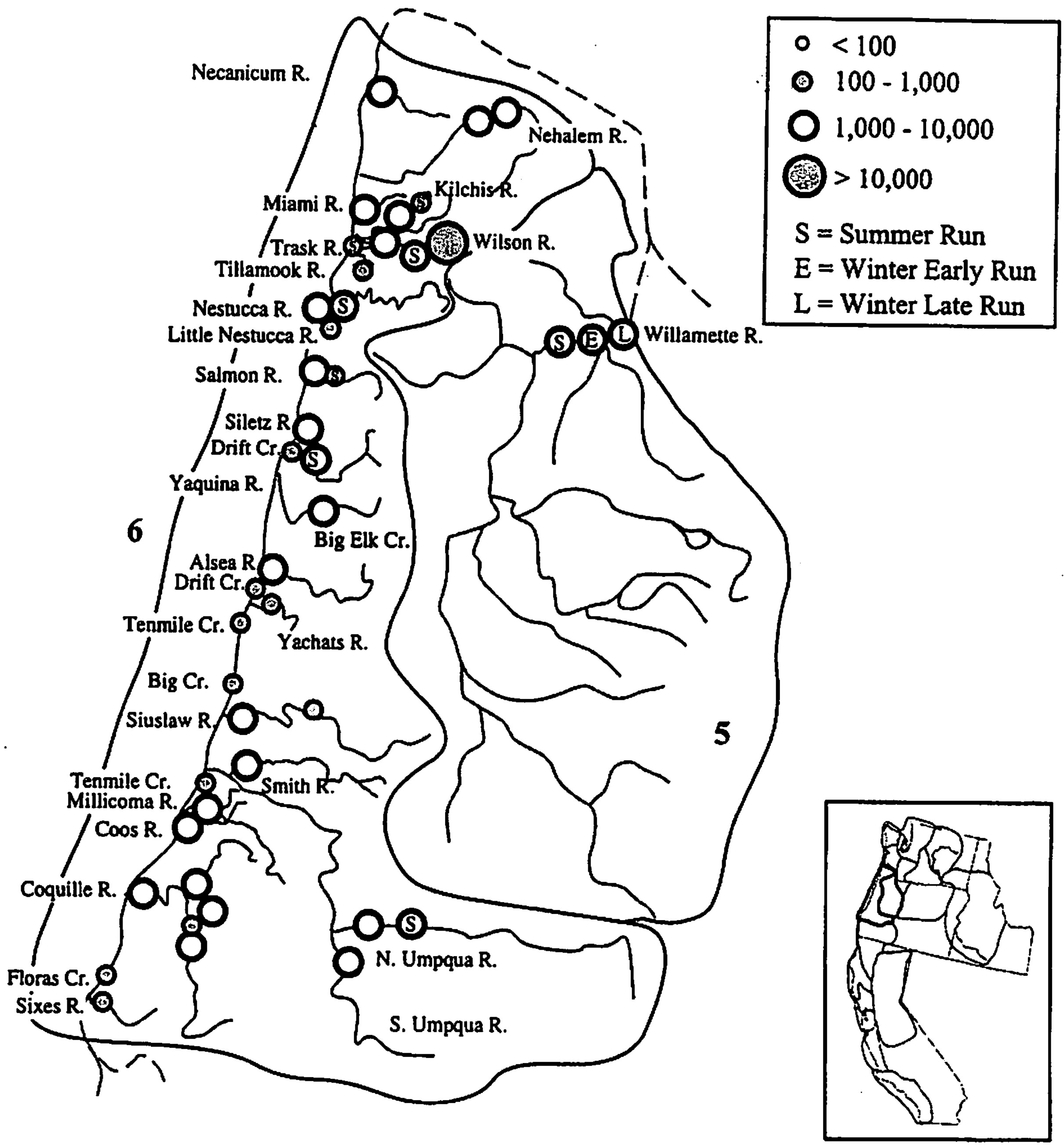


Figure 21. Recent total escapement, or run size, for populations in steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details).

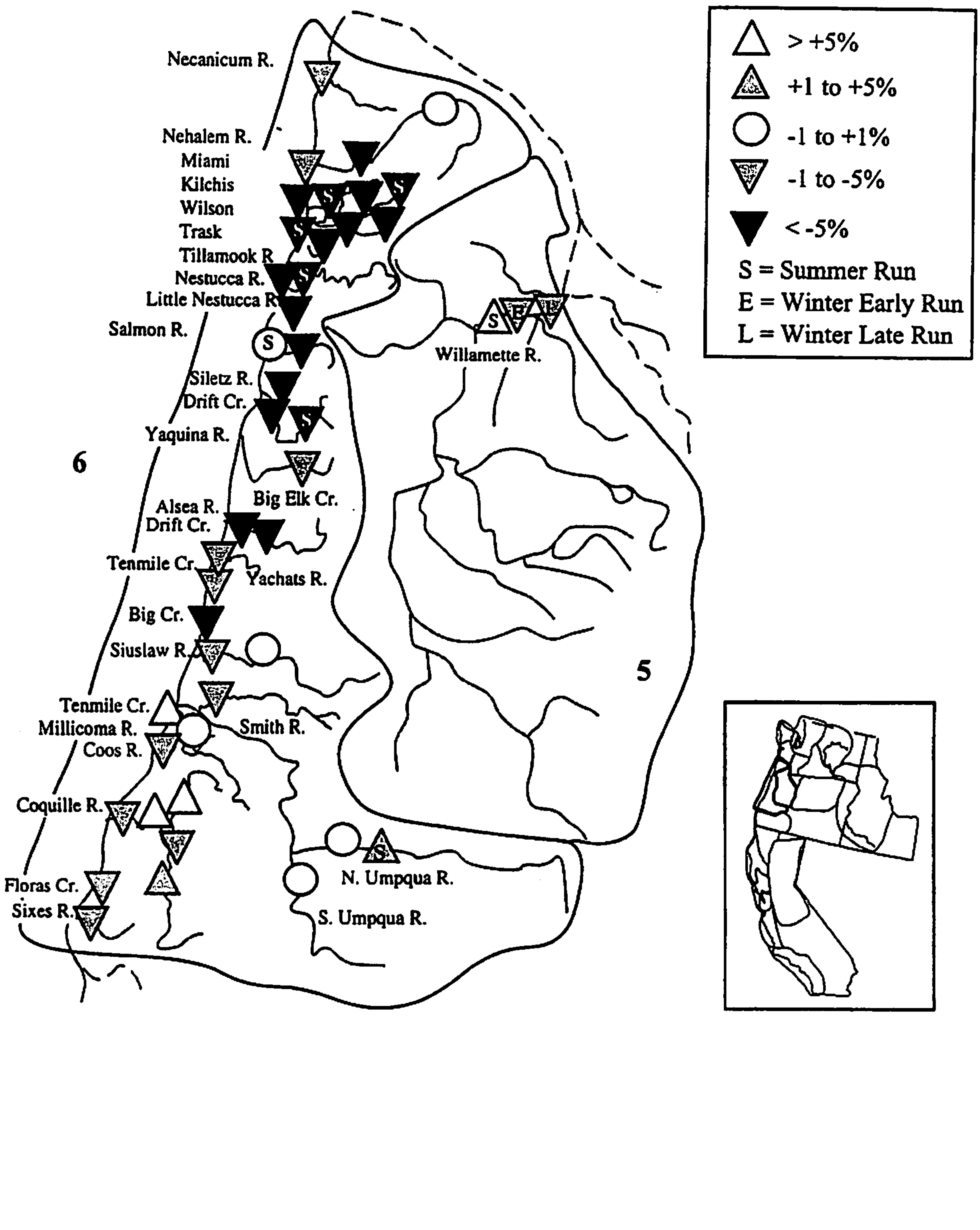


Figure 22. Trends (percent annual change) in total escapement for populations in steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast. All data are for winter steelhead, except as noted (see Appendix E for details).

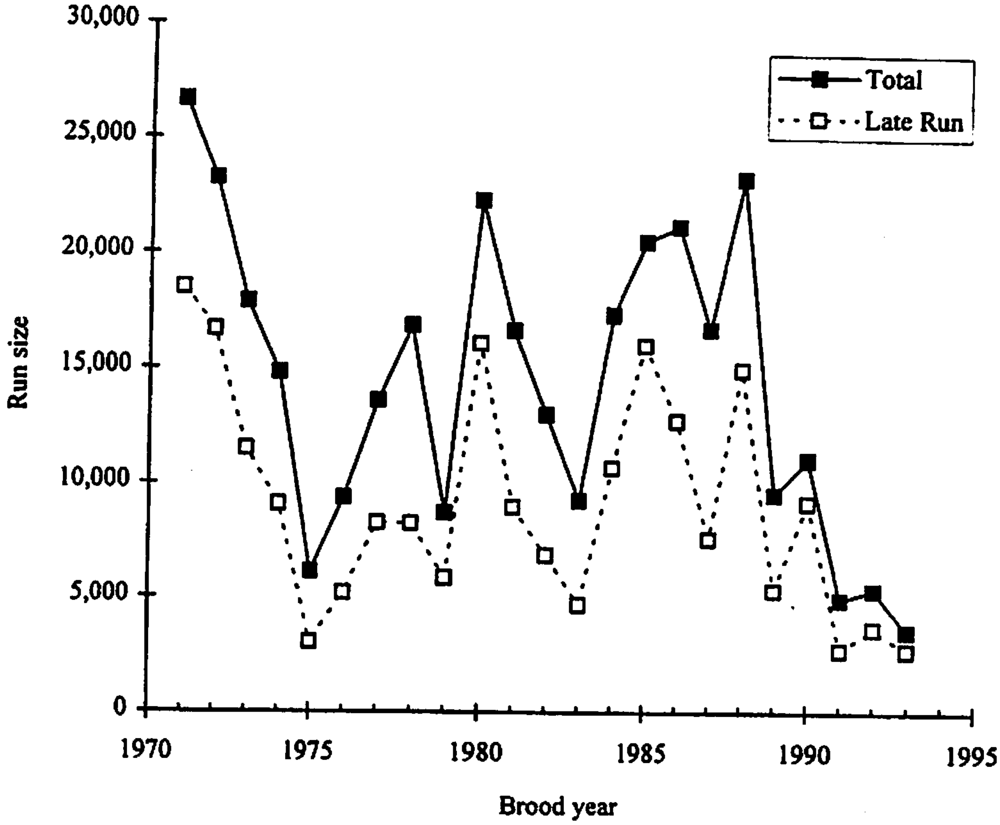


Figure 23. Estimated adult winter steelhead passing Willamette Falls, 1971-93. Data from PSMFC (1994).

the BRT had substantial concern that the majority of natural winter steelhead populations in this ESU may not be self-sustaining. All summer steelhead within the range of this ESU are introduced from outside the area, so are not considered as contributing to natural production of the ESU. Natural reproduction by these introduced summer steelhead may be quite limited.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. While there is some separation in run timing between hatchery and wild winter steelhead, there appears to be sufficient overlap in spawn timing for some genetic introgression from nonlocal hatchery stocks to occur. An additional effect of hatchery production may be directional selection within the natural stocks resulting both from competition with hatchery fish (both winter and summer) and selective fishing pressure that eliminates individuals with early run timing from the natural stocks. Other risk factors relating to hatchery practices were discussed previously in the Background section.

**6) Oregon Coast**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 12 stocks as extinct, at risk, or of special concern (Table 9). Most of the stocks of special concern were classified as such due to hatchery practices. ODFW (Nickelson et al. 1992) considered 21 stocks within the ESU, of which 3, North Umpqua River summer and winter steelhead and Coquille River winter steelhead, were identified as healthy, 17 as depressed, and 1 (Necanicum River) of special concern.

No estimates of historical (pre-1960s) abundance specific to this ESU are available, except for counts at Winchester Dam on the North Umpqua River which began in 1946, and angler catch records which began in 1953. Early angler catch summaries did not distinguish summer and winter steelhead and were not corrected for nonreporting bias, so these have not been relied on in this review. Estimated total run size for the major stocks on the Oregon Coast (including areas south of Cape Blanco) for the early 1980s were given by Light (1987) as approximately 255,000 winter steelhead and 75,000 summer steelhead. Light estimated that 69% of winter and 61% of summer steelhead were of hatchery origin, resulting in naturally produced run sizes of 79,000 winter and 29,000 summer steelhead.

Recent 5-year average total (natural and hatchery) run sizes for streams with adequate data range from 250 to 15,000, corresponding to escapements from 200 to 12,000 (Table 15, Appendix E). Total recent (5-year average) run size for major streams in this ESU was approximately 129,000 (111,000 winter, 18,000 summer), with a total escapement of 96,000 (82,000 winter, 14,000 summer). These totals do not include all streams in the ESU, so they underestimate total ESU run size and escapements. The geographic distribution of escapement is illustrated in Figure 21. Run size and escapement estimates are also based primarily on expansions of angler catch using assumed harvest rates (Kenaston 1989), so they should be viewed as rough approximations.

Regarding freshwater habitat, several minor blockages from dams are documented, and other blockages such as impassable culverts are likely throughout the region. Bottom et al. (1985) identified specific factors affecting salmon habitat in various areas of Oregon,

Table 15. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Oregon Coast steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Necanicum River | W | 3,600 | 2,100 | | -2.4 | 63 |
| Nehalem River | W | 2,500 - 4,000 | 1,500 - 2,400 | | -6.0 to -0.5 | 24 - 37 |
| Miami River | W | 1,400 | 1,100 | | -6.4 | 48 |
| Kilchis River | W | 2,300 | 1,800 | | -7.6 | 66 |
| | S | 300 | 200 | | -5.8 | |
| Wilson River | W | 14,900 | 12,000 | | -6.7 | 51 |
| | S | 2,900 | 2,100 | | -5.4 | |
| Trask River | W | 3,600 | 2,500 | | -8.2 | 32 - 55 |
| | S | 900 | 700 | | -6.7 | |
| Tillamook River | W | 900 | 700 | | -7.7 | 69 |
| Nestucca River | W | 7,400 | 4,400 | | -8.9 | 34 |
| | S | 6,400 | 4,600 | | -5.6 | |
| Little Nestucca River | W | 1,200 | 1,000 | | -11.8 | 79 |
| Salmon River | W | 4,400 | 3,500 | | -7.7 | 70 |
| | S | 500 | 350 | | -0.1 | |
| Siletz River | W | 1,100 - 6,700 | 900 - 4,500 | | -12.4 to -7.6 | 57 - 58 |
| | S | 4,400 | 3,200 | | -10.9 | 90 |
| Yaquina River (Big Elk Cr.) | W | 1,800 | 1,400 | | -2.9 | |
| Alsea River | W | 700 - 6,500 | 600 - 4,000 | | -7.2 to -6.5 | 50 - 91 |
| Yachats River | W | 250 | 200 | | -4.1 | > 10 |
| Tenmile Creek | W | 300 | 250 | | -3.6 | 27 |
| Big Creek | W | 300 | 200 | | -7.0 | > 10 |
| Siuslaw River | W | 700 - 4,600 | 600 - 2,700 | | -4.9 to +0.3 | 49 |
| Smith River | W | 3,700 | 3,000 | | -1.7 | 48 |
| North Umpqua River | W | | 5,600 | | -0.5 | 10 |
| | S | | 2,700 | | +1.0 | 62 |
| South Umpqua River | W | 4,300 | 3,500 | | -0.8 | 43 - 81 |
| Tenmile Creek | W | 800 | 400 | | +5.4 | 80 |
| Coos River | W | 3800 - 6100 | 3100 - 5600 | | -2.5 to -0.5 | 65 - 70 |
| Coquille River | W | 600 - 5,000 | 500 - 3200 | | -3.0 to +16.0 | 55 - 75 |
| Floras Creek | W | 900 | 700 | | -1.4 | 32 |
| Sixes River | W | 1,000 | 800 | | -4.6 | 36 |

including streamflow and temperature problems, riparian habitat losses, and instream habitat problems. They noted that along the Oregon Coast summer temperatures and streamflow reach critical levels for salmonids in areas where there are significant water withdrawals or removal of streamside vegetation had occurred. They reported notable temperature problems in Tillamook Bay tributaries and the Alsea, Siletz, Siuslaw, and Umpqua Rivers. Bottom et al. (1995) also found that loss of riparian vegetation has resulted from agricultural and forestry practices, and that splash dams, debris removal, and stream channelization had caused long-term damage to salmonid habitats.

Sport harvest information was the main abundance data available for most Oregon coastal populations. In 1952, Oregon instituted a punchcard system to record all salmon and steelhead caught by species. However, methods of estimating and reporting catch changed in 1970, and division of catch statistics among tributaries changed substantially in 1977, so earlier data are not directly comparable to those since 1977. Our analyses for Oregon river basins focussed on data collected since those changes (ODFW 1980, 1992, 1993), although trends from longer-term data have been included for comparison in some basins (Appendix E).

Interpreting population abundance from angler catch data presents several problems. First, numbers of fish caught do not directly represent abundance, which must be estimated by applying assumptions about fishing effort and effectiveness. Fishing effort is largely determined by socioeconomic factors, including fishery regulations. Fishing effectiveness is a function of both the skill of the anglers and environmental conditions which affect behavior of both fish and anglers. Both effort and effectiveness may exhibit long-term trends and interannual fluctuations that can obscure the relationship between catch and abundance.

Second, estimates of catch may not be accurate. In Oregon, catch is estimated from returns of punchcards and estimates are corrected for nonreporting bias. While catch estimates are generated separately for each stream basin, the bias correction is calculated statewide and may not be accurate for any particular stream due to local variations in the tendency to return punchcards.

Third, when fishing effort varies across a river basin, catch may reflect only local abundance rather than the total basin population. However, statewide salmon and steelhead fishing effort, as indexed by number of punchcards issued, has been relatively constant since the late 1970s, indicating that angler catch may accurately reflect trends in abundance over large geographic areas. ODFW (1995b) provided evidence that the relationship of angler catch to spawner abundance is weak in some basins, although there is generally a positive correlation. Additionally, fishing effort has been increasingly focused on hatchery fish in recent years, with wild catch and release regulations imposed in many Oregon coastal streams in January 1992 (ODFW 1995b). Thus, recent trends may reflect hatchery production more than natural production throughout the Oregon coast. Trend estimates reported here include angler catch data through 1992 (Table 15, Appendix E). To test for bias due to wild catch and release regulations, we also calculated trends excluding the 1991 and 1992 run years. While the resulting estimates were often different for individual basins, both upward and downward changes were apparent, and overall patterns were similar to those obtained by using the full data set.

The following analysis was made with the assumption that catch trends reflect trends in overall population abundance. We recognize the many problems with this assumption and that the results may not precisely represent trends in the total population in a river basin. However, angler catch is the only information available for most of these populations, and we believe that changes in catch still provide a useful indication of trends in total population abundance. Where alternate trend data were available, we used those data instead of angler catch.

Adequate adult escapement information was available to compute trends for 42 independent stocks within this ESU. Of these, 36 stocks exhibited declines and 6 exhibited increases during the available data series. Trends ranged from a 12% annual decline in Drift Creek on the Siletz River to a 16% annual increase in North Fork Coquille River. Twenty of these trends were significantly different from zero with 18 decreasing and 2 increasing (Appendix E). Upward trends were found only in the southernmost portion of the ESU (Fig. 22), from Siuslaw Bay south. In contrast, longer term trends in angler catch, using data from the early 1950s to the present, generally were increasing. This may reflect longer term stability of populations, or may be an artifact of long-term increases in statewide fishing effort coupled with the differences in bias correction of catch summaries before and after 1970.

Hatchery fish are widespread and escape to spawn naturally throughout the region. Most hatchery stocks used in this region originated from stocks indigenous to the ESU, but many are not native to local river basins. ODFW estimates of hatchery composition for recent winter steelhead escapements were high in many streams, ranging from 10% in the North Umpqua River to greater than 80% in Drift Creek on the Alsea River and in Tenmile Creek south of Umpqua Bay. For summer steelhead, hatchery composition (where reported) ranged from 38% in the South Umpqua River to 90% in the Siletz River. Several summer steelhead stocks have been introduced to rivers with no native summer runs.

Overall, approximately half of the stocks in this ESU for which we have information have hatchery composition in excess of 50%. Few stocks in the region are documented to have escapements above 1,000 fish and no significant decline (Appendix E); most of those that do are in the southern portion of the ESU and have high hatchery influence. While we have little information on the actual contribution of hatchery fish to natural production, given the substantial presence of hatchery fish in the few stocks that are relatively abundant and stable or increasing, the BRT had substantial concern that the majority of natural steelhead populations in this ESU may not be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

**7) Klamath Mountains Province**—This ESU has been evaluated previously (Busby et al. 1994), and is not discussed here.

**8) Northern California**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified three stocks as at risk of extinction: summer steelhead in Redwood Creek, Mad River, and Eel River (Table 9). Higgins et al. (1992) provided a more detailed analysis of some of these stocks and identified 11 summer steelhead stocks as at risk or of concern. They did not evaluate winter steelhead stocks because of insufficient information. The USFS (1993b) identified most stocks on Forest Service lands in this region as either depressed or critical, with only the Little Van Duzen River winter steelhead stock identified as stable (Appendix E).

Estimates of historical (pre-1960s) abundance specific to this ESU were available (Table 16) from dam counts in the upper Eel River (Cape Horn Dam—annual average of 4,400 adult steelhead in the 1930s; McEwan and Jackson 1996), the South Fork Eel River (Benbow Dam—annual average of 19,000 adult steelhead in the 1940s; McEwan and Jackson 1996), and the Mad River (Sweasey Dam—annual average of 3,800 adult steelhead in the 1940s; Murphy and Shapovalov 1951, CDFG 1994). In the mid-1960s, CDFG (1965, table S-3) estimates steelhead spawning populations for many rivers in this ESU totaled 198,000 (Table 17). Estimated total run size for the major stocks in California (entire state) for the early 1980s was given by Light (1987) as approximately 275,000. Of these, 22% were of hatchery origin, resulting in a naturally produced run size of 215,000 steelhead. Roughly half of this production was thought to be in the Klamath River Basin (including the Trinity River), so the total natural production for all ESUs south of Punta Gorda was probably on the order of 100,000 adults. The only current run-size estimates for this area are counts at Cape Horn Dam on the Eel River where an average of 115 total and 30 wild adults were reported (McEwan and Jackson 1996). Summer steelhead snorkel survey data are available for a few tributaries, but they provide no total abundance estimate. Statewide adult summer steelhead abundance is estimated at about 2,000 adults (McEwan and Jackson 1996). Note that estimate apparently refers only to early-summer steelhead entering the rivers in May, June, and July, not including the more numerous "fall-run" steelhead. While we have no overall recent abundance estimate for this ESU (Table 18, Fig. 24), the substantial declines in run size from historic levels at major dams in the region (Table 16) indicate a probable overall decline in abundance from historical levels.

Two substantial habitat blockages are documented: Mathews Dam on the Mad River and Scott Dam on the Eel River (McEwan and Jackson 1996), and other minor blockages (such as impassable culverts) are likely throughout the region. Habitat throughout the north coast of California was severely impacted by catastrophic flooding in 1964. Damage from this flood was probably exacerbated by poor land use practices prior to the event (McEwan and Jackson 1996). Forest practices have also contributed to incremental degradation of stream habitats (Higgins et al. 1992, McEwan and Jackson 1996). Excessive sedimentation and unstable spawning gravels are cited as major habitat problems in this region (CDFG 1991, Higgins et al. 1992). Other habitat problems similar to those cited for the Oregon Coast ESU probably also occur in this region. A high abundance of non-native Sacramento squawfish (*Ptychocheilus grandis*) has been reported recently in the Eel River Basin (Brown

Table 16. Summary of historical abundance estimates for the Northern California evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Eel River | | | |
| Cape Horn Dam | 4,400 | 1930s | McEwan and Jackson 1996 |
| | 1,000 | 1980s | McEwan and Jackson 1996 |
| Benbow Dam | 18,784 | 1940s | Shapovalov and Taft 1954 |
| | 3,355 | 1970s | McEwan and Jackson 1996 |
| Mad River | | | |
| Sweasy Dam | 3,800 | 1940s | Murphy and Shapovalov 1951 |
| | 2,000 | 1960s | McEwan and Jackson 1996 |
| Casper Creek | 114 | 1964 | Graves and Burns 1970 |
| | 102 | 1968 | Graves and Burns 1970 |

Table 17. Estimated steelhead spawning populations for California rivers in the mid-1960s (CDFG 1965, Table S-3), with comparable recent maximum estimates (from Appendix B).

| ESU* | River system | 1960s | Recent |
|---|---|---|---|
| Northern California | | | |
| | Redwood Creek | 10,000 | |
| | Mad River | 6,000 | |
| | Eel River System (Total) | 82,000 | |
| | Mattole River | 12,000 | |
| | Ten Mile River | 9,000 | |
| | Noyo River | 8,000 | |
| | Big River | 12,000 | |
| | Navarro River | 16,000 | |
| | Garcia River | 4,000 | |
| | Gualala River | 16,000 | |
| | Other streams (Humboldt, Mendocino Counties) | 23,000 | |
| | **Total** | **198,000** | |
| Central California Coast | | | |
| | Russian River | 50,000 | 7,000 |
| | San Lorenzo River | 19,000 | 150 |
| | Other streams (Sonoma County to Santa Cruz County) | 25,000 | |
| | **Total** | **94,000** | |
| South-Central California Coast | | | |
| | Pajaro River | 2,000 | 100 |
| | Salinas River | 500 | 100 |
| | Carmel River | 1,500 | 100 |
| | Little Sur River | 500 | 100 |
| | Big Sur River | 250 | 100 |
| | Other streams (Monterey, San Luis Obispo Counties) | 23,000 | |
| | **Total** | **27,750** | |
| Central Valley | | | |
| | Sacramento River System | 26,250 | |
| | Mokelumne River System | 500 | |
| | San Joaquin River System | 0 | |
| | **Total** | **26,750** | |

*ESU = evolutionarily significant unit.

Table 18. Summary of estimated trends in total escapement for the Northern California steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W), summer (S), or combined (C).

| River basin | Run type | Total run size* | Total escapement* | Natural escapement* | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Redwood Creek | S | | | | -3.0 | |
| Mad River | W | | | | -5.0 | |
| | S | | | | -1.1 | |
| Eel River | | | | | | |
| Mainstem | C | | | | -5.8 | |
| Middle Fork | S | | | | +1.8 | |
| South Fork | C | | | | -4.8 | |
| Van Duzen River, South Fork | S | | | | +3.5 | |

*None of the available abundance data are adequate to provide total escapement estimates for river basins occupied by the Northern California evolutionarily significant unit.

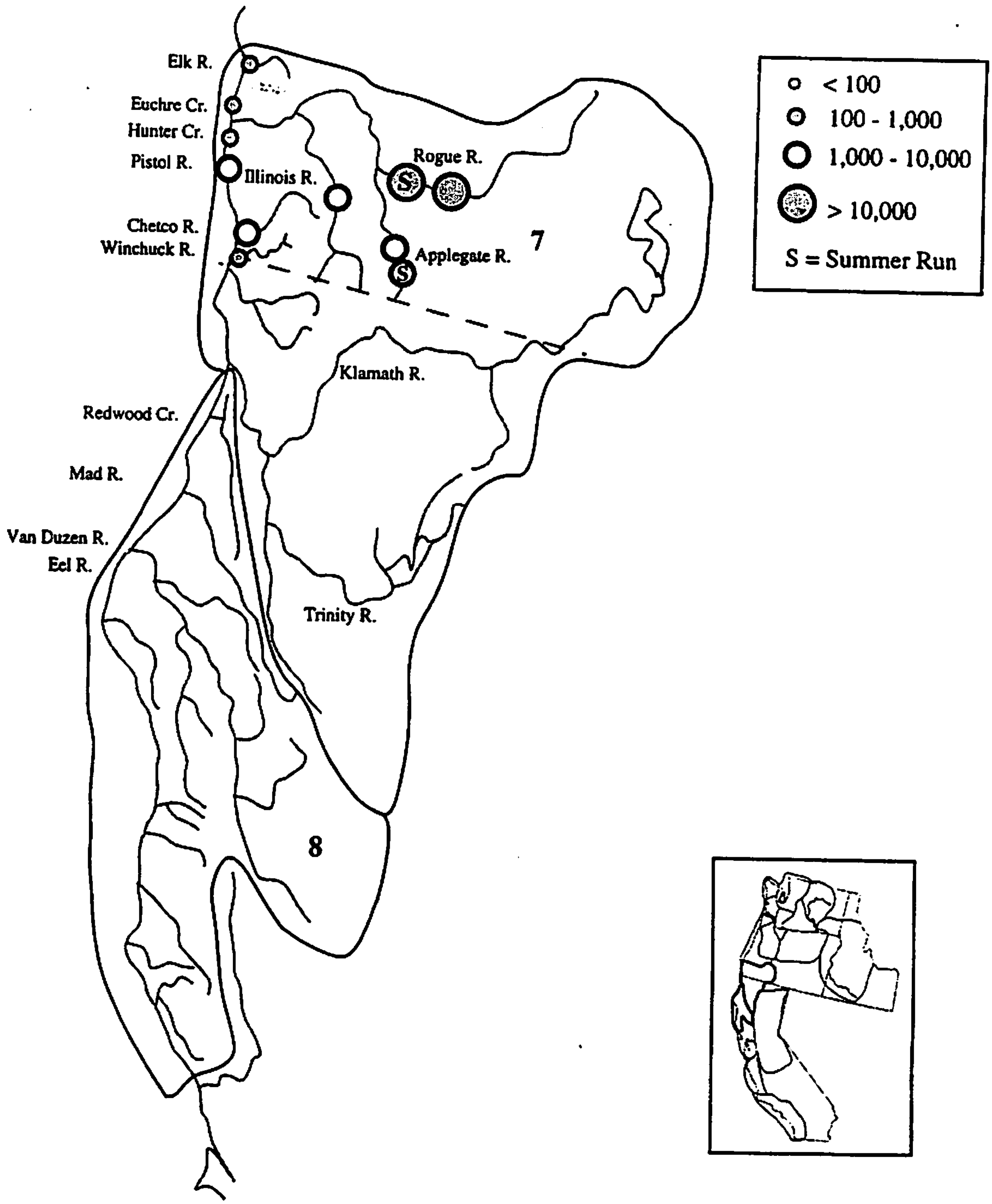


Figure 24. Recent total escapement for populations in steelhead ESU 7-Klamath Mountains Province. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details). Available abundance data for steelhead populations in ESU 8-Northern California are not adequate to provide total escapement estimates for rivers in that area.

and Moyle 1991, Moyle and Yoshiyama 1992), which would suggest increased risk of predation for juvenile steelhead.

Adequate adult escapement information was available to compute trends for seven stocks within this ESU (Table 18, Fig. 25). Of these, five data series exhibit declines and two exhibit increases during the available data series, with a range from 5.8% annual decline to 3.5% annual increase. Three of the declining trends were significantly different from zero (Appendix E). For one long data set (Eel River, Cape Horn Dam counts), a separate trend for the last 21 years (1971-91) was calculated for comparison: while the full-series trend showed significant decline, the recent data showed a lesser, nonsignificant decline, suggesting that the major stock decline occurred prior to 1970.

Hatchery fish are widespread and escaping to spawn naturally throughout the region. According to McEwan and Jackson (1996, p. 37), "despite the large number of hatchery smolts released, steelhead runs in north coast drainages are comprised mostly of naturally produced fish." We have little information on the actual contribution of hatchery fish to natural spawning, and little information on present total run sizes for this ESU. However, given the preponderance of significant negative trends in the available data, there is concern that steelhead populations in this ESU may not be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section. Within this ESU, we have no information regarding spatial or temporal separation of spawning hatchery and natural fish, but there is probably sufficient overlap for some genetic introgression to occur.

**9) Central California Coast**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified two stock groups as at high risk of extinction: Napa River and San Francisco Bay Tributaries (Table 9). Titus et al. (in press) provided a more detailed analysis of stocks south of San Francisco Bay and identified numerous stocks that were declining.

Only two estimates of historical (pre-1960s) abundance specific to this ESU are available: the first reported an average of about 500 adults in Waddell Creek in the 1930s and early 1940s (Shapovalov and Taft 1954), and the second estimated 20,000 steelhead in the San Lorenzo River before 1965 (Johnson 1964) (Table 19). In the mid-1960s, CDFG (1965, table S-3) estimated 94,000 steelhead spawning in many rivers of this ESU (Table 17). We have comparable recent estimates for only the Russian and San Lorenzo Rivers, which contain the two largest stocks in the ESU. Recent total abundance in these two rivers is estimated to be less than 15% of their abundance 30 years ago (Table 17). Additional recent estimates are available for several other streams (Table 20, Fig. 26), but we have no recent estimates for total run size for this ESU.

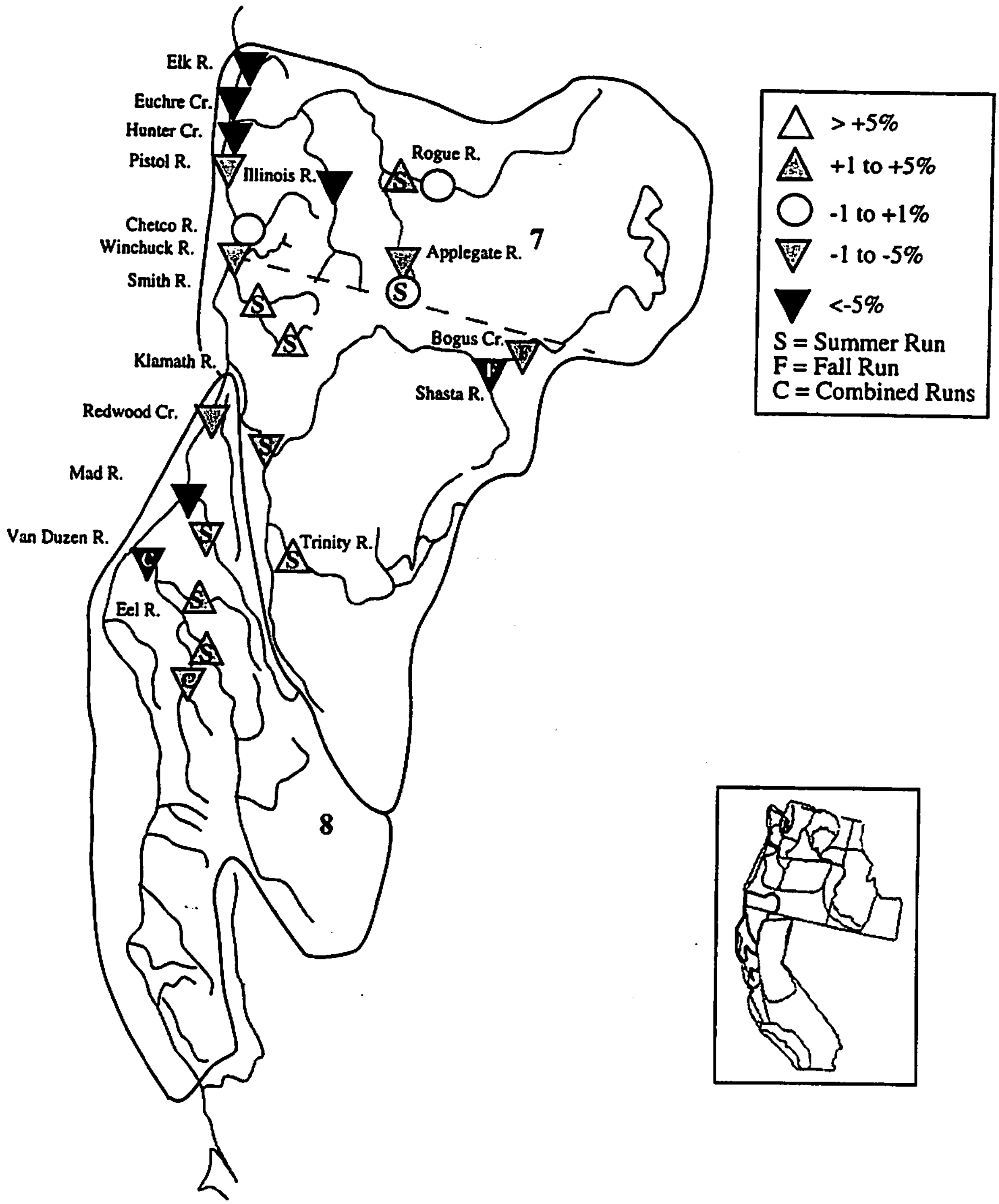


Figure 25. Trends (percent annual change) in total escapement for populations in steelhead ESUs 7-Klamath Mountains Province and 8-Northern California. All data are for winter steelhead, except as noted (see Appendix E for details).

