



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

Peggy J. Busby, Thomas C. Wainwright,  
Gregory J. Bryant\*, Lisa J. Lierheimer,  
Robin S. Waples, F. William Waknitz,  
and Irma V. Lagomarsino\*

National Marine Fisheries Service  
Northwest Fisheries Science Center  
Coastal Zone and Estuarine Studies Division  
2725 Montlake Blvd. E., Seattle, WA 98112-2097

and

\*National Marine Fisheries Service  
Southwest Region  
Protected Species Management Division  
501 W. Ocean Blvd., Suite 4200, Long Beach, CA 90802-4213

August 1996

## **U.S. DEPARTMENT OF COMMERCE**

Michael Kantor, Secretary

## **National Oceanic and Atmospheric Administration**

D. James Baker, Administrator

## **National Marine Fisheries Service**

Rolland A. Schmitten, Assistant Administrator for Fisheries

*“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).*

**This document is available to the public through:**

**National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Road  
Springfield, VA 22161**

## CONTENTS

Executive Summary .....	vii
West Coast Steelhead ESUs .....	vii
Coastal Steelhead ESUs .....	viii
Inland Steelhead ESUs .....	xii
Acknowledgments .....	xiv
Introduction .....	1
Scope and Intent of the Present Document .....	1
Key Questions in ESA Evaluations .....	3
The "Species" Question .....	3
The "Extinction Risk" Question .....	4
Artificial Propagation .....	5
Summary of the West Coast Steelhead Petition .....	6
Petitioners' "Definition of Species and Application to Steelhead Trout" .....	6
Summer steelhead .....	6
A- and B-run steelhead .....	6
Half-pounders .....	6
Southern steelhead .....	7
Information Relating to the Species Question .....	7
Groupings of <i>Oncorhynchus mykiss</i> .....	7
Phylogenetic Groups .....	7
Life History Variations .....	8
Reproductive ecotypes .....	8
A- and B-run steelhead .....	10
Half-pounders .....	10
Rainbow and redband trout .....	11
Environmental Features .....	11
West Coast Ichthyogeography .....	11
Geological events .....	11
Ecoregions .....	12
Ichthyogeographical classification .....	14
Marine and estuarine ichthyogeography .....	14
Hydrology .....	14
Steelhead Life History and Ecology .....	15
Migration and Spawn Timing .....	15
Ageing .....	15
Smolt age .....	15
Ocean age .....	26
Total age .....	26
Repeat Spawning .....	26
Resident Fish .....	35
Steelhead Genetics .....	35

Previous Studies of Population Genetic Structure	35
Protein electrophoresis	35
DNA	40
Chromosomal studies	41
Comparison of Steelhead and Rainbow Trout	42
Run Timing	43
New Studies	43
Synthesis and Discussion	54
Discussion and Conclusions on ESU Determinations	55
Evolutionary Significance of Phylogenetic and Life History Forms	57
Resident fish	57
Coastal Steelhead ESUs	58
1) Puget Sound	58
2) Olympic Peninsula	59
3) Southwest Washington	60
4) Lower Columbia River	61
5) Upper Willamette River	61
6) Oregon Coast	62
7) Klamath Mountains Province	63
8) Northern California	64
9) Central California Coast	64
10) South-Central California Coast	65
11) Southern California	65
12) Central Valley	66
Inland Steelhead ESUs	67
13) Middle Columbia River	67
14) Upper Columbia River	68
15) Snake River Basin	69
Relationship of Steelhead ESUs to State Conservation Management Units	70
Relationship of Steelhead ESUs to Boundaries for Coho Salmon ESUs	71
Artificial Propagation	72
Grand Coulee Fish Maintenance Project	72
Widespread Steelhead Broodstocks	72
Chambers Creek winter steelhead	74
Skamania summer steelhead	74
Alsea River winter steelhead	74
Big Creek and Cowlitz River winter steelhead	74
Eel River winter steelhead	74
Wells Hatchery summer steelhead	75
Lyons Ferry summer steelhead	75
Dworshak summer steelhead	75
Summary of Artificial Propagation by ESU	75
1) Puget Sound	76
2) Olympic Peninsula	76
3) Southwest Washington	76

4) Lower Columbia River	79
5) Upper Willamette River	79
6) Oregon Coast	79
7) Klamath Mountains Province	81
8) Northern California	81
9) Central California Coast	81
10) South-Central California Coast	84
11) Southern California	84
12) Central Valley	84
13) Middle Columbia River	86
14) Upper Columbia River	86
15) Snake River Basin	86
Assessment of Extinction Risk	89
Background	89
Absolute Numbers	89
Historical Abundance and Carrying Capacity	90
Trends in Abundance	92
Factors Causing Variability	93
Threats to Genetic Integrity	93
Recent Events Affecting Extinction Risk	94
Other Risk Factors	95
Approach to Risk Assessment	95
Previous Assessments	95
Data Evaluations	101
Data types	101
Computed statistics	102
Run timing	103
Analysis of Biological Information	104
Coastal Steelhead ESUs	104
1) Puget Sound	104
2) Olympic Peninsula	109
3) Southwest Washington	111
4) Lower Columbia River	113
5) Upper Willamette River	115
6) Oregon Coast	121
7) Klamath Mountains Province	125
8) Northern California	125
9) Central California Coast	130
10) South-Central California Coast	137
11) Southern California	140
12) Central Valley	142
Inland Steelhead ESUs	150
13) Middle Columbia River	150
14) Upper Columbia River	156
15) Snake River Basin	158

Conclusions .....	164
Coastal Steelhead ESU Conclusions .....	165
1) Puget Sound .....	165
2) Olympic Peninsula .....	165
3) Southwest Washington .....	166
4) Lower Columbia River .....	166
5) Upper Willamette .....	167
6) Oregon Coast .....	167
7) Klamath Mountains Province .....	168
8) Northern California .....	168
9) Central California Coast .....	168
10) South-Central California Coast .....	169
11) Southern California .....	169
12) Central Valley .....	169
Inland Steelhead ESU Conclusions .....	170
13) Middle Columbia .....	170
14) Upper Columbia .....	170
15) Snake River Basin .....	171
Citations .....	173
Appendix A - Samples of <i>Oncorhynchus mykiss</i> used in Genetic Analyses .....	197
Appendix B - Petitioned Steelhead Populations Listed by Evolutionarily Significant Unit .....	209
Appendix C - Steelhead Artificial Propagation Facilities .....	217
Appendix D - Releases of Hatchery Steelhead .....	223
Appendix E - Steelhead Abundance Data .....	241
Appendix F - Glossary .....	255

## 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.

## ACKNOWLEDGMENTS

This document represents the combined efforts of dozens of people who submitted information on steelhead directly to NMFS; attended Biological and Technical Committee meetings in Washington, Idaho, Oregon, and California; and answered seemingly endless questions from the authors and biological review team (BRT) members on the telephone. The authors particularly wish to acknowledge Stevan Phelps and Steve Leider of the Washington Department of Fish and Wildlife for generous sharing of newly emerging genetic data, and Jennifer Nielsen of Hopkins Marine Laboratory for sharing her DNA studies in progress. We also wish to thank those that reviewed drafts of this and related documents.

Significant contributions in the compilation and analyses of data were made by Kathleen Neely, Ted Parker, and David Teel, all from NMFS Northwest Fisheries Science Center (NWFSC). The biological review team for this status review included Peggy Busby, Dr. Stephen Grabowski, Dr. Robert Iwamoto, Dr. Conrad Mahnken, Gene Matthews, Dr. Michael Schiewe, Dr. Thomas Wainwright, Dr. Robin Waples, and Dr. John Williams, from NMFS NWFSC; Greg Bryant and Craig Wingert from NMFS Southwest Region (SWR); and Dr. Reg Reisenbichler from the National Biological Service (NBS), Seattle.

## 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<sup>1</sup> of steelhead from the Rogue, Klamath, Mad, and Eel Rivers is evolutionarily significant.

---

<sup>1</sup> 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<sup>1</sup> 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

---

<sup>2</sup> 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<sup>3</sup>, 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,

<sup>3</sup> 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	
<i>O. mykiss irideus</i>	Coastal rainbow trout from Alaska to California (anadromous form is called steelhead)
<i>O. mykiss mykiss</i>	Kamchatka rainbow trout or mikizha (anadromous form is called steelhead)
Redband trout of northern inland basins	
<i>O. mykiss gairdneri</i>	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	
<i>O. mykiss newberrii</i>	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	
<i>O. mykiss aguabonita</i>	California golden trout
<i>O. mykiss gilberti</i>	Kern and Little Kern River golden trout
<i>O. mykiss stonei</i>	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<sup>4</sup>). 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

---

<sup>4</sup> 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 and spawn timing for selected steelhead populations. Continued.

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





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

Location	Months:	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	
Population (run type)																				
Skookumchuck River (O)														S	S	P	P			S
Willapa Bay (O)														S	S	P	P			
<b>Columbia River Basin</b>																				
<b>FRESHWATER ENTRY (S)</b>																				
Grays River, Washington (O)																S	S			S
Elochoman River, Washington (O)																S	P			S
Mill Creek, Washington (O)																S	P			S
Abernathy Creek, Washington (O)																S	P			S
Germany Creek, Washington (O)																S	P			S
Cowlitz River, Washington (O)																S	S			S
Toutle River, Washington (O)																S	P			S
Coweeman River, Washington (O)																S	S			S
Kalama River, Washington (O)																S	P			S
Kalama River, Washington (S)														S	S	S				
Lewis River, Washington (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
Wind River, Washington (S)																S	S			S

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

Location	Months:	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	
Population (run type)																				
White Salmon River, Washington (S)															S	S	S			
Klickitat River, Washington (S)															S	S	S			
Fifteenmile Creek, Oregon (O)															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	S
Entiat River, Washington (S)															S	S	P	S	S	S
Methow River, Washington (S)															S	S	S	S	S	S
Okanogan River, Washington (S)															S	S	S	S	S	S
<b>Snake River Basin</b>																				
"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	Months:	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	
Population (run type)																				
Casper Creek (O)														s	P	s				
Gualala River (O)													s	P	s					
Russian River (O)													s	P	P	s				
<b>SACRAMENTO RIVER BASIN</b>																				
early run (O)														s	P					
late run (O)														s	P	P	s			
American River (O)														s	P	s	s	s		
Feather River (O)														s	P	s	s	s	s	
Mokelumne River (O)														s	P	s	s			
San Gregorio Creek (O)														s	P	s				
Waddell Creek (O)														s	P	P	s	s		
Scott Creek (O)														s	P	P	s	s		
San Lorenzo River (O)														s	P	s				
Carmel River (O)														s	P	P	s			
Santa Ynez River (O)														s	P	P	s	s	s	
Ventura River (O)														s	P	P	s	s	s	
Santa Clara River (O)														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 <sup>a</sup>	Freshwater age							Sample size	Reference
		1	2	3	4	5	7			
<b>Alaska</b>										
Karluk River	S	--	0.36	<b>0.63</b>	0.01	--	--	--	101	Sanders 1985
Anchor River	S	--	0.12	<b>0.85</b>	0.03	--	--	--	90	Sanders 1985
Copper River	S	--	0.08	<b>0.89</b>	0.03	--	--	--	35	Sanders 1985
Situk River	S/O	--	0.13	<b>0.71</b>	0.16	--	--	--	284	Sanders 1985
Sitkoh Creek	O	--	0.04	<b>0.66</b>	0.30	--	--	--	656	Sanders 1985
Karta River	O	--	0.18	<b>0.69</b>	0.13	--	--	--	808	Sanders 1985
<b>British Columbia (mainland)</b>										
Babine River	S	--	0.02	<b>0.82</b>	0.15	0.01	--	--	100	Narver 1969
Cheakamus River	O	--	0.45	<b>0.53</b>	0.02	--	--	--	64	Withler 1966
Capilano River	O	--	0.46	<b>0.53</b>	0.01	--	--	--	70	Withler 1966
Capilano River	S	0.01	0.16	<b>0.83</b>	--	--	--	--	86	Withler 1966
Seymour River	O	--	0.33	<b>0.66</b>	0.02	--	--	--	58	Withler 1966
Seymour River	S	--	0.40	<b>0.60</b>	--	--	--	--	25	Withler 1966
<b>British Columbia (Fraser River Basin)</b>										
Coquitlam River	O	--	0.34	<b>0.66</b>	<0.01	--	--	--	146	Withler 1966
Alouette River	O	0.08	<b>0.66</b>	0.25	<0.01	--	--	--	131	Withler 1966
Chilliwack River	O	0.02	<b>0.62</b>	0.36	<0.01	--	--	--	770	Maher and Larkin 1955
Chehalis River	O	--	0.19	<b>0.68</b>	0.13	--	--	--	111	Withler 1966
Coquihalla River	O	--	0.28	<b>0.67</b>	0.05	--	--	--	39	Withler 1966
Coquihalla River	S	<0.01	0.18	<b>0.75</b>	0.06	--	--	--	150	Withler 1966
<b>British Columbia (Vancouver Island)</b>										
Keogh River	O?	--	0.30	<b>0.60</b>	0.10	--	--	--	1391	Ward and Slaney 1988
Nanaimo River	?	--	<b>0.64</b>	0.35	0.01	--	--	--	228	Narver and Withler 1974
Nahmint River	S	--	0.21	<b>0.78</b>	0.02	--	--	--	58	Narver 1974

Table 4. Smolt age frequency. Continued.

Population	Run type <sup>a</sup>	Freshwater age							Sample size	Reference
		1	2	3	4	5	7			
<b>Washington</b>										
Skagit River	O	<0.01	0.82	0.18	<0.01	--	--	--	n/a <sup>b</sup>	WDFW 1994b
Deer Creek	S	--	0.95	0.05	--	--	--	--	n/a	WDF et al. 1993
Snomish 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
<b>Columbia River Basin</b>										
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	<0.01	349	Mullan et al. 1992

Table 4. Smolt age frequency. Continued.