Table 19. Summary of recent and historical abundance estimates for the Central California Coast evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Russian River | 65,000 | 1970 | CACSS 1988 |
| | 1,750 - 7,000 | 1994 | McEwan and Jackson 1996 |
| Laugunitas Creek | 400 - 500 | 1990s | McEwan and Jackson 1996 |
| San Gregorio | 1,000 | 1973 | Coots 1973 |
| Waddell Creek | 481 | 1933 - 1942 | Shapovalov and Taft 1954 |
| | 250 | 1982 | Shuman 1994 |
| | 150 | 1994 | Shuman 1994 |
| Scott Creek | 400 | 1991 | Nelson 1994 |
| | <100 | 1991 | Reavis 1991 |
| | 300 | 1994 | Titus et al. in press |
| San Vicente Creek | 150 | 1982 | Shuman 1994 |
| | 50 | 1994 | Shuman 1994 |
| San Lorenzo River | 20,000 | before 1965 | Johnson 1964, SWRCB 1982 |
| | 1,614 | 1977 | CDFG 1982 |
| | >3,000 | 1978 | Ricker and Butler 1979 |
| | 600 | 1979 | CDFG 1982 |
| | 3,000 | 1982 | Shuman 1994 |
| | few | 1991 | Reavis 1991 |
| | <150 | 1994 | Shuman 1994 |
| Soquel Creek | 500 - 800 | 1982 | Shuman 1994 |
| | <100 | 1991 | Reavis 1991 |
| | 50 - 100 | 1994 | Shuman 1994 |
| Aptos Creek | 200 | 1982 | Shuman 1994 |
| | <100 | 1991 | Reavis 1991 |
| | 50 - 75 | 1994 | Shuman 1994 |

Table 20. Summary of estimated total run size for the Central California Coast steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Russian River | 1750 - 7000 | | | | |
| Lagunitas Creek | 500 | | | | |
| Waddell Creek | 150 | | | | |
| Scott Creek | <300 | | | | |
| San Vicente Creek | 50 | | | | |
| San Lorenzo River | <150 | | | | |
| Soquel Creek | <100 | | | | |
| Aptos Creek | <100 | | | | |

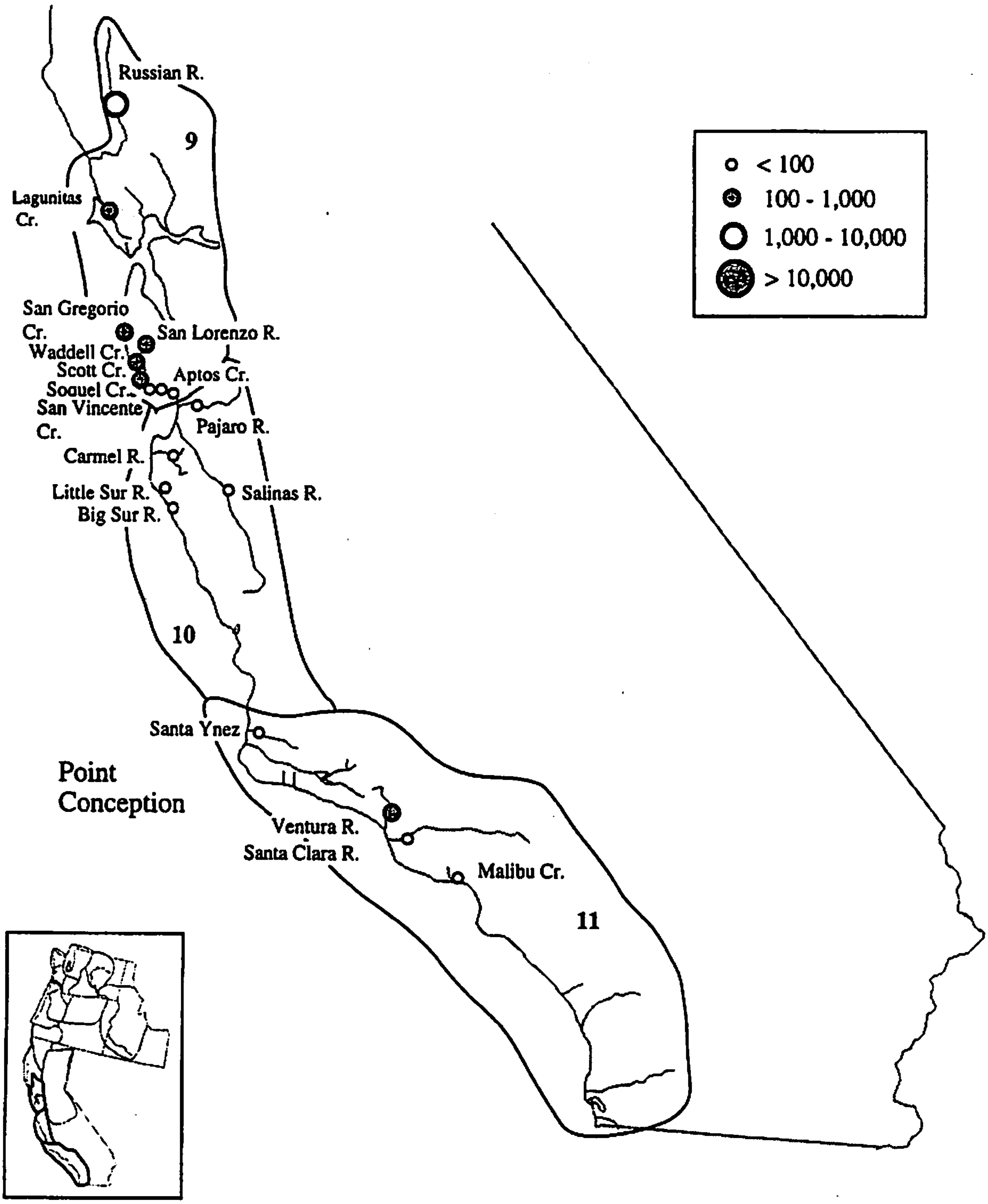


Figure 26. Recent total escapement for populations in steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California. Where no total estimate is available, natural escapement is used. All data are for winter steelhead (see Appendix E for details).

McEwan and Jackson (1996) noted that steelhead in most streams tributary to San Francisco and San Pablo Bays have been extirpated, although small "fair to good" runs of steelhead reportedly occur in coastal Marin County tributaries (Cox[18], Smith[19]).

Two substantial habitat blockages are documented: Coyote and Warm Springs Dams in the Russian River Basin (McEwan and Jackson 1996), and other minor blockages (smaller dams, impassable culverts, etc.) are likely throughout the region Titus et al. (in press) reported blockages on 12 of 46 tributaries in the southern portion of this ESU, and he noted fish passage problems in most other tributaries. Streams in this region probably suffer from a variety of habitat factors, including urbanization and poor land management practices in both forestry and agriculture.

Habitat throughout the north coast of California, including portions occupied by this ESU, was severely impacted by catastrophic flooding in 1964. Damage from this flood was probably exacerbated by poor land use practices prior to the event (McEwan and Jackson 1996). Forest practices have also contributed to incremental degradation of stream habitats (McEwan and Jackson 1996). Dewatering due to irrigation and urban water diversions is also a problem. Titus et al. (in press) documented some of these problems for specific tributaries in the southern portion of this ESU. Other habitat problems similar to those cited for the Oregon Coast ESU probably also occur in this region.

Adequate adult escapement information was not available to compute trends for any stocks within this ESU (Table 20, Fig. 27). However, general trends can be inferred from the comparison of 1960s and 1990s abundance estimates provided above, and these indicate substantial rates of decline in the two largest steelhead stocks (Russian and San Lorenzo Rivers).

Presently, the principal hatchery production in this ESU is from Warm Springs Hatchery on the Russian River and the Monterey Bay Salmon and Trout Project located at Big Creek Hatchery off Scott Creek and at other facilities. There are other small private and cooperative programs producing steelhead within the range of this ESU. Most of the hatchery stocks used in this region originated from stocks indigenous to the ESU, but many are not native to their local river basins (Bryant 1994).

We have little information on the actual contribution of hatchery fish to natural spawning, and little information on present total run sizes or trends for this ESU. However, given the substantial negative trends in the stocks for which we do have data, it is likely that the majority of natural production in this ESU is not self-sustaining. It appears that most of the recent declines in steelhead abundance within this ESU have occurred in the larger river

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[18] B. Cox, California Department of Fish and Game, Region 3, P.O. Box 47, Yountville, CA 94599. Pers. commun., September 1994.

[19] J. Smith , Department of Biological Sciences, San Jose State University, San Jose, CA 95192. Pers. commun., September 1994.

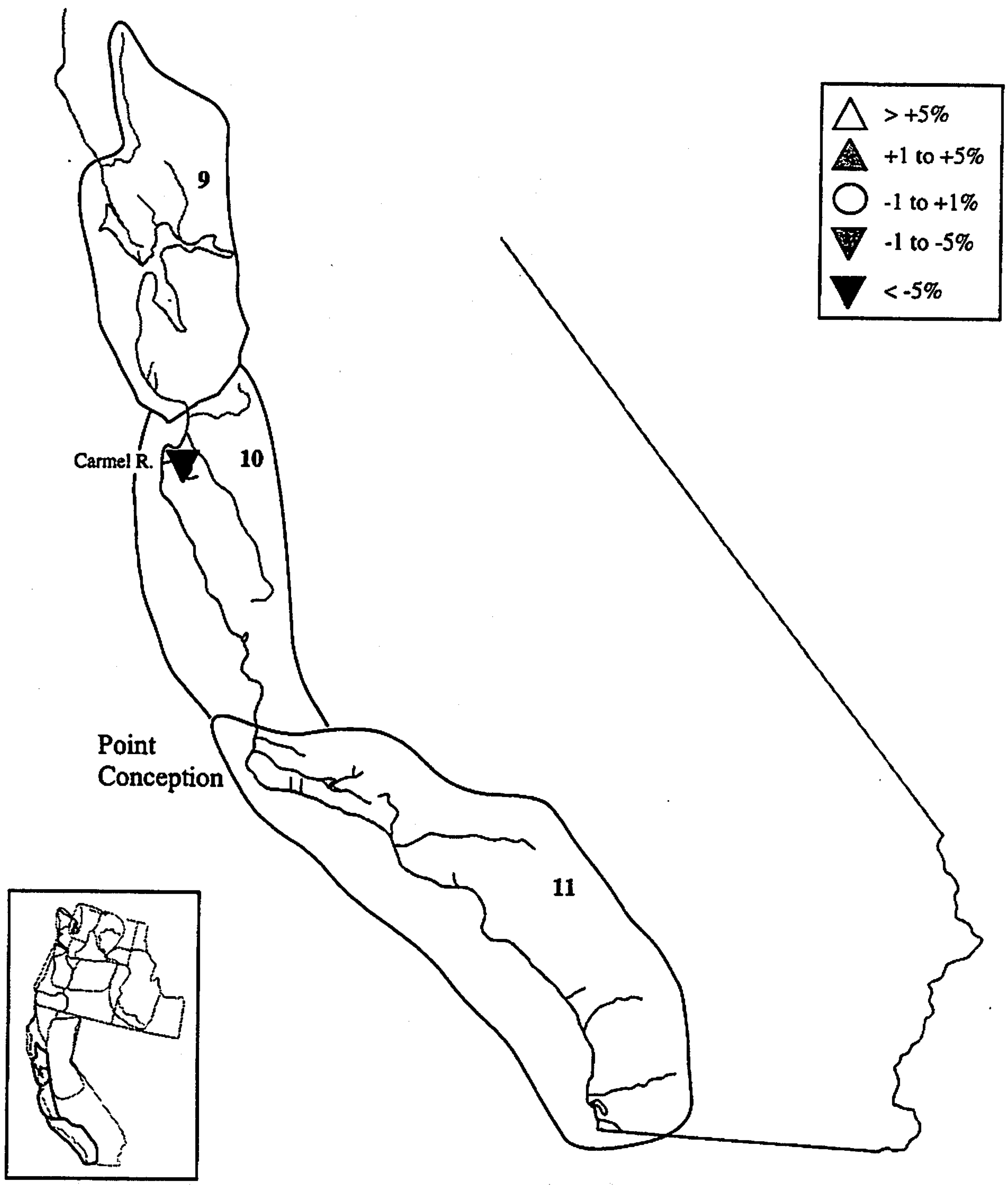



Figure 27. Trends (percent annual change) in total escapement for populations in steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California. All data are for winter steelhead (see Appendix E for details).

systems, while populations in many smaller streams are relatively healthy and probably have not experienced significant recent changes in abundance (Cox footnote 18, Smith footnote 19).

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. General risk factors relating to hatchery practices were discussed previously in the Background section. Within this ESU, we have little information regarding present hatchery production and no information regarding spatial or temporal separation of spawning hatchery and natural fish. However, there is probably sufficient overlap in spawning for some genetic introgression to occur. Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have received insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**10) South-Central California Coast**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified five stocks as at risk (Table 9). Titus et al. (in press) provided a more detailed analysis of stocks south of San Francisco Bay and identified numerous stocks that were declining (Appendix E).

Historical estimates of steelhead abundance are available for a few streams in this region (Table 21). The California Advisory Committee on Salmon and Steelhead (CACSS 1988) cited an estimate of 20,000 steelhead in the Carmel River in 1928. In the mid-1960s, CDFG (1965, table S-3) estimated 27,750 steelhead spawning in many rivers of this ESU (Table 17). However, comparisons with recent estimates for these rivers show a substantial decline during the past 30 years. In contrast to the CDFG (1965) estimates, McEwan and Jackson (1996) reported runs ranging from 1,000 to 2,000 in the Pajaro River in the early 1960s, and Snider (1983) estimated escapement of about 3,200 steelhead for the Carmel River for the 1964-75 period.

While we have no recent estimates of total run size for this ESU, recent run-size estimates are available for five streams (Table 22, Fig. 26). The total of these estimates is less than 500, compared with a total of 4,750 for the same streams in 1965, which indicates a substantial decline for the entire ESU from 1965 levels.

Minor habitat blockages (smaller dams, impassable culverts, etc.) are likely throughout the region. Titus et al (in press) reported blockages on 28 of 66 tributaries in this ESU, and some passage impairments on most other tributaries. Streams in this region probably suffer from a variety of habitat factors similar to those affecting neighboring ESUs. Forest practices have contributed to incremental degradation of stream habitats (McEwan and Jackson 1996), and dewatering due to irrigation and urban water diversions is also a problem.

Table 21. Summary of recent and historical abundance estimates for the South-Central California Coast evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Pajaro River | 1,500 | 1964 | McEwan and Jackson 1996 |
| | 1,000 | 1965 | McEwan and Jackson 1996 |
| | 2,000 | 1966 | McEwan and Jackson 1996 |
| | <100 | 1991 | Nehlsen et al. 1991, Reavis 1991 |
| Salinas River | <100 | 1991 | Nehlsen et al. 1991 |
| Carmel River | 20,000 | 1928 | CACSS 1988 |
| | 3,177 | 1964 - 1975 | Snider 1983 |
| | 2,000 | 1988 | CACSS 1988 |
| | <4,000 | 1988 | Meyer Resources 1988 |
| | few 100s | 1991 | Nehlsen et al. 1991 |
| | few 100s | 1993 | Titus et al. in press |
| Little Sur River | <100 | 1991 | Reavis 1991 |
| Big Sur River | <100 | 1991 | Nehlsen et al. 1991 |
| | few 100s | 1991 | Reavis 1991 |

Table 22. Summary of estimated total run size and trends in total escapement for the South-Central California Coast steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend | Percent hatchery |
|---|---|---|---|---|---|
| Pajaro River | <100 | | | | |
| Salinas River | <100 | | | | |
| Carmel River | 16 | | | -21.9 | |
| Little Sur River | <100 | | | | |
| Big Sur River | <100 | | | | |

Titus et al. (in press) have documented some of these problems for specific tributaries in the southern portion of this ESU.

Adequate adult escapement information was available to compute a trend for only one stock within this ESU: Carmel River above San Clemente Dam (Table 22, Fig. 27). These data show a significant decline of 22% per year from 1963 to 1993, with a recent 5-year average count of only 16 adult steelhead at the dam. However, general trends for the region can be inferred by comparing the 1960s and 1990s abundance estimates provided above.

Presently, there is little hatchery production within this ESU. There are small private and cooperative programs producing steelhead within this ESU, as well as one captive broodstock program intended to conserve the Carmel River steelhead strain (McEwan and Jackson 1996). Most hatchery stocks used in this region originated from stocks indigenous to the ESU, but many are not native to their local river basins (Bryant 1994). We have little information on the actual contribution of hatchery fish to natural spawning, and little information on present total run sizes or trends for this ESU. However, given the substantial reductions from historical abundance and the recent negative trends in the stocks for which we do have data, it is likely that the majority of natural production in this ESU is not self-sustaining.

Past and present hatchery practices probably pose some risk to steelhead in this ESU as discussed previously in the Background section. Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have received insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**11) Southern California**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 11 stocks as extinct and 4 as at high risk (Table 9). Titus et al. (in press) provided a more detailed analysis of these stocks and identified stocks within 14 drainages in this ESU as extinct, at risk, or of concern. They identified only two stocks, those in Arroyo Sequit and Topanga Creek, as showing no significant change in production from historical levels.

Historically, steelhead may have occurred naturally as far south as Baja California. Estimates of historical (pre-1960s) abundance are available for several rivers in this ESU (Table 23): Santa Ynez River, before 1950, 20,000-30,000; Ventura River, pre-1960, 4,000-6,000; Santa Clara River, pre-1960, 7,000-9,000; Malibu Creek, pre-1960, 1,000. In the mid-1960s, CDFG (1965, table S-3) estimated steelhead spawning populations for smaller tributaries in San Luis Obispo County as 20,000, but they provided no estimates for streams farther south.

Table 23. Summary of recent and historical abundance estimates for the Southern California steelhead evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Santa Ynez River | 20,000 - 30,000 | historic | Reavis 1991 |
| | 20,000 | historic | Titus et al. in press |
| | 12,995 - 25,032 | 1940s | Shapovalov and Taft 1954 |
| | 20,000 | 1952 | CDFG 1982 |
| | 100 | 1991 | Reavis 1991 |
| | <100 | 1991 | Nehlsen et al. 1991 |
| | <100 | 1994 | CCC 1994 |
| Gaviota Creek | 10s | 1991 | Reavis 1991 |
| Ventura River | 4,000 - 6,000 | historic | AFS 1991, Hunt et al. 1992, Henke 1994, Titus et al. in press |
| | 4,700 | late 1940s | CDFG 1982 |
| | <100 | 1980 | Moore 1980 |
| | 200 | 1991 | Higgins 1991 |
| | <25 | 1991 | McEwan and Jackson 1996 |
| | few 100s | 1991 | Reavis 1991 |
| | <100 | 1991 | Nehlsen et al. 1991 |
| | 200 | 1993 | Nash 1993 |
| | <200 | 1994 | CCC 1994 |
| Matilija Creek | 2,000 - 2,500 | historic | Clanton and Jarvis 1946 |
| Santa Clara River | 7,000 - 9,000 | historic | Moore 1980 |
| | 9,000 | historic | Moore 1980, Comstock 1992, Henke 1994 |
| | 6 | 1982 | Puckett and Villa 1985 |
| | <100 | 1994 | CCC 1994 |
| | <100 | 1991 | Nehlsen et al. 1991 |
| | few 100s | 1991 | Reavis 1991 |
| Malibu Creek | 1,000 | historic | Nehlsen et al. 1991 |
| | <100 | 1991 | Nehlsen et al. 1991, Reavis 1991 |
| | 60 | 1991 | AFS 1991 |
| | 60 | 1993 | Nash 1993 |

The present total run sizes for 6 streams in this ESU were summarized by Titus et al. (in press); all were less than 200 adults (Table 24, Fig. 26). Titus et al. (in press) concluded that populations have been extirpated from all streams south of Ventura County, with the exception of Malibu Creek in Los Angeles County. However, steelhead are still occasionally reported in streams where stocks were identified by these authors as extirpated.

Titus et al. (in press) cited extensive loss of steelhead habitat due to water development, including impassable dams and dewatering of portions of rivers. They also reported that of 32 tributaries in this region, 21 have blockages due to dams, and 29 have impaired mainstem passage. Habitat problems in this ESU relate primarily to water development resulting in inadequate flows, flow fluctuations, blockages, and entrainment into diversions (McEwan and Jackson 1996, Titus et al. in press). Other problems related to land use practices and urbanization also certainly contribute to stock conditions.

No time series of data are available within this ESU from which to estimate population trends, but Titus et al. (in press) summarized information for steelhead populations based on historical and recent survey information. Of the populations south of San Francisco Bay (including part of the Central California Coast ESU) for which past and recent information was available, they concluded that 20% had no discernible change, 45% had declined, and 35% were extinct. Percentages for the counties comprising this ESU are given in Table 25 and show a very high percentage of declining and extinct populations.

There is no current hatchery production of steelhead within this ESU. The small run sizes and almost universal declines in these populations strongly suggest that natural production is not self-sustaining.

The influence of hatchery practices on this ESU is not well documented. Common risk factors relating to hatchery practices were discussed previously in the Background section. In some populations, there may be genetic introgression from past steelhead plants and from planting of rainbow trout (Nielsen footnote 9). Habitat fragmentation and population declines have also resulted in small, isolated populations that may face genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We do not have sufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**12) Central Valley**—Only Nehlsen et al. (1991) have provided a status assessment for stocks within this ESU; they identified one stock (Sacramento River) as at high risk (Table 9). However, this stock represents all the known populations of steelhead within the ESU.

Historical abundance estimates are available for some stocks within this ESU (Table 26), but no overall estimates are available prior to 1961, when Hallock et al. (1961) estimated a total run size of 40,000 steelhead in the Sacramento River, including

Table 24. Summary of estimated total run size for the Southern California steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Santa Ynez River | <100 | | | | |
| Ventura River | <200 | | | | |
| Santa Clara River | <100 | | | | |
| Malibu Creek | <100 | | | | |

Table 25. Percentage of steelhead populations in three risk categories in southern California counties. Includes only those populations for which recent information exists. Based on data in Titus et al. (in press).

| County | No discernible decline | Declining | Extinct |
|---|---|---|---|
| San Mateo | 50% | 50% | 0% |
| Santa Cruz | 19 | 81 | 0 |
| Monterey | 50 | 42 | 8 |
| San Luis Obispo | 25 | 62 | 13 |
| Santa Barbara | 0 | 27 | 73 |
| Ventura/Los Angeles | 9 | 27 | 64 |
| Orange/San Diego | 0 | 0 | 100 |

Table 26. Summary of recent and historical abundance estimates for the Central Valley steelhead evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Sacramento River Basin | 40,000 | 1961 | Hallock et al. 1961 |
| American River | 19,583 | 1971, 1972 | Stanley 1976 |
| upper Sacramento River | 20,540 | 1950s | Hallock et al. 1961 |
| | 10,000 | 1994 | McEwan and Jackson 1996 |
| Red Bluff Diversion Dam | 11,187 | 1967 | McEwan and Jackson 1996 |
| | 2,202 | 1990 | McEwan and Jackson 1996 |
| Yuba River | 2,000 | 1984 | McEwan and Jackson 1996 |
| Deer Creek | 1,006 | 1964 | McEwan and Jackson 1996 |
| Mill Creek | 417 - 2,269 | 1953 - 1963 | McEwan and Jackson 1996 |
| Mokelumne River | <50 | 1974 - 1994 | McEwan and Jackson 1996 |
| Tuolumne River | 66 | 1940 | McEwan and Jackson 1996 |

San Francisco Bay. In the mid-1960s, CDFG (1965, table S-3) estimated steelhead spawning populations for the rivers in this ESU, totaling almost 27,000 fish (Table 17).

We have limited data on recent abundance for this ESU (Table 27, Fig. 28), but its present total run size based on dam counts, hatchery returns, and past spawning surveys is probably less than 10,000 fish. Both natural and hatchery runs have declined since the 1960s. Counts at Red Bluff Diversion Dam averaged 1,400 fish over the last 5 years, compared with runs in excess of 10,000 fish in the late 1960s. Recent run-size estimates for the hatchery produced American River stock average less than 1,000 fish, compared to 12,000-19,000 in the early 1970s (McEwan and Jackson 1996).

Historically, steelhead occurred naturally throughout the Sacramento and San Joaquin River Basins; however, stocks have been extirpated from large areas of the Sacramento River Basin and possibly from the entire San Joaquin River Basin. The California Advisory Committee on Salmon and Steelhead (CACSS 1988) reported a reduction in Central Valley steelhead habitat from 6,000 miles historically to 300 miles at present. Reynolds et al. (1993, p. III-1) reported that 95% of salmonid habitat in California's Central Valley has been lost, largely due to mining and water development activities. They also noted (p. IV-8) that declines in Central Valley steelhead stocks are "due mostly to water development, inadequate instream flows, rapid flow fluctuations, high summer water temperatures in streams immediately below reservoirs, diversion dams which block access, and entrainment of juveniles into unscreened or poorly screened diversions." Thus, overall habitat problems in this ESU relate primarily to water development resulting in inadequate flows, flow fluctuations, blockages, and entrainment into diversions (McEwan and Jackson 1996). Other problems related to land use practices (agriculture and forestry) and urbanization have also certainly contributed to stock declines.

Adequate adult escapement information was available to compute a trend for only one stock within this ESU: the Sacramento River population above Red Bluff Diversion Dam (Table 27, Fig. 29). This data series showed a significant decline of 9% per year from 1966 to 1992 (Table 27, Appendix E). McEwan and Jackson (1996) cite substantial declines in hatchery returns within the basin as well. Most indigenous natural production of steelhead in this ESU occurs in upper Sacramento River tributaries (Antelope, Deer, and Mill Creeks) below Red Bluff Diversion Dam. Fish passing over that dam are primarily of hatchery origin (70-90%). The American, Feather, and Yuba Rivers, and possibly the upper Sacramento and Mokelumne Rivers, also have naturally spawning populations (CDFG 1995), but these populations have had substantial hatchery influence and their ancestry is not clearly known. The Yuba River had an estimated run size of 2,000 in 1984, and though recent run sizes are unknown the population appears to be stable and supports a fishery (McEwan and Jackson 1996). However, the status of native, natural fish in this stock is unknown: the stock has been influenced by Feather River Hatchery fish, and biologists familiar with the stock report that the Yuba River supports almost no natural production of steelhead (Hallock 1989). Nevertheless, CDFG (1995) asserted that "a substantial portion of the returning adults are progeny of naturally spawning adults from the Yuba River." This stock currently receives no hatchery steelhead plants and is managed as a naturally sustained population (CDFG 1995, McEwan and Jackson 1996).

Table 27. Summary of estimated total run size and trends in total escapement for the Central Valley steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Sacramento River (upper) | 1,500 | | | -9.0 | |

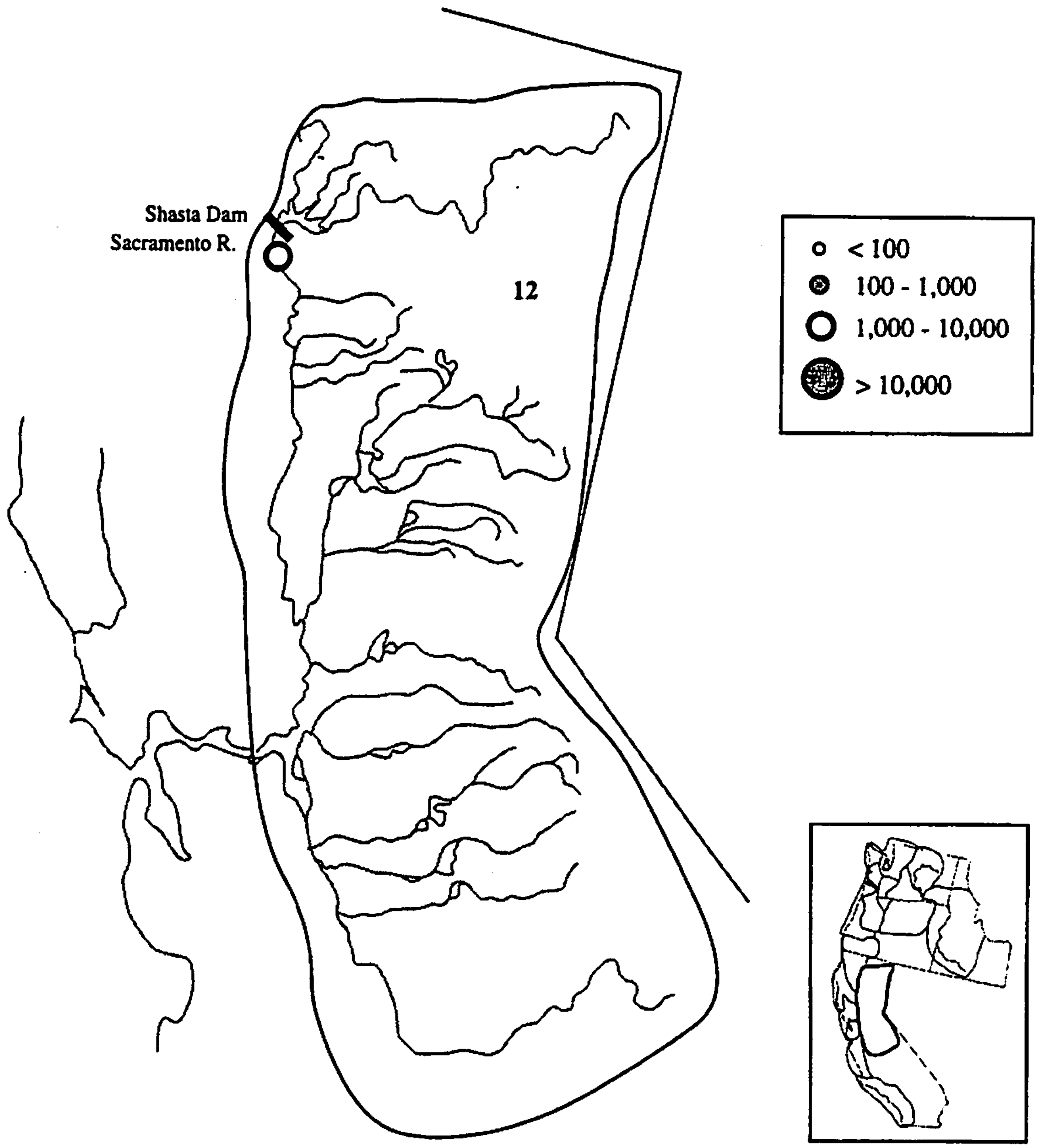



Figure 28. Recent total escapement for populations in steelhead ESU 12-Central Valley. Where no total estimate is available, natural escapement is used. All data are for winter steelhead (see Appendix E for details).

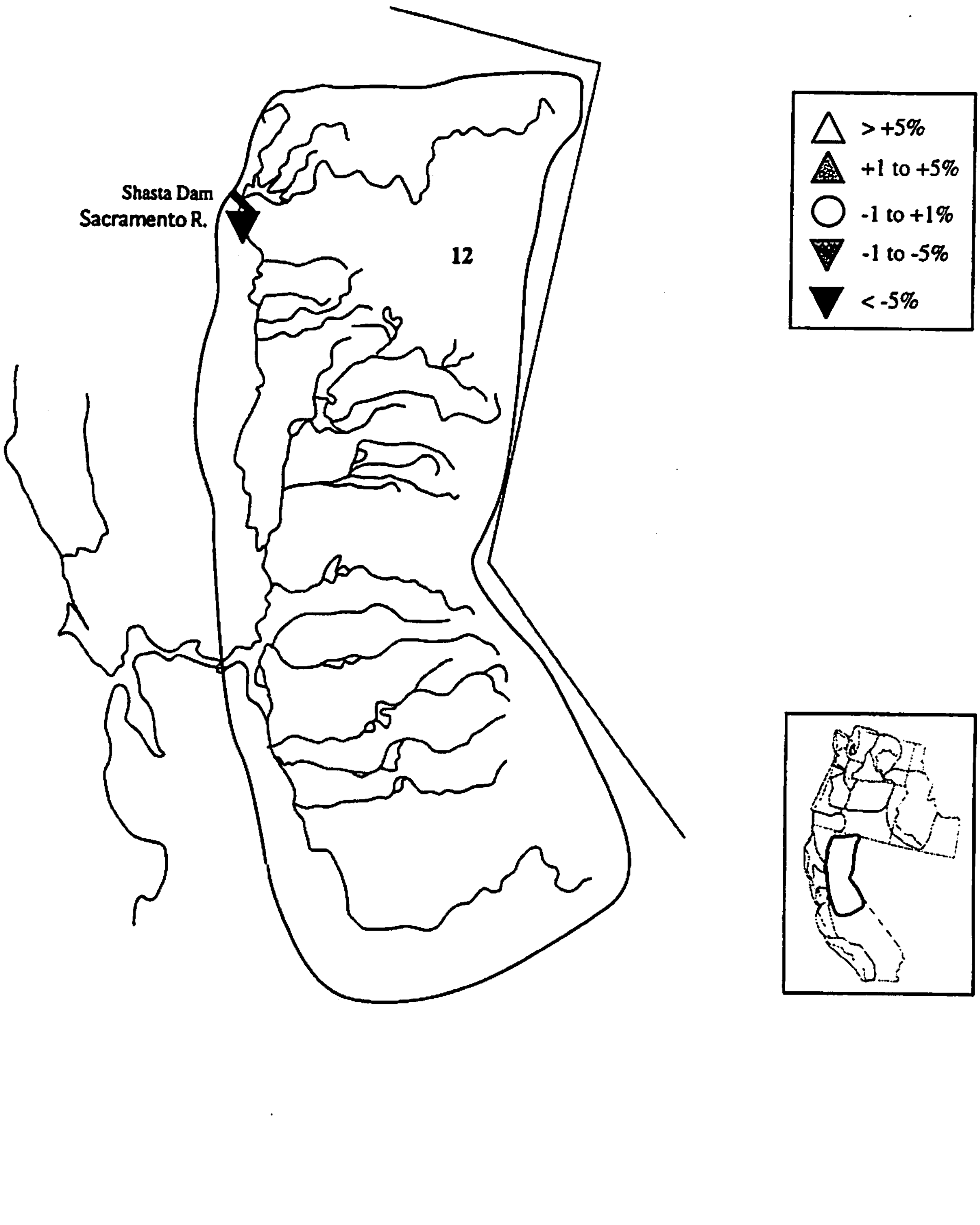



Figure 29. Trends (percent annual change) in total escapement for populations in steelhead ESU 12-Central Valley. All data are for winter steelhead (see Appendix E for details).