Population	Run type <sup>a</sup>	Freshwater age							Sample size	Reference
		1	2	3	4	5	7			
<b>Snake River Basin</b>										
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
<b>Oregon</b>										
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
<b>California</b>										
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

<sup>a</sup>O = Ocean maturing; S = Stream maturing.<sup>b</sup>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 <sup>+1</sup>), most Columbia River inland steelhead are 4 years old at maturity (2/1<sup>+1</sup>). 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<sup>+1</sup>). 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<sup>+1</sup>) in the Clearwater River (Whitt 1954) to 7 year-old spawners (3/3<sup>+1</sup>) 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 <sup>a</sup>	Ocean age at first spawning migration					Sample size	Reference	
		0	1	2	3	4			5
<b>Alaska</b>									
Karluk River	S	--	0.18	<b>0.79</b>	0.03	--	--	62	Sanders 1985
Anchor River	S	--	0.26	<b>0.74</b>	--	--	--	80	Sanders 1985
Upper Copper River	S	--	0.17	<b>0.77</b>	0.06	--	--	30	Sanders 1985
Situk River	S/O	--	--	<b>0.57</b>	0.43	--	--	211	Sanders 1985
Sitkoh Creek	O	--	--	<b>0.59</b>	0.41	--	--	497	Sanders 1985
Karta River	O	--	<0.01	<b>0.72</b>	0.27	--	--	542	Sanders 1985
<b>British Columbia (mainland)</b>									
Babine River	S	--	0.10	<b>0.72</b>	0.18	--	--	100	Narver 1969
Cheakamus River	O	--	--	<b>0.52</b>	0.40	0.08	--	64	Withler 1966
Capilano River	O	--	--	<b>0.67</b>	0.33	--	--	70	Withler 1966
Capilano River	S	--	0.01	<b>0.56</b>	0.42	0.01	--	86	Withler 1966
Seymour River	O	--	0.07	<b>0.57</b>	0.34	0.02	--	58	Withler 1966
Seymour River	S	--	--	<b>0.64</b>	0.36	--	--	25	Withler 1966
<b>British Columbia (Fraser River Basin)</b>									
Coquitlam River	O	--	0.01	<b>0.73</b>	0.23	0.03	--	146	Withler 1966
Alouette River	O	--	--	<b>0.50</b>	0.46	0.04	--	131	Withler 1966
Chilliwack River	O	--	<0.01	<b>0.50</b>	0.49	<0.01	--	770	Maier and Larkin 1955
Chehalis River	O	--	--	<b>0.50</b>	0.50	<0.01	--	111	Withler 1966
Coquihalla River	O	--	0.05	<b>0.64</b>	0.31	--	--	39	Withler 1966
Coquihalla River	S	--	0.12	<b>0.83</b>	0.05	--	--	150	Withler 1966

Table 5. Ocean age frequency. Continued.

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

Table 5. Ocean age frequency. Continued.

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

<sup>a</sup>O = Ocean maturing; S = Stream maturing.<sup>b</sup>Sample size not indicated in reference.<sup>c</sup>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 <sup>a</sup>	Life history (frequency)		Sample size	Reference		
		Primary	Secondary				
<b>Alaska</b>							
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
<b>British Columbia (mainland)</b>							
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
<b>British Columbia (Fraser River Basin)</b>							
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	Maier 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
<b>British Columbia (Vancouver Island)</b>							
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 <sup>a</sup>	Life history (frequency)		Sample size	Reference
		Primary	Secondary		
<b>Washington</b>					
Skagit River	O	2/2 (0.48)	2/3 (0.33)	n/a <sup>b</sup>	WDFW 1994b
Deer Creek	S	2/1 (0.95)	3/1 (0.05)	n/a	WDFW 1994b
Snomish 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
<b>Columbia River Basin</b>					
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 <sup>a</sup>	Life history (frequency)		Sample size	Reference
		Primary	Secondary		
<b>Snake River Basin</b>					
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
<b>Oregon</b>					
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 <sup>c</sup>	O	2/2 (0.60)	3/2 (0.17)	547	ODFW 1990
<b>California</b>					
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

<sup>a</sup>O = Ocean maturing; S = Stream maturing.

<sup>b</sup>Sample size not indicated in reference.

<sup>c</sup>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.

Population	Run type <sup>a</sup>	Spawning migration					Sample size	Reference
		1	2	3	4	5		
<b>British Columbia (mainland)</b>								
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
<b>British Columbia (Fraser River Basin)</b>								
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
<b>Washington</b>								
Skagit River	O	0.92	0.07	0.01	--	--	n/a <sup>b</sup>	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
<b>Columbia River Basin</b>								
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 <sup>a</sup>	Spawning migration					Sample size	Reference
		1	2	3	4	5		
<b>Oregon</b>								
Alsea River	O	<b>0.89</b>	0.09	0.02	--	--	1,223	Chapman 1958
Siuslaw River	O	<b>0.86</b>	0.11	0.02	--	0.01	125	Lindsay et al. 1991
Rogue River	S	<b>0.79</b>	0.17	0.04	--	--	4,058	ODFW 1994d
<b>California</b>								
Mad River	O	<b>0.77</b>	0.17	0.06	--	--	35	Forsgren 1979
Jacoby Creek	O	<b>0.83</b>	0.17	--	--	--	109	Harper 1980
Sacramento River	O	<b>0.83</b>	0.14	0.02	0.01	--	n/a	Hallock 1989
Waddell Creek	O	<b>0.83</b>	0.15	0.02	<0.01	--	3,888	Shapovalov and Taft 1954

<sup>a</sup>O = Ocean-maturing; S = Stream-maturing.<sup>b</sup>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<sup>5</sup> 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<sup>2</sup>. 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

---

<sup>5</sup> Residual *O. mykiss* are those that have an anadromous lineage but are themselves 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<sup>6</sup>). 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<sup>7</sup>, 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<sup>8</sup> 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

---

<sup>6</sup> D. Teel, unpubl. data. National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112-2097.

<sup>7</sup> R. Roseburg, USFWS, P.O. Box 18, Ahsahka, ID 83520. Pers. commun., November 1994.

<sup>8</sup> N. Buroker, 21617 88th Ave. West, Edmonds, WA 98026. Pers. commun., March 1993.

distribution) information (Nielsen<sup>9</sup>). 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.

---

<sup>9</sup> 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<sup>10</sup>). 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

---

<sup>10</sup> 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).

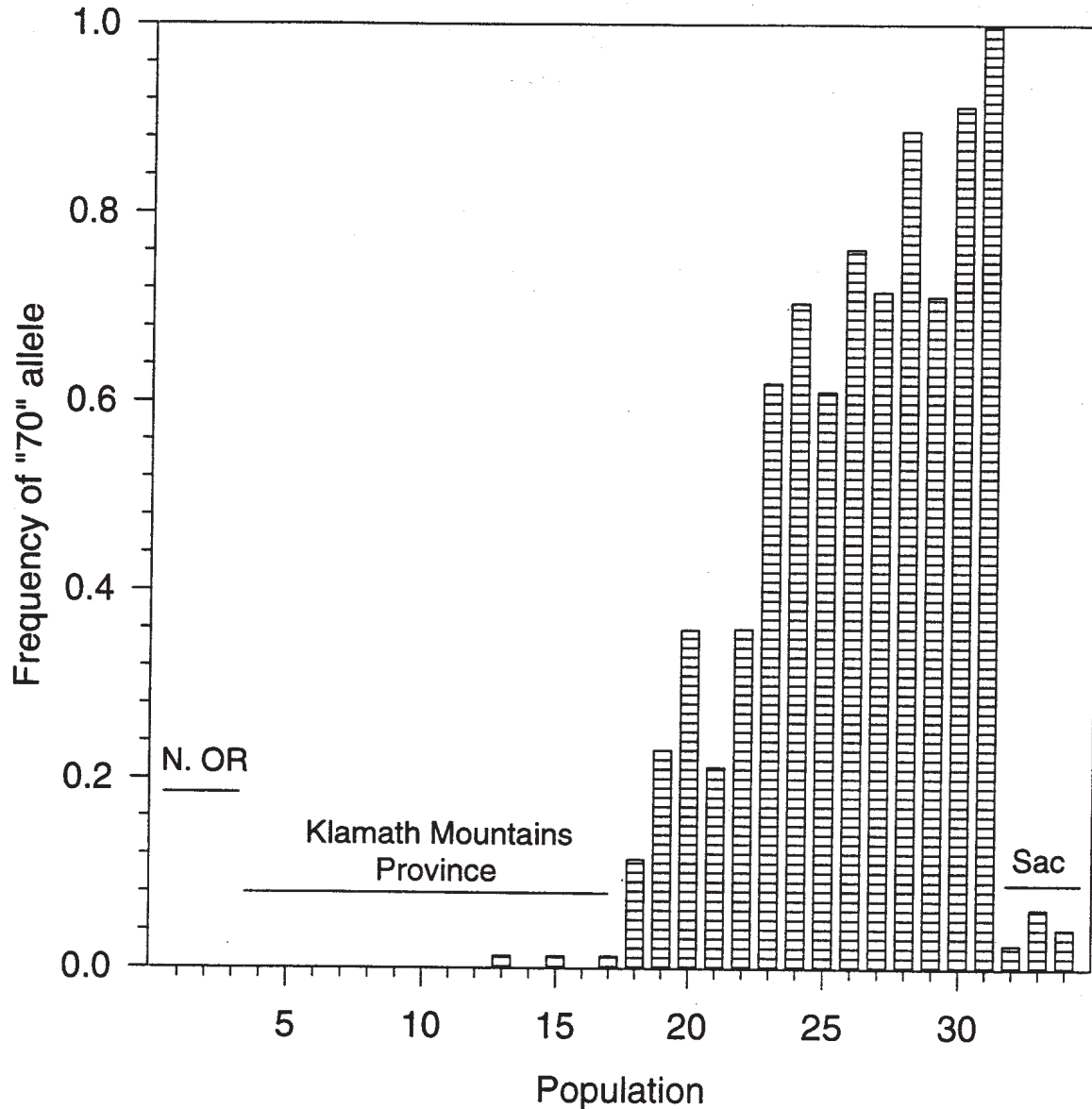


Figure 2. Variation in frequency of the "70" allele at the gene locus *FBALD-3\** in 34 samples of steelhead from southern Oregon to southern California analyzed by NMFS. 1 = Nehalem R.; 2 = Yaquina R.; 3 = Bandon Hatchery; 4 = Elk R.; 5 = Lobster Cr.; 6 = upper Butte Cr.; 7 = Cole Rivers Hatchery; 8 = 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).

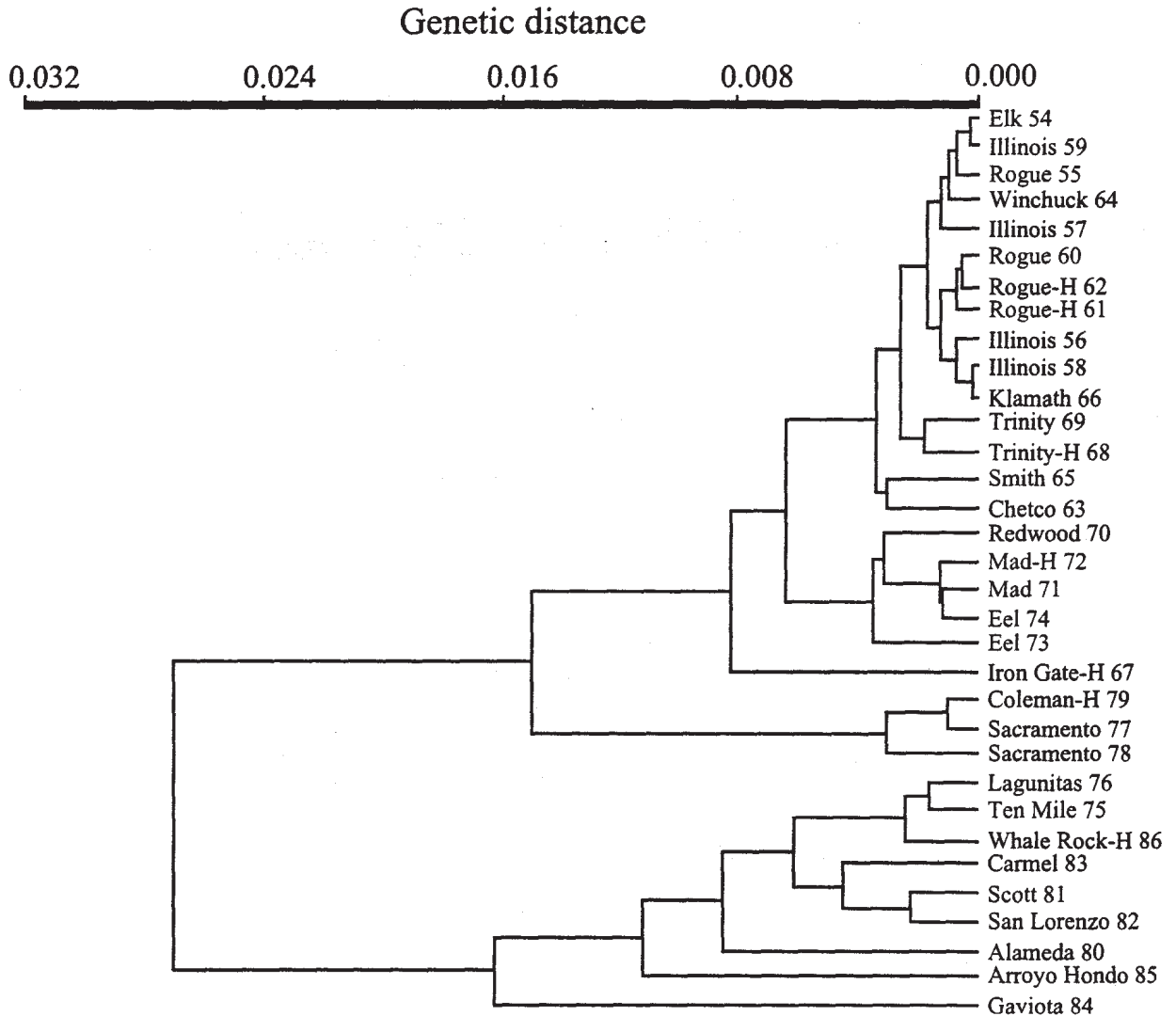


Figure 3. Dendrogram based on unweighted pair-group method analysis (UPGMA) clustering of pairwise genetic distance values (Nei 1978) among 33 hatchery (-H) and natural steelhead populations from southern Oregon to southern California. Analysis was based on data for 51 polymorphic gene loci scored in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