There are reports of a small remnant steelhead run in the Stanislaus River, steelhead were observed in the Tuolumne River in 1983, and large rainbow trout (possibly steelhead) have been observed at Merced River Hatchery recently (McEwan and Jackson 1996). Wild stocks in Mill, Deer, and Antelope Creeks and other upper Sacramento tributaries may be native or mostly native, but these populations are nearly extirpated. Given the widespread recent declines in abundance and the large proportion of hatchery production in the basin as a whole, natural production in this ESU is unlikely to be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Common risk factors relating to hatchery practices were discussed previously in the Background section. We have little information regarding spatial or temporal separation of spawning hatchery and natural fish within this ESU, but there is probably sufficient overlap for some genetic introgression to occur. There is also a substantial problem with straying of hatchery fish within this ESU (Hallock 1989). Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We do not have sufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**Inland Steelhead ESUs**

**13) Middle Columbia River**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified six stocks as at risk or of concern (Table 9). WDF et al. (1993) considered six stocks within the ESU, four of which were considered to be of native origin and predominantly natural production. They considered the status of these four stocks as one depressed and three unknown. The remaining two stocks were considered depressed.

Estimates of historical (pre-1960s) abundance specific to this ESU are available for the Yakima River, with an estimated run size of 100,000 (WDF et al. 1993, Appendix 3). If we assume that other basins had comparable run sizes for their drainage areas, the total historical run size for this ESU might have been in excess of 300,000. Total run sizes for the major stocks in the Columbia River above Bonneville Dam, including stocks in the Upper Columbia River and Snake River Basin ESUs and parts of the Southwest Washington and Lower Columbia River ESUs, were estimated by Light (1987) as approximately 4,000 winter steelhead and 210,000 summer steelhead in the early 1980s. Based on dam counts for this period, the Middle Columbia River ESU represented the majority of this total run estimate, so the run returning to this ESU was probably somewhat below 200,000 at that time. Light estimated that the total run (summer and winter steelhead combined) was of 80% hatchery origin. We have estimated run sizes for this ESU by subtracting adult steelhead counts at Lower Granite and Priest Rapids Dams from those at Bonneville Dam for the period 1975-93 (Fig. 30). The most recent 5-year average run size was 142,000, with a naturally produced

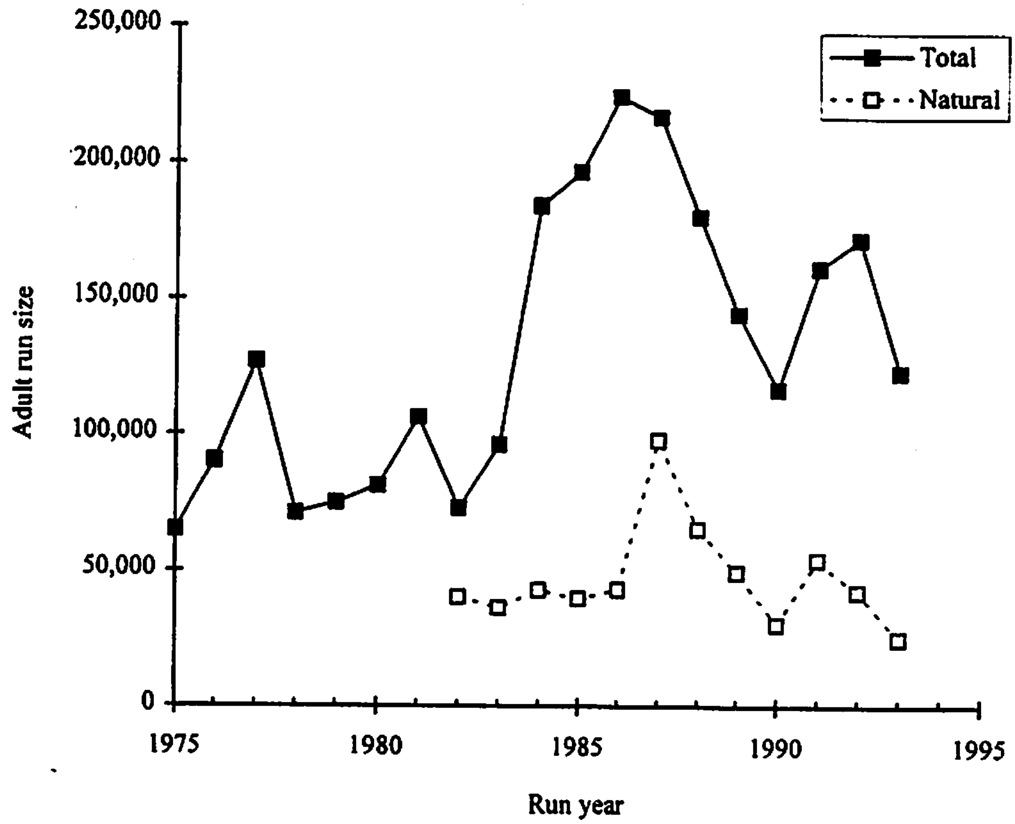



Figure 30. Estimated adult run size for steelhead ESU 13-Middle Columbia River, based on the difference between the count of steelhead passing Bonneville Dam and those passing Lower Granite Dam (Snake River) and Priest Rapids Dam (upper Columbia River), i.e. [Bonneville - (Lower Granite + Priest Rapids)]. Calculated from data in CRFMP TAC (1991), PSMFC (1994), and IDFG (1995).

component of 39,000. These data indicate approximately 74% hatchery fish in the total run to this ESU.

We have recent escapement or run size estimates for only the following five basins in this ESU (Table 28, Fig. 31). 1) For the main Deschutes River (counted at Sherars Falls), total recent 5-year average run size was approximately 11,000, with a natural escapement of 3,000. Hatchery escapement to spawning grounds, calculated by subtracting Pelton Ladder and other hatchery returns from the counts at Sherars Falls has averaged about 4,000 adults over the last five brood years (BPA 1992). 2) For Warm Springs River steelhead passing above Warm Springs NFH, escapement has averaged 150 adults over the last 5 years. 3) In the Umatilla River, escapement counted at Three Mile Dam has averaged 1,700 adults over the last 5 years. 4) In the Yakima River, total escapement has averaged 1,300 adults, with a natural escapement of 1,200 adults over the last 5 years. 5) ODFW (1995a) suggested that five subbasins of the John Day River each have runs in excess of 1,000, so the total run size for the John Day River is probably in excess of 5,000 fish.

The only substantial habitat blockage at present in this ESU is at Pelton Dam on the Deschutes River, but minor blockages from smaller dams, impassable culverts, etc., are likely throughout the region. Several dams in the John Day River Basin previously blocked habitat, but they have since been modified with ladders (CBFWA 1990); however, there is a possibility that local native stocks were extirpated before these ladders were built.

Bottom et al. (1985) noted that high summer and low winter temperatures are limiting factors for salmonids in many streams in this region. They noted that flows below recommended levels occur in the Umatilla and John Day Rivers, that extreme temperature conditions exist in the lower John Day River, and that water withdrawals and overgrazing have seriously reduced summer flows in the principal summer steelhead spawning and rearing tributaries of the Deschutes River. There is little or no late summer flow in sections of the lower Umatilla and Walla Walla Rivers. Riparian vegetation is heavily impacted by overgrazing and other agricultural practices, timber harvest, road building, and channelization. Of stream segments inventoried within this ESU, riparian restoration is needed for between 37% and 84% of the river bank in various basins. Instream habitat is also affected by these same factors, as well as by past gold dredging and severe sedimentation due to poor land management practices.

Stock trend data are available for various basins from dam counts, spawner surveys, and angler catch. Because the relationship of angler catch to natural stock abundance is unclear in this region and alternate data were available for most basins, we have not relied on angler catch data in our evaluations of this ESU; trends in angler catch are included in Appendix E for comparison. For these evaluations, spawner survey data for individual tributaries have been aggregated by subbasin to avoid frequent zero counts and to provide more representative regional trends.

Of the 14 independent stock indices for which we could compute trends (Appendix E), 10 have been declining and 4 increasing during the available data series, with a range from 20% annual decline to 14% annual increase (Table 28, Fig. 32). Eight of these trends

Table 28. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Middle Columbia River steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Klickitat River | S | | 2,400 | | -9.2 | |
| Yakima River | S | 1,000 | 850 | 800 | +14.0 | 5 |
| Fifteenmile Creek | W | | | | -5.4 | |
| Deschutes River | S | 11,300 | | 3,000 | +2.6 | 50 |
| John Day River | S | | >5,000 | | -14.6 | |
| Umatilla River | S | 1,700 | | | +0.7 | < 25 |
| Touchet River | S | 650 | 300 | 300 | -2.7 | 7 |

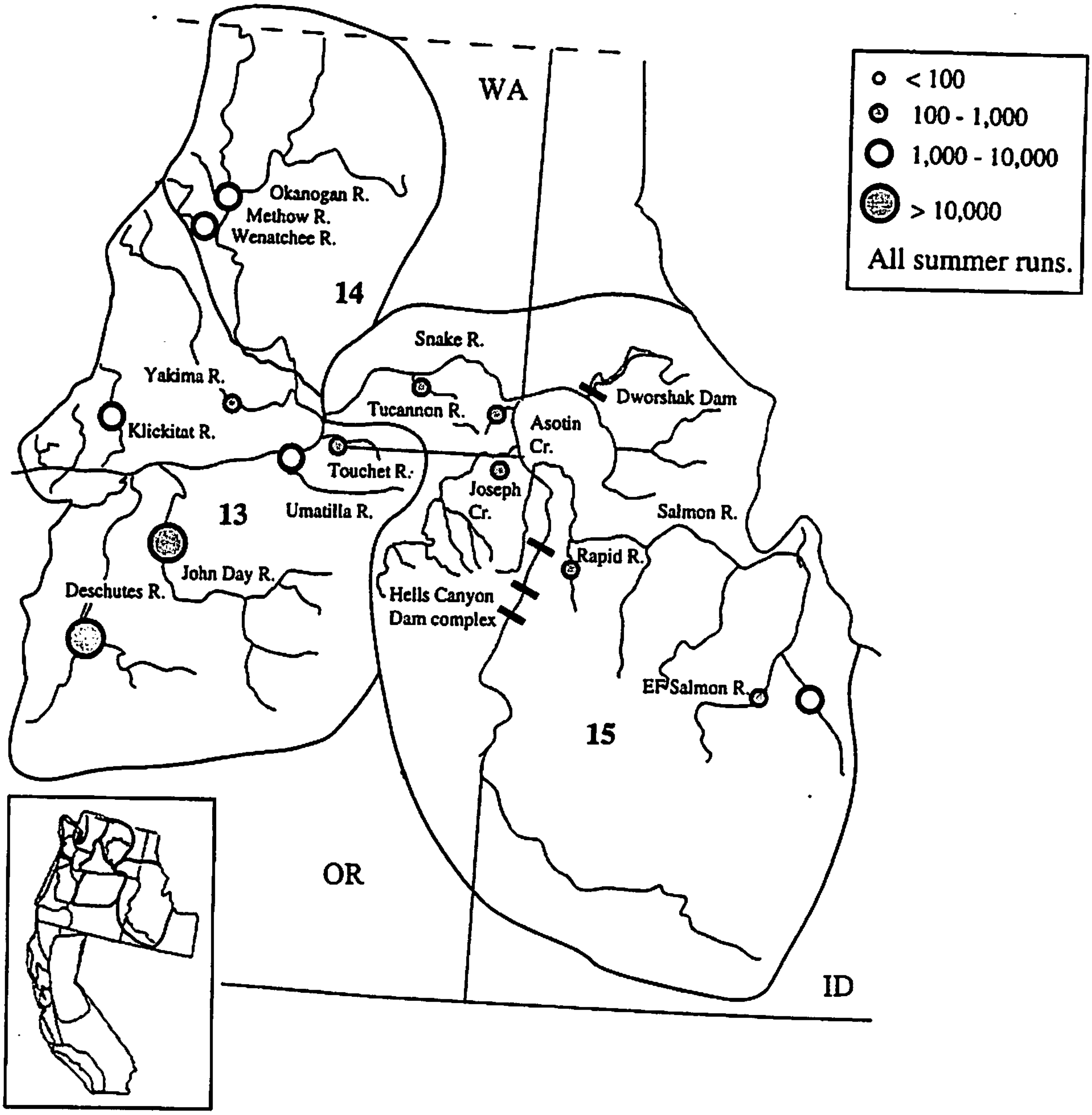



Figure 31. Recent total escapement for populations in steelhead ESUs 13-Middle Columbia River, 14-Upper Columbia River, and 15-Snake River Basin. Where no total estimate is available, natural escapement is used. All data are for summer steelhead (see Appendix E for details).

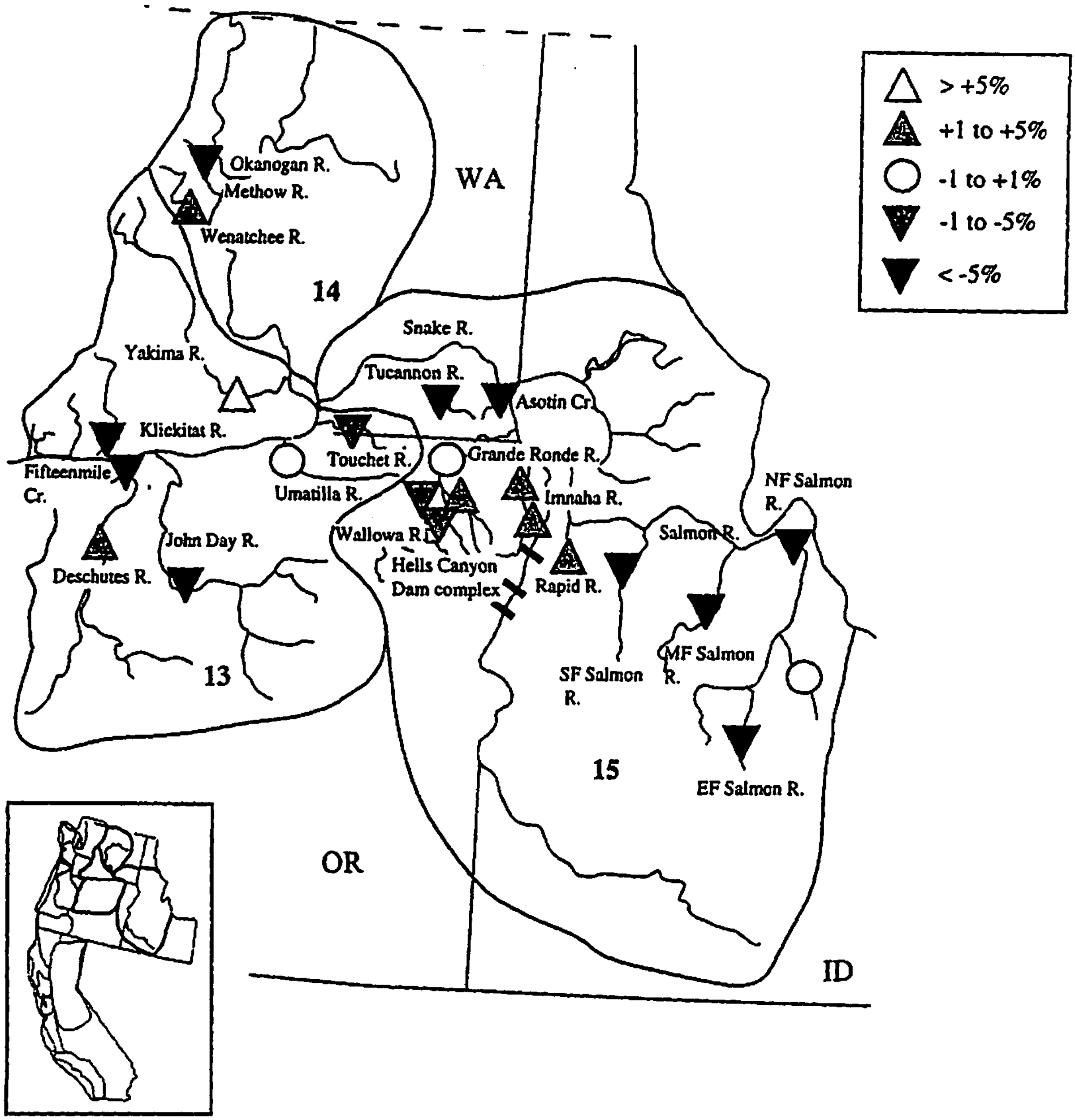



Figure 32. Trends (percent annual change) in total escapement for populations in steelhead ESUs 13-Middle Columbia River, 14-Upper Columbia River, and 15-Snake River Basin. All data are for summer steelhead (see Appendix E for details).

were significantly different from zero, with seven negative and one positive (Appendix E). Of the major basins, the Yakima, Umatilla, and Deschutes Rivers show upward trends overall, although all trends in the Deschutes River tributaries are downward and the Yakima River is recovering from a period of extremely low abundance in the early 1980s. The John Day River probably represents the largest native, natural spawning stock in the region, and combined spawner surveys for this basin have been declining at a rate of about 15% per year since 1985. However, estimates of total run size for the ESU based on differences in counts at dams (Fig. 30) show an overall increase in steelhead abundance, with a relatively stable naturally produced component. It is likely that recent trends in most basins have been negatively affected by recent drought in the region.

Hatchery fish are widespread and escaping to spawn naturally throughout the region. Hatchery production in this region is derived primarily from within-basin stocks. Recent estimates of the proportion of natural spawners that are of hatchery origin (Table 28, Appendix E) range from low in the Yakima, Walla Walla, and John Day Rivers, to moderate in the Umatilla and Deschutes Rivers. However, we have little information on the actual contribution of hatchery production to natural spawning. The relatively low natural run sizes in individual streams for which we have estimates, the preponderance of negative trends in abundance, and the widespread presence of hatchery fish lead to concern that some natural steelhead populations in this ESU may not be self-sustaining. There is particular concern that Yakima River steelhead and winter steelhead stocks in the Klickitat River and Fifteenmile Creek may be at risk.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**14) Upper Columbia River**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified six stocks as at risk or of concern (Table 9). WDF et al. (1993) assessed three stocks within the ESU, of which all were considered to be of mixed origin, wild production, and depressed. WDF et al. considered only the wild component of mixed stocks in reaching their conclusions.

Estimates of historical (pre-1960s) abundance specific to this ESU are available from fish counts at dams. Counts at Rock Island Dam from 1933 to 1959 averaged 2,600-3,700, suggesting a pre-fishery run size in excess of 5,000 adults for tributaries above Rock Island Dam (Chapman et al. 1994). However, runs may already have been depressed by lower Columbia River fisheries at this time. The following recent 5-year (1989-93) average natural escapement estimates are available: 800 steelhead in the Wenatchee River and 450 steelhead in the Methow and Okanogan Rivers (Table 29, Fig. 31). Recent average total escapement

Table 29. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Upper Columbia River steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for summer steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Wenatchee River | 2,700 | 2,500 | 800 | +2.6 | 65 |
| Methow & Okanogan Rivers | 4,700 | 2,400 | 450 | -12.0 | 81 |

estimates for these stocks were 2,500 and 2,400, respectively. Average total run size at Priest Rapids Dam for the same period was approximately 9,600 adult steelhead.

Substantial habitat blockages occurred with the construction of Chief Joseph and Grand Coulee Dams, as well as smaller dams on tributary rivers. Habitat problems for this ESU are largely related to irrigation diversions and hydroelectric dams, as well as degraded riparian and instream habitat from urbanization and livestock grazing.

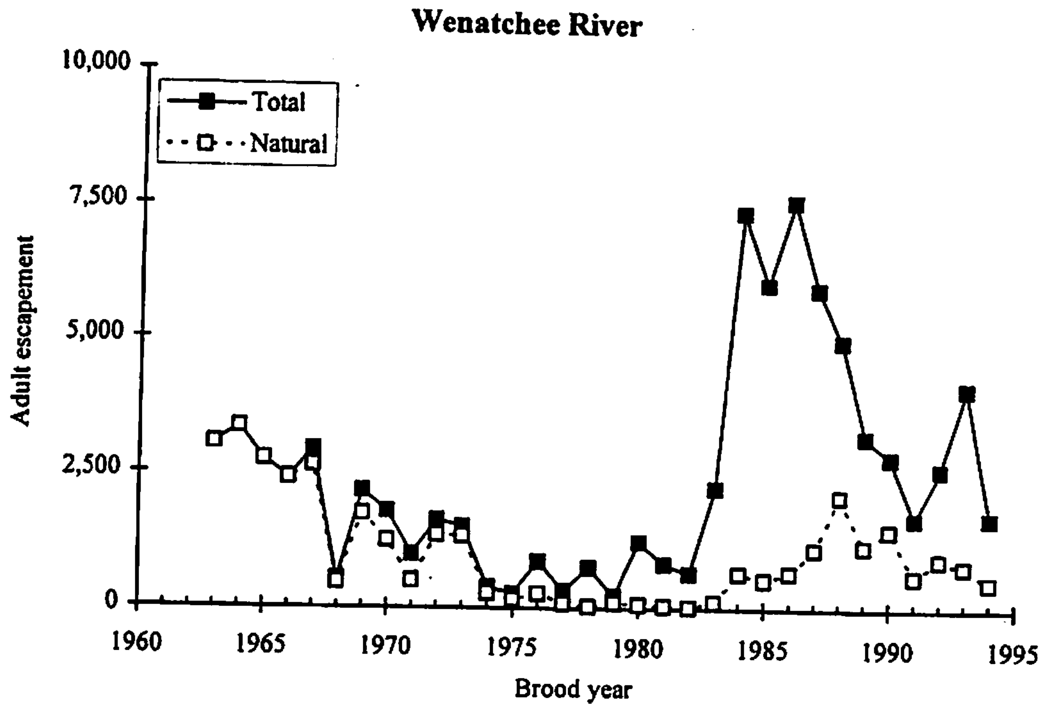
Trends in total (natural and hatchery) adult escapement are available for the Wenatchee River (2.6% annual increase, 1962-93) and the Methow and Okanogan Rivers combined (12% annual decline, 1982-93) (Table 29, Figs. 32 & 33). These two stocks represent most of the escapement to natural spawning habitat within the range of the ESU, although the Entiat River also has a small spawning run (WDF et al. 1993).

Hatchery fish are widespread and escaping to spawn naturally throughout the region. The hatchery stock used in this region originated from stocks indigenous to the ESU during the Grand Coulee Fish Maintenance Project, but represents a blend of fish from all basins within the ESU and from areas above Grand Coulee Dam. Spawning escapement is strongly dominated by hatchery production, with estimates of recent contributions averaging 65% in the Wenatchee River and 81% in the Methow and Okanogan Rivers. WDFW estimated adult replacement ratios of only 0.3:1.0 in the Wenatchee River and 0.25:1.0 in the Entiat River and concluded that both these stocks and the Methow/Okanogan stock are not self-sustaining without substantial hatchery supplementation. WDF et al. (1993) suggested that the original Okanogan stock may be extinct, "except perhaps for resident morphs (rainbow trout) in Salmon and Omak creeks." This ESU might not exist today if there were not hatchery production based on indigenous stocks.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section. The stocks above Rock Island Dam are largely driven by hatchery production. Although the major hatchery production in these rivers has been derived from stocks indigenous to the ESU, there are distinct genetic risks associated with hatchery supplementation.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have received insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**15) Snake River Basin**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 13 stocks as at risk or of concern (Table 9). WDF et al. (1993) assessed three stocks within the ESU, of which all were considered to be of mixed origin and composite production; all three stocks were identified as depressed.



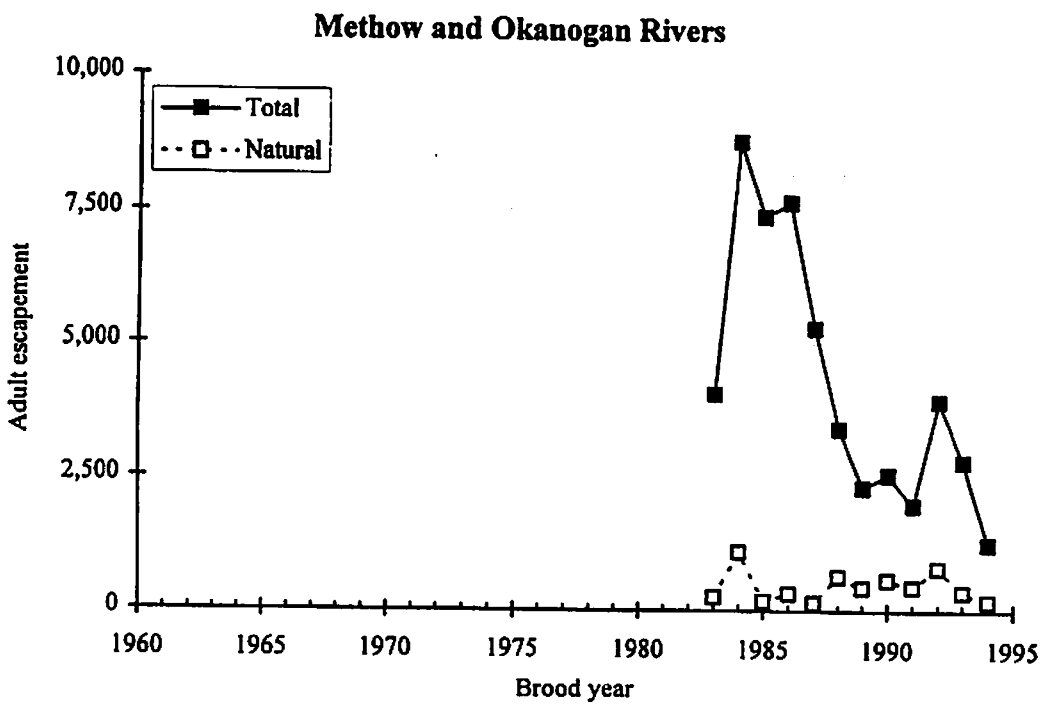




Figure 33. Estimated spawning escapement for Wenatchee and Methow/Okanogan summer steelhead stocks. Data from WDFW (1994b).

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Light (1987) estimated that 80% of the total Columbia River Basin run above Bonneville Dam (summer and winter steelhead combined) was of hatchery origin. All steelhead in the Snake River Basin are summer steelhead and for management purposes are divided into "A-run" and "B-run" fish. This division is based on several life history differences including spawner size and run timing. Although there is little information for most stocks within this ESU, there are recent run size or escapement estimates for several stocks (Table 30, Fig. 31). Total recent 5-year average escapement above Lower Granite Dam was approximately 71,000, with a natural component of 9,400 (7,000 A-run and 2,400 B-run). Run-size estimates are available for only a few tributaries within the ESU, all with small populations (Table 30, Appendix E).

There have been several substantial habitat blockages in this ESU, the major ones being the Hells Canyon Dam complex on the mainstem Snake River and Dworshak Dam on the North Fork Clearwater River. Minor blockages (from smaller dams, impassable culverts, etc.) are likely throughout the region. Bottom et al. (1985) noted that high summer and low winter temperatures are limiting for salmonids in many streams in eastern Oregon. They noted that flows below recommended levels occur in the Grande Ronde River, especially in late fall through early spring, and that water withdrawals and low flows are severe in several areas of that basin.

Riparian vegetation is heavily impacted by overgrazing and other agricultural practices, timber harvest, road building and channelization. Prime steelhead spawning areas have been degraded by overgrazing in several parts of the Grande Ronde Basin. Of inventoried segments of streams in the Grande Ronde River Basin, restoration is needed for between 38% (upper basin) and 59% (lower basin) of river bank. Instream habitat is also affected by these same factors, as well as past gold dredging and severe sedimentation due to poor land management practices. Although not as clearly documented, similar habitat problems can be expected in other basins within this ESU. One of the most significant habitat problems facing steelhead in this ESU is substantial modification of the migration corridor by hydroelectric power development in the mainstem Snake and Columbia Rivers.

The aggregate trend in abundance for this ESU (indexed at Lower Granite Dam) has been upward since 1975, although natural escapement has been declining during the same period (Fig. 34). However, the aggregate trend has been downward (with wide fluctuations) over the past 10 years, recently reaching levels below those observed at Ice Harbor Dam in the early 1960s. Naturally produced escapement has declined sharply in the last 10 years. Adult abundance trend information is available for several individual stocks from a variety of sources, including spawner surveys, dam counts, and angler catch (Table 30, Fig. 32). Because of the focus of angler catch on hatchery fish in this region and the availability of other estimates, we have not used angler catch trends in our evaluations, although they are included in Appendix E for comparison.

Of the 13 stock indices (excluding the Lower Granite Dam counts discussed above) for which we had adequate information to compute trends, 9 have been declining and 4 increasing during the available data series, with a range from 30% annual decline to 4%

Table 30. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Snake River Basin steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for summer steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Tucannon River | 700 | 400 | 140 | -18.3 | 57 |
| Asotin Creek | 200 | 200 | | -19.7 | |
| Grande Ronde River | | | | -3.5 to +3.9 | |
| Imnaha River (Camp Creek) | | | | +1.4 | > 50 |
| Rapid River | 80 | | | +1.7 | |
| Salmon River | 150 - 1400 | | 20 - 40 | -30.0 to +0.1 | |

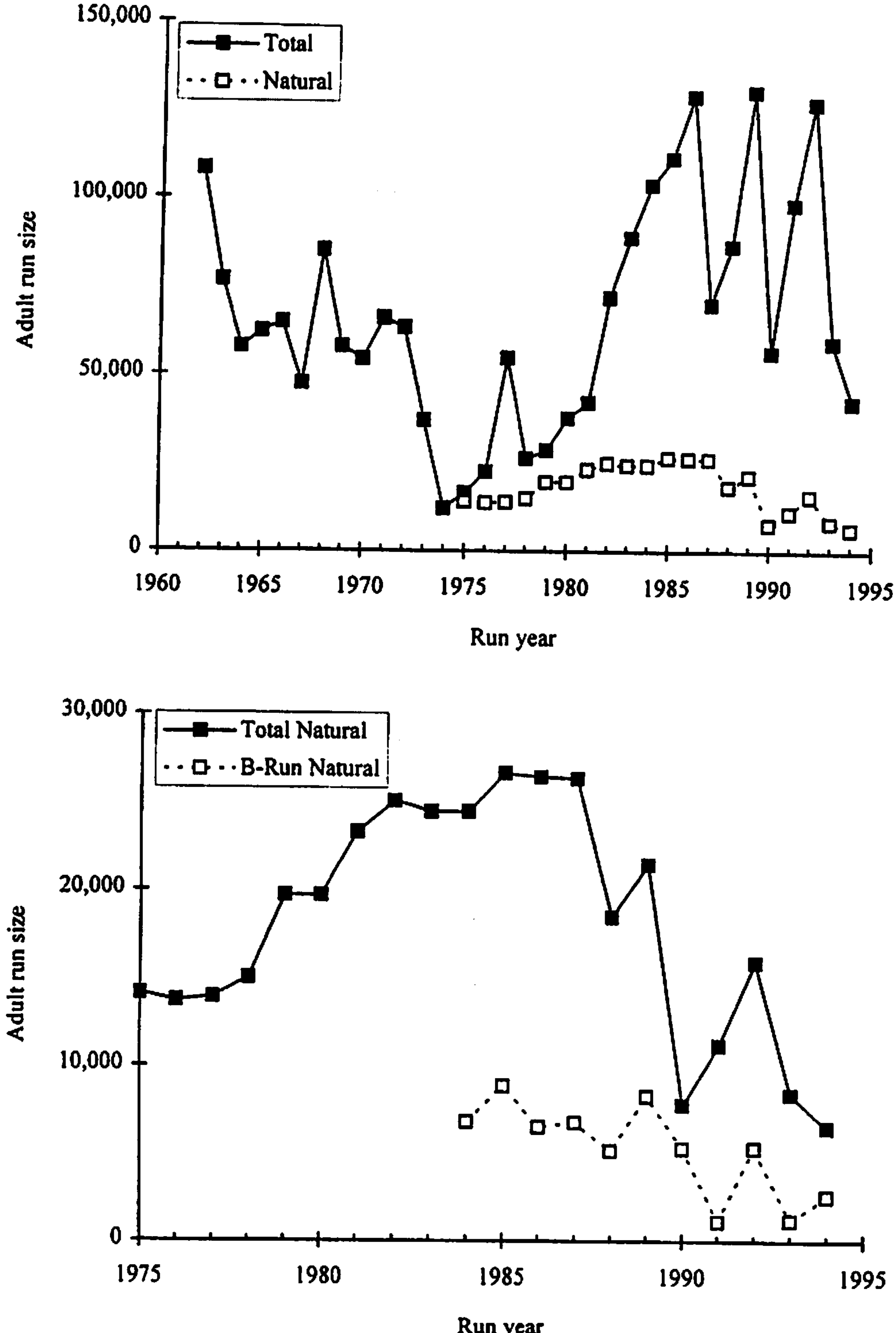



Figure 34. Estimated abundance of adult Snake River summer steelhead. Upper panel: total run size with natural run broken out beginning in 1975. Lower panel: natural run size, with natural B-run broken out beginning in 1984. Based on counts of fish passing above Lower Granite Dam (1975-94) or Ice Harbor Dam (1962-74). Data from CRFMP TAC (1991), PSMFC (1994), and IDFG (1995).

annual increase. Four of the negative trends were significantly different from zero (Appendix E). In addition to these adult abundance data, the focus of IDFG's steelhead monitoring program is juvenile (parr) surveys in wild or natural production areas. Most of the individual juvenile data series available to us were too short to compute reliable trends, but summaries presented by Leitzinger and Petrosky (in press) showed declines in average parr density over the past 7 or 8 years for both A- and B-run steelhead in both wild and natural production areas. From 1985 to 1993, estimates of mean percent of rated parr carrying capacity for these surveys ranged from as low as 11.2% (wild-production B-run) to 62.1% (wild-production A-run). The Columbia River Fisheries Management Plan Technical Advisory Committee found that A-run steelhead densities were closer to rated capacities than were B-run steelhead, but noted that "percent carrying capacity indicates that all surveyed areas are underseeded" (CRFMP TAC 1991, p. 6). It is likely that recent trends in most basins have been negatively affected by recent drought in the region.

Hatchery fish are widespread and escape to spawn naturally throughout the region. During the past 5 years, an average of 86% of adult steelhead passing Lower Granite Dam were of hatchery origin. Only two hatchery composition estimates are available for individual stocks: 0% for Joseph Creek (Grande Ronde River), and 57% for the Tucannon River. We have little information on the actual contribution of hatchery production to natural spawning, and on natural escapements for most stocks in this ESU. In general, there are wild production areas with limited hatchery influence remaining in the Selway River, lower Clearwater River, Middle and South Forks of the Salmon River, and the lower Salmon River (Leitzinger and Petrosky in press). In other areas, such as the upper Salmon River, there appears to be little or no natural production of locally native steelhead (IDFG 1995). Given the relatively low natural run sizes to individual streams for which we have estimates, the declines in natural returns at Lower Granite Dam, the declines in parr density estimates, and the widespread presence of hatchery fish, we conclude that the majority of natural steelhead populations in this ESU are probably not self-sustaining at this time.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices, discussed previously. Common risk factors relating to hatchery practices were discussed previously in the Background section.

An additional concern in this ESU is the status of steelhead native to the North Fork of the Clearwater River, now maintained at Dworshak NFH. While this hatchery population is presently fairly large, it represents the only remaining gene pool for steelhead native to that tributary. This population has not had access to its native habitat for 25 years.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

## Conclusions

The BRT concluded that of the 14 ESUs reviewed here, 5 ESUs are presently in danger of extinction: Central California Coast, South-Central California Coast, Southern California, Central Valley, and Upper Columbia River. Four were classified as likely to become endangered in the foreseeable future: Lower Columbia River, Oregon Coast, Northern California, and Snake River Basin. The Puget Sound, Olympic Peninsula, Southwest Washington, and Upper Willamette ESUs were classified as not presently likely to become extinct or endangered. The BRT concluded that the remaining ESU (Middle Columbia River) was not presently in danger of extinction, but BRT members failed to agree on a conclusion regarding its likelihood of becoming endangered. A 15th ESU (Klamath Mountains Province) was reviewed previously (Busby et al. 1994) and is discussed here only for comparison.

Because of the requirements of the ESA, we have focused on factors contributing to risk of extinction or endangerment, rather than on more positive indicators of population "health." We identified some risk factors that are of concern for natural populations in all ESUs considered. Primary concerns for ESUs identified as either in danger of extinction or likely to become so are outlined for each ESU.

The other ESUs (those not judged to be in danger nor likely to become so) are generally distinguished by three characteristics. First, although population abundance in these ESUs may be below historical levels, naturally reproducing steelhead still occupy most of the historical range of the ESU in numbers that are sufficient to avoid most small-population risk problems. Second, while trends in the past few years may be downward, we did not find evidence that natural populations have failed to maintain themselves over longer time spans. Third, hatchery production does not appear to pose a major genetic risk to the natural populations in these ESUs, either because the level of hatchery production is relatively low or because there is evidence of substantial reproductive isolation between hatchery and natural populations.

Several factors relating to the status of steelhead populations were of substantial concern in all ESUs. Population trends since the mid-1980s have been downward in almost all ESUs. While this may reflect recent changes in regional climate patterns, it is unclear whether climate change is the sole cause of declines. It is also unclear if or when climate conditions may improve. Widespread degradation of both freshwater and estuarine habitats within the region is a concern, as are the potential results of continuing habitat destruction. The widespread production of hatchery fish raises concern for genetic integrity in most ESUs and is also of concern in determining the sustainability of natural production. Although in most cases available data are not sufficient to tell whether hatchery fish are having a strong negative impact on naturally produced steelhead, competition with introduced stocks for limited habitat could mask problems with the sustainability of natural stocks. Finally, many of the conclusions for specific ESUs involve a substantial degree of uncertainty resulting from lack of information on population abundance, trends, resident fish, and interactions between hatchery and natural fish.

## Coastal Steelhead ESU Conclusions

**1) Puget Sound**—The BRT concluded that the Puget Sound steelhead ESU is neither presently in danger of extinction nor likely to become endangered in the foreseeable future. Despite this conclusion, the BRT has several concerns about the overall health of this ESU and about the status of certain stocks within the ESU. Recent trends in stock abundance are predominantly downward, although this may be largely due to recent climate conditions. Yet trends in the two largest stocks (Skagit and Snohomish Rivers) have been upward.

The majority of steelhead produced within the Puget Sound region appear to be of hatchery origin, but most hatchery fish are harvested, and estimates of hatchery fish escaping to spawn naturally are all less than 15% of total natural escapement, except for the Tahuya and Morse Creek/Independents stocks where the hatchery proportion is approximately 50%. We are particularly concerned that the majority of hatchery production originates from a single stock (Chambers Creek), which could increase genetic homogenization of the resource despite management efforts to minimize introgression of the hatchery gene pool into natural populations via separation of hatchery and natural run timing and high harvest rates focused on hatchery runs.

The status of certain stocks within the ESU is also of concern, especially the depressed status of most stocks in the Hood Canal area and the steep declines of Lake Washington winter steelhead and Deer Creek summer steelhead.

These conclusions are tempered by two substantial uncertainties. First, there is very little information regarding the abundance and status of summer steelhead in the Puget Sound region. Although the numbers of summer steelhead have historically been small relative to winter steelhead, they represent a substantially different life history strategy and loss of these fish would diminish the ecological and genetic diversity of the entire ESU. Second, there is uncertainty regarding the degree of interaction between hatchery and natural stocks. Although WDFW's conclusion that there is little overlap in spawning between natural and hatchery stocks of winter steelhead throughout the ESU is generally supported by available evidence, for many basins it is based largely on models and assumptions regarding run timing rather than empirical data.

**2) Olympic Peninsula**—The BRT concluded that the Olympic Peninsula steelhead ESU is neither presently in danger of extinction nor likely to become endangered in the foreseeable future. Despite this conclusion, the BRT has several concerns about the overall health of this ESU and about the status of certain stocks within it. The majority of recent abundance trends are upward (including three of the four largest stocks), although trends in several stocks are downward. These downward trends may be largely due to recent climate conditions. There is widespread production of hatchery steelhead within this ESU, largely derived from a few parent stocks, and this could increase genetic homogenization of the resource despite management efforts to minimize introgression of the hatchery gene pool into natural populations. Estimates of the proportion of hatchery fish on natural spawning grounds range from 16% to 44%, with the two stocks with the largest abundance of natural spawners (Queets and Quillayute) having the lowest hatchery proportions.

These conclusions are tempered by substantial uncertainties. As for the Puget Sound ESU, there is very little information regarding the abundance and status of summer steelhead in this region and the degree of interaction between hatchery and natural stocks.

**3) Southwest Washington**—The BRT concluded that the Southwest Washington steelhead ESU is neither presently in danger of extinction nor likely to become endangered in the foreseeable future. The latter conclusion was not unanimous, and a minority concluded that downward trends, coupled with introductions of hatchery fish from outside the ESU, indicated likelihood of becoming endangered. Almost all stocks for which we have data within this ESU have been declining in the recent past, although this may be largely due to recent climate conditions. The BRT members had a strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU, and a great concern for the status of summer steelhead in this ESU. There is widespread production of hatchery steelhead within this ESU, largely from parent stocks outside the ESU. This production could substantially change the genetic composition of the resource, despite management efforts to minimize introgression of the hatchery gene pool into natural populations. Estimates of the proportion of hatchery fish on natural spawning grounds range from 9% in the Chehalis River, the largest producer of steelhead in the ESU, to 82% in the Clatskanie River.

As for the Puget Sound and Olympic Peninsula ESUs, these conclusions are tempered by substantial uncertainties regarding the abundance and status of summer steelhead in this region, and the degree of interaction between hatchery and natural stocks.

**4) Lower Columbia River**—The BRT concluded that the Lower Columbia River steelhead ESU is not presently in danger of extinction, but it is likely to become endangered in the foreseeable future. The latter conclusion was not unanimous, and there were two distinct minority opinions: one minority of the BRT concluded that there was little likelihood that this ESU will become endangered, while another minority was uncertain whether native steelhead still exist in this region. The majority of stocks for which we have data within this ESU have been declining in the recent past, but some have been increasing strongly. However, the strongest upward trends are those of either non-native stocks (Lower Willamette River and Clackamas River summer steelhead) or stocks that are recovering from major habitat disruption and are still at low abundance (mainstem and North Fork Toutle River). The data series for most stocks are quite short, so the preponderance of downward trends may reflect the general coastwide decline in steelhead in recent years. The BRT members had strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU, and strong concern for the status of summer steelhead in this ESU. There is widespread production of hatchery steelhead within this ESU, and several stocks for which we have estimates of hatchery composition average more than 50% hatchery fish in natural escapement. Concerns about hatchery influence are especially strong for summer steelhead and Oregon winter steelhead stocks, where there appears to be substantial overlap in spawning between hatchery and natural fish.

The major area of uncertainty in this evaluation is the degree of interaction between hatchery and natural stocks within the ESU. WDFW's conclusion that there is little overlap in spawning between natural and hatchery stocks of winter steelhead throughout the ESU is generally supported by available evidence; however, with the exception of detailed studies of the Kalama River winter stock, it is based largely on models and assumptions regarding run timing rather than empirical data. There is apparently strong overlap in spawning between hatchery and natural summer steelhead in Washington tributaries. We have no information regarding potential spawning separation between hatchery and natural fish in Oregon tributaries to the Lower Columbia River.

**5) Upper Willamette**—The BRT concluded that the Upper Willamette steelhead ESU is neither presently in danger of extinction, nor likely to become endangered in the foreseeable future. The latter conclusion was not unanimous, and a minority of the BRT concluded that the small numbers and declining trend in the native stock, coupled with other risk factors, indicate a likelihood of becoming endangered. While historical information regarding this ESU is lacking, geographic range and historical abundance are believed to have been relatively small compared to other ESUs, and current production probably represents a larger proportion of historical production than is the case in other Columbia River Basin ESUs.

Native winter steelhead within this ESU have been declining on average since 1971, and have exhibited large fluctuations in abundance. The main production of native (late-run) winter steelhead is in the North Fork Santiam River, where estimates of hatchery proportion in natural spawning range from 14% to 54%. The BRT members had strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU, and strong concern for potential ecological interactions between introduced stocks and native stocks. There is widespread production of hatchery steelhead within the range of this ESU, predominantly of non-native summer and early-run winter steelhead.

There are two major areas of uncertainty in this evaluation. First, the degree of interaction between hatchery and natural stocks within the ESU is unknown. We have no information regarding potential spawning separation between hatchery and natural fish. Second, some of the trends for these populations are based on angler catch data, which may not be a good indicator of actual trends in population (see discussion in the Background section above).

**6) Oregon Coast**—The BRT concluded that the Oregon Coast steelhead ESU is not presently in danger of extinction, but that it is likely to become endangered in the foreseeable future. The latter conclusion was not unanimous, with a minority of the BRT concluding that there is little likelihood that this ESU will become endangered. Most steelhead populations within this ESU have been declining in the recent past (although this may be largely due to recent climate conditions), with increasing trends restricted to the southernmost portion of the ESU, south of Siuslaw Bay. The BRT members had strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within this ESU and strong concern for potential ecological interactions between introduced stocks and native stocks. There is widespread production of hatchery steelhead within this ESU, largely based on out-of-basin stocks, and approximately half of the streams (including the majority of those with upward trends) are estimated to have more than 50% hatchery fish in natural spawning escapements. Given the substantial contribution of hatchery fish to natural spawning throughout the ESU, and the generally declining or slightly increasing trends in abundance, it is likely that natural stocks are not replacing themselves throughout the ESU.

There are two major areas of uncertainty in this evaluation. First, the degree of interaction between hatchery and natural stocks within the ESU is unknown. We have no information regarding potential spawning separation between hatchery and natural fish, nor about the spawning success of hatchery produced fish. Second, the majority of trends for these populations are based on angler catch data, which may not be a good indicator of actual trends in population abundance.

**7) Klamath Mountains Province**—The BRT has previously concluded that this ESU is not presently in danger of extinction, but that it is likely to become endangered in the foreseeable future (Busby et al. 1994). Although historical trends in overall abundance within the ESU are not clearly known, there has been substantial replacement of natural fish with hatchery produced fish. While absolute abundance remains fairly high, since about 1970 trends in abundance have been downward in most steelhead populations for which we have data within the ESU, and a number of populations are considered by various agencies and groups to be at some risk of extinction. Declines in summer steelhead populations are of particular concern. Most natural populations of steelhead within the area experience a substantial infusion of naturally spawning hatchery fish each year. After accounting for the contribution of these hatchery fish, we were unable to identify any steelhead populations that are naturally self-sustaining.

**8) Northern California**—The BRT concluded that the Northern California steelhead ESU is not presently in danger of extinction, but that it is likely to become endangered in the foreseeable future. Population abundances are very low relative to historical estimates (1930s dam counts), and recent trends are downward in stocks for which we have data, except for two small summer steelhead stocks. Summer steelhead abundance is very low. There is particular concern regarding sedimentation and channel restructuring due to floods, apparently resulting in part from poor land management practices. The abundance of introduced Sacramento squawfish as a predator in the Eel River is also of concern. For certain rivers (particularly the Mad River), the BRT is concerned about the influence of hatchery stocks, both in terms of genetic introgression and of potential ecological interactions between introduced stocks and native stocks.

There are two major areas of uncertainty in this evaluation. First, we lack information on steelhead run sizes throughout the ESU. Our conclusions were based largely on evidence of habitat degradation and the few dam counts and survey index estimates of stock trends in the region. Second, the genetic heritage of the natural winter steelhead population in the Mad River is uncertain.

**9) Central California Coast**—The BRT concluded that the Central California Coast steelhead ESU is presently in danger of extinction. The southernmost portion of the ESU (south of Scott and Waddell Creeks, including one of two major rivers within the ESU) and the portion within San Francisco and San Pablo Bays, appears to be at extreme risk. In the northern coastal portion of the ESU, steelhead abundance in the Russian River has been reduced roughly sevenfold since the mid-1960s, but abundance in smaller streams appears to be stable at low levels. There is particular concern about sedimentation and channel restructuring due to floods, apparently resulting in part from poor land management practices.

There are two major areas of uncertainty in this evaluation. First, due to the lack of information on steelhead run sizes throughout the ESU, our conclusions were based largely on evidence of habitat degradation and the few estimates of abundance and stock trends in the region. Second, the genetic heritage of the natural populations in tributaries to San Francisco and San Pablo Bays is uncertain, making it difficult to determine which of these populations should be considered part of the ESU.

**10) South-Central California Coast**—The BRT concluded that the South-Central California Coast steelhead ESU is presently in danger of extinction. Total abundance is extremely low, and most stocks for which we have data in the ESU show recent downward trends. There is particular concern about sedimentation and channel restructuring due to floods, which apparently result in part from poor land management practices. There is also concern about the genetic effects of widespread stocking of rainbow trout.

The major area of uncertainty in this evaluation is the lack of information on steelhead run sizes throughout the ESU. Our conclusions were based largely on evidence of habitat degradation and the few estimates of abundance and stock trends in the region.

**11) Southern California**—The BRT concluded that the Southern California steelhead ESU is presently in danger of extinction. Steelhead have already been extirpated from much of their historical range in this region. The BRT members had strong concern about the widespread degradation, destruction, and blockage of freshwater habitats within the region, and the potential results of continuing habitat destruction and water allocation problems. There is also concern about the genetic effects of widespread stocking of rainbow trout.

There are two major areas of uncertainty in this evaluation. First, accurate run size and trend estimates are lacking for natural steelhead stocks in this ESU. Second, the relationship between resident and anadromous forms of the biological species is unclear.

**12) Central Valley**—The BRT concluded that the Central Valley steelhead ESU is presently in danger of extinction. Steelhead have already been extirpated from most of their historical range in this region. Habitat concerns in this ESU focus on the widespread degradation, destruction, and blockage of freshwater habitats within the region, and the potential results of continuing habitat destruction and water allocation problems. The BRT members also had strong concerns about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU and about potential ecological interactions between introduced stocks and native stocks. There is widespread production of hatchery steelhead within this ESU.

There are two major areas of uncertainty in this evaluation. First, there is a total lack of recent run-size estimates for natural steelhead stocks in this ESU. Second, there is a substantial question regarding the genetic heritage of remaining natural populations, making it difficult to determine which populations should be considered part of the ESU.

**Inland Steelhead ESU Conclusions**

**13) Middle Columbia**—The BRT concluded that the Middle Columbia steelhead ESU is not presently in danger of extinction, but reached no conclusion regarding its likelihood of becoming endangered in the foreseeable future. All BRT members felt special concern for the status of this ESU and concluded that NMFS should carefully evaluate conservation measures affecting this ESU and continue monitoring its status. There is particular concern about Yakima River stocks and winter steelhead stocks. Winter steelhead are reported within this ESU only in the Klickitat River and Fifteenmile Creek; we have no abundance information for winter steelhead in the Klickitat River, but they have been declining in abundance in Fifteenmile Creek.

Total steelhead abundance in the ESU appears to have been increasing recently, but the majority of natural stocks for which we have data within this ESU have been declining, including those in the John Day River, which is the largest producer of wild, natural steelhead. The BRT members expressed strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU. There is widespread production of hatchery steelhead within this ESU, but it is largely based on within-basin stocks. Estimated proportion of hatchery fish on spawning grounds ranges from low, in the Yakima, Walla Walla, and John Day Rivers to moderate in the Umatilla and Deschutes Rivers. Habitat degradation due to grazing and water diversions has been documented throughout the ESU.

There are three major areas of uncertainty in this evaluation. First, run-size estimates are lacking for most populations. Second, the degree of interaction between hatchery and natural stocks within the ESU is uncertain; we have little information regarding potential spawning separation between hatchery and natural fish. Third, the relationship between anadromous and resident forms of *O. mykiss* is unclear; we have little information regarding abundance of resident fish or their interactions with anadromous fish, but resident forms may play an important role in some areas of this ESU.

**14) Upper Columbia**—The BRT concluded that the Upper Columbia steelhead ESU is presently in danger of extinction. While total abundance of populations within this ESU has been relatively stable or increasing, this appears to be occurring only because of major hatchery supplementation programs. Estimates of the proportion of hatchery fish in spawning escapement are 65% (Wenatchee River) and 81% (Methow and Okanogan Rivers). The major concern for this ESU is the clear failure of natural stocks to replace themselves. The BRT members are also strongly concerned about problems of genetic homogenization due to hatchery supplementation within the ESU and about the apparent high harvest rates on steelhead smolts in rainbow trout fisheries and the degradation of freshwater habitats within the region, especially the effects of grazing, irrigation diversions, and hydroelectric dams.

There are two major areas of uncertainty in this evaluation. First, the relationship between resident and anadromous forms of the biological species is unclear, both in terms of native rainbow trout in the streams presently supporting steelhead and in terms of potential residualized (footnote 5) steelhead above Grand Coulee Dam. Second, there is uncertainty regarding the genetic heritage of naturally spawning fish within the ESU.

**15) Snake River Basin**—The BRT concluded that the Snake River Basin steelhead ESU is not presently in danger of extinction, but it is likely to become endangered in the foreseeable future. The latter conclusion was not unanimous, and a minority of the BRT concluded that there was little likelihood that this ESU will become endangered. While total (hatchery + natural) run size has increased since the mid-1970s, there has been a severe recent decline in natural run size. The majority of natural stocks for which we have data within this ESU have been declining. Parr densities in natural production areas have been substantially below estimated capacity in recent years. Downward trends and low parr densities indicate a particularly severe problem for B-run steelhead, the loss of which would substantially reduce life history diversity within this ESU.

The BRT has a strong concern about the pervasive opportunity for genetic introgression from hatchery stocks within the ESU. There is widespread production of hatchery steelhead within this ESU. The total Snake River steelhead run at Lower Granite Dam is estimated to average 86% hatchery fish in recent years. Estimates of proportion of hatchery fish in spawning escapement for Snake River tributaries range from 0% in Joseph Creek to above 80% in the upper Salmon River (IDFG 1995). The BRT members also were concerned about the degradation of freshwater habitats within the region, especially the effects of grazing, irrigation diversions, and hydroelectric dams.

There are three major areas of uncertainty in this evaluation. First, there is a lack of run-size estimates for most populations. Second, the degree of interaction between hatchery and natural stocks within the ESU is unknown. We have little information regarding interactions between hatchery and natural fish. Third, the relationship between anadromous and resident forms of *O. mykiss* is unclear; we have little information regarding abundance of resident fish or their interactions with anadromous fish.

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# Appendix A

**Appendix A-1 - Samples of Oncorhynchus mykiss used in Genetic Analyses**

**Appendix A-2 - Mapped locations of the Samples of O. mykiss used in Genetic Analyses**

Appendix A-1. Samples of *Oncorhynchus mykiss* used in the genetic analyses for this report. Samples are referred to in figures by the sample codes shown here. Analyses were conducted at the genetics laboratory facilities of the Washington Department of Fish and Wildlife (WDFW) in Olympia and the National Marine Fisheries Service (NMFS) in Seattle, Washington. Sample locations are mapped in Appendix A-2.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| **Puget Sound Region** | | | | | | |
| 1 | Nooksack | South Fork Nooksack River | WA | 111 | 1994 | WDFW |
| 2 | Skagit | Lower Skagit River | WA | 111 | 1994 | WDFW |
| 3 | Skagit | South Fork Sauk River | WA | 119 | 1994 | WDFW |
| 4 | Skagit | Sauk River | WA | 119 | 1994 | WDFW |
| 5 | Skagit | Suiattle River | WA | 111 | 1994 | WDFW |
| 6 | Skagit | Upper Skagit River | WA | 111 | 1994 | WDFW |
| 7 | Skagit | Cascade River | WA | 50 | 1994 | WDFW |
| 8 | Stillaguamish | North Fork Stillaguamish River | WA | 122 | 1993 | WDFW |
| 9 | Stillaguamish | Deer Creek (North Fork Stillaguamish River) | WA | 115 | 1993-94 | WDFW |
| 10 | Snoqualmie | Pilchuck River | WA | 235 | 1993-94 | WDFW |
| 11 | Skykomish | Skykomish River | WA | 123 | 1993 | WDFW |
| 12 | Skykomish | North Fork Skykomish River | WA | 123 | 1993 | WDFW |
| 13 | Snoqualmie | Snoqualmie River | WA | 124 | 1993 | WDFW |
| 14 | Snoqualmie | Tolt River | WA | 124 | 1993 | WDFW |
| 15 | Cedar | Cedar River (Lake Washington) | WA | 232 | 1993-94 | WDFW |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| 16 | Cedar-RT | Cedar River rainbow trout (Lake Washington) | WA | 49 | 1994 | WDFW |
| 17 | Green | Green River (Duwamish River) | WA | 232 | 1993-94 | WDFW |
| 18 | Puyallup | White River | WA | 74 | 1994 | WDFW |
| 19 | Puyallup | Puyallup River | WA | 32 | 1994 | WDFW |
| 20 | Nisqually | Nisqually River | WA | 49 | 1994 | WDFW |
| **Hood Canal Region** | | | | | | |
| 21 | Tahuya | Tahuya River | WA | 111 | 1994 | WDFW |
| 22 | Skokomish | Skokomish River | WA | 111 | 1994 | WDFW |
| 23 | Dosewallips | Dosewallips River | WA | 53 | 1994 | WDFW |
| **Strait of Juan de Fuca Region** | | | | | | |
| 24 | Dungeness | Dungeness River | WA | 111 | 1994 | WDFW |
| 25 | Morse | Morse Creek | WA | 50 | 1994 | WDFW |
| 26 | Elwha-RT | Indian Creek rainbow trout | WA | 30 | 1994 | WDFW |
| 27 | Elwha-RT | Lake Mills rainbow trout | WA | 53 | 1994 | WDFW |
| 28 | Elwha-RT | Little River rainbow trout | WA | 49 | 1994 | WDFW |
| 29 | Elwha-RT | Little River rainbow trout | WA | 15 | 1994 | WDFW |
| 30 | Elwha-RT | Glines Creek rainbow trout | WA | 22 | 1994 | WDFW |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| 31 | Pysht | Pysht River | WA | 50 | 1994 | WDFW |
| 32 | Hoko | Hoko River | WA | 111 | 1994 | WDFW |
| **Coastal Washington Region** | | | | | | |
| 33 | Quillayute | Sol Duc River[b] | WA | 52 | 1994 | WDFW |
| 34 | Quillayute | Bogachiel River | WA | 47 | 1994 | WDFW |
| 35 | Quillayute | Calawah River | WA | 52 | 1994 | WDFW |
| 36 | Quillayute | Sitkum River | WA | 111 | 1994 | WDFW |
| 37 | Humptulips | Humptulips River | WA | 49 | 1994 | WDFW |
| 38 | Humptulips | East Fork Humptulips River | WA | 50 | 1994 | WDFW |
| 39 | Humptulips | West Fork Humptulips River | WA | 50 | 1994 | WDFW |
| 40 | Chehalis | Wynoochee River | WA | 51 | 1994 | WDFW |
| 41 | Chehalis | Satsop River | WA | 64 | 1994 | WDFW |
| 42 | Chehalis | Upper Chehalis River | WA | 49 | 1994 | WDFW |
| 43 | North | North River | WA | 49 | 1994 | WDFW |
| 44 | Willapa | Willapa River | WA | 111 | 1994 | WDFW |
| 45 | Nemah | Nemah River | WA | 44 | 1994 | WDFW |
| 46 | Naselle | Naselle River | WA | 45 | 1994 | WDFW |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| **Coastal Columbia River Basin** | | | | | | |
| 47 | Grays | Grays River | WA | 111 | 1994 | WDFW |
| 48 | Kalama | Kalama River | WA | 236 | 1994 | WDFW |
| 49 | Washougal | Washougal River | WA | 132 | 1993-94 | WDFW |
| 50 | Wind | Wind River | WA | 132 | 1993-94 | WDFW |
| 51 | Wind | Panther Creek | WA | 55 | 1994 | WDFW |
| **Coastal Oregon Region** | | | | | | |
| 52 | Nehalem | Salmonberry River | OR | 39 | 1992 | NMFS |
| 53 | Yaquina | Mill Creek | OR | 43 | 1992 | NMFS |
| 54 | Elk | Elk River | OR | 40 | 1992 | NMFS |
| 55 | Rogue | Lobster Creek | OR | 40 | 1992 | NMFS |
| 56 | Illinois | Grayback Creek | OR | 40 | 1992 | NMFS |
| 57 | Illinois | Briggs Creek | OR | 40 | 1992 | NMFS |
| 58 | Illinois | Lawson Creek | OR | 30 | 1992 | NMFS |
| 59 | Illinois | Indigo Creek | OR | 40 | 1992 | NMFS |
| 60 | Rogue | Little Butte Creek | OR | 40 | 1992 | NMFS |
| 61 | Rogue-H | Cole Rivers Hatchery, winter steelhead | OR | 40 | 1992 | NMFS |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| 62 | Rogue-H | Cole Rivers Hatchery, summer steelhead | OR | 60 | 1992 | NMFS |
| 63 | Chetco | Eel Creek | OR | 56 | 1992 | NMFS |
| 64 | Winchuck | Winchuck River | OR | 39 | 1992 | NMFS |
| **Northern California Region** | | | | | | |
| 65 | Smith | Siskiyou Fork Smith River | CA | 40 | 1992 | NMFS |
| 66 | Klamath | Camp Creek | CA | 40 | 1992 | NMFS |
| 67 | Iron Gate-H | Iron Gate Hatchery | CA | 60 | 1992 | NMFS |
| 68 | Trinity-H | Trinity River Hatchery | CA | 60 | 1992 | NMFS |
| 69 | Trinity | Cedar Creek (Horse-Linto Creek) | CA | 39 | 1992 | NMFS |
| 70 | Redwood | Redwood Creek Estuary (Humboldt County) | CA | 40 | 1992 | NMFS |
| 71 | Mad | Cañon Creek | CA | 40 | 1992 | NMFS |
| 72 | Mad-H | Mad River Hatchery | CA | 40 | 1992 | NMFS |
| 73 | Eel | Middle Fork Eel River | CA | 50 | 1994 | NMFS |
| 74 | Eel | Grizzly Creek (Van Duzen River) | CA | 40 | 1992 | NMFS |
| 75 | Ten Mile | Ten Mile River | CA | 50 | 1994 | NMFS |
| 76 | Lagunitas | Lagunitas Creek | CA | 44 | 1994 | NMFS |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| **Sacramento River Basin and San Francisco Bay** | | | | | | |
| 77 | Sacramento | Deer Creek | CA | 16 | 1994 | NMFS |
| 78 | Sacramento | Mill Creek | CA | 36 | 1994 | NMFS |
| 79 | Coleman-H | Coleman National Fish Hatchery | CA | 60 | 1994 | NMFS |
| 80 | Alameda | Alameda Creek | CA | 50 | 1994 | NMFS |
| **South of San Francisco Bay** | | | | | | |
| 81 | Scott | Scott Creek | CA | 50 | 1994 | NMFS |
| 82 | San Lorenzo | San Lorenzo River | CA | 51 | 1994 | NMFS |
| 83 | Carmel | Carmel River | CA | 50 | 1994 | NMFS |
| 84 | Gaviota | Gaviota Creek | CA | 55 | 1994 | NMFS |
| 85 | Arroyo Hondo | Arroyo Hondo Creek | CA | 55 | 1994 | NMFS |
| 86 | Whale Rock-H | Whale Rock Hatchery | CA | 55 | 1994 | NMFS |
| **Washington state rainbow trout hatcheries** | | | | | | |
| 87 | Tokul-RT-H | Tokul Creek Hatchery rainbow trout | WA | 100 | 1990 | WDFW |
| 88 | South Tacoma-RT-H | South Tacoma Hatchery rainbow trout | WA | 100 | 90 | WDFW |
| 89 | Spokane-RT-H | Spokane Hatchery rainbow trout | WA | 100 | 1990 | WDFW |
| 90 | Goldendale-RT-H | Goldendale Hatchery rainbow trout | WA | 100 | 90 | WDFW |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| 91 | Goldendale-RT-H | Goldendale Hatchery rainbow trout collected from Naches rearing pond | WA | 53 | 1990 | WDFW |
| **Inland Columbia River Basin** | | | | | | |
| 92 | Big White Salmon | Big White Salmon River | WA | 302 | 1992-93 | WDFW |
| 93 | Klickitat | Upper Klickitat River | WA | 484 | 1991, 1994 | WDFW |
| 94 | Klickitat | Bowman Creek | WA | 121 | 1991 | WDFW |
| 95 | Klickitat | Little Klickitat River | WA | 121 | 1991 | WDFW |
| 96 | Klickitat | Lower Klickitat River | WA | 121 | 1994 | WDFW |
| 97 | Yakima | Satus Creek | WA | 333 | 1989-90 | WDFW |
| 98 | Yakima | Toppenish Creek | WA | 111 | 1990 | WDFW |
| 99 | Yakima | Wapatox Trap | WA | 111 | 1987 | WDFW |
| 100 | Yakima | Teanaway River | WA | 111 | 1991 | WDFW |
| 101 | Yakima | Roza Trap | WA | 111 | 1989 | WDFW |
| 102 | Yakima | Chandler Trap | WA | 111 | 1987 | WDFW |
| **Snake River Basin** | | | | | | |
| 103 | Tucannon | Lower Tucannon River | WA | 143 | 1989-90 | NMFS |
| 104 | Tucannon | Upper Tucannon River | WA | 184 | 1989-90 | NMFS |
| 105 | Dworshak-H | Dworshak National Fish Hatchery | ID | 200 | 1989, 1991 | NMFS |

Appendix A-1. Samples of *O. mykiss* used in the genetic analyses for this report. Continued.

| Sample code | Sample name[a] | Location sampled | State | Sample size | Year collected | Genetics laboratory |
|---|---|---|---|---|---|---|
| 106 | Selway | Gedney Creek | ID | 83 | 1990 | NMFS |
| 107 | Lochsa | Fish Creek | ID | 176 | 1989-90 | NMFS |
| 108 | Grande Ronde | Chesnimnus Creek | OR | 200 | 1989-90 | NMFS |
| 109 | Grande Ronde | Deer Creek | OR | 200 | 1989-90 | NMFS |
| 110 | Imnaha | Lick Creek | OR | 192 | 1989-90 | NMFS |
| 111 | Imnaha | Camp Creek | OR | 99 | 1990 | NMFS |
| 112 | Imnaha | Grouse Creek | OR | 99 | 1990 | NMFS |
| 113 | Imnaha | Little Sheep Creek | OR | 200 | 1989-90 | NMFS |

[a]Samples of rainbow trout are indicated by the suffix "RT;" samples from hatchery fish are indicated by the suffix "H."

[b]The name of this river has two common spellings. Prior to 1992, the accepted spelling was Soleduck River; in 1992, the spelling was officially changed to Sol Duc River by the State of Washington Board on Geographic Names, P.O. Box 47032, Olympia, WA 98504-7032.

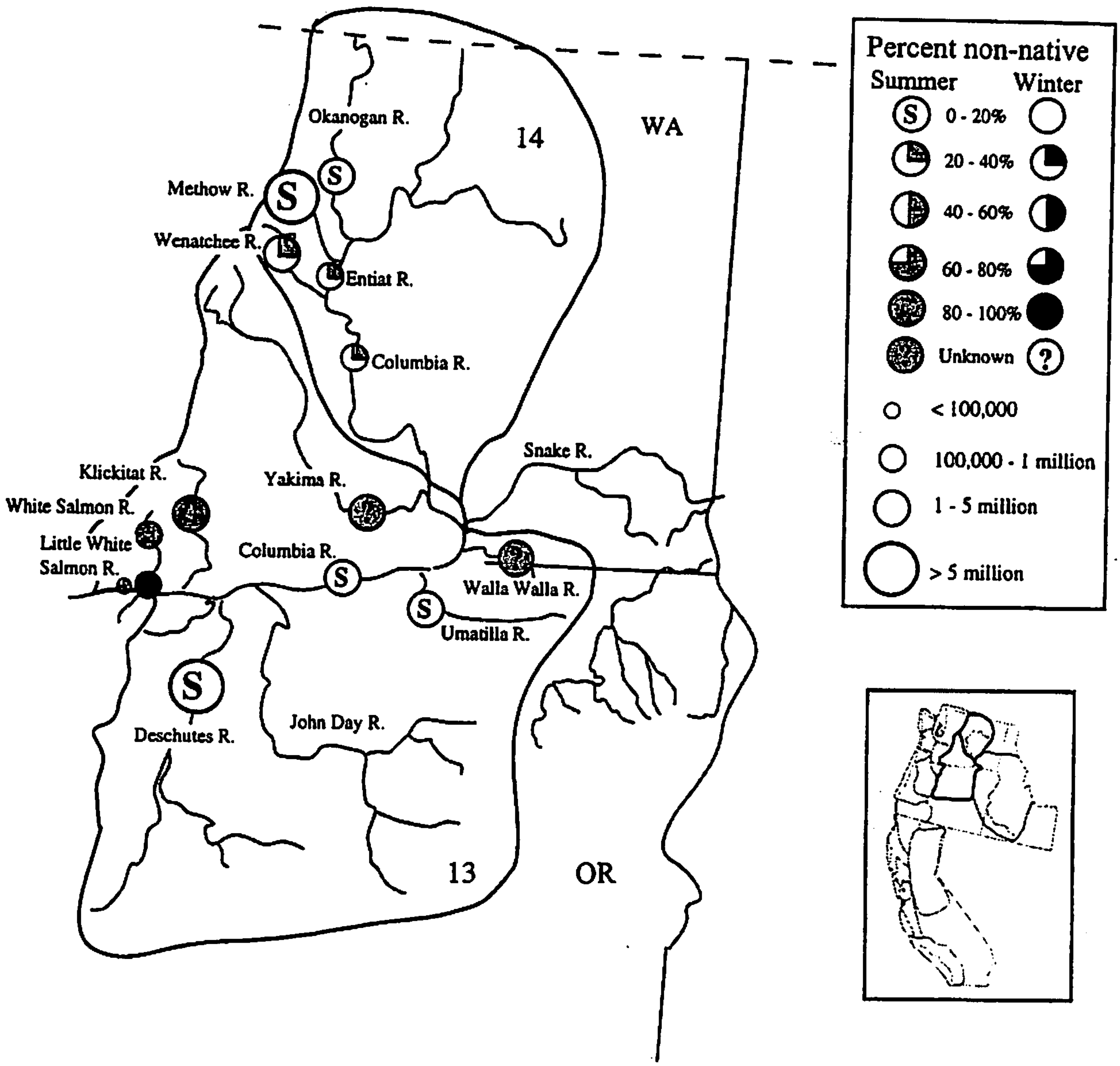


Figure 16. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 13-Middle Columbia River and 14-Upper Columbia River, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Shelldrake 1993, ODFW 1994c, WDFW 1994a).