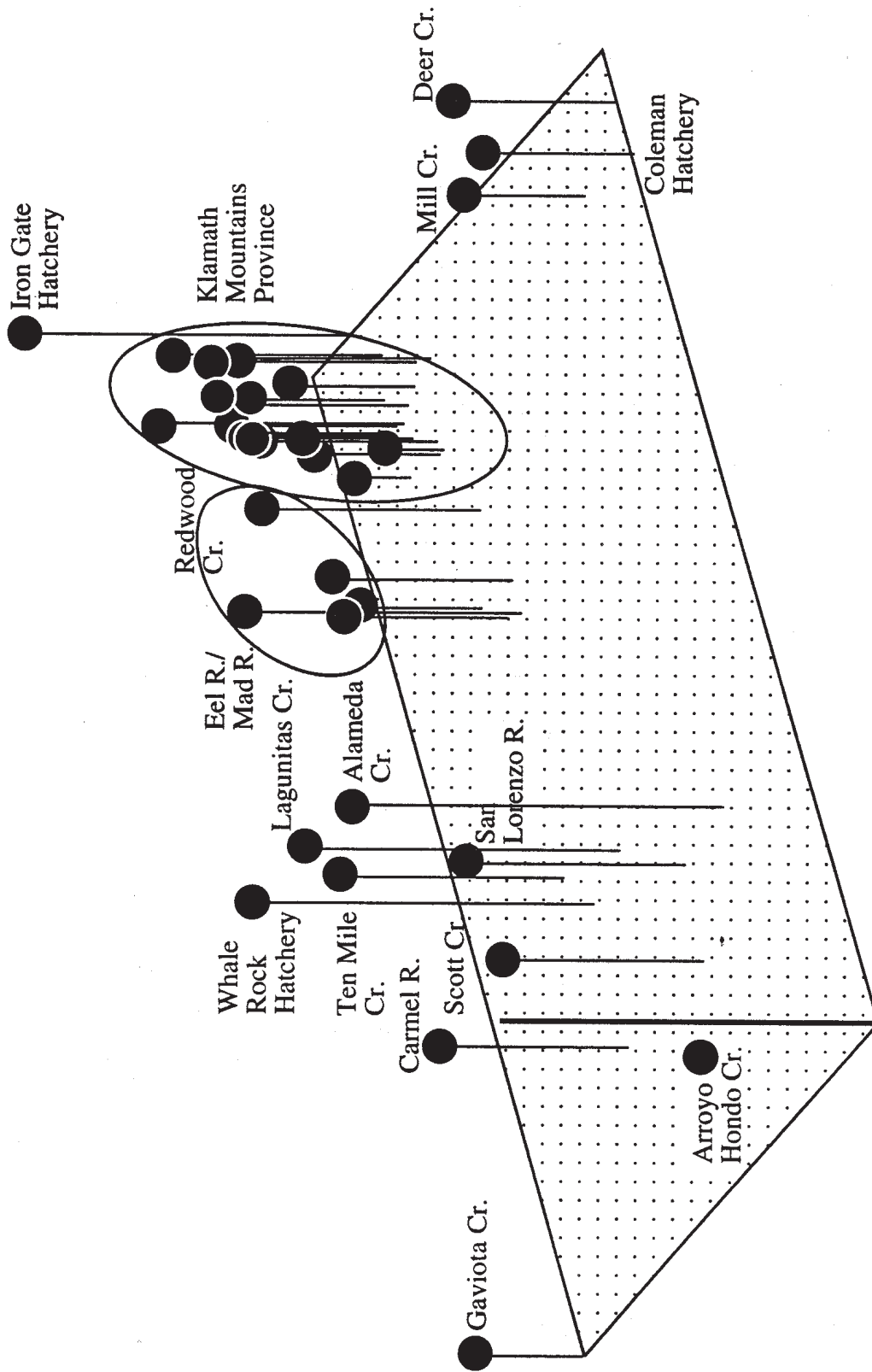


Figure 4. Multidimensional scaling plot (MDS) of genetic distance values used in Figure 3.

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

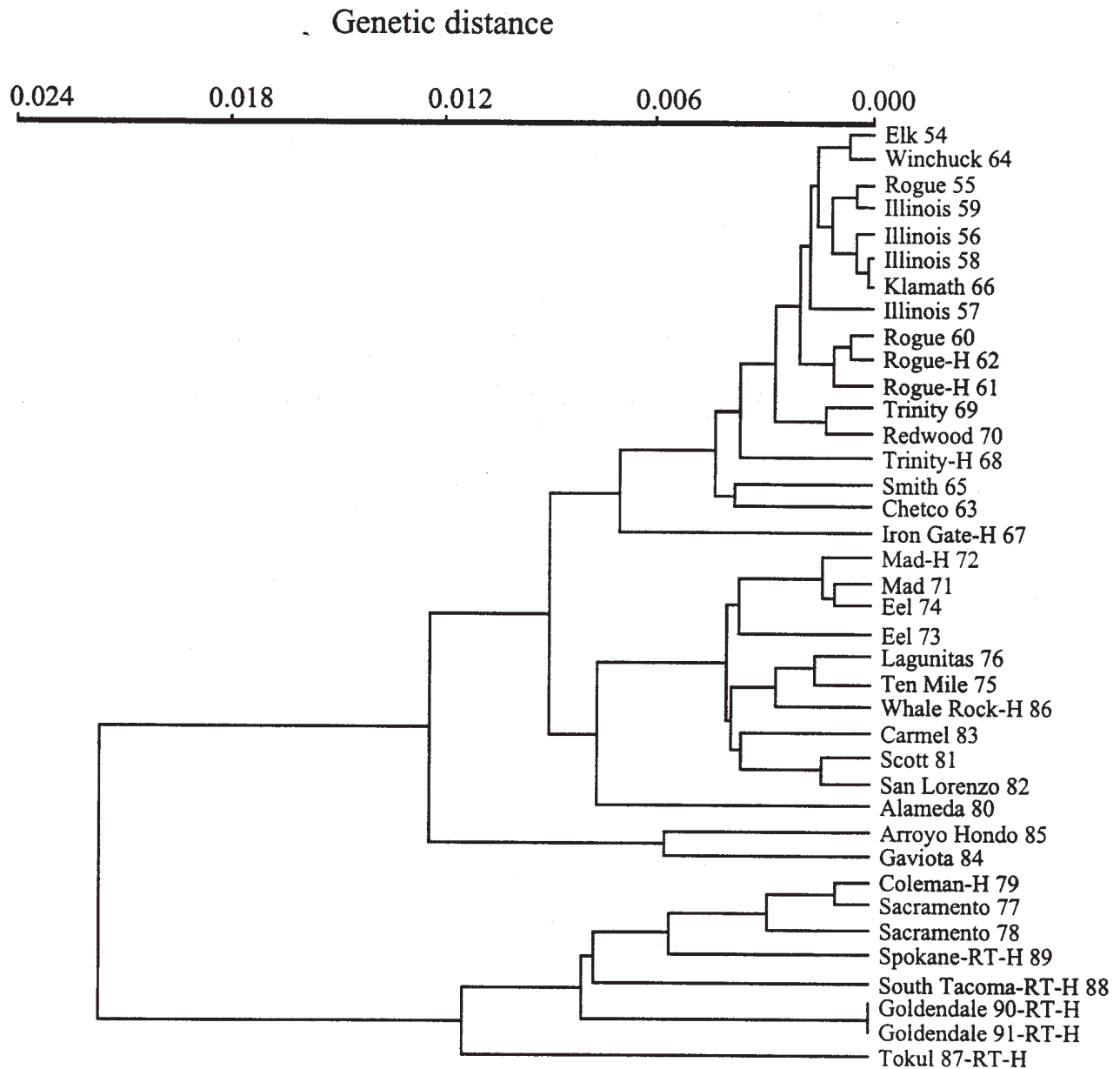


Figure 5. Dendrogram based on unweighted pair-group method analysis (UPGMA) clustering of pairwise genetic distance values (Nei 1978) among 33 hatchery (H) and natural steelhead populations from southern Oregon to southern California and 5 hatchery stocks of rainbow trout (RT) from Washington. Analysis 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.

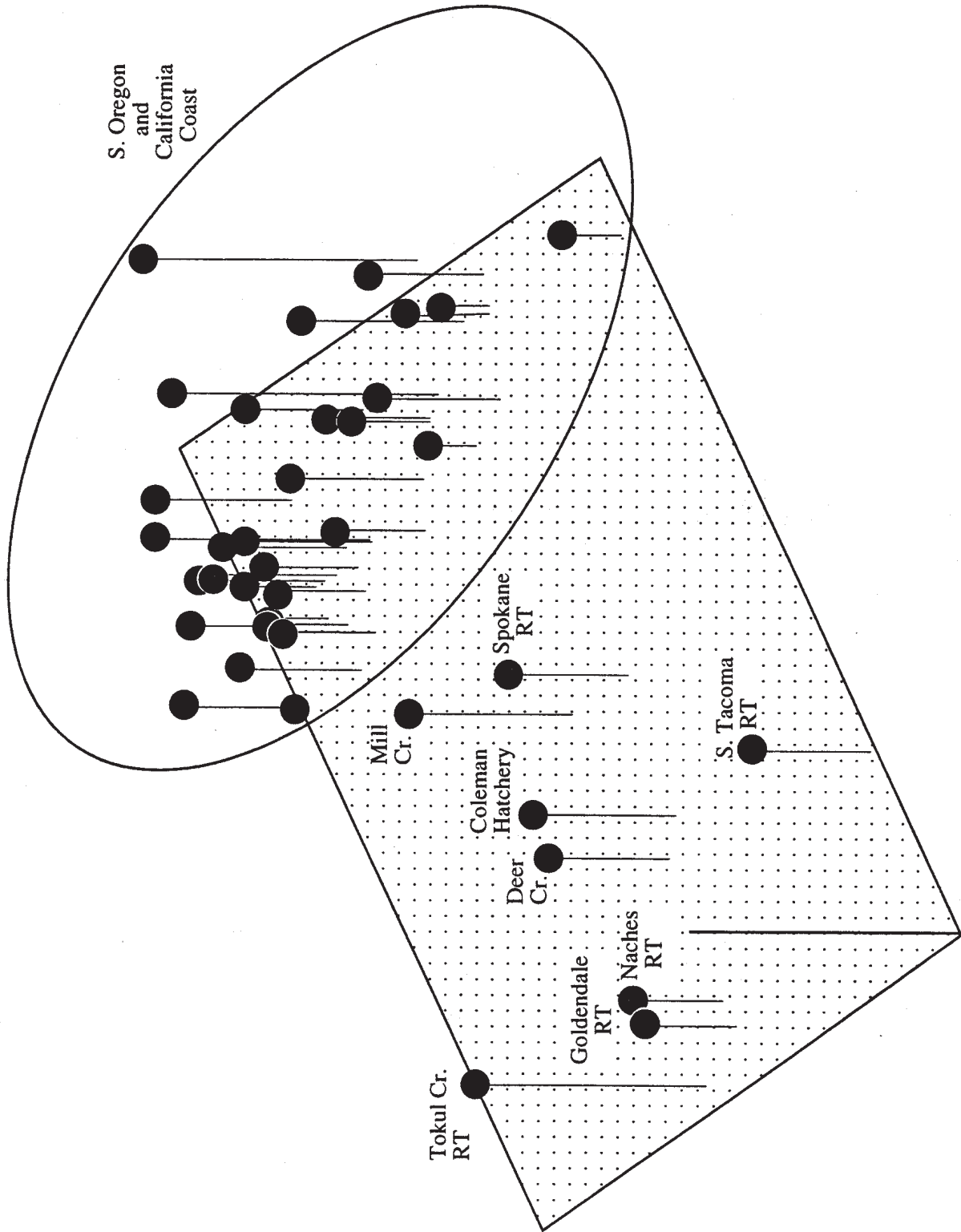


Figure 6. Multidimensional scaling plot of genetic distance values used in Figure 5 (RT = rainbow trout).



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<sup>11</sup>). 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.

---

<sup>11</sup> S. Phelps, Washington Department of Fish and Wildlife, Olympia, WA. Pers. commun., November 1994.

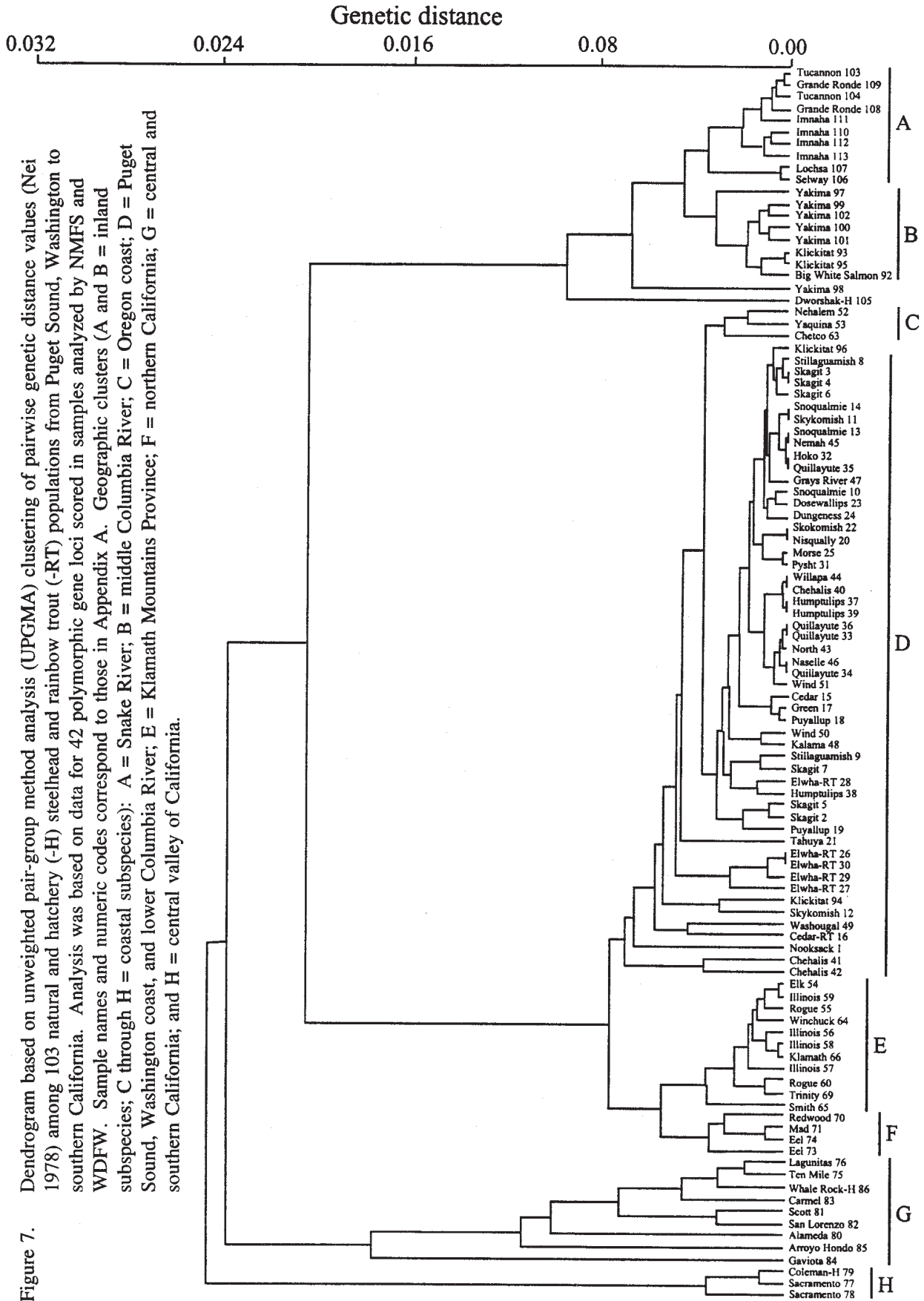


Figure 7. Dendrogram based on unweighted pair-group method analysis (UPGMA) clustering of pairwise genetic distance values (Nei 1978) among 103 natural and hatchery (-H) steelhead and rainbow trout (-RT) populations from Puget Sound, Washington to southern California. Analysis was based on data for 42 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.

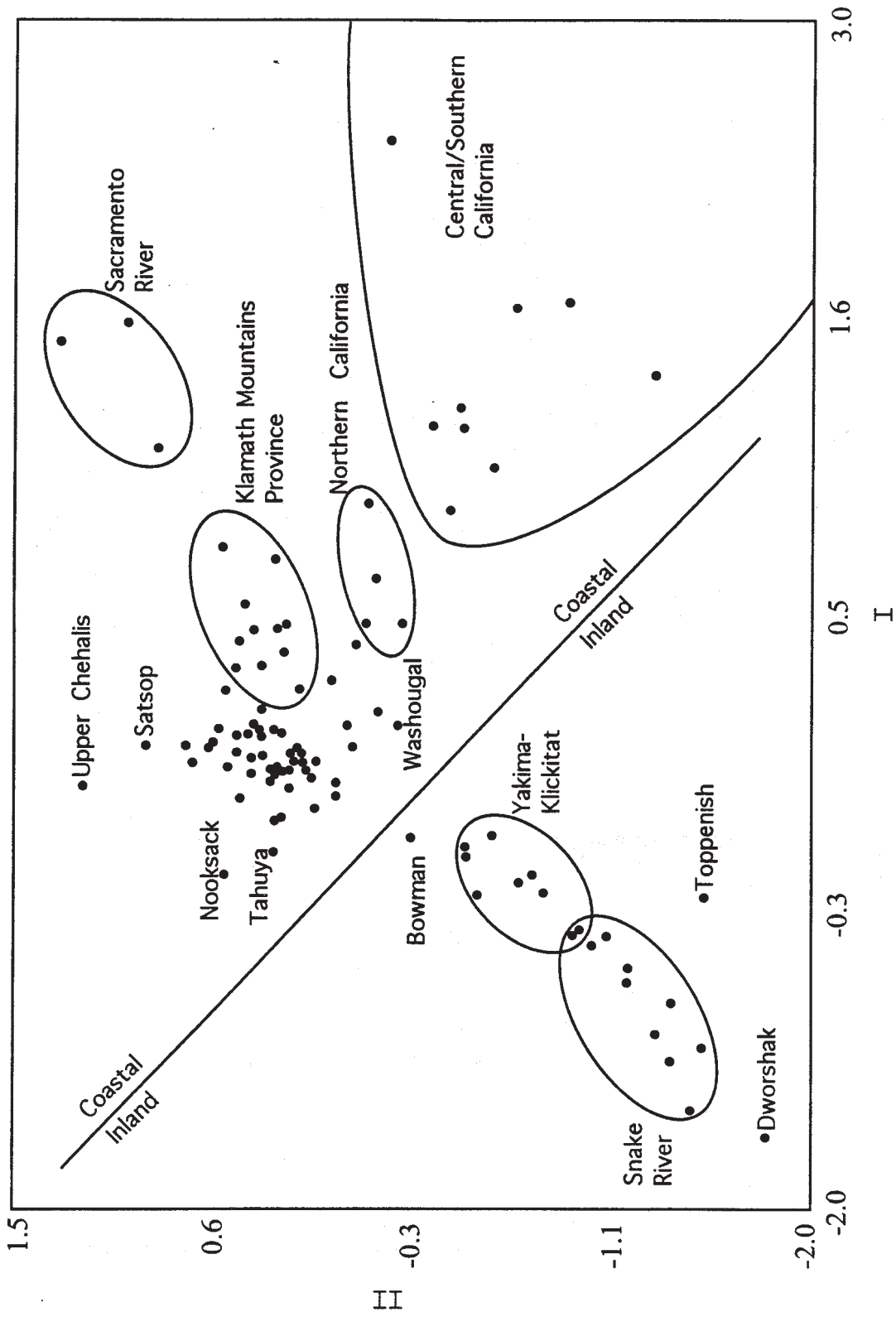


Figure 8. Multidimensional scaling plot of genetic distance values used in Figure 7.

## 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.

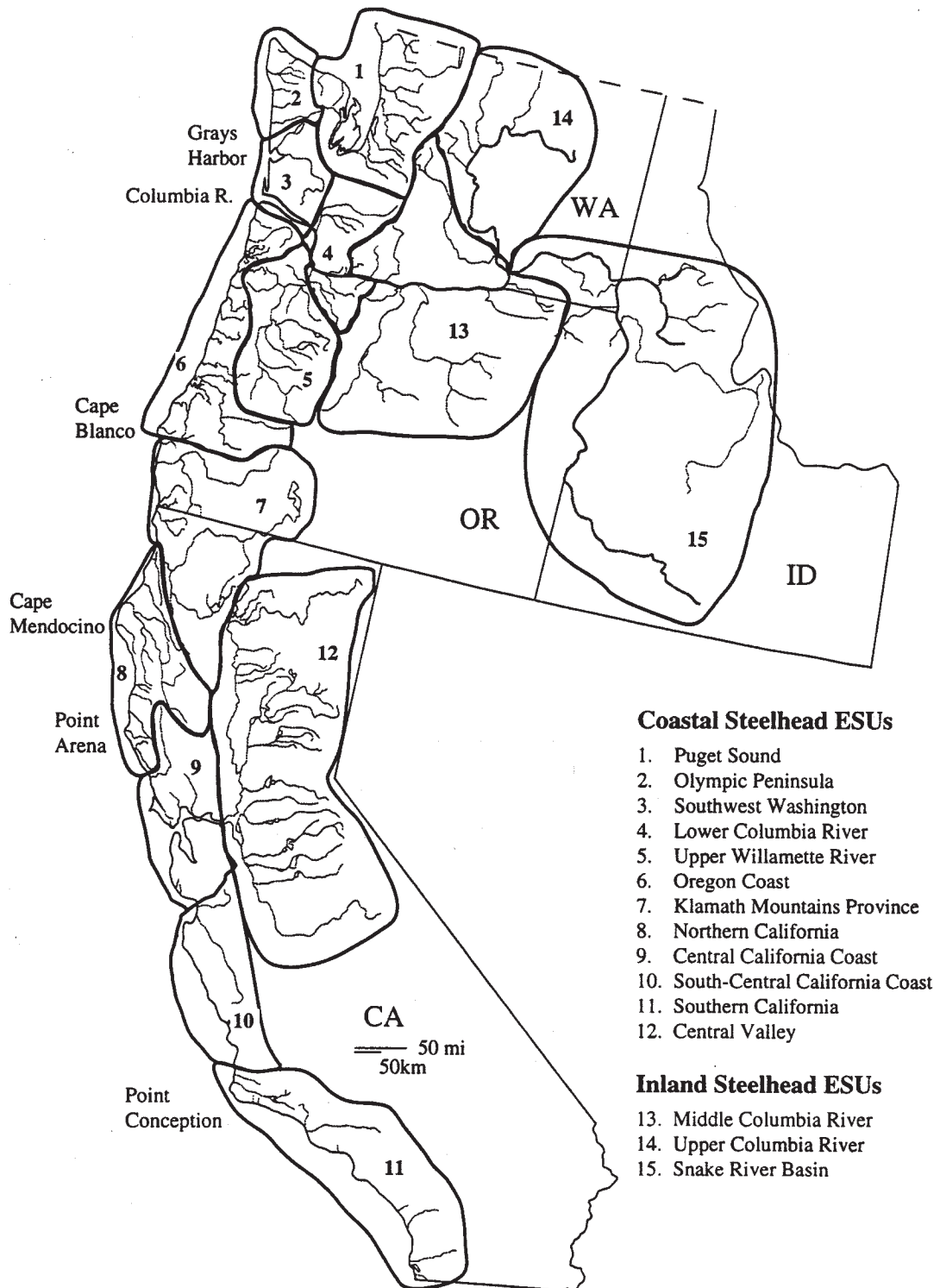


Figure 9. Map of the approximate historic geographic ranges of proposed evolutionarily significant units (ESUs) for west coast steelhead (present distribution may be less). See text for more detail.

## 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<sup>12</sup>), 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

---

<sup>12</sup> 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 translocation 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, Percy et al. 1990, Percy 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<sup>13</sup> 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

---

<sup>13</sup> 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
<i>Revised below to include new data (IDFG 1995)*</i>		
Alaska (4)	62,000	<i>0.3</i>
British Columbia (22)	616,000	<i>3.1</i>
Washington (44)	6,782,000	<i>34.5</i>
<i>Idaho (4)*</i>	<i>5,372,000</i>	<i>27.3</i>
Oregon (26)	4,537,000	<i>23.1</i>
California (9)	2,304,000	<i>11.7</i>
Total (109)	<i>19,673,000</i>	<i>100.0</i>

\*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<sup>14</sup>). 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<sup>15</sup>. 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

---

<sup>14</sup> B. Will, Manager, Rowdy Creek Fish Hatchery, P.O. Box 328, Smith River, CA 95567. Pers. commun., May 1995.

<sup>15</sup> 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).