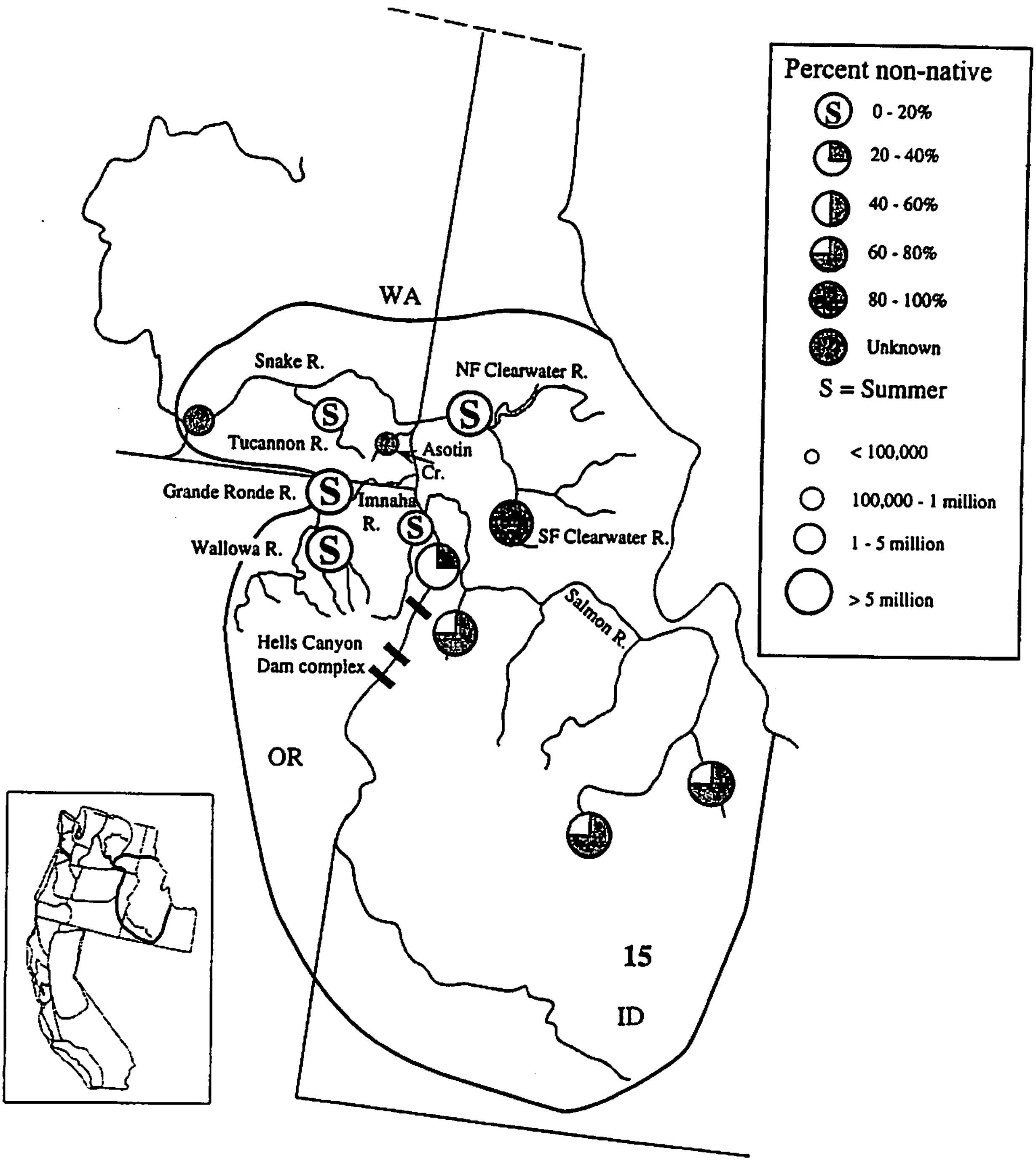


Figure 17. Total releases of hatchery steelhead into rivers occupied by steelhead ESU 15-Snake River Basin, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Hutchison 1993, Shelldrake 1993, ODFW 1994c, WDFW 1994a). All data are for summer steelhead.

The Hells Canyon Complex forms the second series of dams (Hells Canyon, Oxbow, and Brownlee Dams); these block anadromous fish passage to the upper Snake River Basin. Steelhead mitigation facilities for the Hells Canyon Complex include Oxbow, Pahsimeroi, and Niagara Springs Steelhead Hatcheries. One goal of the Hells Canyon Complex mitigation was to relocate part of the upper Snake River steelhead run to the Salmon River. To accomplish this, steelhead broodstock are collected at Hells Canyon Dam, spawned at Oxbow Hatchery, and the fertilized eggs are transferred to rearing facilities, such as Niagara Springs Steelhead Hatchery (Hutchison 1993). These steelhead are subsequently released as smolts at various locations within the Salmon River Basin, primarily near Sawtooth and Pahsimeroi Hatcheries (Hutchison 1993, Kiefer[16]). These activities resulted in the development of the "Pahsimeroi stock," which was originally composed of indigenous Salmon River Basin steelhead combined with upper Snake River steelhead. This Pahsimeroi stock was also used to start the steelhead program at Sawtooth Hatchery. In recent years, wild steelhead have been passed above Pahsimeroi and Sawtooth Hatcheries, and only hatchery-origin fish have been used for broodstock.

Within the Snake River Basin, Dworshak NFH and Clearwater Hatchery appear to be the only facilities that have not incorporated out-of-basin steelhead into their broodstock.

## ASSESSMENT OF EXTINCTION RISK

### Background

As outlined in the Introduction above, NMFS considers a variety of information in evaluating the level of risk facing an ESU. Aspects of several of these risk considerations are common to all west coast steelhead ESUs. These are discussed in general below; more specific discussion of factors for each of the 14 ESUs under consideration here can be found in the following sections. The status of the Klamath Mountains Province ESU (ESU 7), has already been considered (Busby et al. 1994), and is referred to here only for comparison.

### Absolute Numbers

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

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[16] S. Kiefer, Fisheries Staff Biologist, Idaho Department of Fish and Game, 600 South Walnut, Box 25, Boise, ID 83707-0025. Pers. commun., June 1995.

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

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

Because the ESA (and NMFS policy) mandates that we focus on viability of natural populations, we attempted to distinguish natural fish from hatchery produced fish in this review. All statistics were based on data that indicated the total number or density of adults spawning in natural habitat (i.e., "naturally spawning fish"). The total of all naturally spawning fish (i.e., "total escapement") is divided into two components (Fig. 18): "Hatchery produced" fish which are reared as juveniles in a hatchery but return as adults to spawn naturally; and "natural" fish which are progeny of naturally spawning fish.

**Historical Abundance and Carrying Capacity**

The relationship of current abundance and habitat capacity to that which existed historically is an important consideration in evaluating risk. Knowledge of historical population conditions provides a perspective of the conditions under which present stocks evolved, as well as the basis for establishing long-term trends in populations. Comparison of present and past habitat capacity can also indicate long-term population trends and problems of population fragmentation. The relationship of present abundance to present carrying capacity is important for understanding the health of populations, but the fact that a population.is near its current capacity does not in itself mean that it is healthy. For a population that is near capacity, there may be limits to the effectiveness of short-term management actions in increasing abundance. For such a population, competition and other interactions between hatchery and natural fish may also be important considerations because the addition of hatchery fish may further increase population density in a limited habitat.

For steelhead, quantitative abundance estimates are rarely available for periods before the 1950s. The main exceptions are long-term counts at dams in the Columbia River Basin and northern California that extend back to the 1930s or 1940s. Quantitative assessments of habitat are quite rare, although rough estimates of carrying capacity are frequently made for setting management goals. From the evidence available, it is clear that production of natural steelhead is now substantially below historical levels for all ESUs considered here, although

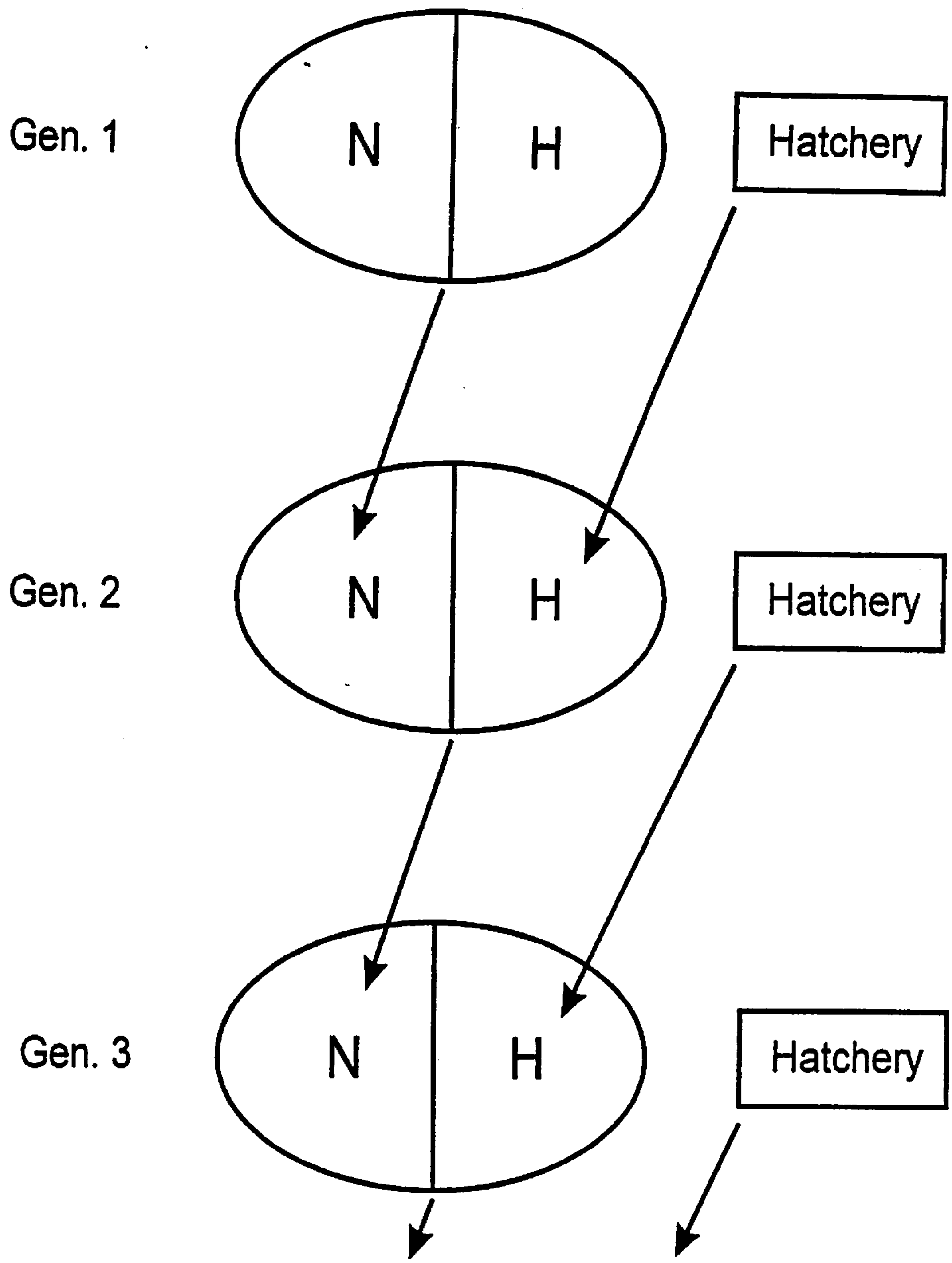


Figure 18. Schematic diagram of mixing of naturally and hatchery produced fish in natural habitat. Ovals represent the total spawning in natural habitat each generation. This total can be composed of naturally produced (N) and hatchery produced (H) offspring of individuals in the previous generation.

this decline in natural production has been offset to a variable extent by increasing hatchery production in many areas.

Although no analysis of the proportion of total habitat lost due to blockages has been attempted by us, there have been significant blockages of freshwater habitat in every ESU. Freshwater and estuarine habitats are also degraded throughout the entire region considered here, although the severity of degradation varies among ESUs and is described in the individual ESU summaries below.

**Trends in Abundance**

Short- and long-term trends in abundance are a primary indicator of risk in salmonid populations. Trends may be calculated from a variety of quantitative data, including dam or weir counts, stream surveys, and catch data. These data sources and methods are discussed in more detail below, under Approach to Risk Assessment. Regular sampling has not been conducted for many steelhead populations, and data series are quite short for most of those populations with sampling data. Where data series were lacking, we inferred general trends by comparing historical and recent abundance estimates, or by considering trends in habitat quantity or condition.

The important role of artificial propagation (in the form of hatcheries) for Pacific salmon and steelhead requires careful consideration in ESA evaluations. Artificial propagation has implications both for evaluating production trends and for evaluating the genetic integrity of populations. Waples (1991b) and Hard et al. (1992) discussed the role of artificial propagation in ESU determinations and emphasized the need to focus on natural production in a threatened or endangered status determination. To address this need, and because of the ESA's emphasis on ecosystem conservation, our analysis focused on naturally reproducing steelhead. A fundamental question in ESA risk assessments is whether natural production is sufficient to maintain the population without the continued infusion of artificially produced fish. A full answer to this question is difficult without extensive studies of relative production and interactions between hatchery and natural fish. When such information is lacking, the presence of hatchery fish in natural populations leads to substantial uncertainty in evaluating the status of a natural population.

One method of approaching this issue is to calculate the natural cohort replacement ratio, defined as the number of naturally spawning adults that are naturally produced in one generation divided by the number of naturally spawning adults (regardless of parentage) in the previous generation. Because data for steelhead are rarely sufficient for this calculation, we did not attempt to estimate this ratio in this report. However, the ratio can be approximated from the average population trend if the degree of hatchery contribution to natural spawning can be estimated (Busby et al. 1994, Appendix B). Where such estimates were available, the presence of hatchery fish among natural spawners was taken into consideration in evaluating the sustainability of natural production for individual populations within the ESUs identified.

Recent coastwide trends in steelhead abundance provided a larger perspective for this review. Between the 1890s and the 1960s, total U.S. commercial catch of steelhead declined

sevenfold, but this may reflect restrictions on the fishery more than declines in abundance. Rough estimates of total coastwide steelhead run size made in 1972 and 1987 were similar (Sheppard 1972, Light 1987). By all accounts, however, there has been significant replacement of natural production with hatchery fish. Throughout British Columbia, Washington, and Oregon, both natural and hatchery steelhead stocks have exhibited recent decreases in survival, which may be due at least in part to climate and ocean production (Cooper and Johnson 1992).

**Factors Causing Variability**

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

**Threats to Genetic Integrity**

In addition to its effect on natural replacement rates, artificial propagation can have a substantial impact on the genetic integrity of natural salmon and steelhead populations. This can occur in several ways. First, stock transfers that result in interbreeding of hatchery and natural fish can lead to loss of fitness in local populations and loss of diversity among populations. The latter is important to maintaining long-term viability of an ESU because genetic diversity among salmonid populations helps to buffer overall productivity against periodic or unpredictable changes in the environment (Riggs 1990, Fagen and Smoker 1989). Ricker (1972) and Taylor (1991) summarized some of the evidence for local adaptations in Pacific salmonids that may be at risk from stock transfers.

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

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

For smaller steelhead stocks (either natural or hatchery), small-population effects (inbreeding, genetic drift) can also be important concerns for genetic integrity. Inbreeding and genetic drift are well understood at the theoretical level, and researchers have found evidence of inbreeding depression in various fish species (Allendorf and Ryman 1987). Other studies have shown that hatchery practices commonly used with anadromous Pacific

salmonids have the potential to affect genetic integrity (e.g., Simon et al. 1986, Withler 1988, Waples and Teel 1990). However, we are not aware of empirical evidence for inbreeding depression or loss of genetic variability in any natural or hatchery populations of Pacific salmon or steelhead.

One type of genetic change in hatchery populations—advancement of run timing—is particularly relevant to west coast steelhead because it is a commonly used management strategy, particularly in Washington state. The logic behind this strategy is that displacing the run timing of hatchery fish from that of natural populations will reduce the possibility for genetic interactions between hatchery and natural fish and will allow for selective harvest of hatchery fish. For coastal steelhead in Washington, WDFW has provided information indicating substantial separation in peak run timing between hatchery and natural winter steelhead, and this pattern may occur in other coastal areas as well. However, run timing separation is seldom complete, and WDFW has found genetic evidence for substantial hatchery introgression in several winter steelhead populations (Phelps et al. 1994; see discussion under Steelhead Genetics, page 37). This issue is discussed further below under Approach to Risk Assessment (see page 103).

**Recent Events Affecting Extinction Risk**

A variety of factors, both natural and human-induced, affect the degree of risk facing salmonid populations. Because of time lags between these events and their effects, as well as variability within populations, recent changes in any of these factors may affect current risk without any apparent change in available population statistics. Thus, consideration of these effects must go beyond examination of recent abundance and trends. Unfortunately, forecasting future effects is rarely straightforward and usually involves qualitative evaluations based on informed professional judgement. Events affecting populations may include natural changes in the environment or human-induced changes, either beneficial or detrimental. Possible future effects of recent or proposed conservation measures have not been taken into account in this analysis, but we have considered documented changes in the natural environment. A key question regarding the role of recent events is, given our uncertainty regarding the future, how we evaluate the risk that a population may not persist.

Most Pacific salmonid stocks south of British Columbia have been affected by changes in ocean production that occurred during the 1970s (Pearcy 1992, Lawson 1993). Cooper and Johnson (1992) described a widespread decline in both natural and hatchery steelhead production since 1985, extending from British Columbia through Oregon. They attributed this decline largely to ocean factors but did not identify specific effects. However, climate conditions are known to have changed recently in the Pacific Northwest and much of the Pacific coast has also been experiencing drought conditions in recent years, which may have depressed freshwater production. We do not know whether these climate conditions represent a long-term shift in conditions which will continue affecting stocks into the future, or whether they indicate short-term environmental fluctuations which may be reversed in the near future.

**Other Risk Factors**

Other risk factors typically considered for salmonid populations include disease prevalence, predation, and changes in life history characteristics such as spawning age or size. We have not found evidence that any of these factors are widespread throughout any steelhead ESU. Various diseases have been reported as problems in some hatcheries, but we have found no reports of substantial disease problems in natural steelhead populations.

Bacterial kidney disease, *Ceratomyxa shasta*, and infectious hematopoietic necrosis are reported to be problems within steelhead hatcheries in northern California (Foott et al. 1994). Chapman et al. (1994) reported several diseases in Columbia River Basin steelhead hatcheries. Predation by marine mammals or introduced freshwater fishes is important for individual populations, as noted in the ESU summaries below.

## Approach to Risk Assessment

**Previous Assessments**

In considering the status of ESUs, we evaluated both qualitative and quantitative information. Qualitative evaluations included aspects of several of the risk considerations outlined above, as well as recent, published assessments by agencies or conservation groups of the status of west coast steelhead stocks (Nehlsen et al. 1991; Higgins et al. 1992; Nickelson et al. 1992; WDF et al. 1993; USFS 1993a,b; Titus et al. in press). These evaluations are summarized in Appendix E.

Nehlsen et al. (1991) considered salmonid stocks throughout Washington, Idaho, Oregon, and California and enumerated all stocks that they found to be extinct or at risk of extinction. Stocks that did not appear in their summary were excluded either because they were not at risk of extinction or there was insufficient information to classify them. They classified stocks as extinct (X), possibly extinct (A+), at high risk of extinction (A), at moderate risk of extinction (B), or of special concern (C). They considered it likely that stocks at high risk of extinction have reached the threshold for classification as endangered under the ESA. Stocks were placed in this category if they had declined from historic levels and were continuing to decline, or if they had spawning escapements less than 200. Stocks were classified as at moderate risk of extinction if they had declined from historic levels but appeared to be stable at a level above 200 spawners. They believed that stocks in this category had reached the threshold for classification as threatened under the ESA. They classified a stock as of special concern if a relatively minor disturbance could threaten it, if insufficient data were available for it, or if it were influenced by large releases of hatchery fish or possessed some unique character. For steelhead, they classified 98 stocks as follows: 23 extinct, 1 possibly extinct, 27 high risk, 17 moderate risk, and 30 special concern (Table 9).

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| | none | none | **winter steelhead**<br>Dewatto R.<br>**summer steelhead**<br>Tolt R.<br>Deer Cr. | **winter steelhead**<br>Lake Washington<br>Tahuya R.<br>**summer steelhead**<br>S.F. Nooksack R. | **winter steelhead**<br>Nooksack R.<br>Skokomish R.<br>Samish R. |
| 2-Olympic Peninsula | | | | | |
| | none | none | none | none | none |
| 3-Southwest Washington | | | | | |
| | none | none | none | **winter steelhead**<br>small Columbia R. tributaries | **winter steelhead**<br>Grays R.<br>Elochoman R. |
| 4-Lower Columbia River | | | | | |
| | **summer steelhead**<br>Sandy R. | **summer steelhead**<br>White Salmon R. | **winter steelhead**<br>White Salmon R.<br>Wind R.<br>Hood R.<br>**summer steelhead**<br>Cowlitz R.<br>N.F. Lewis R.<br>Washougal R. | **winter steelhead**<br>Cowlitz R.<br>Washougal R.<br>Clackamas R.<br>small tributaries<br>**summer steelhead**<br>Hood R.<br>Wind R. | **winter steelhead**<br>Coweeman R.<br>Toutle R.<br>Kalama R.<br>Lewis R.<br>**summer steelhead**<br>E.F. Lewis R. |
| 5-Upper Willamette River | | | | | |
| | none | none | none | none | **winter steelhead**<br>Calapooia R. |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 6-Oregon Coast | | | | | |
| | **summer steelhead**<br>S. Umpqua R. | none | none | **summer steelhead**<br>Siletz R. | **winter steelhead**<br>Tillamook R.<br>Nestucca R.<br>Salmon R.<br>Siletz R.<br>Yaquina R.<br>Alsea R.<br>Yachats R.<br>Tenmile Cr.<br>Big Cr.<br>Siuslaw R. |
| 7-Klamath Mountains Province | | | | | |
| | none | none | **summer steelhead**<br>Smith R. | **winter steelhead**<br>Illinois R.<br>**summer steelhead**<br>Rogue R.<br>Klamath R. | none |
| 8-Northern California | | | | | |
| | none | none | **summer steelhead**<br>Redwood Cr.<br>Mad R. | **summer steelhead**<br>Eel R. | none |
| 9-Central California Coast | | | | | |
| | none | none | **winter steelhead**<br>Napa R.<br>San Francisco<br>Bay tributaries | none | none |

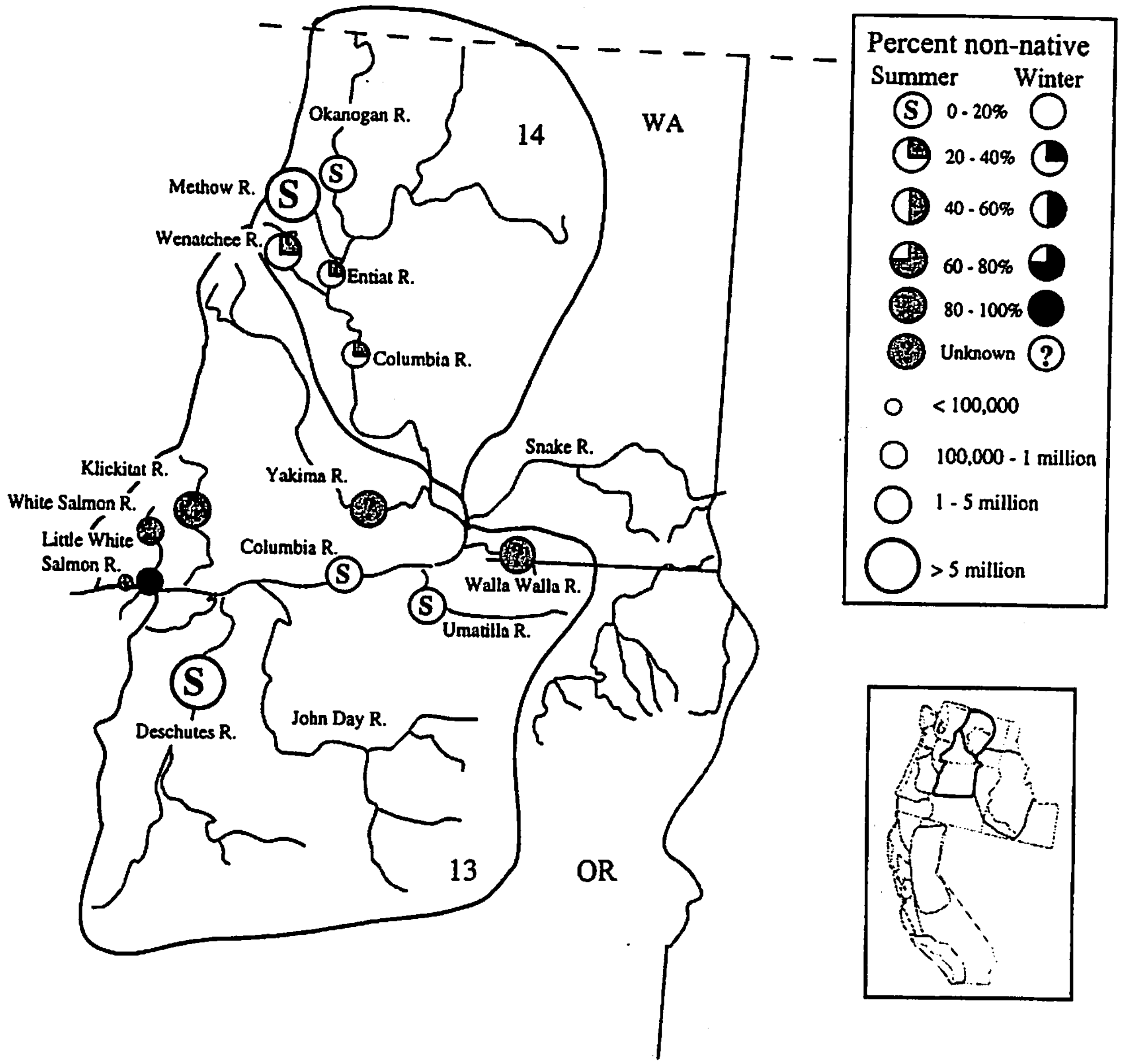


Figure 16. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 13-Middle Columbia River and 14-Upper Columbia River, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Shelldrake 1993, ODFW 1994c, WDFW 1994a).

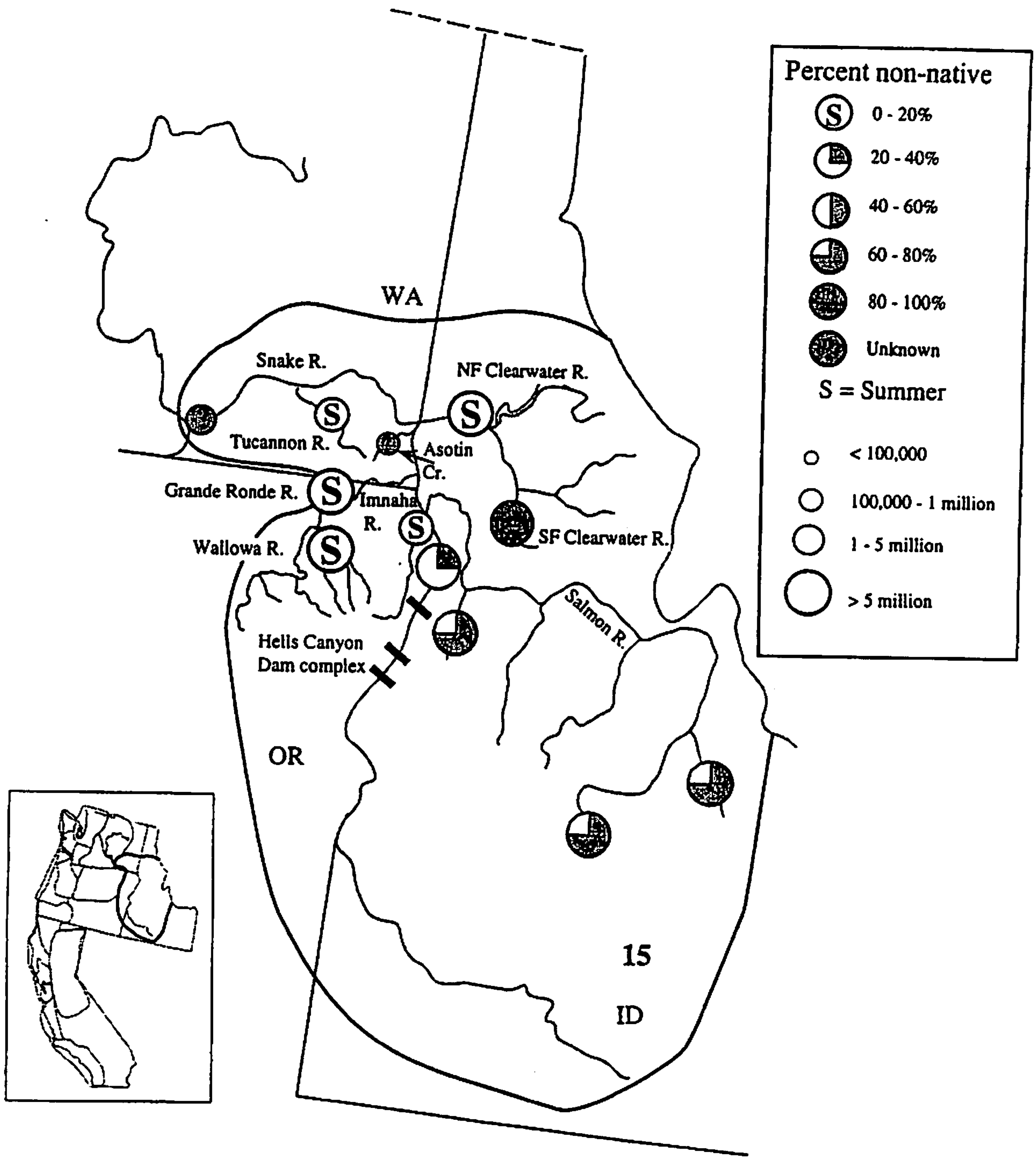


Figure 17. Total releases of hatchery steelhead into rivers occupied by steelhead ESU 15-Snake River Basin, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Hutchison 1993, Shelldrake 1993, ODFW 1994c, WDFW 1994a). All data are for summer steelhead.

The Hells Canyon Complex forms the second series of dams (Hells Canyon, Oxbow, and Brownlee Dams); these block anadromous fish passage to the upper Snake River Basin. Steelhead mitigation facilities for the Hells Canyon Complex include Oxbow, Pahsimeroi, and Niagara Springs Steelhead Hatcheries. One goal of the Hells Canyon Complex mitigation was to relocate part of the upper Snake River steelhead run to the Salmon River. To accomplish this, steelhead broodstock are collected at Hells Canyon Dam, spawned at Oxbow Hatchery, and the fertilized eggs are transferred to rearing facilities, such as Niagara Springs Steelhead Hatchery (Hutchison 1993). These steelhead are subsequently released as smolts at various locations within the Salmon River Basin, primarily near Sawtooth and Pahsimeroi Hatcheries (Hutchison 1993, Kiefer[16]). These activities resulted in the development of the "Pahsimeroi stock," which was originally composed of indigenous Salmon River Basin steelhead combined with upper Snake River steelhead. This Pahsimeroi stock was also used to start the steelhead program at Sawtooth Hatchery. In recent years, wild steelhead have been passed above Pahsimeroi and Sawtooth Hatcheries, and only hatchery-origin fish have been used for broodstock.

Within the Snake River Basin, Dworshak NFH and Clearwater Hatchery appear to be the only facilities that have not incorporated out-of-basin steelhead into their broodstock.

## ASSESSMENT OF EXTINCTION RISK

### Background

As outlined in the Introduction above, NMFS considers a variety of information in evaluating the level of risk facing an ESU. Aspects of several of these risk considerations are common to all west coast steelhead ESUs. These are discussed in general below; more specific discussion of factors for each of the 14 ESUs under consideration here can be found in the following sections. The status of the Klamath Mountains Province ESU (ESU 7), has already been considered (Busby et al. 1994), and is referred to here only for comparison.

#### Absolute Numbers

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

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[16] S. Kiefer, Fisheries Staff Biologist, Idaho Department of Fish and Game, 600 South Walnut, Box 25, Boise, ID 83707-0025. Pers. commun., June 1995.

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

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

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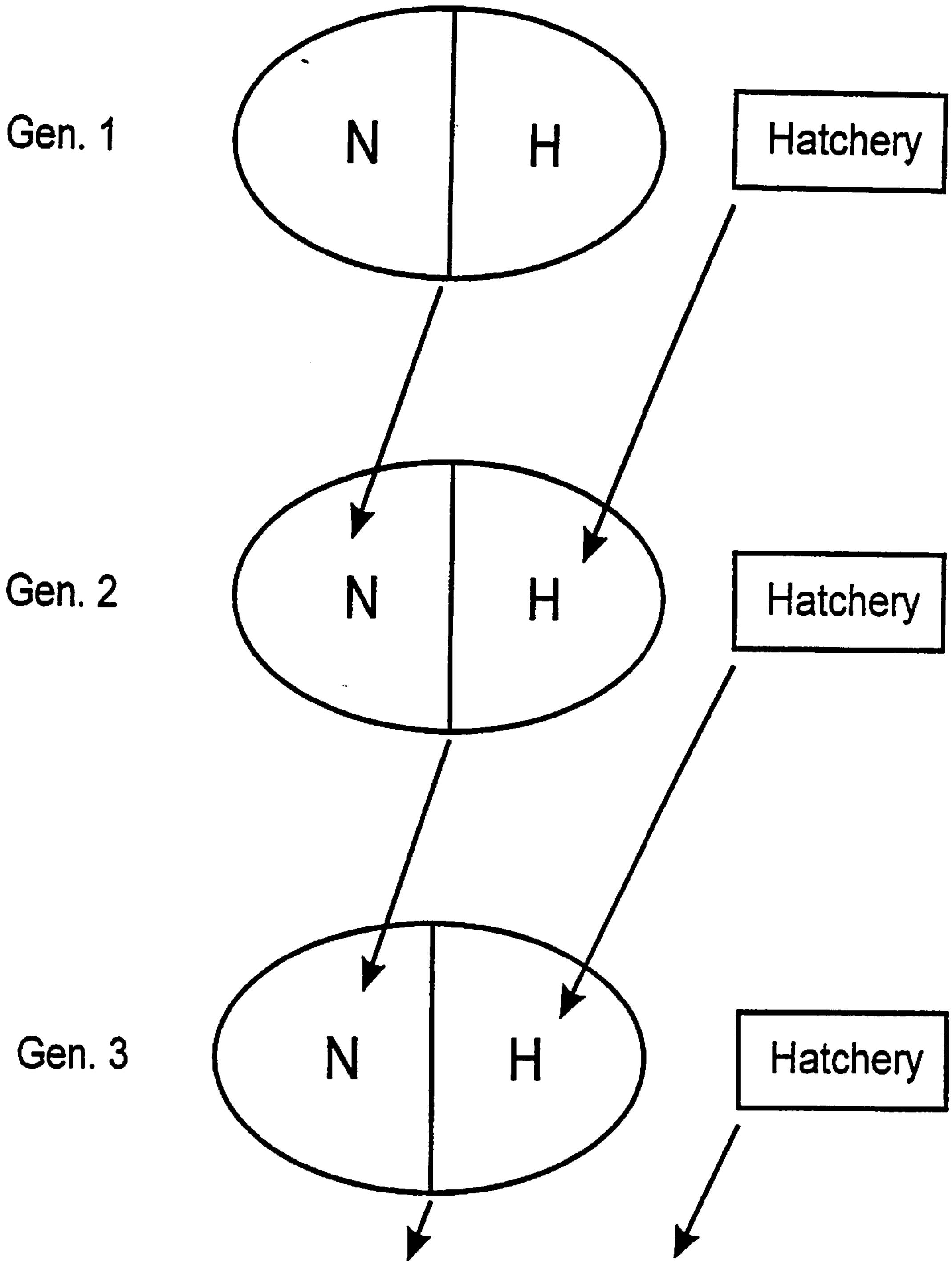


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### Previous Assessments

In considering the status of ESUs, we evaluated both qualitative and quantitative information. Qualitative evaluations included aspects of several of the risk considerations outlined above, as well as recent, published assessments by agencies or conservation groups of the status of west coast steelhead stocks (Nehlsen et al. 1991; Higgins et al. 1992; Nickelson et al. 1992; WDF et al. 1993; USFS 1993a,b; Titus et al. in press). These evaluations are summarized in Appendix E.