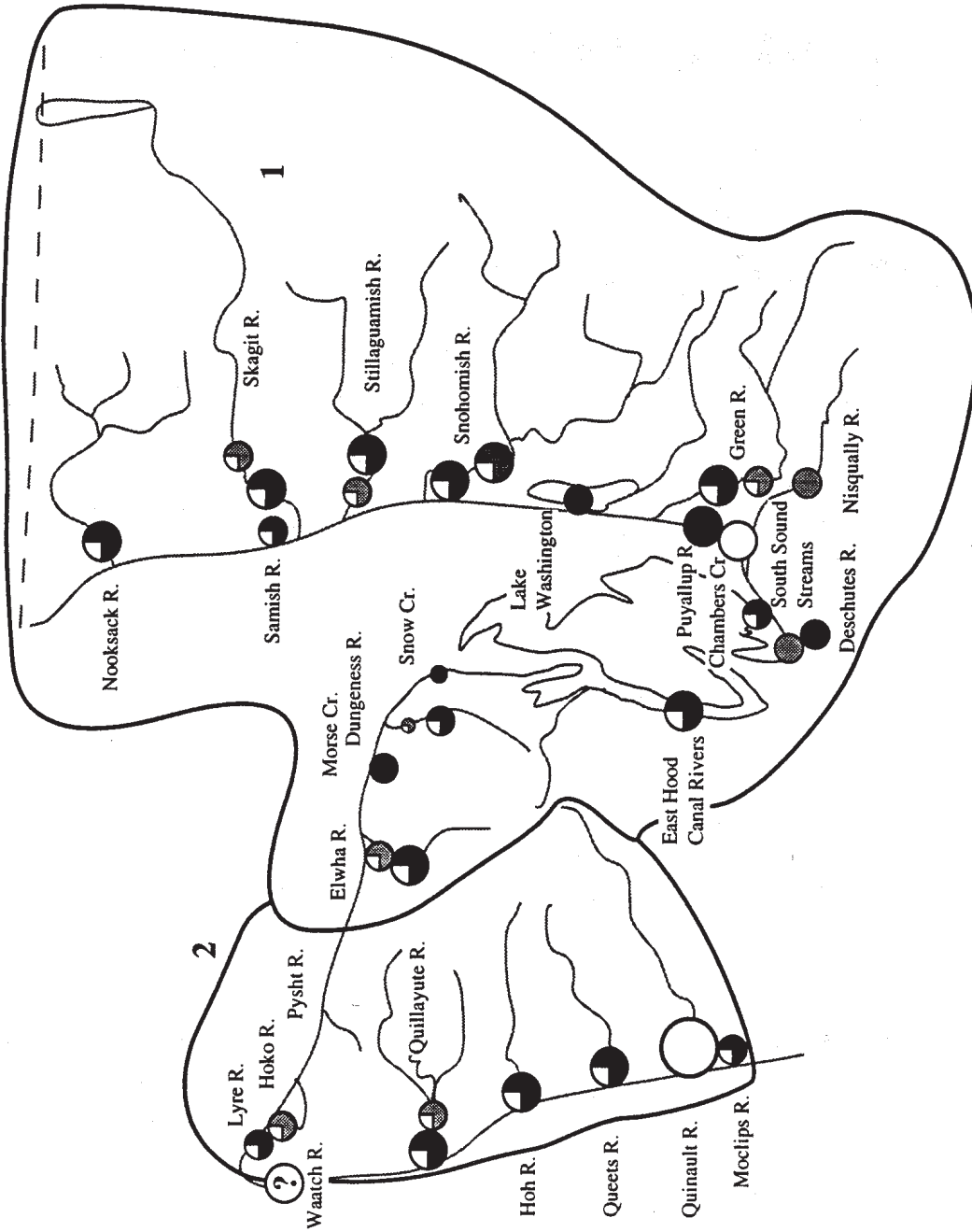
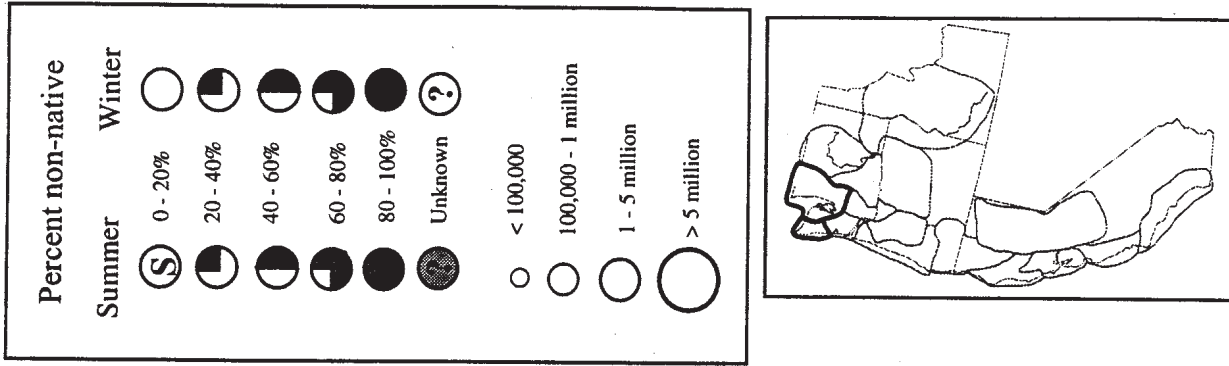


Figure 10. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 1-Puget Sound and 2-Olympic Peninsula, for the period 1980-94. Size of circles represents the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Huew et al. 1990, WDF et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

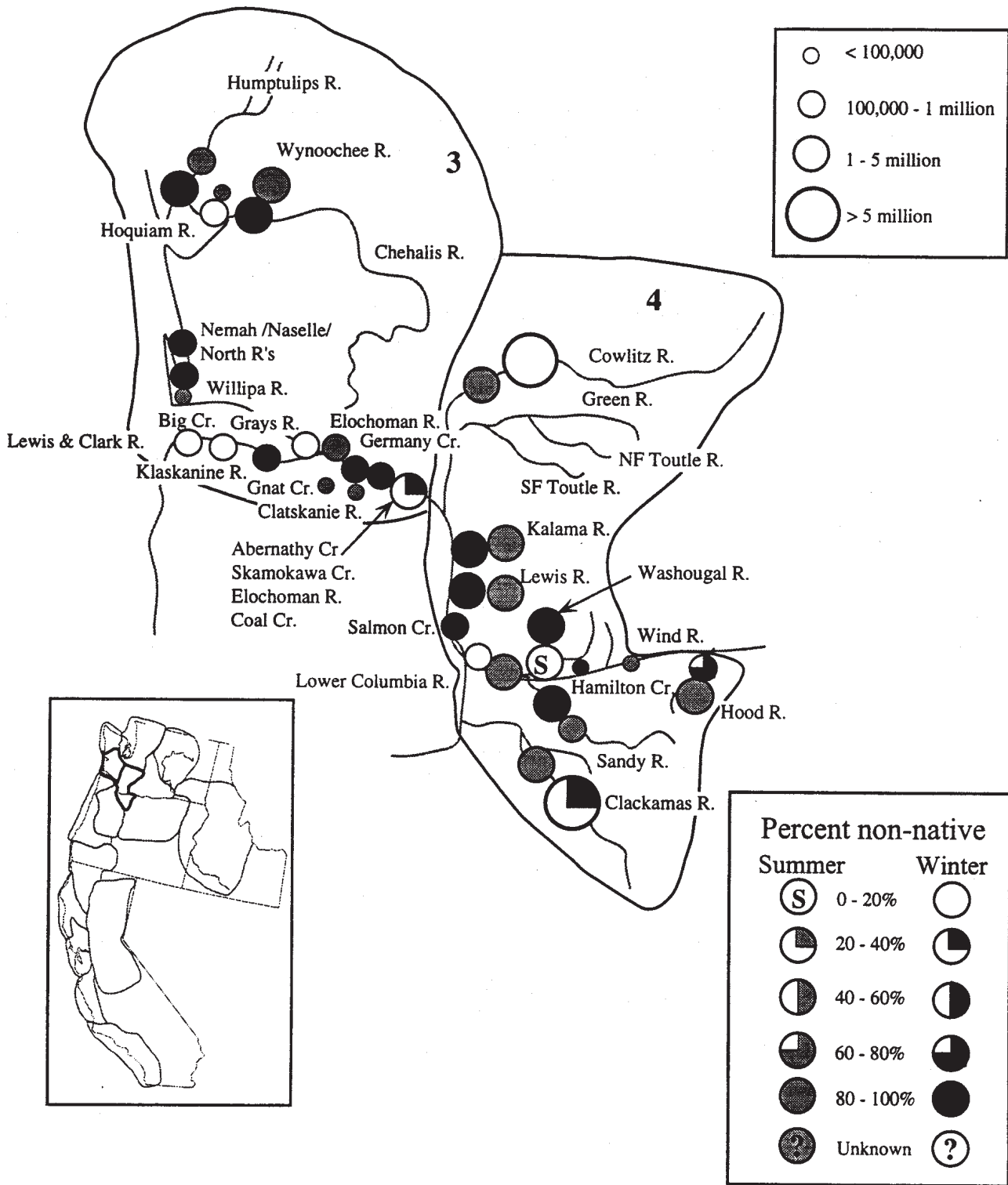


Figure 11. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 3-Southwest Washington and 4-Lower Columbia River, for the period 1980-94. Size of circles represents the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al.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

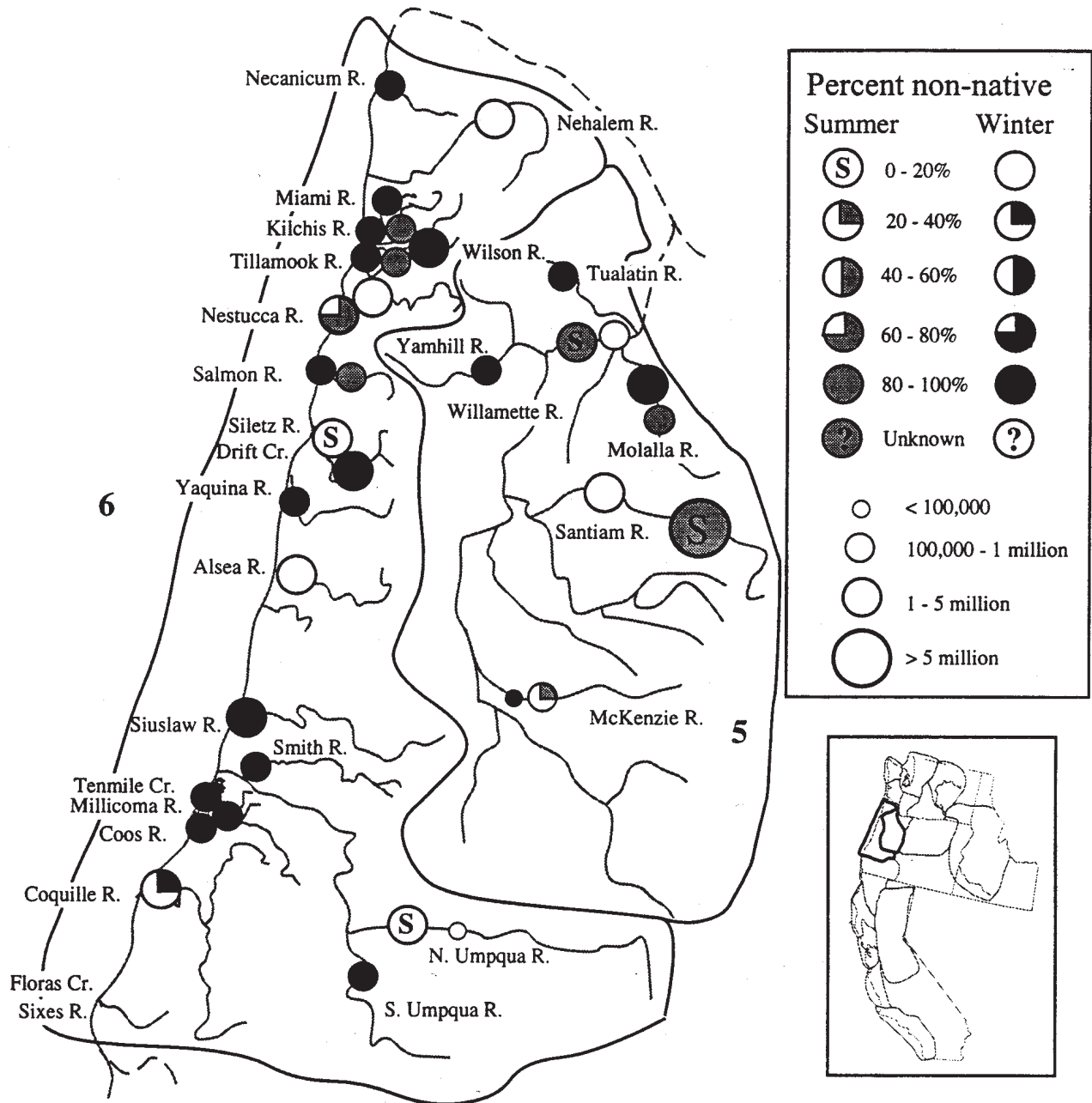


Figure 12. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985,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

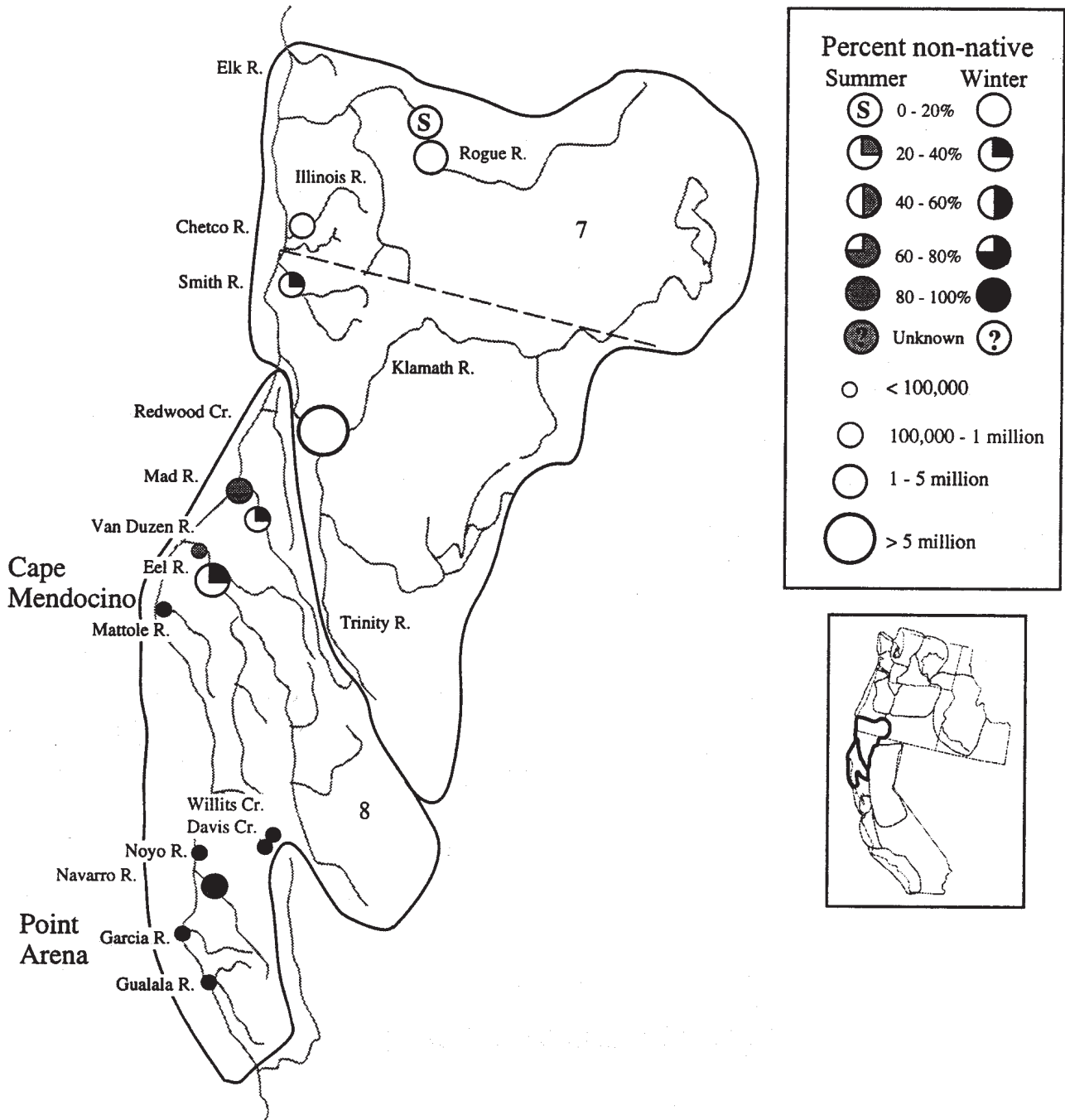


Figure 13. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 7-Klamath Mountains Province and 8-Northern California, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (CDFG 1994,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



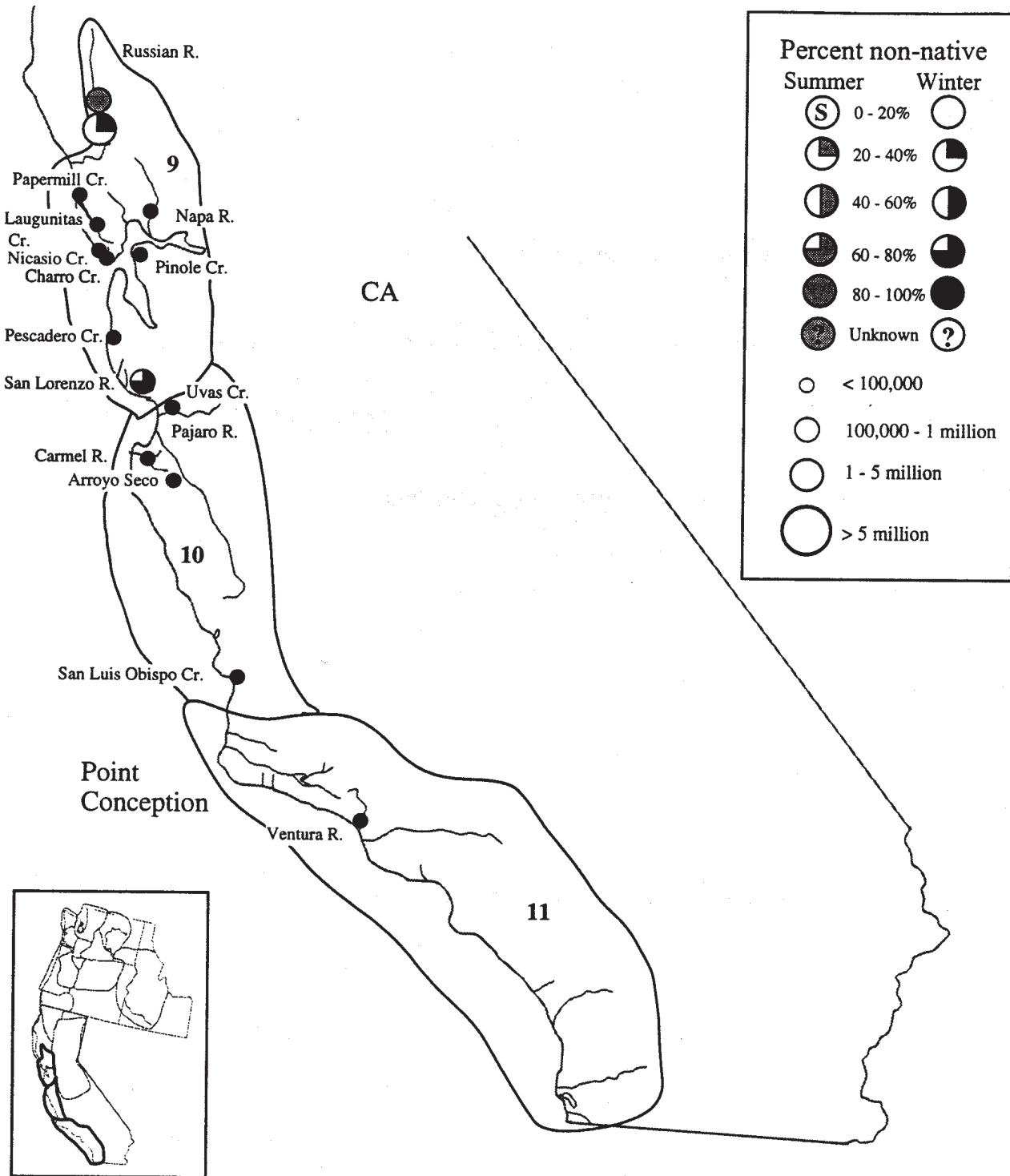


Figure 14. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California, for the period 1971-90. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised 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

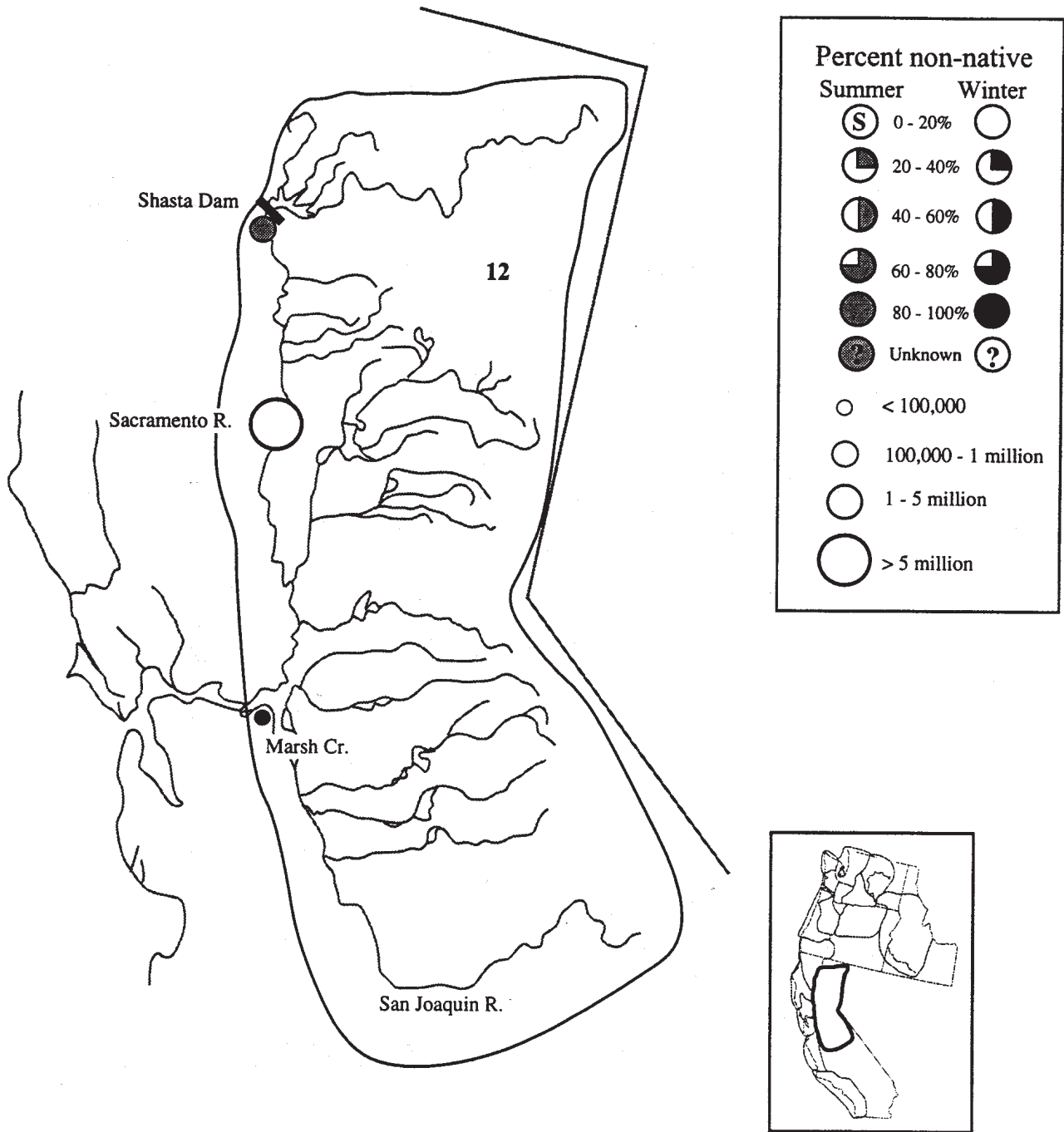


Figure 15. Total releases of hatchery steelhead into rivers occupied by steelhead ESU 12-Central Valley, for the period 1971-90. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (CDFG 1994, Cramer et al. 1995).

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.

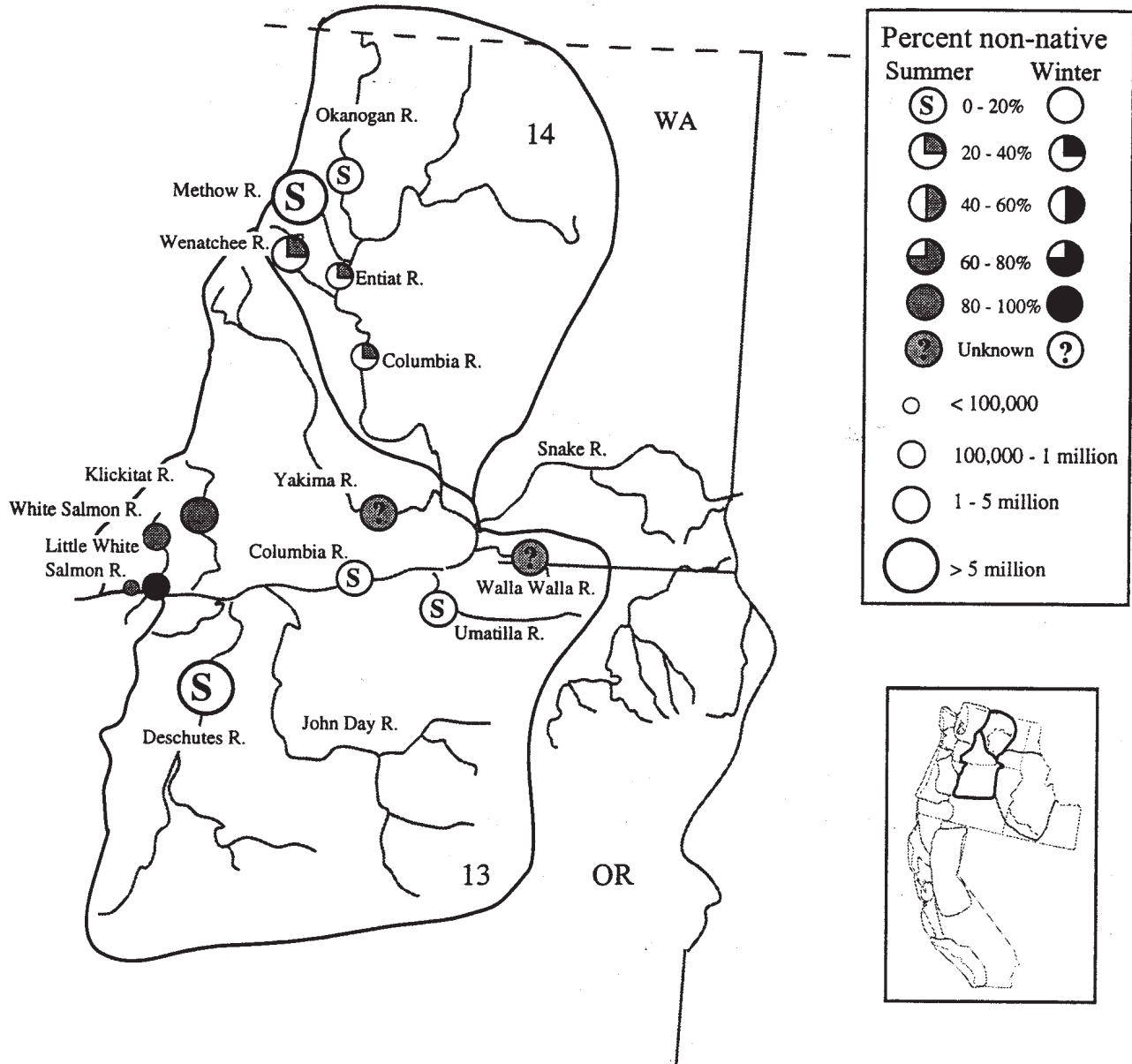


Figure 16. Total releases of hatchery steelhead into rivers occupied by steelhead ESUs 13-Middle Columbia River and 14-Upper Columbia River, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et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