Nehlsen et al. (1991) considered salmonid stocks throughout Washington, Idaho, Oregon, and California and enumerated all stocks that they found to be extinct or at risk of extinction. Stocks that did not appear in their summary were excluded either because they were not at risk of extinction or there was insufficient information to classify them. They classified stocks as extinct (X), possibly extinct (A+), at high risk of extinction (A), at moderate risk of extinction (B), or of special concern (C). They considered it likely that stocks at high risk of extinction have reached the threshold for classification as endangered under the ESA. Stocks were placed in this category if they had declined from historic levels and were continuing to decline, or if they had spawning escapements less than 200. Stocks were classified as at moderate risk of extinction if they had declined from historic levels but appeared to be stable at a level above 200 spawners. They believed that stocks in this category had reached the threshold for classification as threatened under the ESA. They classified a stock as of special concern if a relatively minor disturbance could threaten it, if insufficient data were available for it, or if it were influenced by large releases of hatchery fish or possessed some unique character. For steelhead, they classified 98 stocks as follows: 23 extinct, 1 possibly extinct, 27 high risk, 17 moderate risk, and 30 special concern (Table 9).

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| | none | none | **winter steelhead**<br>Dewatto R. | **winter steelhead**<br>Lake Washington<br>Tahuya R. | **winter steelhead**<br>Nooksack R.<br>Skokomish R.<br>Samish R. |
| | | | **summer steelhead**<br>Tolt R.<br>Deer Cr. | **summer steelhead**<br>S.F. Nooksack R. | |
| 2-Olympic Peninsula | | | | | |
| | none | none | none | none | none |
| 3-Southwest Washington | | | | | |
| | none | none | none | **winter steelhead**<br>small Columbia R. tributaries | **winter steelhead**<br>Grays R.<br>Elochoman R. |
| 4-Lower Columbia River | | | | | |
| | **summer steelhead**<br>Sandy R. | **summer steelhead**<br>White Salmon R. | **winter steelhead**<br>White Salmon R.<br>Wind R.<br>Hood R. | **winter steelhead**<br>Cowlitz R.<br>Washougal R.<br>Clackamas R.<br>small tributaries | **winter steelhead**<br>Coweeman R.<br>Toutle R.<br>Kalama R.<br>Lewis R. |
| | | | **summer steelhead**<br>Cowlitz R.<br>N.F. Lewis R.<br>Washougal R. | **summer steelhead**<br>Hood R.<br>Wind R. | **summer steelhead**<br>E.F. Lewis R. |
| 5-Upper Willamette River | | | | | |
| | none | none | none | none | **winter steelhead**<br>Calapooia R. |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 6-Oregon Coast | | | | | |
| | **summer steelhead** | none | none | **summer steelhead** | **winter steelhead** |
| | S. Umpqua R. | | | Siletz R. | Tillamook R.<br>Nestucca R.<br>Salmon R.<br>Siletz R.<br>Yaquina R.<br>Alsea R.<br>Yachats R.<br>Tenmile Cr.<br>Big Cr.<br>Siuslaw R. |
| 7-Klamath Mountains Province | | | | | |
| | none | none | **summer steelhead** | **winter steelhead** | none |
| | | | Smith R. | Illinois R. | |
| | | | | **summer steelhead** | |
| | | | | Rogue R.<br>Klamath R. | |
| 8-Northern California | | | | | |
| | none | none | **summer steelhead** | **summer steelhead** | none |
| | | | Redwood Cr.<br>Mad R. | Eel R. | |
| 9-Central California Coast | | | | | |
| | none | none | **winter steelhead** | none | none |
| | | | Napa R.<br>San Francisco<br>Bay tributaries | | |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 10-South-Central California Coast | | | | | |
| | none | none | **winter steelhead**<br>Pajaro R.<br>Carmel R. | **winter steelhead**<br>Salinas R. | **winter steelhead**<br>Big Sur R.<br>Little Sur R. |
| 11-Southern California | | | | | |
| | **winter steelhead**<br>Gaviota Cr.<br>Rincon Cr.<br>Los Angeles R.<br>San Gabriel R.<br>Santa Ana R.<br>San Diego R.<br>San Luis Rey R.<br>San Mateo Cr.<br>Santa Margarita R.<br>Sweetwater R.<br>Maria Ygnacio R. | none | **winter steelhead**<br>Santa Ynez R.<br>Santa Clara R.<br>Ventura R.<br>Malibu Cr. | none | none |
| 12-Central Valley | | | | | |
| | none | none | **winter steelhead**<br>Sacramento R. | none | none |
| 13-Middle Columbia River | | | | | |
| | none | none | **winter steelhead**<br>Klickitat R.<br>small tributaries<br>**summer steelhead**<br>small tributaries | **winter steelhead**<br>Fifteenmile Cr. | **summer steelhead**<br>Klickitat R.<br>Walla Walla R. |

Table 9. Steelhead stocks identified by Nehlsen et al. (1991) as at some risk of extinction. Continued.

| ESU[a] | Extinct[b] | Possibly extinct | High rish | Moderate risk | Special concern |
|---|---|---|---|---|---|
| 1-Puget Sound | | | | | |
| 14-Upper Columbia River | | | | | |
| | **summer steelhead** | none | **summer steelhead** | none | **summer steelhead** |
| | Spokane R. | | Entiat R. | | Wenatchee R. |
| | Pend Oreille R. | | Methow R. | | |
| | | | Okanogan R. | | |
| 15-Snake River Basin | | | | | |
| | **summer steelhead** | none | none | **summer steelhead** | **summer steelhead** |
| | Powder R. | | | Asotin Cr. | Tucannon R. |
| | Burnt R. | | | | Salmon R. |
| | Weiser R. | | | | Clearwater R. |
| | Payette R. | | | | Imnaha R. |
| | Malheur R. | | | | |
| | Boise R. | | | | |
| | Owyhee R. | | | | |
| | Bruneau R. | | | | |

[a]ESU = evolutionarily significant unit.

[b]Due to lack of information on steelhead stocks that are presumed to be extinct, the relationship of these stocks, and the relationship of any residualized, resident forms, to adjacent steelhead ESUs is uncertain. They are listed here based on geography and to give a complete presentation of the stocks identified by Nehlsen et al. (1991).

Higgins et al. (1992) used the same classification scheme as Nehlsen et al. (1991) but provided a more detailed review of some northern California salmonid stocks. In this review, their evaluation is relevant only to the northern California ESU.

Nickelson et al. (1992) rated coastal Oregon (excluding Columbia River Basin) salmon and steelhead stocks on the basis of their status over the past 20 years. They used the following classifications: *depressed* (spawning habitat underseeded, declining trends, or recent escapements below long-term average), *healthy* (spawning habitat fully seeded and stable or increasing trends), or *of special concern* (300 or fewer spawners or a problem with hatchery interbreeding). They classified 27 steelhead populations in coastal Oregon as follows: 21 depressed, 1 special concern, and 5 healthy.

WDF et al. (1993) categorized all salmon and steelhead stocks in Washington on the basis of stock origin (*native, non-native, mixed*, or *unknown*), production type (*wild, composite*, or *unknown*) and status (*healthy, depressed, critical*, or *unknown*). Status categories were defined as follows: *healthy*, "experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock;" *depressed*, "production is below expected levels ... but above the level where permanent damage to the stock is likely;" and *critical*, "experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred." Of the 141 steelhead stocks identified, 36 were classified as healthy, 1 as critical, 44 as depressed, and 60 as unknown. Most of those classified as unknown are small stocks without large fisheries.

USFS (1993a,b) provided verbal descriptions of the status of steelhead stocks on Forest Service lands and noted their agreement or disagreement with status designations in other reviews. In Appendix E, we have grouped their comments into status categories based on key phrases used in their descriptions: *stable* or *healthy* (S); *unknown* (U); *depressed, declining, low*, or *moderate risk of extinction* (D); *critical, high risk of extinction*, or *severely depressed* (C); *extinct* (X); and *not present* (N).

Titus et al. (in press) provided a detailed review of steelhead populations south of San Francisco Bay, classifying them by categories based on presence or absence of the species and general trends in abundance. They used special symbols to categorize population status, as follows: steelhead present, no discernable change from historical levels (X); production reduced from historical levels, or likely so (<); current presence or absence unknown (?); extinct (E).

We encountered several problems in applying results of these studies to ESA evaluations, with a major problem being that the definition of "stock" or "population" varied considerably in scale among studies, and sometimes among regions within a study. Identified units range in size from large river basins (e.g., "Sacramento River" in Nehlsen et al. 1991), to minor coastal streams and tributaries (Titus et al. in press).

A second problem was the definition of categories used to classify stock status. Only Nehlsen et al. (1991) and Higgins et al. (1992) used categories intended to relate to ESA "threatened" or "endangered" status, and they applied their own interpretations of these terms to individual stocks, not to ESUs as defined here. Nickelson et al. (1992) and WDF et al. (1993) used general terms describing the status of stocks that could not be directly related to the considerations important in ESA evaluations. For example, the WDF et al. (1993) definition of healthy could conceivably include a stock at substantial extinction risk due to loss of habitat, hatchery fish interactions, or environmental variation (although this does not appear to be the case for any steelhead stocks).

A third problem is the selection of stocks or populations to include in the review. Nehlsen et al. (1991) and Higgins et al. (1992) did not evaluate (or even identify) stocks not perceived to be at risk, so it is difficult to determine the proportion of stocks they considered to be at risk in any given area. For steelhead, WDF et al. (1993) included only stocks considered to be substantially wild and included data only for the wild component for streams that have both hatchery and natural fish escaping to spawn (Johnson[17]), giving an incomplete evaluation of steelhead utilizing natural habitat.

**Data Evaluations**

Quantitative evaluations of data included comparisons of current and historical abundance of steelhead and calculation of recent trends in escapement and the proportion of natural spawning attributable to hatchery fish. Historical abundance information for these ESUs is largely anecdotal. Time series data are available for many populations, but data extent and quality varied among ESUs. We compiled and analyzed this information to provide several summary statistics of natural spawning abundance, including (where available) recent total spawning run size and escapement, percent annual change in total escapement, recent naturally produced spawning run size and escapement, and average percentage of natural spawners that were of hatchery origin.

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

**Data types**—Quantitative assessments were based on historical and recent run-size estimates and time series of freshwater spawner and juvenile survey data, harvest rate estimates, and counts of adults migrating past dams. We considered this information separately for each ESU. Because of the disparity of data sources and quality for the different ESUs, data sources and analyses are described separately for each ESU. Information on stock abundance was compiled from a variety of state, federal, and tribal agency records. We believe these records to be complete in terms of existing long-term adult abundance information for steelhead in the region covered. Principal data sources were

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[17] T. Johnson, Washington Department of Fish and Wildlife, 283236 Hwy. 101, Port Townsend, WA 98368. Pers. commun., March 1995.

angler catch estimates, dam or weir counts, and stream surveys. None of these sources provided a complete measure of adult spawner abundance for any of the streams; specific problems are discussed below for each data type.

Sport harvest information was the main abundance data available for most Oregon coastal populations. In 1952, Oregon instituted a punchcard system to record all salmon and steelhead caught by species. There are a variety of problems in interpreting abundance trends from sport harvest data; these are discussed in detail in the Oregon Coast ESU section below.

Counts of adult steelhead at dams and weirs are available from several river basins along the coast. These counts are probably the most accurate estimates available of total spawning run abundance, but often represent only small portions of the total population in each river basin. As with angler catches, these counts typically represent a combination of hatchery produced and natural fish, and thus are not a direct index of natural population trends.

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

**Computed statistics**—To represent current run size or escapement where recent data were available, we computed the geometric mean of the most recent 5 years reported (or fewer years if data series is shorter than 5 years). We tried to use only estimates that reflect the total abundance for an entire river basin or tributary, avoiding index counts or dam counts that represent only a small portion of available habitat. For Oregon angler catch data for coastal streams, catch was expanded to total run size and escapement (run size minus catch) using the methods and harvest rate estimates of Kenaston (1989). For the inland streams, we had no estimates of harvest rate to do this expansion. To avoid some local bias problems in areas with few anglers, catch data were used only for streams with an average catch greater than 100 steelhead per year. Where time-series data were not available, we relied on recent estimates from state agency reports; time periods included in such estimates varied considerably.

Where adequate data were available, trends in total escapement (or run size if escapement data were not available) were calculated for all data sets with more than 5 years of data, based on total escapement or an escapement index (such as fish per mile from a stream survey). As an indication of overall steelhead population trends in individual streams, we calculated average (over the available data series) percent annual change in adult spawner indices within each river basin. Trends were calculated as the slope ($a$) of the regression of ln(abundance) against years, corresponding to the biological model $N(t) = b \cdot e^{at}$, where $b$ is abundance at time $t$=0. Slopes significantly different from zero ($P<0.05$) were noted. The regressions provided direct estimates of mean instantaneous rates of population change ($a$); these values were subsequently converted to percent annual change, calculated as $100 \cdot (e^{a} - 1)$.

No attempt was made to account for the influence of hatchery produced fish on these estimates, so the estimated trends include any supplementation effect of hatchery fish.

Percentages of hatchery fish in spawning escapements were computed from 5-year geometric means of hatchery and natural escapement data where estimates of both were available. In most cases, however, we had to rely on recent estimates from state agencies. The time span and methods used in such estimates were often not reported, so the reliability of many of these estimates is unknown. For many Washington winter steelhead populations, we were able to calculate this percentage from WDFW steelhead inventory tables (WDFW 1994b) which provided estimates of both natural (late-run) and hatchery (early-run) spawner abundance. In Oregon, the main source for hatchery percentage estimates was the ODFW 1992 Wild Fish Management Policy report (Chilcote et al. 1992). Many of the estimates in that report were based on scale analysis of fish sampled from angler catches, and thus probably overestimate the proportion of hatchery fish actually spawning because the sport fishery selects for a higher proportion of hatchery fish in many areas. ODFW (1995a,b) has provided improved estimates for several stocks, which we used where available.

**Run timing**—An issue that may play a significant role in determining the nature and extent of interactions between hatchery and wild steelhead is separation of run timing. It is common for hatchery stocks of steelhead to return and spawn several weeks or months earlier than the natural populations they were derived from. This can occur either through selection for early returning adults in broodstock collection, or through faster growth and higher survival in the hatchery of progeny from early spawning fish. Earlier spawning for hatchery steelhead has at least two advantages from a fishery management perspective. First, the longer growth period makes it easier to produce hatchery fish that smolt in 1 year. Second, separation of spawn timing for natural and hatchery fish provides an opportunity to maximize harvest of hatchery fish while minimizing impacts on natural populations. Because winter steelhead generally spawn later than summer steelhead, winter steelhead provide the greatest opportunity for advancement of run and spawn timing in the hatchery.

State agencies in Washington and Oregon have adopted somewhat different approaches to the issue of run timing in hatchery steelhead. The Washington Department of Fisheries and Wildlife has intentionally developed early spawning hatchery stocks of winter steelhead for planting into coastal and lower Columbia River drainages. The early run timing is meant to accomplish two major objectives: provide an opportunity for high harvest rates on early returning hatchery fish without undue risk to wild fish, and minimize opportunities for interbreeding between naturally spawning hatchery fish and wild fish.

In contrast, the Oregon Department of Fish and Wildlife has not vigorously promoted altered run timing in their hatchery steelhead stocks. Although steelhead from Oregon coastal hatcheries commonly return and spawn somewhat earlier than their natural counterparts, the timing difference is not generally as great as in Washington. It should be noted, however, that WDFW generally uses only a few regional donor stocks (Chambers Creek and Skamania throughout Western Washington; Elochoman, Cowlitz and Skamania in the Lower Columbia River; Wells in the Upper Columbia River), so that stock transfers from a few regional hatcheries provide advanced-run stock to a multitude of rivers. On the other hand, ODFW, although relying on some regional donor stocks, also maintains many individual hatchery populations that are indigenous to the river into which they are planted (e.g., North Umpqua, Chetco, Deschutes, Clackamas Rivers). Therefore, advanced-run fish have not been distributed throughout the Oregon state hatchery system as extensively as have those in Washington.

In reviewing the status of individual ESUs of west coast steelhead, we considered the risks posed by artificial propagation to be important, particularly in combination with other risk factors indicating declines in abundance. Information submitted to the ESA Administrative Record for West Coast Steelhead indicates that, in general, the current WDFW policy to encourage run and spawn time separation between hatchery and natural winter steelhead and to maintain very high (80-90%) harvest rates on hatchery steelhead has resulted in less overlap on the natural spawning grounds than is the case for winter steelhead in Oregon. This factor was a consideration in the BRT's conclusions that some of the ESUs for coastal steelhead in Washington state are not at risk of extinction or endangerment (see below). However, BRT conclusions on this issue should be regarded as preliminary because information about the degree of interactions that actually occur between hatchery and natural fish is still incomplete.

Furthermore, although the WDFW strategy may be effective in reducing opportunities for direct interactions between hatchery and natural steelhead adults, those genetic and ecological interactions that do occur may be more deleterious to the natural population. A considerable body of evidence indicates that run and spawn timing in salmonids can have a strong genetic component, and it is not likely that substantially altered spawn timing would be advantageous to the natural population in the long term. In the short term, juvenile progeny of early spawning hatchery fish that do survive will be larger and may outcompete their natural counterparts. In addition, high harvest rates focused on hatchery fish may eliminate early natural spawners, resulting in a selective shift in natural run timing.

## Analysis of Biological Information

### Coastal Steelhead ESUs

**1) Puget Sound**—Previous assessments of steelhead within the range of this ESU have identified several stocks as being at risk or of concern. Nehlsen et al. (1991) identified nine stocks as at some degree of risk or concern (Table 9). WDF et al. (1993) considered 53 stocks within the ESU, of which 31 were considered to be of native origin and predominantly natural production. Their assessment of these 31 stocks was 11 healthy, 3 depressed, 1 critical, and 16 unknown. Their assessment of the remaining (not native/natural) stocks was 3 healthy, 11 depressed, and 8 unknown (Appendix E).

No estimates of historical (pre-1960s) abundance specific to the Puget Sound ESU are available. Total run size for Puget Sound in the early 1980s can be calculated from estimates in Light (1987) as approximately 100,000 winter steelhead and 20,000 summer steelhead. Light provided no estimate of hatchery proportions specific to Puget Sound streams, but for

Puget Sound and coastal Washington combined, he estimated that 70% of steelhead in ocean runs were of hatchery origin. The percentage in escapement to spawning grounds would be substantially lower due to differential harvest and hatchery rack returns.

Recent 5-year average natural escapements for streams with adequate data range from less than 100 to 7,200, with corresponding total run sizes of 550-19,800 (Table 10). Total recent run size for major stocks in this ESU was greater than 45,000, with total natural escapement of about 22,000. The geographic distribution of escapement is illustrated in Figure 19.

There are substantial habitat blockages by dams in the Skagit and Elwha River Basins, and minor blockages, for example, impassable culverts, throughout the region. The Washington State salmon and steelhead stock inventory (SASSI) (WDF et al. 1993) appendices note habitat problems, including flooding, unstable soils, and poor land management practices, for most stocks in this region. In general, habitat has been degraded from its pristine condition, and this trend is likely to continue with further population growth and resultant urbanization in the Puget Sound region. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than are winter steelhead.

Of the 21 independent stocks for which we had adequate adult escapement information to compute trends (Appendix E), 17 have been declining and 4 increasing during the available data series, with a range from 18% annual decline (Lake Washington winter steelhead) to 7% annual increase (Skykomish River winter steelhead). Eleven of these trends (9 negative, 2 positive) were significantly different from zero. Note that these trends are for the late run wild component of winter steelhead populations; no adult trend data are available for summer steelhead. In addition, most of these trends are based on relatively short data series and may be influenced by recent climate conditions. The two basins producing the largest numbers of steelhead (Skagit and Snohomish Rivers) both have overall upward trends. Trends for individual river basins are summarized in Table 10 and Figure 20.

Hatchery fish are widespread, spawn naturally throughout the Puget Sound region, and are largely derived from a single stock (Chambers Creek). The proportion of spawning escapement comprised of hatchery fish ranged from less than 1% (Nisqually River) to 51% (Morse Creek). In general, hatchery proportions are higher in Hood Canal and the Strait of Juan de Fuca than in Puget Sound proper (Table 10). Most hatchery fish in this region originated from stocks indigenous to the ESU, but they are generally not native to their local river basins. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region. Given the lack of strong trends in abundance for the major stocks and the apparent limited contribution of hatchery fish to production of the late-run winter stocks, most winter steelhead stocks in the Puget Sound ESU appear to be naturally self-sustaining at this time. However, there are clearly isolated problems with sustainability of some steelhead runs in this ESU, notably with Deer Creek summer steelhead (although juvenile abundance for this stock increased in 1994) and with Lake Washington winter steelhead. Summer steelhead stocks within this ESU are all small, occupy limited habitat, and in most cases are subject to introgression by hatchery fish. While

Table 10. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Puget Sound steelhead evolutionarily significant unit, by major river basin. Where no estimate for whole basin is available, ranges for individual stocks are given (see Appendix B for details). Run size and escapement are total adult steelhead; trend is percent annual change in total escapement (or an index of total escapement). Only basins with data are included. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Nooksack River | | | | -11.6 to -7.9 | |
| Samish River | | | 850 | | |
| Skagit River | 11,100 | 7,700 | 7,200 | +2.0 | 5 |
| Stillaguamish River | | | 1,200 | -6.3 | |
| Snohomish River | 19,800 | 8,000 | 6,800 | +3.1 | 12 |
| Lake Washington | | | 300 | -17.5 | |
| Green River | 4,300 | 1,700 | 1,500 | -1.7 | 12 |
| Puyallup River | 3,300 | 2,000 | 1,900 | -5.2 | 5 |
| Nisqually River | 1,900 | 1,200 | 1,200 | -5.1 | < 1 |
| Dewatto River | | | 30 | -1.2 | |
| Tahuya River | | | 100 | -0.6 | 49 |
| Skokomish River | | | 650 | -3.5 | |
| Snow Creek | | | 30 | -8.9 | |
| Dungeness River | | | 400 | -5.5 | |
| Morse Creek | 550 | 200 | 100 | -12.3 | 51 |

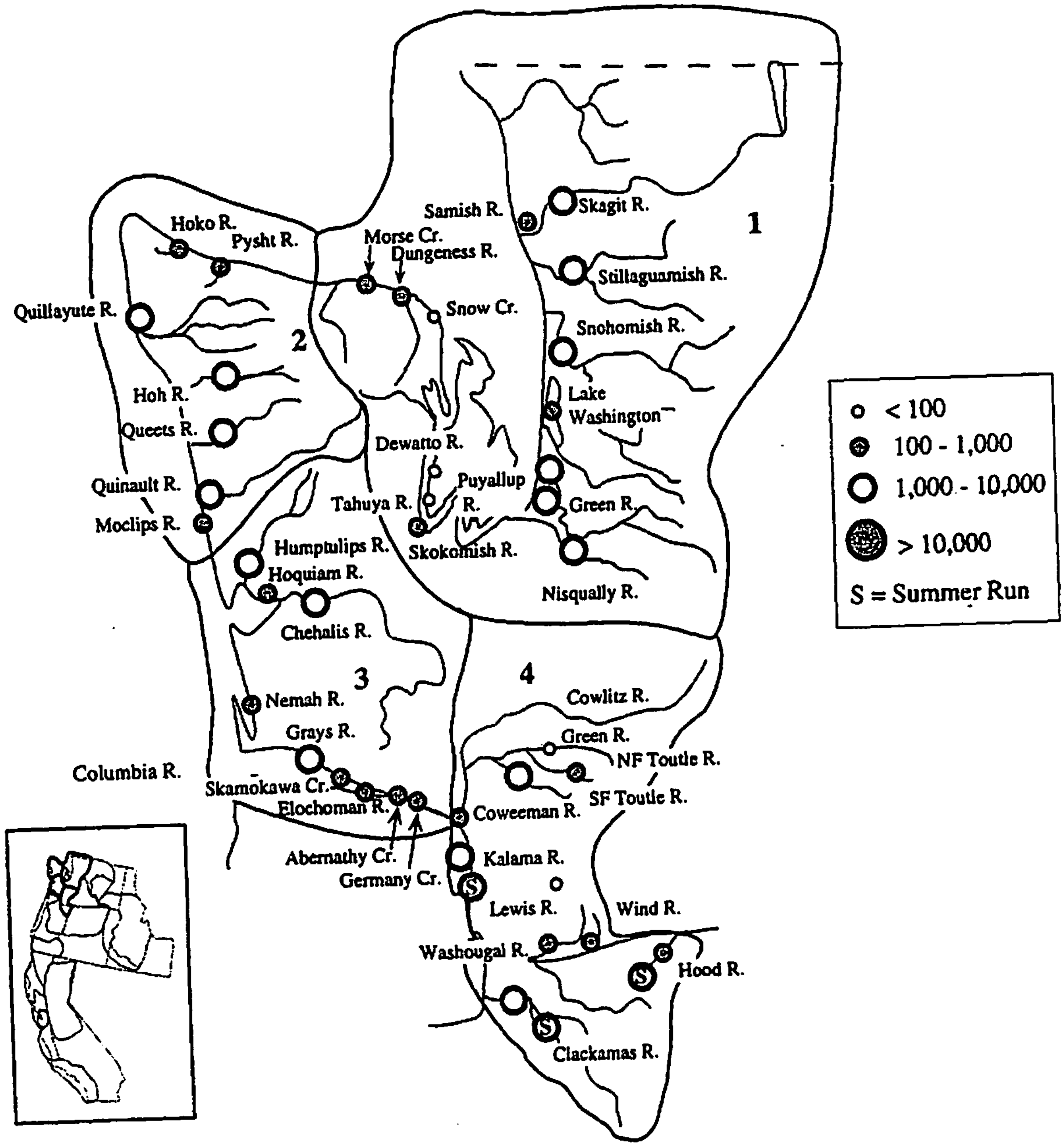


Figure 19. Recent total escapement for populations in steelhead ESUs 1-Puget Sound, 2-Olympic Peninsula, 3-Southwest Washington, and 4-Lower Columbia River. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details).

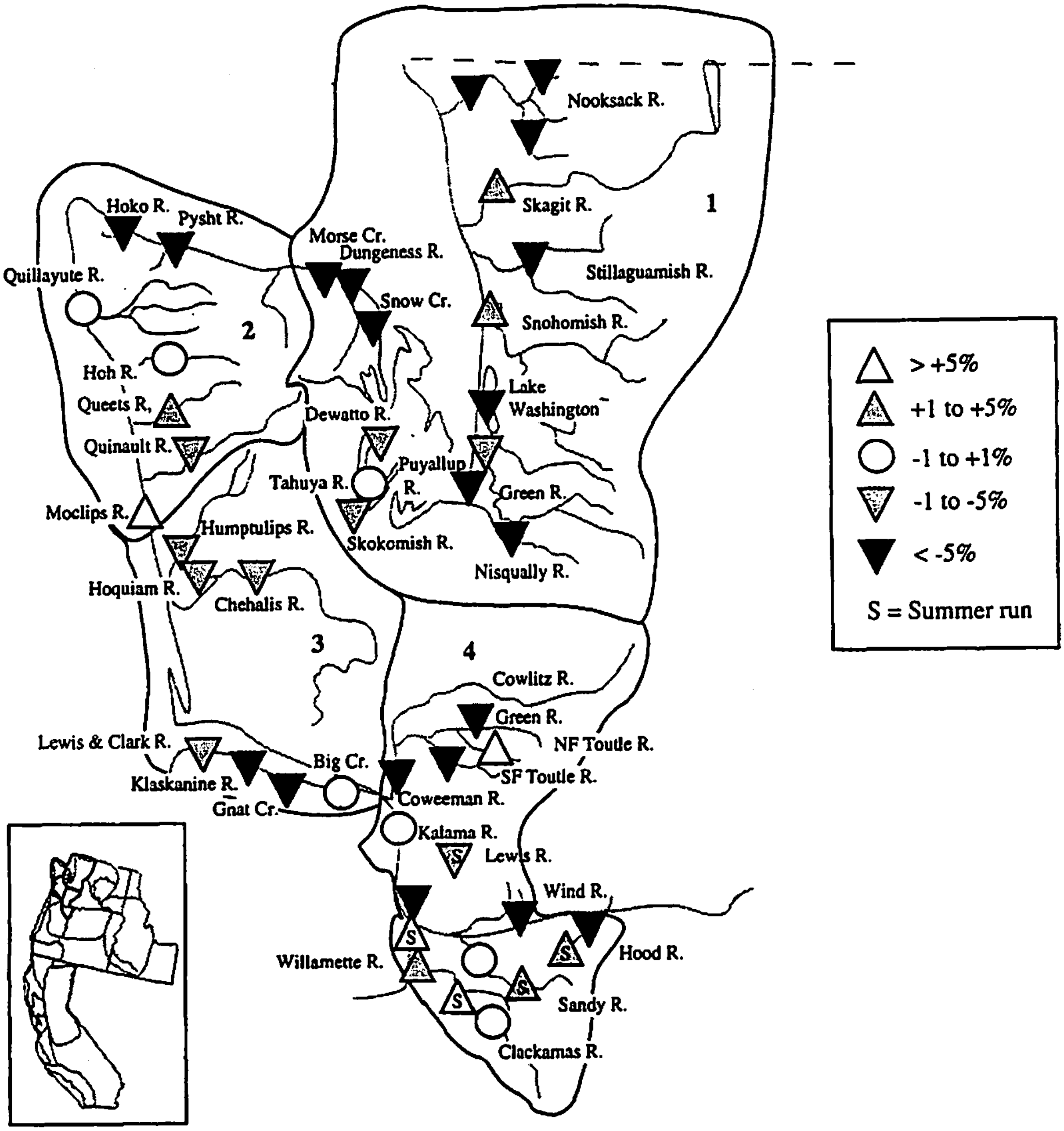


Figure 20. Trends (percent annual change) in total escapement for populations in steelhead ESUs 1-Puget Sound, 2-Olympic Peninsula, 3-Southwest Washington, and 4-Lower Columbia River. All data are for winter steelhead, except as noted (see Appendix E for details).

there are few data to assess the status of these summer runs, there is cause for concern regarding their sustainability.

At present, the major threat to genetic integrity for Puget Sound steelhead comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

**2) Olympic Peninsula**—Previous assessments of stocks within this ESU have not identified any stocks as being at risk or of special concern. Nehlsen et al. (1991) identified no stocks as at risk (Table 9). WDF et al. (1993) considered 31 stocks within the ESU, of which 23 were considered to be of native origin and predominantly natural production. The status of these 23 stocks was assessed as 11 healthy and 12 unknown, while the status of the eight remaining (not native/natural) stocks was two healthy and six unknown (Appendix E).

No estimates of historical (pre-1960s) abundance specific to the Olympic Peninsula ESU are available. Total run size for the major stocks in the Olympic Peninsula ESU during the early 1980s was calculated from estimates in Light (1987) as approximately 60,000 winter steelhead. Light provided no estimate of hatchery proportion in these streams, but for Puget Sound and coastal Washington together, he estimated that 70% of steelhead were of hatchery origin. Recent 5-year average natural escapements for streams with adequate data range from 250 to 6,900, with corresponding total run sizes of 450-19,700 (Table 11, Appendix E). Total recent (1989-93 average) run size for major streams in this ESU was approximately 54,000, with a natural escapement of 20,000 fish. The geographic distribution of this escapement is illustrated in Figure 19.

No major habitat blockages are known for these streams, but minor blockages (such as impassable culverts) are likely throughout the region. SASSI appendices (WDF et al. 1993) note freshwater habitat problems largely relating to poor land management practices, and recent poor ocean productivity affecting most stocks in this region. Clearcut logging has been extensive throughout most watersheds in this area, with the exception of the upper reaches of the larger rivers that drain Olympic National Park. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than winter steelhead.

Of the 12 independent stocks for which we had adequate adult escapement information to compute trends (Appendix E), 7 have been declining and 5 increasing during the available data series, with a range from 8% annual decline to 14% annual increase. Three of the downward trends were significantly different from zero, but three of the four river basins producing the largest numbers of natural fish have upward trends in basinwide total numbers (Table 11, Fig. 20). Note that these trends are all for winter steelhead populations; no adult trend data are available for summer steelhead.

Hatchery fish are widespread and escaping to spawn naturally throughout the region, with hatchery production largely derived from a few parent stocks. Estimated proportions of hatchery fish in natural spawning habitat range from 16% (Quillayute River) to 44% (Quinault River). However, the two largest producers of natural fish (Quillayute and Queets

Table 11. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Olympic Peninsula steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Pysht River | 650 | 400 | 250 | -5.8 | 43 |
| Hoko River | | | 550 | -7.6 | |
| Quillayute River | 19,700 | 8,300 | 6,900 | +0.6 | 16 |
| Hoh River | | | 2,300 | +0.2 | |
| Queets River | 13,400 | 7,400 | 5,900 | +4.3 | 19 |
| Quinault River | 16,400 | 6,300 | 3,400 | -1.8 | 44 |
| Moclips River | 450 | 400 | 250 | +13.6 | 37 |

Rivers) had the lowest proportions. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region. Given the lack of strong trends in abundance and the apparent limited contribution of hatchery fish to production of the late-run winter stocks, most winter steelhead stocks in the Olympic Peninsula ESU appear to be naturally sustaining at this time. However, there are clearly isolated problems with sustainability of some winter steelhead runs in this ESU, notably the Pysht/Independents stock, which has a small population with a strongly declining trend over the available data series (even though it has been exceeding harvest management goals recently), and the Quinault River stock, which has a declining trend and substantial hatchery contribution to natural spawning.

At present, the major threat to genetic integrity for Olympic Peninsula steelhead comes from past and present hatchery practices. Risk factors relating to these hatchery practices were discussed previously in the Background section.

**3) Southwest Washington**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified three stock groups as at risk or of concern: moderate risk for small Columbia River tributaries and special concern for the Grays and Elochoman Rivers (Table 9). WDF et al. (1993) considered 22 stocks within the ESU, of which 19 were considered to be of native origin and predominantly natural production. The status of these 19 stocks was 6 healthy, 6 depressed, and 7 unknown. The status of the remaining three stocks (not native/natural or unknown origin) was one healthy, one depressed, and one unknown. Most healthy stocks were in tributaries to Grays Harbor, and most depressed stocks were in lower Columbia River tributaries (Appendix E).

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Recent 5-year average natural escapements in individual tributaries with adequate data range from 150 to 2,300, with the Chehalis River and its tributaries representing the bulk of production (Appendix E). Total recent (5-year average) natural escapement for major streams in this ESU was approximately 13,000 (Table 12). The geographic distribution of escapement is illustrated in Figure 19.

No major habitat blockages are known for these streams, but minor blockages (such as impassable culverts) are likely throughout the region. Habitat problems for most stocks in this ESU are similar to those in adjacent coastal ESUs. Clearcut logging has been extensive throughout most watersheds in this area. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than are winter steelhead.