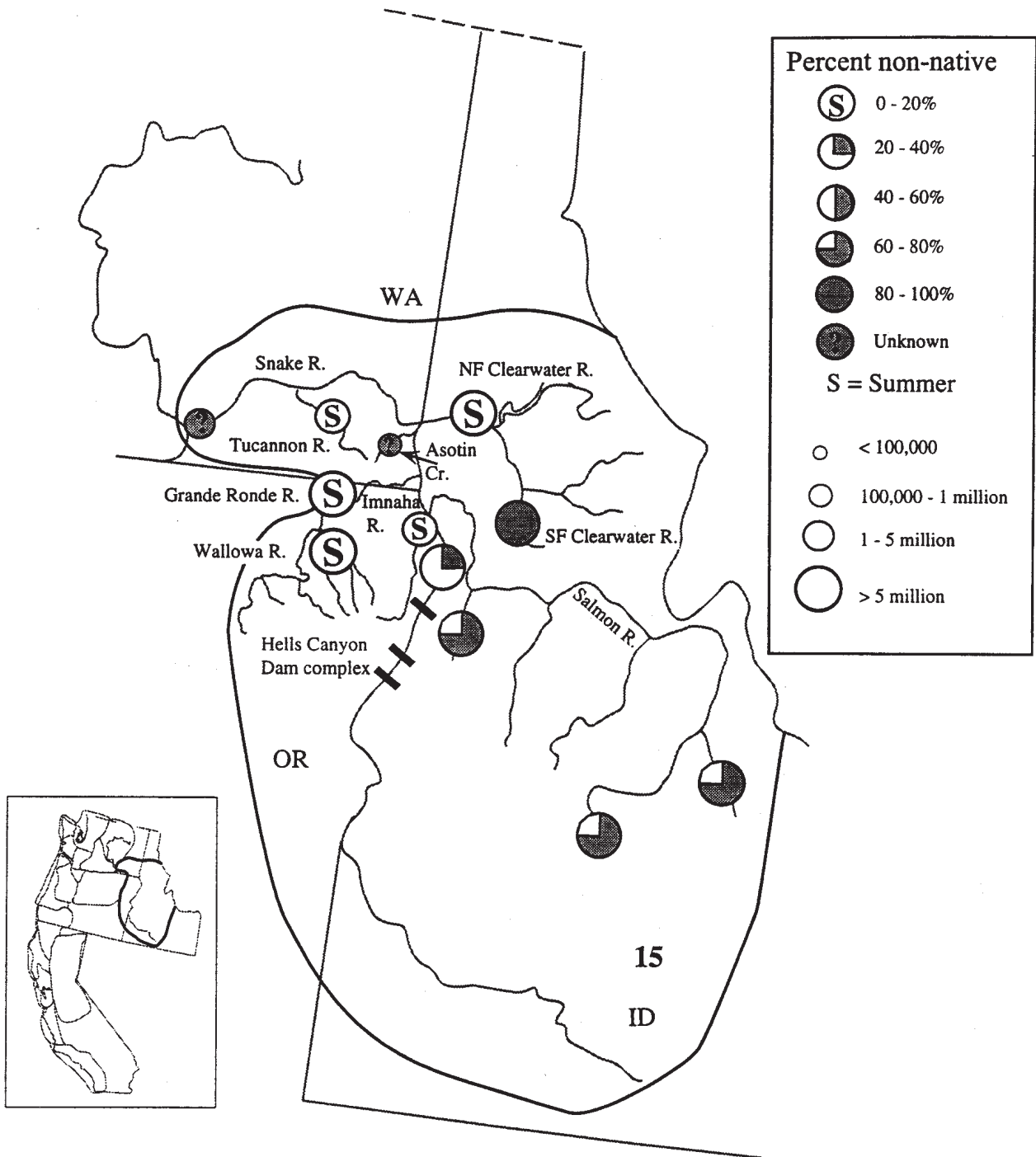


Figure 17. Total releases of hatchery steelhead into rivers occupied by steelhead ESU 15-Snake River Basin, for the period 1980-94. Size of circles represent the magnitude of releases; shading indicates proportion of releases comprised of non-native stocks (Howell et al. 1985, Hutchison 1993, Shell Drake 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<sup>16</sup>). 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).

---

<sup>16</sup> 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



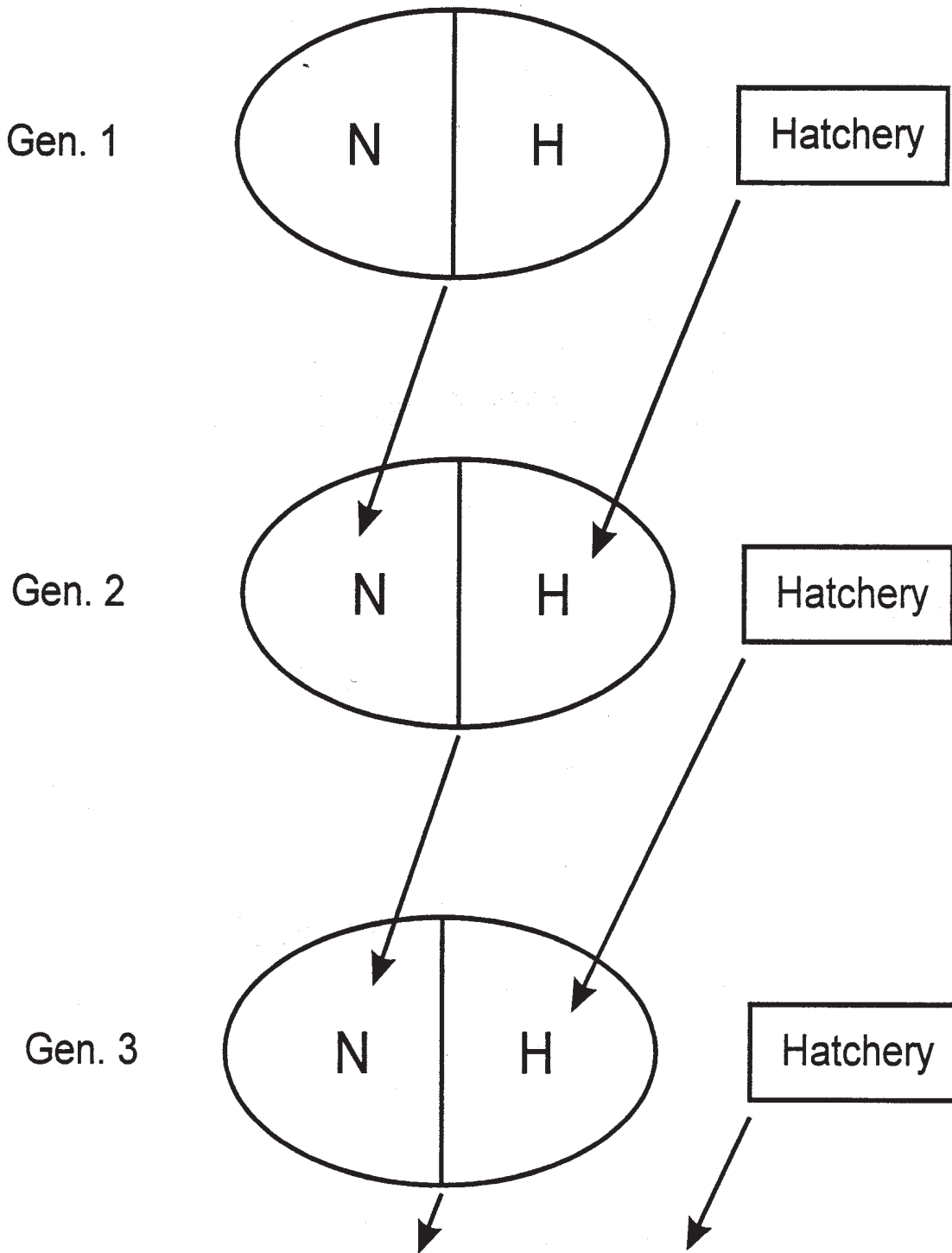


Figure 18. Schematic diagram of mixing of naturally and hatchery produced fish in natural habitat. Ovals represent the total spawning in natural habitat each generation. This total can be composed of naturally produced (N) and hatchery produced (H) offspring of individuals in the previous generation.

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

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

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

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

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



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

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

<sup>a</sup>ESU = evolutionarily significant unit.

<sup>b</sup>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<sup>17</sup>), 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

---

<sup>17</sup> 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  $\ln(\text{abundance})$  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



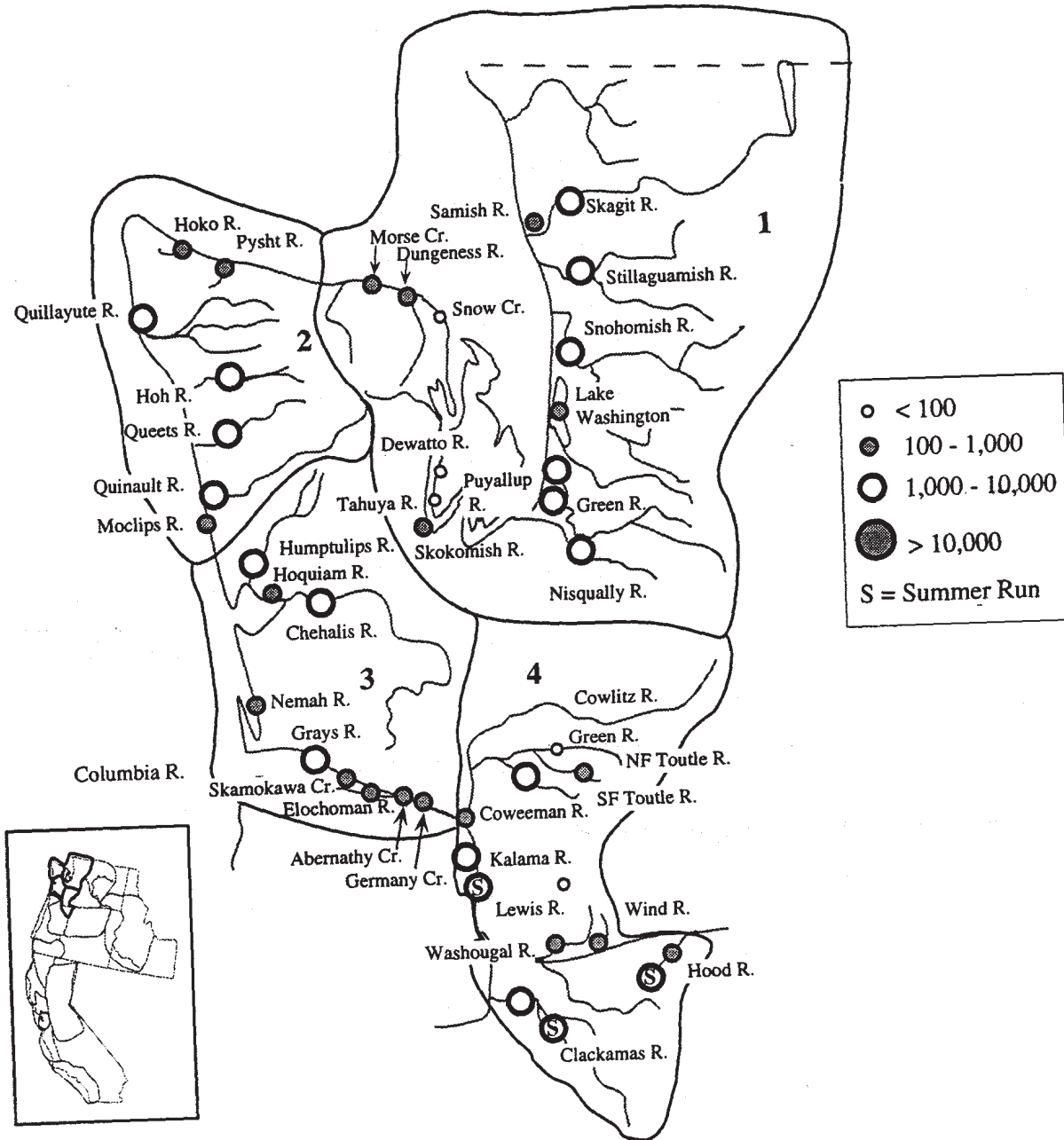


Figure 19. Recent total escapement for populations in steelhead ESUs 1-Puget Sound, 2-Olympic Peninsula, 3-Southwest Washington, and 4-Lower Columbia River. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details).