All but one (Wynoochee River) of the 12 independent stocks for which we had adequate adult escapement information to compute trends (Appendix E) have been declining during the available data series, with a range from 7% annual decline to 0.4% annual increase. Six of the downward trends were significantly different from zero. However, most of the data series used for trend calculations were short, beginning in the mid-1980s; thus, the trends may largely reflect the effects of recent climate conditions.

Table 12. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Southwest Washington steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Humptulips River | 4,100 | 2,500 | 2,300 | -3.5 | 10 |
| Hoquiam River | | | 600 | -4.2 | |
| Chehalis River | 13,600 | 8,500 | 7,700 | -1.1 | 9 |
| Nemah River | | | 650 | | |
| Grays River | | 1,200 | 900 | | 23 |
| Skamokawa Creek | | 300 | 250 | | 6 |
| Elochoman River | | 900 | 250 | | 72 |
| Abernathy Creek | | 200 | 150 | | 25 |
| Germany Creek | | 200 | 150 | | 23 |
| Lewis & Clark River | | | | -1.7 | 50 |
| Klaskanine River | | | | -5.2 | 55 |
| Big Creek | | | | -5.2 | |
| Gnat Creek | | | | -0.3 | |

For Washington streams, these trends are for the late run wild component of winter steelhead populations; Oregon data included all stock components. Most of the Oregon trends are based on angler catch data, and so may not reflect trends in underlying population abundance (see discussion for the Oregon Coast ESU). In general, stock condition appears to be healthier in southwest Washington than in the lower Columbia River Basin (Appendix E). Trends for individual river basins are summarized in Table 12 and Figure 20.

Hatchery fish, largely from parent stocks outside the ESU, are widespread and escaping to spawn naturally throughout the region. This could substantially change the genetic composition of the resource despite management efforts to minimize introgression of the hatchery gene pool into natural populations. Estimates of proportion of hatchery fish on natural spawning grounds range from 9% in the Chehalis River, the largest producer of steelhead in the ESU, to 82% in the Clatskanie River. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region. However, some Washington stocks (notably lower Columbia River tributaries—Table 12) appear to have received substantial hatchery contributions to their wild spawning components, and Nehlsen et al. (1991) identified two stocks in this ESU as of special concern due to hatchery influence (Table 9).

The preponderance of negative trends in abundance, the contribution of non-native hatchery fish to production, and the poor condition of stocks in lower Columbia River tributaries are causes for concern for the future of this ESU.

Again the major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

**4) Lower Columbia River**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 19 stocks as at risk or of concern (Table 9). WDF et al. (1993) considered 23 stocks within the ESU, of which 19 were considered to be of native origin and predominantly natural production. The status of these 19 stocks was 2 healthy, 10 depressed, and 7 unknown. All four of the remaining (not native/natural or unknown origin) stocks were classified as depressed.

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Total run size for the major stocks in the lower Columbia River (below Bonneville Dam, including the upper Willamette ESU) for the early 1980s can be calculated from the estimates of Light (1987) as approximately 150,000 winter steelhead and 80,000 summer steelhead. Light estimated that 75% of the total run (summer and winter steelhead combined) was of hatchery origin. Recent 5-year average natural escapements for streams with adequate data range from less than 100 to 1,100 (Table 13, Appendix E). Total recent (5-year average) run size for major streams in this ESU was greater than 16,000, but this total includes only the few basins for which estimates are available. The geographic distribution of escapement is illustrated in Figure 19.

Table 13. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Lower Columbia River steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Cowlitz River | W | | 100 - 1,000 | 90 - 950 | -16.5 to +47.9 | 0 - 35 |
| Kalama River | W | 2,300 | 1,400 | 900 | +0.1 | 32 |
| | S | 6,600 | 3,300 | 1,100 | -1.2 | 66 |
| Lewis River (East Fork) | | | | 90 | -15.7 | |
| Washougal River | | | | 100 | | |
| Wind River | S | | 600 | 300 | -7.8 | 53 |
| Sandy River | W | | | | -0.4 | > 30 |
| | S | | | | +3.4 | |
| Lower Willamette River | W | | | | +2.5 | |
| | S | | | | +9.3 | |
| Clackamas River | W | 1,300 | | | -0.4 | 70 |
| | S | 3,500 | | | +10.8 | |
| Hood River | W | 750 | | | -7.3 | > 40 |
| | S | 1,500 | | | +4.2 | 80 |

Significant habitat blockages resulted from dams on the Sandy River, and minor blockages (such as impassable culverts) are likely throughout the region. Habitat problems for most stocks in this ESU are similar to those in adjacent coastal ESUs. Clearcut logging has been extensive throughout most watersheds in this area, and urbanization is a substantial concern in the Portland and Vancouver areas. Because of their limited distribution in upper tributaries, summer steelhead appear to be at more risk from habitat degradation than are winter steelhead.

Of the 18 stocks for which we had adequate adult escapement information to compute trends (Appendix E), 11 have been declining and 7 increasing during the available data series, with a range from 24% annual decline to 48% annual increase. Eight of these trends (five negative, three positive) were significantly different from zero. Most of the data series for this ESU are short, beginning only in the late 1970s to the mid-1980s; thus they may be heavily influenced by short-term climate effects. Some of the Washington trends (notably those for the Cowlitz and Kalama River Basins) have been influenced (positively or negatively) by the 1980 eruption of Mount St. Helens; we have not attempted to correct for this here. For Washington streams, these trends are for the late run wild component of winter steelhead populations; Oregon data included all stock components. Most of the Oregon trends are based on angler catch, and so they may not reflect trends in underlying population abundance—see discussion under the Oregon Coast ESU. Trends for individual river basins are summarized in Table 13 and Figure 20.

Hatchery fish are widespread and escaping to spawn naturally throughout the region. Most of the hatchery stocks used originated primarily from stocks within the ESU, but many are not native to local river basins. WDFW has provided information supporting substantial temporal separation between hatchery and natural winter steelhead in this region; however, some Washington stocks (notably Kalama River winter and summer steelhead—Appendix E) appear to have substantial hatchery contribution to wild spawning, and Nehlsen et al. (1991) identified several stocks in this ESU as of special concern due to hatchery influence (Table 9). ODFW estimates of hatchery composition indicate a range from about 30% (Sandy River and Tanner Creek winter steelhead) to 80% (Hood River summer steelhead) hatchery fish in spawning escapements. Estimates for Hood River winter steelhead range from 0% (ODFW 1995b) to greater than 40% (ODFW 1995a). Given the relatively low natural run sizes to individual streams, the preponderance of negative trends in abundance, and the apparent substantial contribution of hatchery fish to production, the BRT had substantial concern that the majority of natural steelhead populations in this ESU (both winter and summer) may not be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed under Background above.

**5) Upper Willamette River**—The only previous assessment of risk to stocks within this ESU is that of Nehlsen et al. (1991), who identified one stock (Calapooia River) as of special concern (Table 9).

No estimates of historical (pre-1960s) abundance specific to this ESU are available. Total recent 5-year average run size for this ESU can be estimated from counts at Willamette Falls for the years 1989-93. Dam counts indicate that the late-run (native) winter steelhead average run size was approximately 4,200, while early-run winter and summer steelhead averaged 1,900 and 9,700, respectively (Table 14, Fig. 21, Appendix E). Only the late-run winter steelhead are included in this ESU; other runs are mentioned because of their possible ecological interactions with the native stock. Adequate angler catch data were available to derive approximate average winter steelhead escapement for three tributaries: Mollala River, 2,300 (predominantly non-native); North Fork Santiam River, 2,000; South Fork Santiam River, 550.

Substantial habitat blockages resulted from Detroit, Big Cliff and Green Peter Dams on the Santiam River, and flood control dams on the mainstem Willamette. Other blockages such as smaller dams or impassable culverts are likely throughout the region. Habitat problems for most stocks in this ESU are similar to those in adjacent coastal ESUs. Clearcut logging has been common throughout most watersheds in this area, and there is extensive urbanization in the Willamette Valley. Bottom et al. (1985) identified specific factors affecting salmon habitat in various areas of Oregon, including streamflow and temperature problems, riparian habitat losses, and instream habitat problems. Within the Willamette Valley, they noted that temperatures and streamflows reach critical levels for salmonids in places where there are significant water withdrawals or removal of streamside vegetation, that loss of riparian vegetation results from agricultural practices and rural and urban development, that bank erosion is severe in several areas of the basin, and that splash dams, debris removal and stream channelization have caused long-term damage to salmonid habitats.

Total basin run size or escapement estimates exhibit declines for both total winter and late winter steelhead, while summer steelhead estimates exhibit an increase (Table 14, Fig. 22). However, all of these basinwide estimates have exhibited large fluctuations (Fig. 23). Of the three tributary winter steelhead stocks for which we had adequate adult escapement information to compute trends, two have been declining and one increasing over the available data series, with a range from 4.9% annual decline to 2.4% annual increase. None of these trends were significantly different from zero (Table 14, Appendix E). Note that two of these trends, those from the North and South Forks of the Santiam River, are based on angler catch, and so may not reflect trends in underlying population abundance—see discussion for the Oregon Coast ESU.

Hatchery fish are widespread throughout the region. Both summer steelhead and early-run winter steelhead have been introduced to the basin and escape to spawn naturally in substantial numbers. Indigenous late-run winter steelhead are also produced in the Santiam River Basin. Estimates of hatchery composition for winter steelhead escapements are available only for the North Fork Santiam River and the Mollala River. These estimates are variable, ranging from 14% (ODFW 1995b) to 54% (ODFW 1995a) on the North Fork Santiam River alone. There is probably some temporal and spatial separation in spawning between the early and late winter stocks. While we have little information on the actual contribution of hatchery fish to natural production, given the generally low numbers of fish escaping to tributaries and the general declines in winter steelhead abundance in the basin,

Table 14. Summary of estimated total run size and trends in total escapement for the Upper Willamette River steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Willamette River | W - Early | 1,900 | | | -4.5 | |
| | W - Late | 4,200 | | | -3.5 | |
| | S | 9,700 | | | +13.5 | |

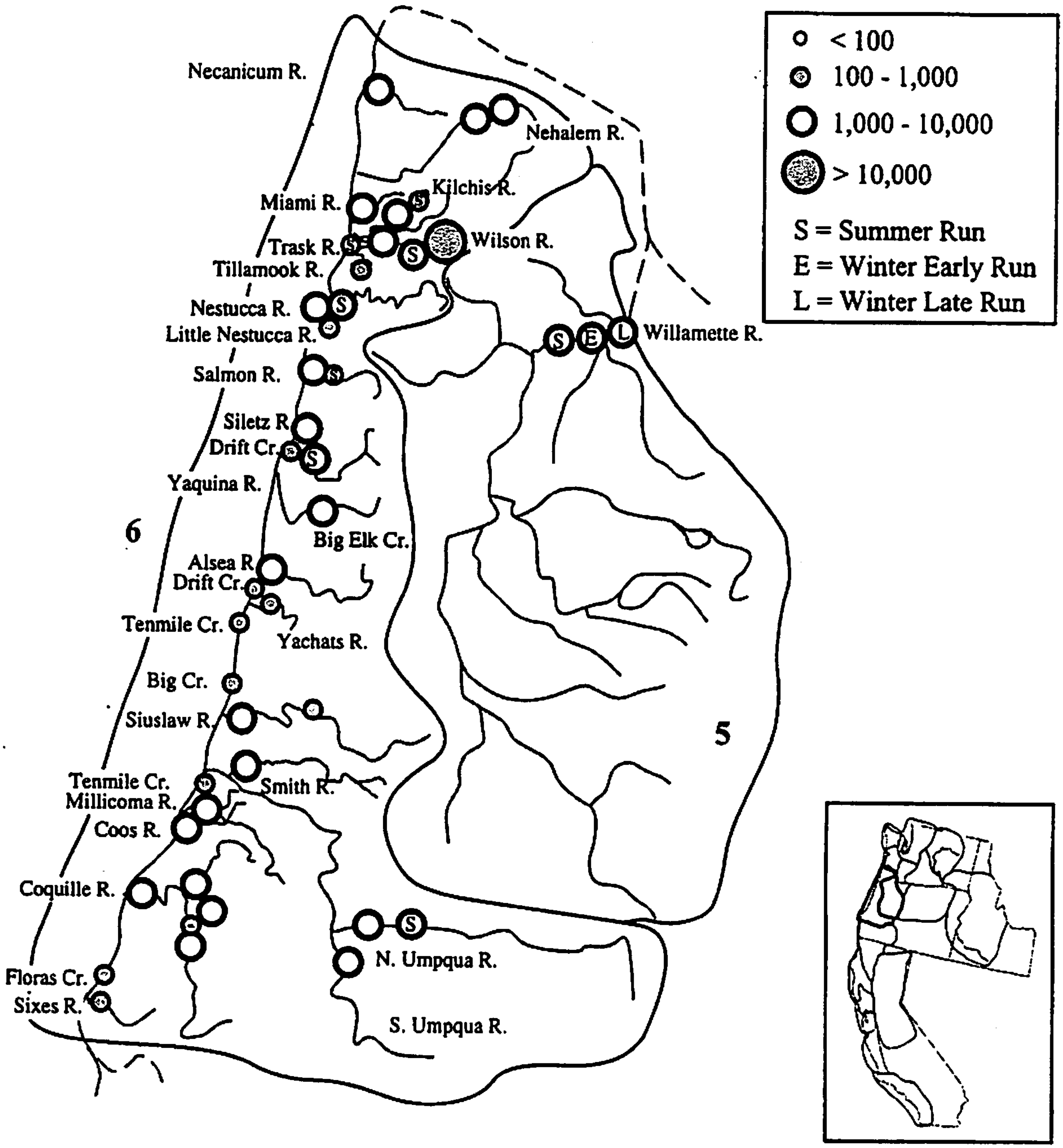


Figure 21. Recent total escapement, or run size, for populations in steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details).

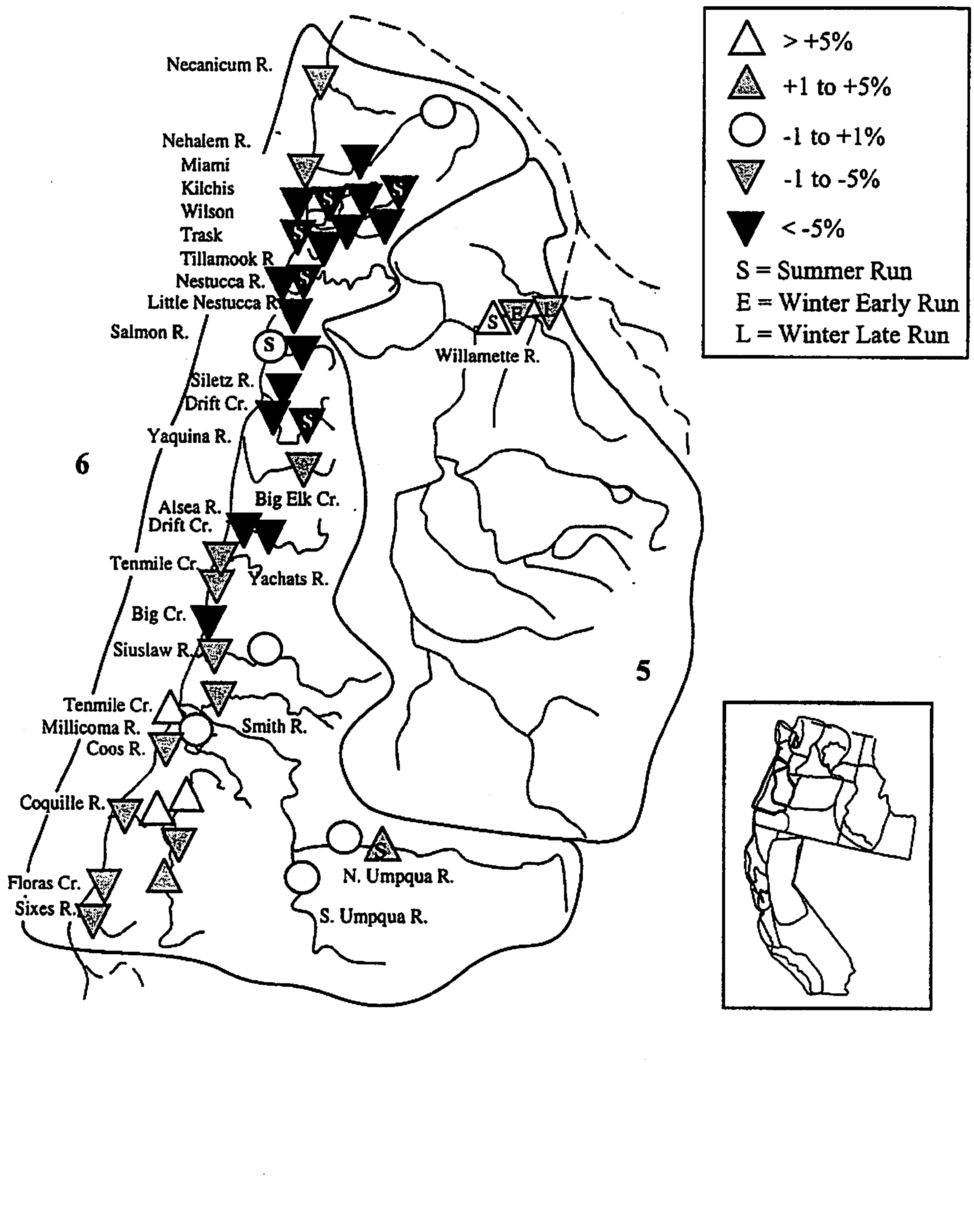


Figure 22. Trends (percent annual change) in total escapement for populations in steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast. All data are for winter steelhead, except as noted (see Appendix E for details).

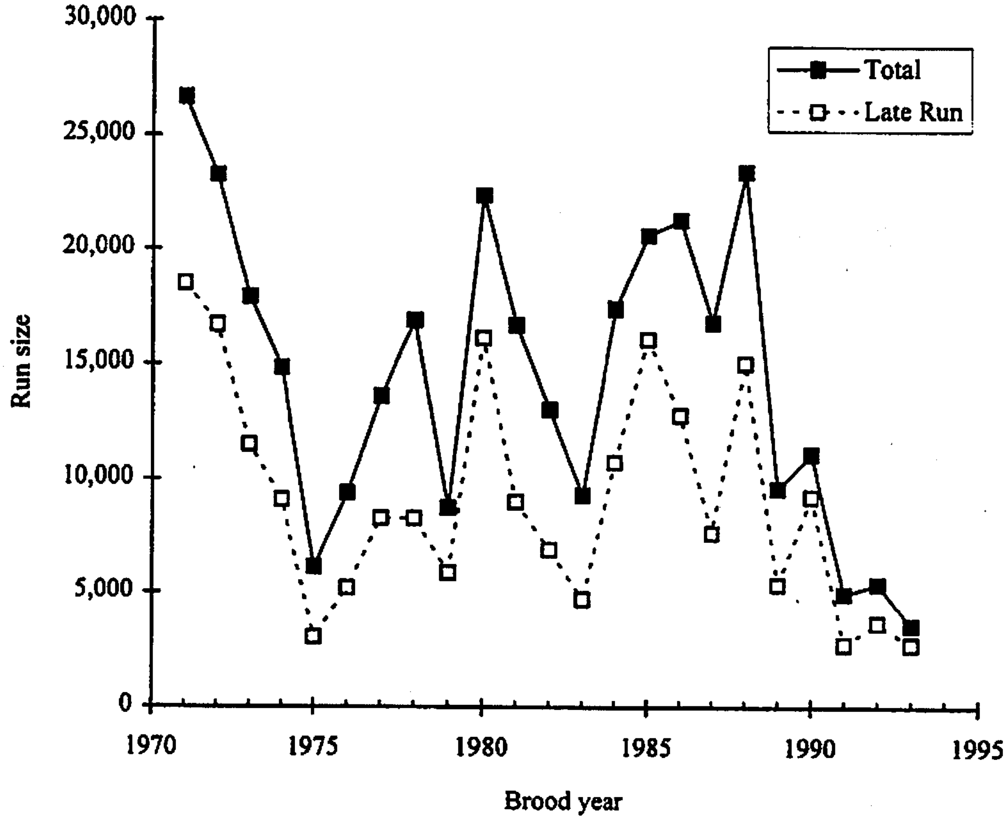


Figure 23. Estimated adult winter steelhead passing Willamette Falls, 1971-93. Data from PSMFC (1994).

the BRT had substantial concern that the majority of natural winter steelhead populations in this ESU may not be self-sustaining. All summer steelhead within the range of this ESU are introduced from outside the area, so are not considered as contributing to natural production of the ESU. Natural reproduction by these introduced summer steelhead may be quite limited.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. While there is some separation in run timing between hatchery and wild winter steelhead, there appears to be sufficient overlap in spawn timing for some genetic introgression from nonlocal hatchery stocks to occur. An additional effect of hatchery production may be directional selection within the natural stocks resulting both from competition with hatchery fish (both winter and summer) and selective fishing pressure that eliminates individuals with early run timing from the natural stocks. Other risk factors relating to hatchery practices were discussed previously in the Background section.

**6) Oregon Coast**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 12 stocks as extinct, at risk, or of special concern (Table 9). Most of the stocks of special concern were classified as such due to hatchery practices. ODFW (Nickelson et al. 1992) considered 21 stocks within the ESU, of which 3, North Umpqua River summer and winter steelhead and Coquille River winter steelhead, were identified as healthy, 17 as depressed, and 1 (Necanicum River) of special concern.

No estimates of historical (pre-1960s) abundance specific to this ESU are available, except for counts at Winchester Dam on the North Umpqua River which began in 1946, and angler catch records which began in 1953. Early angler catch summaries did not distinguish summer and winter steelhead and were not corrected for nonreporting bias, so these have not been relied on in this review. Estimated total run size for the major stocks on the Oregon Coast (including areas south of Cape Blanco) for the early 1980s were given by Light (1987) as approximately 255,000 winter steelhead and 75,000 summer steelhead. Light estimated that 69% of winter and 61% of summer steelhead were of hatchery origin, resulting in naturally produced run sizes of 79,000 winter and 29,000 summer steelhead.

Recent 5-year average total (natural and hatchery) run sizes for streams with adequate data range from 250 to 15,000, corresponding to escapements from 200 to 12,000 (Table 15, Appendix E). Total recent (5-year average) run size for major streams in this ESU was approximately 129,000 (111,000 winter, 18,000 summer), with a total escapement of 96,000 (82,000 winter, 14,000 summer). These totals do not include all streams in the ESU, so they underestimate total ESU run size and escapements. The geographic distribution of escapement is illustrated in Figure 21. Run size and escapement estimates are also based primarily on expansions of angler catch using assumed harvest rates (Kenaston 1989), so they should be viewed as rough approximations.

Regarding freshwater habitat, several minor blockages from dams are documented, and other blockages such as impassable culverts are likely throughout the region. Bottom et al. (1985) identified specific factors affecting salmon habitat in various areas of Oregon,

Table 15. Summary of estimated total run size and escapement, trends in total escapement, and proportion of hatchery fish in escapement for the Oregon Coast steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W) or summer (S).

| River basin | Run type | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Necanicum River | W | 3,600 | 2,100 | | -2.4 | 63 |
| Nehalem River | W | 2,500 - 4,000 | 1,500 - 2,400 | | -6.0 to -0.5 | 24 - 37 |
| Miami River | W | 1,400 | 1,100 | | -6.4 | 48 |
| Kilchis River | W | 2,300 | 1,800 | | -7.6 | 66 |
| | S | 300 | 200 | | -5.8 | |
| Wilson River | W | 14,900 | 12,000 | | -6.7 | 51 |
| | S | 2,900 | 2,100 | | -5.4 | |
| Trask River | W | 3,600 | 2,500 | | -8.2 | 32 - 55 |
| | S | 900 | 700 | | -6.7 | |
| Tillamook River | W | 900 | 700 | | -7.7 | 69 |
| Nestucca River | W | 7,400 | 4,400 | | -8.9 | 34 |
| | S | 6,400 | 4,600 | | -5.6 | |
| Little Nestucca River | W | 1,200 | 1,000 | | -11.8 | 79 |
| Salmon River | W | 4,400 | 3,500 | | -7.7 | 70 |
| | S | 500 | 350 | | -0.1 | |
| Siletz River | W | 1,100 - 6,700 | 900 - 4,500 | | -12.4 to -7.6 | 57 - 58 |
| | S | 4,400 | 3,200 | | -10.9 | 90 |
| Yaquina River (Big Elk Cr.) | W | 1,800 | 1,400 | | -2.9 | |
| Alsea River | W | 700 - 6,500 | 600 - 4,000 | | -7.2 to -6.5 | 50 - 91 |
| Yachats River | W | 250 | 200 | | -4.1 | > 10 |
| Tenmile Creek | W | 300 | 250 | | -3.6 | 27 |
| Big Creek | W | 300 | 200 | | -7.0 | > 10 |
| Siuslaw River | W | 700 - 4,600 | 600 - 2,700 | | -4.9 to +0.3 | 49 |
| Smith River | W | 3,700 | 3,000 | | -1.7 | 48 |
| North Umpqua River | W | | 5,600 | | -0.5 | 10 |
| | S | | 2,700 | | +1.0 | 62 |
| South Umpqua River | W | 4,300 | 3,500 | | -0.8 | 43 - 81 |
| Tenmile Creek | W | 800 | 400 | | +5.4 | 80 |
| Coos River | W | 3800 - 6100 | 3100 - 5600 | | -2.5 to -0.5 | 65 - 70 |
| Coquille River | W | 600 - 5,000 | 500 - 3200 | | -3.0 to +16.0 | 55 - 75 |
| Floras Creek | W | 900 | 700 | | -1.4 | 32 |
| Sixes River | W | 1,000 | 800 | | -4.6 | 36 |

including streamflow and temperature problems, riparian habitat losses, and instream habitat problems. They noted that along the Oregon Coast summer temperatures and streamflow reach critical levels for salmonids in areas where there are significant water withdrawals or removal of streamside vegetation had occurred. They reported notable temperature problems in Tillamook Bay tributaries and the Alsea, Siletz, Siuslaw, and Umpqua Rivers. Bottom et al. (1995) also found that loss of riparian vegetation has resulted from agricultural and forestry practices, and that splash dams, debris removal, and stream channelization had caused long-term damage to salmonid habitats.

Sport harvest information was the main abundance data available for most Oregon coastal populations. In 1952, Oregon instituted a punchcard system to record all salmon and steelhead caught by species. However, methods of estimating and reporting catch changed in 1970, and division of catch statistics among tributaries changed substantially in 1977, so earlier data are not directly comparable to those since 1977. Our analyses for Oregon river basins focussed on data collected since those changes (ODFW 1980, 1992, 1993), although trends from longer-term data have been included for comparison in some basins (Appendix E).

Interpreting population abundance from angler catch data presents several problems. First, numbers of fish caught do not directly represent abundance, which must be estimated by applying assumptions about fishing effort and effectiveness. Fishing effort is largely determined by socioeconomic factors, including fishery regulations. Fishing effectiveness is a function of both the skill of the anglers and environmental conditions which affect behavior of both fish and anglers. Both effort and effectiveness may exhibit long-term trends and interannual fluctuations that can obscure the relationship between catch and abundance.

Second, estimates of catch may not be accurate. In Oregon, catch is estimated from returns of punchcards and estimates are corrected for nonreporting bias. While catch estimates are generated separately for each stream basin, the bias correction is calculated statewide and may not be accurate for any particular stream due to local variations in the tendency to return punchcards.

Third, when fishing effort varies across a river basin, catch may reflect only local abundance rather than the total basin population. However, statewide salmon and steelhead fishing effort, as indexed by number of punchcards issued, has been relatively constant since the late 1970s, indicating that angler catch may accurately reflect trends in abundance over large geographic areas. ODFW (1995b) provided evidence that the relationship of angler catch to spawner abundance is weak in some basins, although there is generally a positive correlation. Additionally, fishing effort has been increasingly focused on hatchery fish in recent years, with wild catch and release regulations imposed in many Oregon coastal streams in January 1992 (ODFW 1995b). Thus, recent trends may reflect hatchery production more than natural production throughout the Oregon coast. Trend estimates reported here include angler catch data through 1992 (Table 15, Appendix E). To test for bias due to wild catch and release regulations, we also calculated trends excluding the 1991 and 1992 run years. While the resulting estimates were often different for individual basins, both upward and downward changes were apparent, and overall patterns were similar to those obtained by using the full data set.

The following analysis was made with the assumption that catch trends reflect trends in overall population abundance. We recognize the many problems with this assumption and that the results may not precisely represent trends in the total population in a river basin. However, angler catch is the only information available for most of these populations, and we believe that changes in catch still provide a useful indication of trends in total population abundance. Where alternate trend data were available, we used those data instead of angler catch.

Adequate adult escapement information was available to compute trends for 42 independent stocks within this ESU. Of these, 36 stocks exhibited declines and 6 exhibited increases during the available data series. Trends ranged from a 12% annual decline in Drift Creek on the Siletz River to a 16% annual increase in North Fork Coquille River. Twenty of these trends were significantly different from zero with 18 decreasing and 2 increasing (Appendix E). Upward trends were found only in the southernmost portion of the ESU (Fig. 22), from Siuslaw Bay south. In contrast, longer term trends in angler catch, using data from the early 1950s to the present, generally were increasing. This may reflect longer term stability of populations, or may be an artifact of long-term increases in statewide fishing effort coupled with the differences in bias correction of catch summaries before and after 1970.

Hatchery fish are widespread and escape to spawn naturally throughout the region. Most hatchery stocks used in this region originated from stocks indigenous to the ESU, but many are not native to local river basins. ODFW estimates of hatchery composition for recent winter steelhead escapements were high in many streams, ranging from 10% in the North Umpqua River to greater than 80% in Drift Creek on the Alsea River and in Tenmile Creek south of Umpqua Bay. For summer steelhead, hatchery composition (where reported) ranged from 38% in the South Umpqua River to 90% in the Siletz River. Several summer steelhead stocks have been introduced to rivers with no native summer runs.

Overall, approximately half of the stocks in this ESU for which we have information have hatchery composition in excess of 50%. Few stocks in the region are documented to have escapements above 1,000 fish and no significant decline (Appendix E); most of those that do are in the southern portion of the ESU and have high hatchery influence. While we have little information on the actual contribution of hatchery fish to natural production, given the substantial presence of hatchery fish in the few stocks that are relatively abundant and stable or increasing, the BRT had substantial concern that the majority of natural steelhead populations in this ESU may not be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section.

**7) Klamath Mountains Province**—This ESU has been evaluated previously (Busby et al. 1994), and is not discussed here.

**8) Northern California**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified three stocks as at risk of extinction: summer steelhead in Redwood Creek, Mad River, and Eel River (Table 9). Higgins et al. (1992) provided a more detailed analysis of some of these stocks and identified 11 summer steelhead stocks as at risk or of concern. They did not evaluate winter steelhead stocks because of insufficient information. The USFS (1993b) identified most stocks on Forest Service lands in this region as either depressed or critical, with only the Little Van Duzen River winter steelhead stock identified as stable (Appendix E).

Estimates of historical (pre-1960s) abundance specific to this ESU were available (Table 16) from dam counts in the upper Eel River (Cape Horn Dam—annual average of 4,400 adult steelhead in the 1930s; McEwan and Jackson 1996), the South Fork Eel River (Benbow Dam—annual average of 19,000 adult steelhead in the 1940s; McEwan and Jackson 1996), and the Mad River (Sweasey Dam—annual average of 3,800 adult steelhead in the 1940s; Murphy and Shapovalov 1951, CDFG 1994). In the mid-1960s, CDFG (1965, table S-3) estimates steelhead spawning populations for many rivers in this ESU totaled 198,000 (Table 17). Estimated total run size for the major stocks in California (entire state) for the early 1980s was given by Light (1987) as approximately 275,000. Of these, 22% were of hatchery origin, resulting in a naturally produced run size of 215,000 steelhead. Roughly half of this production was thought to be in the Klamath River Basin (including the Trinity River), so the total natural production for all ESUs south of Punta Gorda was probably on the order of 100,000 adults. The only current run-size estimates for this area are counts at Cape Horn Dam on the Eel River where an average of 115 total and 30 wild adults were reported (McEwan and Jackson 1996). Summer steelhead snorkel survey data are available for a few tributaries, but they provide no total abundance estimate. Statewide adult summer steelhead abundance is estimated at about 2,000 adults (McEwan and Jackson 1996). Note that estimate apparently refers only to early-summer steelhead entering the rivers in May, June, and July, not including the more numerous "fall-run" steelhead. While we have no overall recent abundance estimate for this ESU (Table 18, Fig. 24), the substantial declines in run size from historic levels at major dams in the region (Table 16) indicate a probable overall decline in abundance from historical levels.

Two substantial habitat blockages are documented: Mathews Dam on the Mad River and Scott Dam on the Eel River (McEwan and Jackson 1996), and other minor blockages (such as impassable culverts) are likely throughout the region. Habitat throughout the north coast of California was severely impacted by catastrophic flooding in 1964. Damage from this flood was probably exacerbated by poor land use practices prior to the event (McEwan and Jackson 1996). Forest practices have also contributed to incremental degradation of stream habitats (Higgins et al. 1992, McEwan and Jackson 1996). Excessive sedimentation and unstable spawning gravels are cited as major habitat problems in this region (CDFG 1991, Higgins et al. 1992). Other habitat problems similar to those cited for the Oregon Coast ESU probably also occur in this region. A high abundance of non-native Sacramento squawfish (*Ptychocheilus grandis*) has been reported recently in the Eel River Basin (Brown

Table 16. Summary of historical abundance estimates for the Northern California evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Eel River | | | |
| Cape Horn Dam | 4,400 | 1930s | McEwan and Jackson 1996 |
| | 1,000 | 1980s | McEwan and Jackson 1996 |
| Benbow Dam | 18,784 | 1940s | Shapovalov and Taft 1954 |
| | 3,355 | 1970s | McEwan and Jackson 1996 |
| Mad River | | | |
| Sweasy Dam | 3,800 | 1940s | Murphy and Shapovalov 1951 |
| | 2,000 | 1960s | McEwan and Jackson 1996 |
| Casper Creek | 114 | 1964 | Graves and Burns 1970 |
| | 102 | 1968 | Graves and Burns 1970 |

Table 17. Estimated steelhead spawning populations for California rivers in the mid-1960s (CDFG 1965, Table S-3), with comparable recent maximum estimates (from Appendix B).

| ESU* | River system | 1960s | Recent |
|---|---|---|---|
| Northern California | | | |
| | Redwood Creek | 10,000 | |
| | Mad River | 6,000 | |
| | Eel River System (Total) | 82,000 | |
| | Mattole River | 12,000 | |
| | Ten Mile River | 9,000 | |
| | Noyo River | 8,000 | |
| | Big River | 12,000 | |
| | Navarro River | 16,000 | |
| | Garcia River | 4,000 | |
| | Gualala River | 16,000 | |
| | Other streams (Humboldt, Mendocino Counties) | 23,000 | |
| | **Total** | **198,000** | |
| Central California Coast | | | |
| | Russian River | 50,000 | 7,000 |
| | San Lorenzo River | 19,000 | 150 |
| | Other streams (Sonoma County to Santa Cruz County) | 25,000 | |
| | **Total** | **94,000** | |
| South-Central California Coast | | | |
| | Pajaro River | 2,000 | 100 |
| | Salinas River | 500 | 100 |
| | Carmel River | 1,500 | 100 |
| | Little Sur River | 500 | 100 |
| | Big Sur River | 250 | 100 |
| | Other streams (Monterey, San Luis Obispo Counties) | 23,000 | |
| | **Total** | **27,750** | |
| Central Valley | | | |
| | Sacramento River System | 26,250 | |
| | Mokelumne River System | 500 | |
| | San Joaquin River System | 0 | |
| | **Total** | **26,750** | |

*ESU = evolutionarily significant unit.

Table 18. Summary of estimated trends in total escapement for the Northern California steelhead evolutionarily significant unit, by major river basin, as in Table 10. Run types are winter (W), summer (S), or combined (C).

| River basin | Run type | Total run size* | Total escapement* | Natural escapement* | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|---|
| Redwood Creek | S | | | | -3.0 | |
| Mad River | W | | | | -5.0 | |
| | S | | | | -1.1 | |
| Eel River | | | | | | |
| Mainstem | C | | | | -5.8 | |
| Middle Fork | S | | | | +1.8 | |
| South Fork | C | | | | -4.8 | |
| Van Duzen River, South Fork | S | | | | +3.5 | |

*None of the available abundance data are adequate to provide total escapement estimates for river basins occupied by the Northern California evolutionarily significant unit.

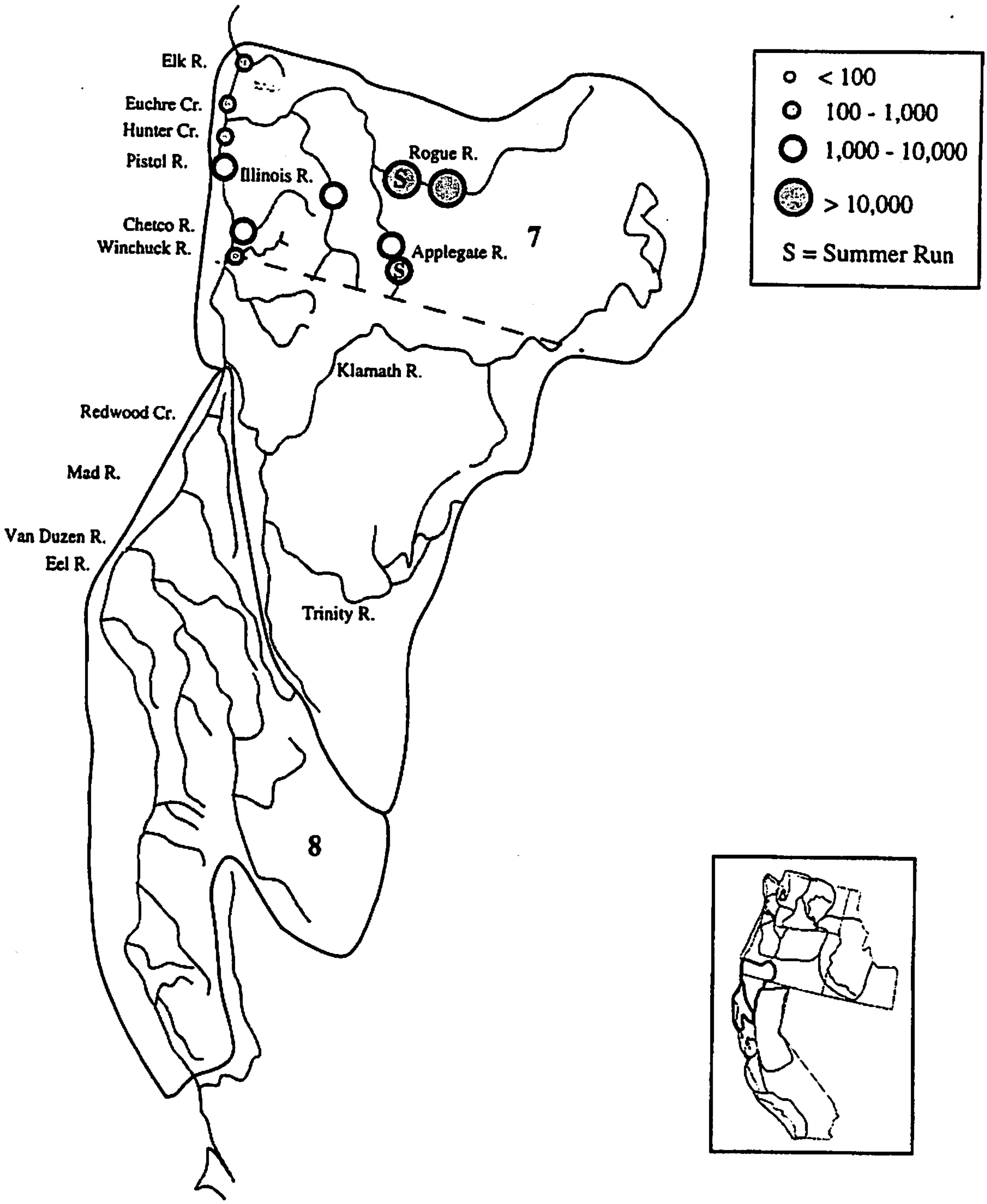


Figure 24. Recent total escapement for populations in steelhead ESU 7-Klamath Mountains Province. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details). Available abundance data for steelhead populations in ESU 8-Northern California are not adequate to provide total escapement estimates for rivers in that area.

and Moyle 1991, Moyle and Yoshiyama 1992), which would suggest increased risk of predation for juvenile steelhead.

Adequate adult escapement information was available to compute trends for seven stocks within this ESU (Table 18, Fig. 25). Of these, five data series exhibit declines and two exhibit increases during the available data series, with a range from 5.8% annual decline to 3.5% annual increase. Three of the declining trends were significantly different from zero (Appendix E). For one long data set (Eel River, Cape Horn Dam counts), a separate trend for the last 21 years (1971-91) was calculated for comparison: while the full-series trend showed significant decline, the recent data showed a lesser, nonsignificant decline, suggesting that the major stock decline occurred prior to 1970.

Hatchery fish are widespread and escaping to spawn naturally throughout the region. According to McEwan and Jackson (1996, p. 37), "despite the large number of hatchery smolts released, steelhead runs in north coast drainages are comprised mostly of naturally produced fish." We have little information on the actual contribution of hatchery fish to natural spawning, and little information on present total run sizes for this ESU. However, given the preponderance of significant negative trends in the available data, there is concern that steelhead populations in this ESU may not be self-sustaining.

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. Risk factors relating to hatchery practices were discussed previously in the Background section. Within this ESU, we have no information regarding spatial or temporal separation of spawning hatchery and natural fish, but there is probably sufficient overlap for some genetic introgression to occur.

**9) Central California Coast**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified two stock groups as at high risk of extinction: Napa River and San Francisco Bay Tributaries (Table 9). Titus et al. (in press) provided a more detailed analysis of stocks south of San Francisco Bay and identified numerous stocks that were declining.

Only two estimates of historical (pre-1960s) abundance specific to this ESU are available: the first reported an average of about 500 adults in Waddell Creek in the 1930s and early 1940s (Shapovalov and Taft 1954), and the second estimated 20,000 steelhead in the San Lorenzo River before 1965 (Johnson 1964) (Table 19). In the mid-1960s, CDFG (1965, table S-3) estimated 94,000 steelhead spawning in many rivers of this ESU (Table 17). We have comparable recent estimates for only the Russian and San Lorenzo Rivers, which contain the two largest stocks in the ESU. Recent total abundance in these two rivers is estimated to be less than 15% of their abundance 30 years ago (Table 17). Additional recent estimates are available for several other streams (Table 20, Fig. 26), but we have no recent estimates for total run size for this ESU.

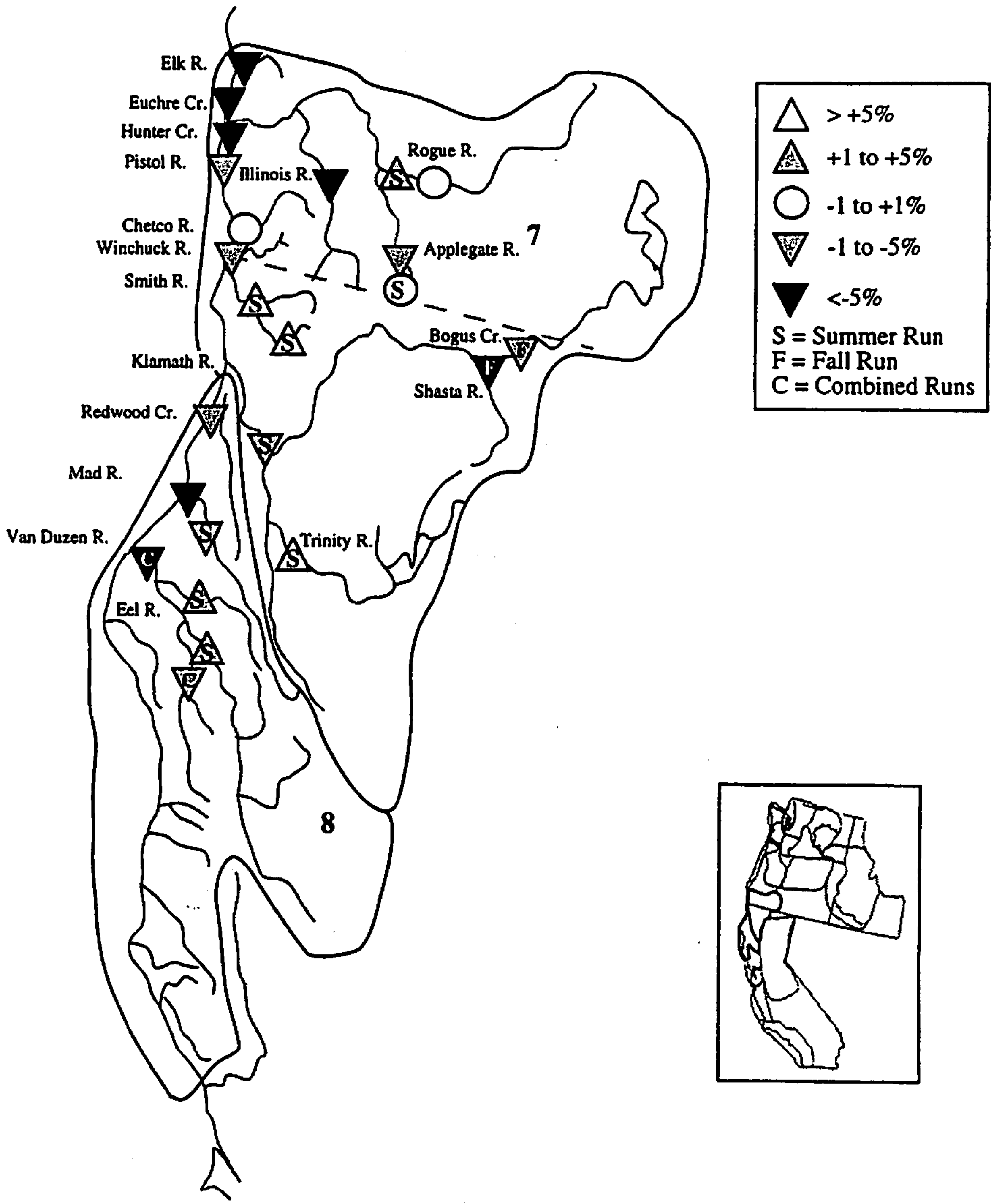


Figure 25. Trends (percent annual change) in total escapement for populations in steelhead ESUs 7-Klamath Mountains Province and 8-Northern California. All data are for winter steelhead, except as noted (see Appendix E for details).

Table 19. Summary of recent and historical abundance estimates for the Central California Coast evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Russian River | 65,000 | 1970 | CACSS 1988 |
| | 1,750 - 7,000 | 1994 | McEwan and Jackson 1996 |
| Laugunitas Creek | 400 - 500 | 1990s | McEwan and Jackson 1996 |
| San Gregorio | 1,000 | 1973 | Coots 1973 |
| Waddell Creek | 481 | 1933 - 1942 | Shapovalov and Taft 1954 |
| | 250 | 1982 | Shuman 1994 |
| | 150 | 1994 | Shuman 1994 |
| Scott Creek | 400 | 1991 | Nelson 1994 |
| | <100 | 1991 | Reavis 1991 |
| | 300 | 1994 | Titus et al. in press |
| San Vicente Creek | 150 | 1982 | Shuman 1994 |
| | 50 | 1994 | Shuman 1994 |
| San Lorenzo River | 20,000 | before 1965 | Johnson 1964, SWRCB 1982 |
| | 1,614 | 1977 | CDFG 1982 |
| | >3,000 | 1978 | Ricker and Butler 1979 |
| | 600 | 1979 | CDFG 1982 |
| | 3,000 | 1982 | Shuman 1994 |
| | few | 1991 | Reavis 1991 |
| | <150 | 1994 | Shuman 1994 |
| Soquel Creek | 500 - 800 | 1982 | Shuman 1994 |
| | <100 | 1991 | Reavis 1991 |
| | 50 - 100 | 1994 | Shuman 1994 |
| Aptos Creek | 200 | 1982 | Shuman 1994 |
| | <100 | 1991 | Reavis 1991 |
| | 50 - 75 | 1994 | Shuman 1994 |

Table 20. Summary of estimated total run size for the Central California Coast steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Russian River | 1750 - 7000 | | | | |
| Lagunitas Creek | 500 | | | | |
| Waddell Creek | 150 | | | | |
| Scott Creek | <300 | | | | |
| San Vicente Creek | 50 | | | | |
| San Lorenzo River | <150 | | | | |
| Soquel Creek | <100 | | | | |
| Aptos Creek | <100 | | | | |

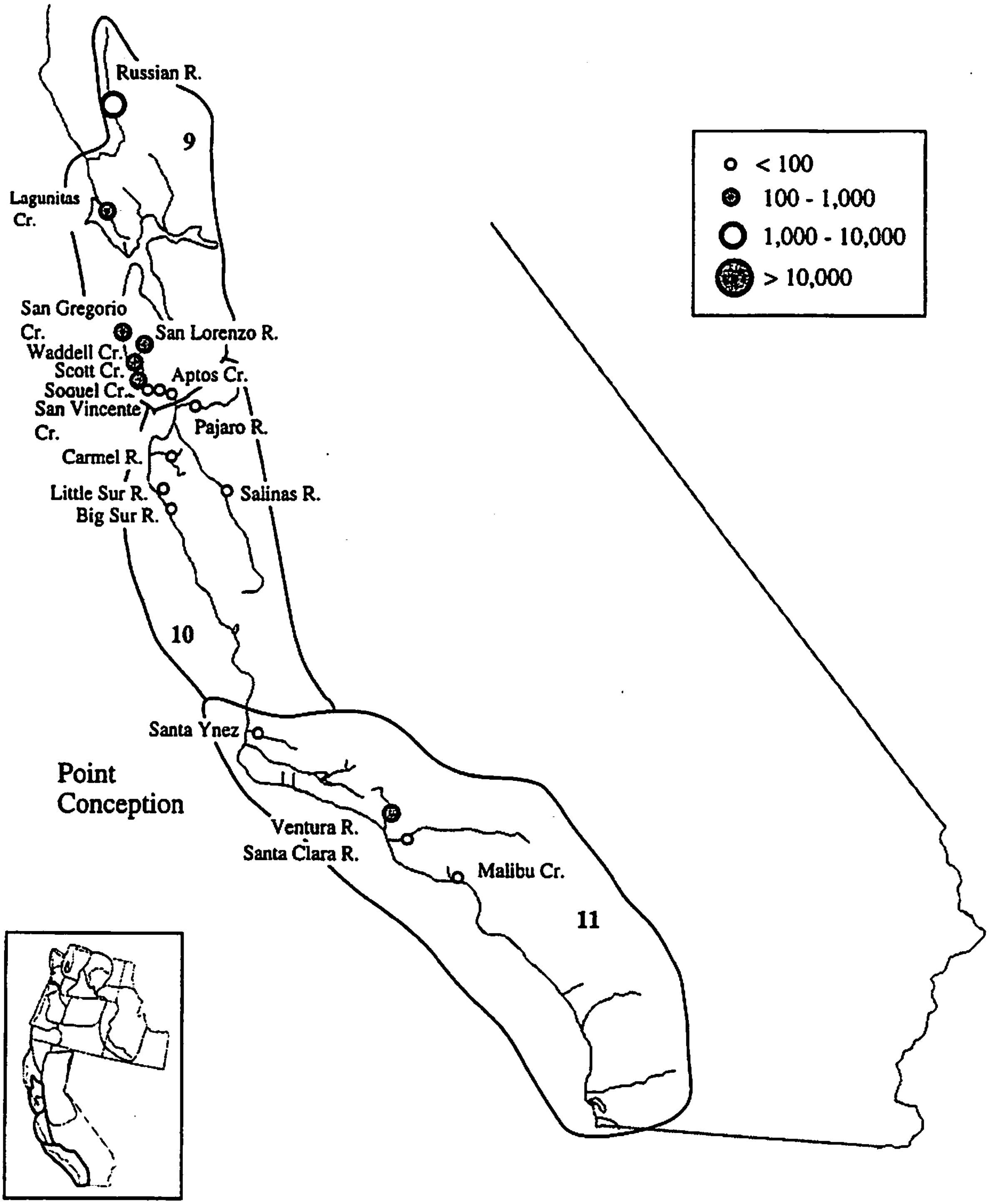


Figure 26. Recent total escapement for populations in steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California. Where no total estimate is available, natural escapement is used. All data are for winter steelhead (see Appendix E for details).

McEwan and Jackson (1996) noted that steelhead in most streams tributary to San Francisco and San Pablo Bays have been extirpated, although small "fair to good" runs of steelhead reportedly occur in coastal Marin County tributaries (Cox[18], Smith[19]).

Two substantial habitat blockages are documented: Coyote and Warm Springs Dams in the Russian River Basin (McEwan and Jackson 1996), and other minor blockages (smaller dams, impassable culverts, etc.) are likely throughout the region Titus et al. (in press) reported blockages on 12 of 46 tributaries in the southern portion of this ESU, and he noted fish passage problems in most other tributaries. Streams in this region probably suffer from a variety of habitat factors, including urbanization and poor land management practices in both forestry and agriculture.

Habitat throughout the north coast of California, including portions occupied by this ESU, was severely impacted by catastrophic flooding in 1964. Damage from this flood was probably exacerbated by poor land use practices prior to the event (McEwan and Jackson 1996). Forest practices have also contributed to incremental degradation of stream habitats (McEwan and Jackson 1996). Dewatering due to irrigation and urban water diversions is also a problem. Titus et al. (in press) documented some of these problems for specific tributaries in the southern portion of this ESU. Other habitat problems similar to those cited for the Oregon Coast ESU probably also occur in this region.

Adequate adult escapement information was not available to compute trends for any stocks within this ESU (Table 20, Fig. 27). However, general trends can be inferred from the comparison of 1960s and 1990s abundance estimates provided above, and these indicate substantial rates of decline in the two largest steelhead stocks (Russian and San Lorenzo Rivers).

Presently, the principal hatchery production in this ESU is from Warm Springs Hatchery on the Russian River and the Monterey Bay Salmon and Trout Project located at Big Creek Hatchery off Scott Creek and at other facilities. There are other small private and cooperative programs producing steelhead within the range of this ESU. Most of the hatchery stocks used in this region originated from stocks indigenous to the ESU, but many are not native to their local river basins (Bryant 1994).

We have little information on the actual contribution of hatchery fish to natural spawning, and little information on present total run sizes or trends for this ESU. However, given the substantial negative trends in the stocks for which we do have data, it is likely that the majority of natural production in this ESU is not self-sustaining. It appears that most of the recent declines in steelhead abundance within this ESU have occurred in the larger river

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[18] B. Cox, California Department of Fish and Game, Region 3, P.O. Box 47, Yountville, CA 94599. Pers. commun., September 1994.

[19] J. Smith , Department of Biological Sciences, San Jose State University, San Jose, CA 95192. Pers. commun., September 1994.

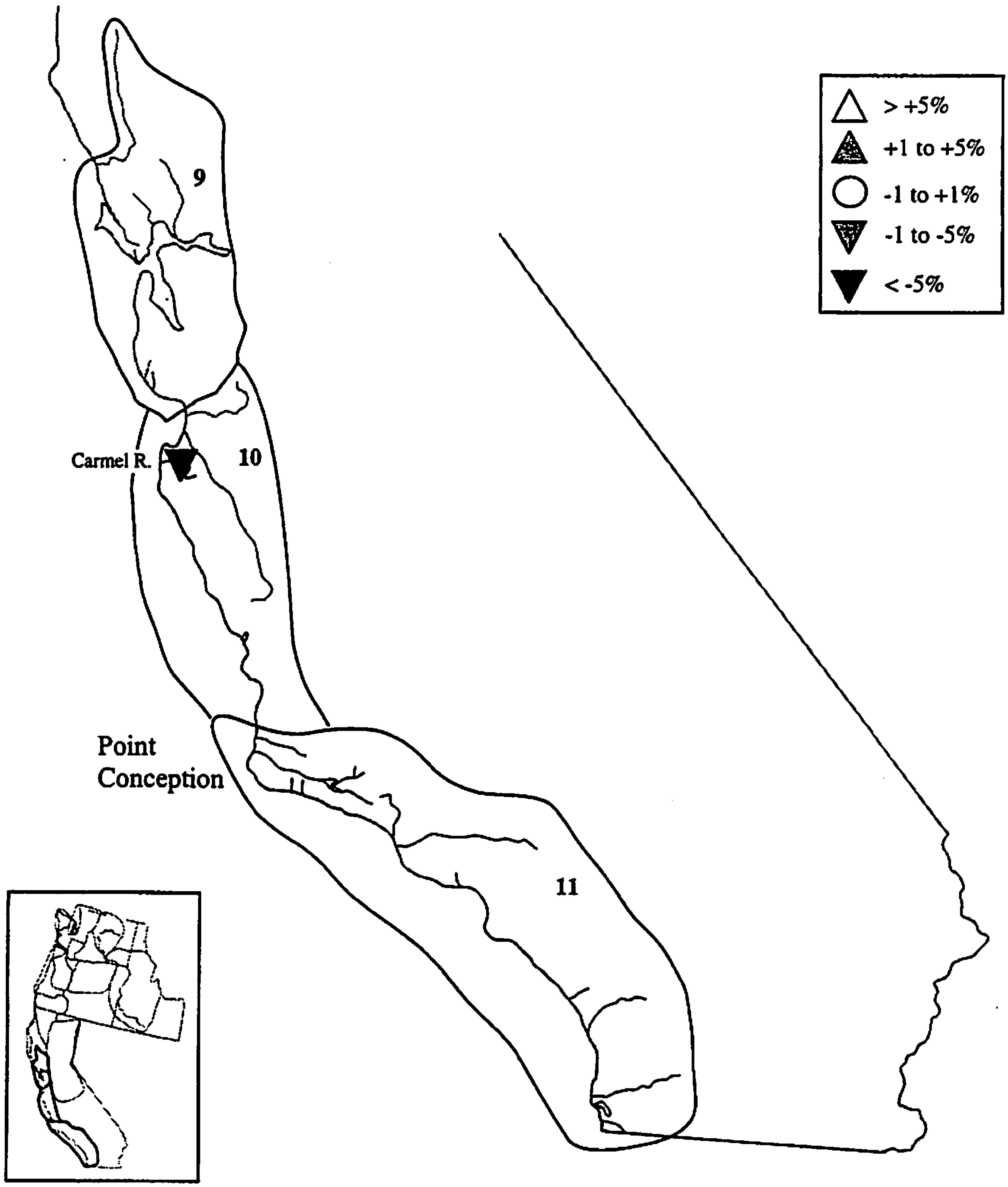


Figure 27. Trends (percent annual change) in total escapement for populations in steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California. All data are for winter steelhead (see Appendix E for details).

systems, while populations in many smaller streams are relatively healthy and probably have not experienced significant recent changes in abundance (Cox footnote 18, Smith footnote 19).

The major present threat to genetic integrity for steelhead in this ESU comes from past and present hatchery practices. General risk factors relating to hatchery practices were discussed previously in the Background section. Within this ESU, we have little information regarding present hatchery production and no information regarding spatial or temporal separation of spawning hatchery and natural fish. However, there is probably sufficient overlap in spawning for some genetic introgression to occur. Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have received insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**10) South-Central California Coast**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified five stocks as at risk (Table 9). Titus et al. (in press) provided a more detailed analysis of stocks south of San Francisco Bay and identified numerous stocks that were declining (Appendix E).

Historical estimates of steelhead abundance are available for a few streams in this region (Table 21). The California Advisory Committee on Salmon and Steelhead (CACSS 1988) cited an estimate of 20,000 steelhead in the Carmel River in 1928. In the mid-1960s, CDFG (1965, table S-3) estimated 27,750 steelhead spawning in many rivers of this ESU (Table 17). However, comparisons with recent estimates for these rivers show a substantial decline during the past 30 years. In contrast to the CDFG (1965) estimates, McEwan and Jackson (1996) reported runs ranging from 1,000 to 2,000 in the Pajaro River in the early 1960s, and Snider (1983) estimated escapement of about 3,200 steelhead for the Carmel River for the 1964-75 period.

While we have no recent estimates of total run size for this ESU, recent run-size estimates are available for five streams (Table 22, Fig. 26). The total of these estimates is less than 500, compared with a total of 4,750 for the same streams in 1965, which indicates a substantial decline for the entire ESU from 1965 levels.

Minor habitat blockages (smaller dams, impassable culverts, etc.) are likely throughout the region. Titus et al (in press) reported blockages on 28 of 66 tributaries in this ESU, and some passage impairments on most other tributaries. Streams in this region probably suffer from a variety of habitat factors similar to those affecting neighboring ESUs. Forest practices have contributed to incremental degradation of stream habitats (McEwan and Jackson 1996), and dewatering due to irrigation and urban water diversions is also a problem.

Table 21. Summary of recent and historical abundance estimates for the South-Central California Coast evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Pajaro River | 1,500 | 1964 | McEwan and Jackson 1996 |
| | 1,000 | 1965 | McEwan and Jackson 1996 |
| | 2,000 | 1966 | McEwan and Jackson 1996 |
| | <100 | 1991 | Nehlsen et al. 1991, Reavis 1991 |
| Salinas River | <100 | 1991 | Nehlsen et al. 1991 |
| Carmel River | 20,000 | 1928 | CACSS 1988 |
| | 3,177 | 1964 - 1975 | Snider 1983 |
| | 2,000 | 1988 | CACSS 1988 |
| | <4,000 | 1988 | Meyer Resources 1988 |
| | few 100s | 1991 | Nehlsen et al. 1991 |
| | few 100s | 1993 | Titus et al. in press |
| Little Sur River | <100 | 1991 | Reavis 1991 |
| Big Sur River | <100 | 1991 | Nehlsen et al. 1991 |
| | few 100s | 1991 | Reavis 1991 |

Table 22. Summary of estimated total run size and trends in total escapement for the South-Central California Coast steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend | Percent hatchery |
|---|---|---|---|---|---|
| Pajaro River | <100 | | | | |
| Salinas River | <100 | | | | |
| Carmel River | 16 | | | -21.9 | |
| Little Sur River | <100 | | | | |
| Big Sur River | <100 | | | | |

Titus et al. (in press) have documented some of these problems for specific tributaries in the southern portion of this ESU.

Adequate adult escapement information was available to compute a trend for only one stock within this ESU: Carmel River above San Clemente Dam (Table 22, Fig. 27). These data show a significant decline of 22% per year from 1963 to 1993, with a recent 5-year average count of only 16 adult steelhead at the dam. However, general trends for the region can be inferred by comparing the 1960s and 1990s abundance estimates provided above.

Presently, there is little hatchery production within this ESU. There are small private and cooperative programs producing steelhead within this ESU, as well as one captive broodstock program intended to conserve the Carmel River steelhead strain (McEwan and Jackson 1996). Most hatchery stocks used in this region originated from stocks indigenous to the ESU, but many are not native to their local river basins (Bryant 1994). We have little information on the actual contribution of hatchery fish to natural spawning, and little information on present total run sizes or trends for this ESU. However, given the substantial reductions from historical abundance and the recent negative trends in the stocks for which we do have data, it is likely that the majority of natural production in this ESU is not self-sustaining.

Past and present hatchery practices probably pose some risk to steelhead in this ESU as discussed previously in the Background section. Habitat fragmentation and population declines resulting in small, isolated populations also pose genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We have received insufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**11) Southern California**—Previous assessments within this ESU have identified several stocks as being at risk or of special concern. Nehlsen et al. (1991) identified 11 stocks as extinct and 4 as at high risk (Table 9). Titus et al. (in press) provided a more detailed analysis of these stocks and identified stocks within 14 drainages in this ESU as extinct, at risk, or of concern. They identified only two stocks, those in Arroyo Sequit and Topanga Creek, as showing no significant change in production from historical levels.

Historically, steelhead may have occurred naturally as far south as Baja California. Estimates of historical (pre-1960s) abundance are available for several rivers in this ESU (Table 23): Santa Ynez River, before 1950, 20,000-30,000; Ventura River, pre-1960, 4,000-6,000; Santa Clara River, pre-1960, 7,000-9,000; Malibu Creek, pre-1960, 1,000. In the mid-1960s, CDFG (1965, table S-3) estimated steelhead spawning populations for smaller tributaries in San Luis Obispo County as 20,000, but they provided no estimates for streams farther south.

Table 23. Summary of recent and historical abundance estimates for the Southern California steelhead evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Santa Ynez River | 20,000 - 30,000 | historic | Reavis 1991 |
| | 20,000 | historic | Titus et al. in press |
| | 12,995 - 25,032 | 1940s | Shapovalov and Taft 1954 |
| | 20,000 | 1952 | CDFG 1982 |
| | 100 | 1991 | Reavis 1991 |
| | <100 | 1991 | Nehlsen et al. 1991 |
| | <100 | 1994 | CCC 1994 |
| Gaviota Creek | 10s | 1991 | Reavis 1991 |
| Ventura River | 4,000 - 6,000 | historic | AFS 1991, Hunt et al. 1992, Henke 1994, Titus et al. in press |
| | 4,700 | late 1940s | CDFG 1982 |
| | <100 | 1980 | Moore 1980 |
| | 200 | 1991 | Higgins 1991 |
| | <25 | 1991 | McEwan and Jackson 1996 |
| | few 100s | 1991 | Reavis 1991 |
| | <100 | 1991 | Nehlsen et al. 1991 |
| | 200 | 1993 | Nash 1993 |
| | <200 | 1994 | CCC 1994 |
| Matilija Creek | 2,000 - 2,500 | historic | Clanton and Jarvis 1946 |
| Santa Clara River | 7,000 - 9,000 | historic | Moore 1980 |
| | 9,000 | historic | Moore 1980, Comstock 1992, Henke 1994 |
| | 6 | 1982 | Puckett and Villa 1985 |
| | <100 | 1994 | CCC 1994 |
| | <100 | 1991 | Nehlsen et al. 1991 |
| | few 100s | 1991 | Reavis 1991 |
| Malibu Creek | 1,000 | historic | Nehlsen et al. 1991 |
| | <100 | 1991 | Nehlsen et al. 1991, Reavis 1991 |
| | 60 | 1991 | AFS 1991 |
| | 60 | 1993 | Nash 1993 |

The present total run sizes for 6 streams in this ESU were summarized by Titus et al. (in press); all were less than 200 adults (Table 24, Fig. 26). Titus et al. (in press) concluded that populations have been extirpated from all streams south of Ventura County, with the exception of Malibu Creek in Los Angeles County. However, steelhead are still occasionally reported in streams where stocks were identified by these authors as extirpated.

Titus et al. (in press) cited extensive loss of steelhead habitat due to water development, including impassable dams and dewatering of portions of rivers. They also reported that of 32 tributaries in this region, 21 have blockages due to dams, and 29 have impaired mainstem passage. Habitat problems in this ESU relate primarily to water development resulting in inadequate flows, flow fluctuations, blockages, and entrainment into diversions (McEwan and Jackson 1996, Titus et al. in press). Other problems related to land use practices and urbanization also certainly contribute to stock conditions.

No time series of data are available within this ESU from which to estimate population trends, but Titus et al. (in press) summarized information for steelhead populations based on historical and recent survey information. Of the populations south of San Francisco Bay (including part of the Central California Coast ESU) for which past and recent information was available, they concluded that 20% had no discernible change, 45% had declined, and 35% were extinct. Percentages for the counties comprising this ESU are given in Table 25 and show a very high percentage of declining and extinct populations.

There is no current hatchery production of steelhead within this ESU. The small run sizes and almost universal declines in these populations strongly suggest that natural production is not self-sustaining.

The influence of hatchery practices on this ESU is not well documented. Common risk factors relating to hatchery practices were discussed previously in the Background section. In some populations, there may be genetic introgression from past steelhead plants and from planting of rainbow trout (Nielsen footnote 9). Habitat fragmentation and population declines have also resulted in small, isolated populations that may face genetic risk from inbreeding, loss of rare alleles, and genetic drift.

In evaluating the status of this ESU, we have not accounted for abundance or trends in populations of resident *O. mykiss* (rainbow trout), which may be a significant part of the ESU. We do not have sufficient information regarding resident trout in this region to reasonably evaluate their status or their interactions with anadromous steelhead.

**12) Central Valley**—Only Nehlsen et al. (1991) have provided a status assessment for stocks within this ESU; they identified one stock (Sacramento River) as at high risk (Table 9). However, this stock represents all the known populations of steelhead within the ESU.

Historical abundance estimates are available for some stocks within this ESU (Table 26), but no overall estimates are available prior to 1961, when Hallock et al. (1961) estimated a total run size of 40,000 steelhead in the Sacramento River, including

Table 24. Summary of estimated total run size for the Southern California steelhead evolutionarily significant unit, by major river basin, as in Table 10. All data are for winter steelhead.

| River basin | Total run size | Total escapement | Natural escapement | Trend (%/yr) | Percent hatchery |
|---|---|---|---|---|---|
| Santa Ynez River | <100 | | | | |
| Ventura River | <200 | | | | |
| Santa Clara River | <100 | | | | |
| Malibu Creek | <100 | | | | |

Table 25. Percentage of steelhead populations in three risk categories in southern California counties. Includes only those populations for which recent information exists. Based on data in Titus et al. (in press).

| County | No discernible decline | Declining | Extinct |
|---|---|---|---|
| San Mateo | 50% | 50% | 0% |
| Santa Cruz | 19 | 81 | 0 |
| Monterey | 50 | 42 | 8 |
| San Luis Obispo | 25 | 62 | 13 |
| Santa Barbara | 0 | 27 | 73 |
| Ventura/Los Angeles | 9 | 27 | 64 |
| Orange/San Diego | 0 | 0 | 100 |

Table 26. Summary of recent and historical abundance estimates for the Central Valley steelhead evolutionarily significant unit. Excludes estimates from CDFG (1965) presented in Table 17.

| River basin | Abundance | Years | Reference |
|---|---|---|---|
| Sacramento River Basin | 40,000 | 1961 | Hallock et al. 1961 |
| American River | 19,583 | 1971, 1972 | Stanley 1976 |
| upper Sacramento River | 20,540 | 1950s | Hallock et al. 1961 |
| | 10,000 | 1994 | McEwan and Jackson 1996 |
| Red Bluff Diversion Dam | 11,187 | 1967 | McEwan and Jackson 1996 |
| | 2,202 | 1990 | McEwan and Jackson 1996 |
| Yuba River | 2,000 | 1984 | McEwan and Jackson 1996 |
| Deer Creek | 1,006 | 1964 | McEwan and Jackson 1996 |
| Mill Creek | 417 - 2,269 | 1953 - 1963 | McEwan and Jackson 1996 |
| Mokelumne River | <50 | 1974 - 1994 | McEwan and Jackson 1996 |
| Tuolumne River | 66 | 1940 | McEwan and Jackson 1996 |