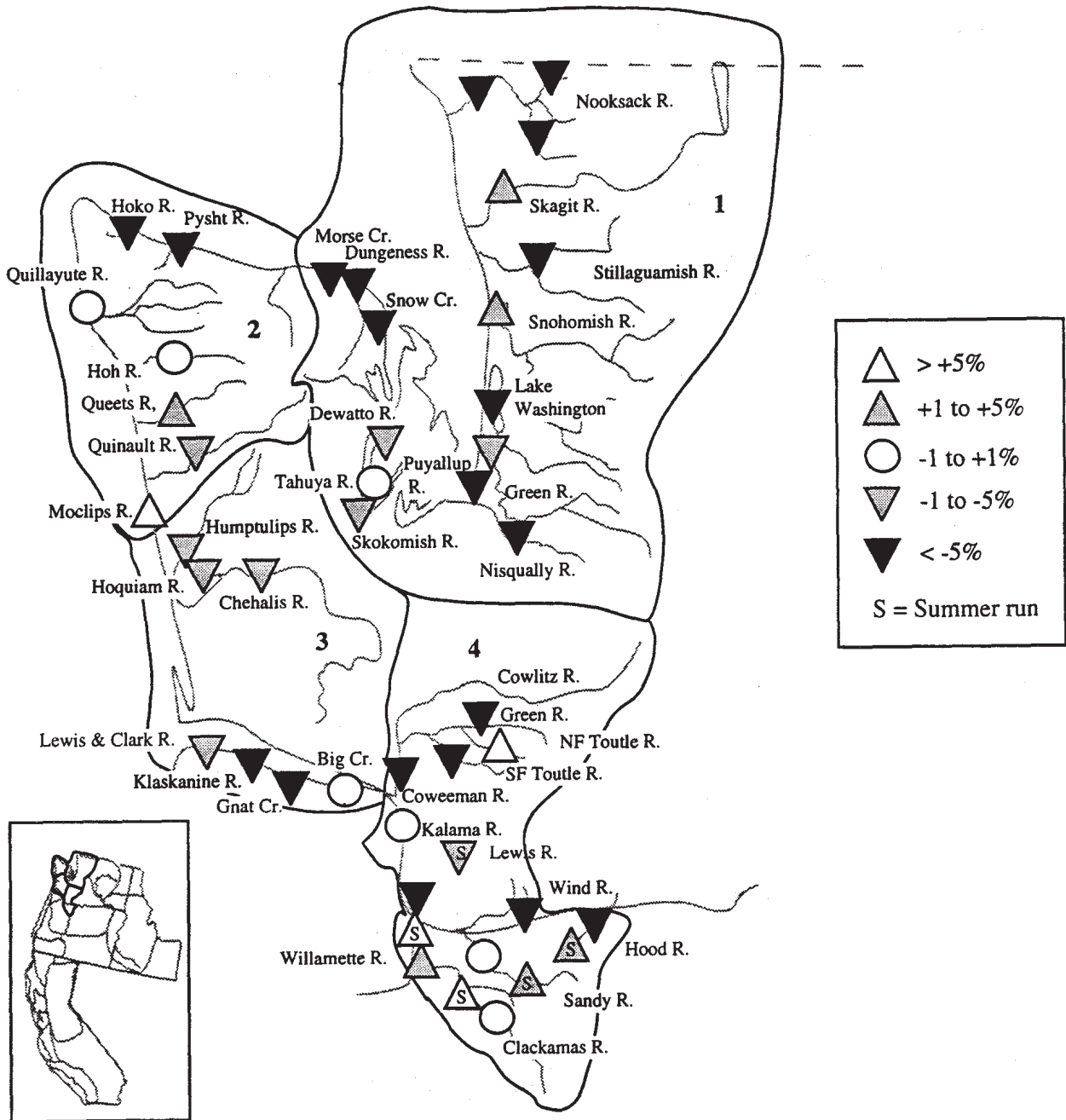


Figure 20. Trends (percent annual change) in total escapement for populations in steelhead ESUs 1-Puget Sound, 2-Olympic Peninsula, 3-Southwest Washington, and 4-Lower Columbia River. All data are for winter steelhead, except as noted (see Appendix E for details).

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
Humtulsips 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	

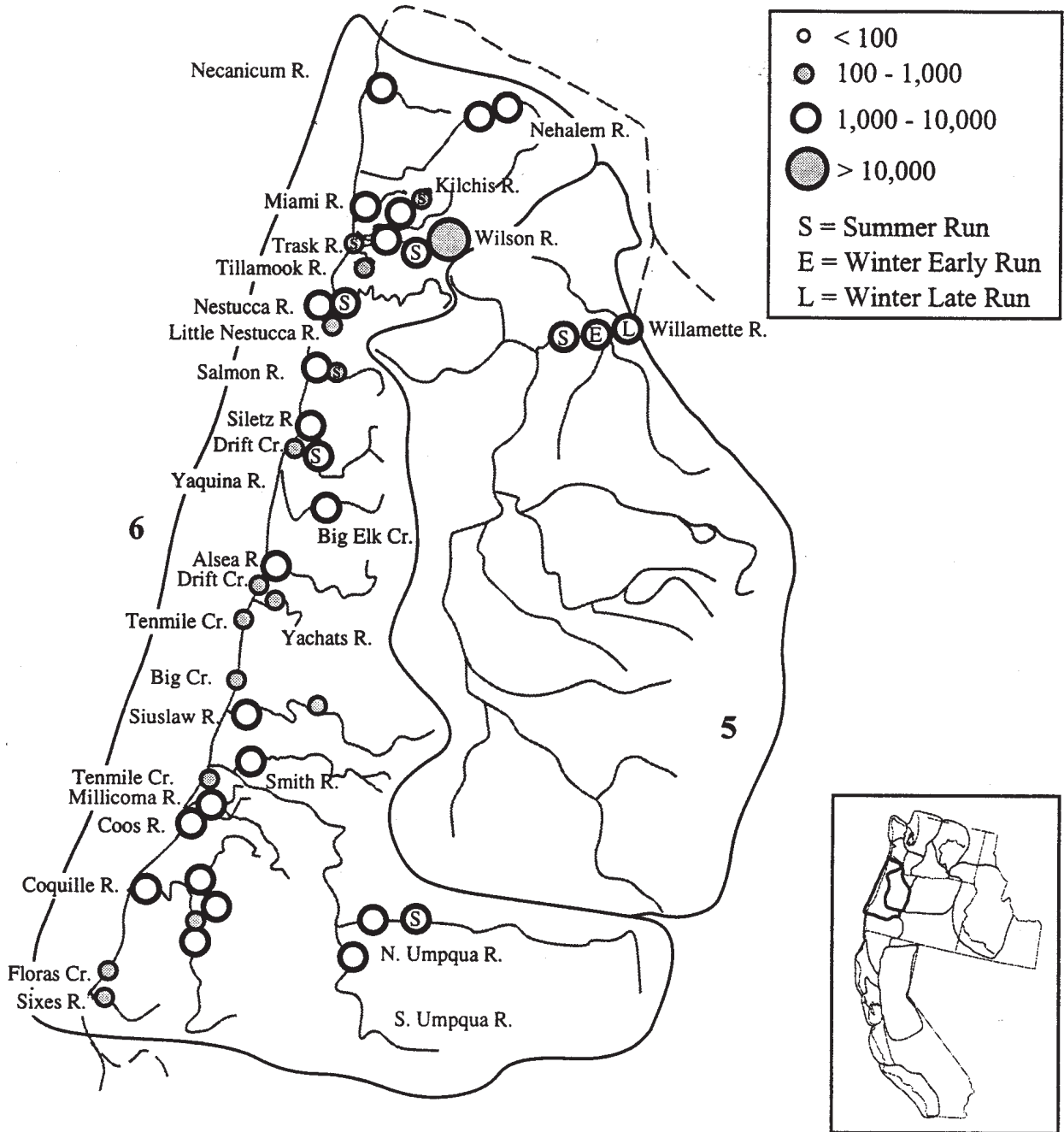


Figure 21. Recent total escapement, or run size, for populations in steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details).

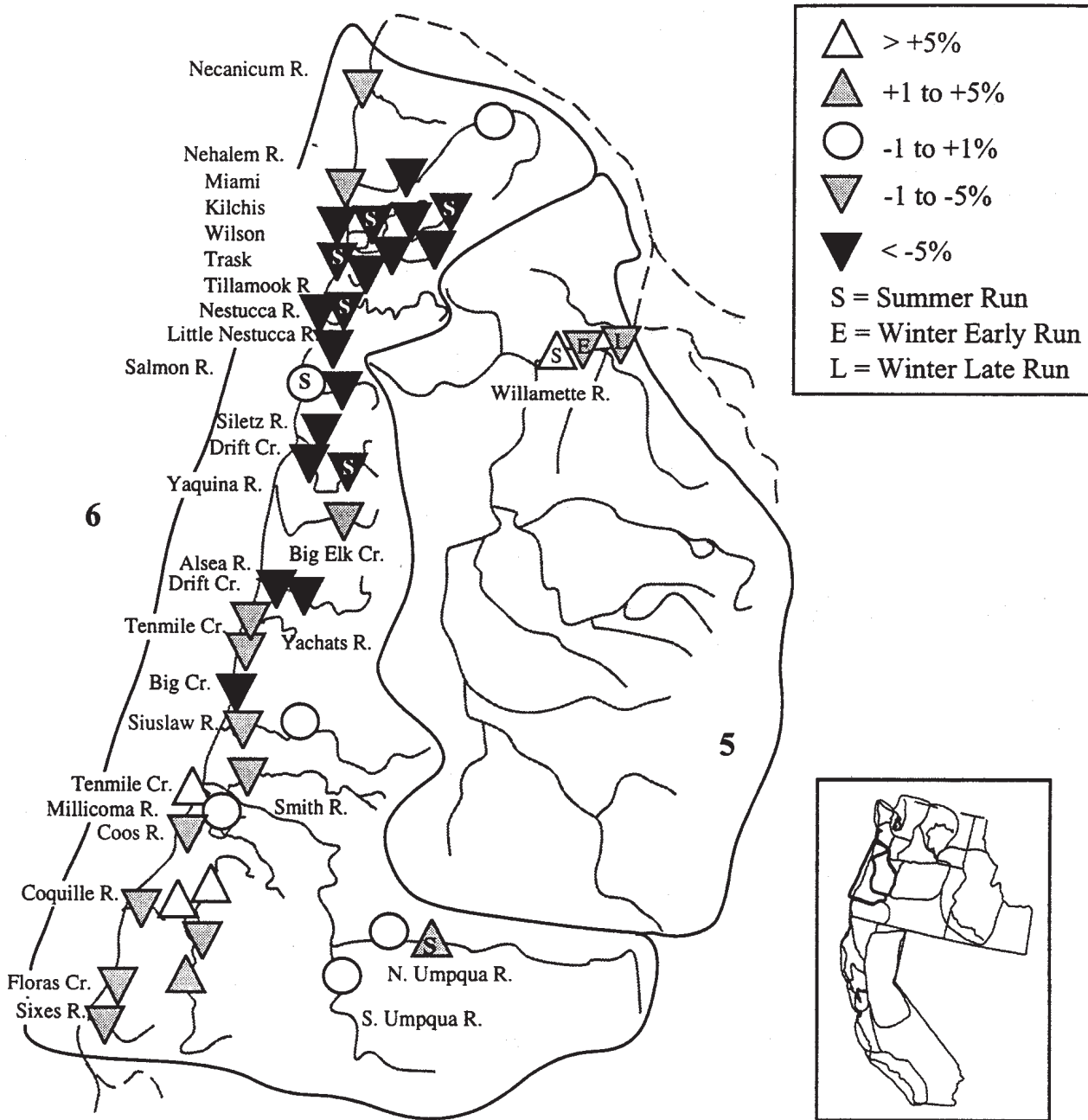


Figure 22. Trends (percent annual change) in total escapement for populations in steelhead ESUs 5-Upper Willamette River and 6-Oregon Coast. All data are for winter steelhead, except as noted (see Appendix E for details).

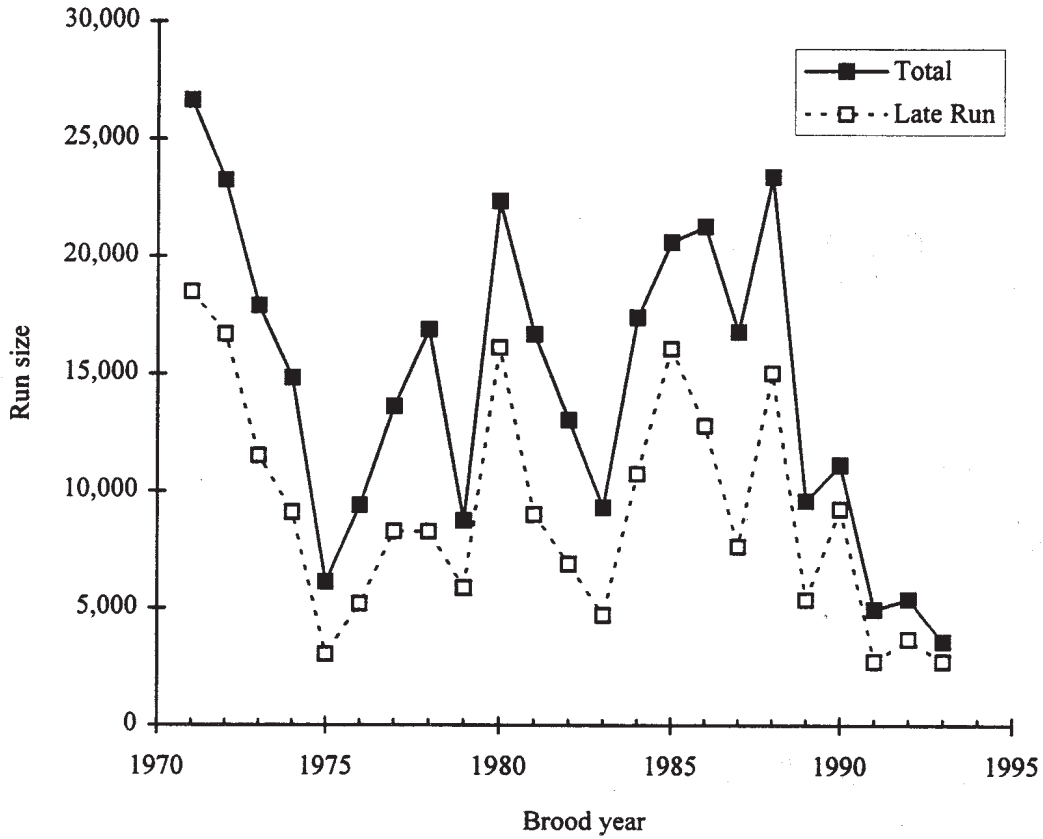


Figure 23. Estimated adult winter steelhead passing Willamette Falls, 1971-93. Data from PSMFC (1994).

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	
Alesea 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
<b>Eel River</b>			
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
<b>Mad River</b>			
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	
	<b>Total</b>	<b>198,000</b>	
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	
	<b>Total</b>	<b>94,000</b>	
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	
	<b>Total</b>	<b>27,750</b>	
Central Valley			
	Sacramento River System	26,250	
	Mokelumne River System	500	
	San Joaquin River System	0	
	<b>Total</b>	<b>26,750</b>	

\*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.

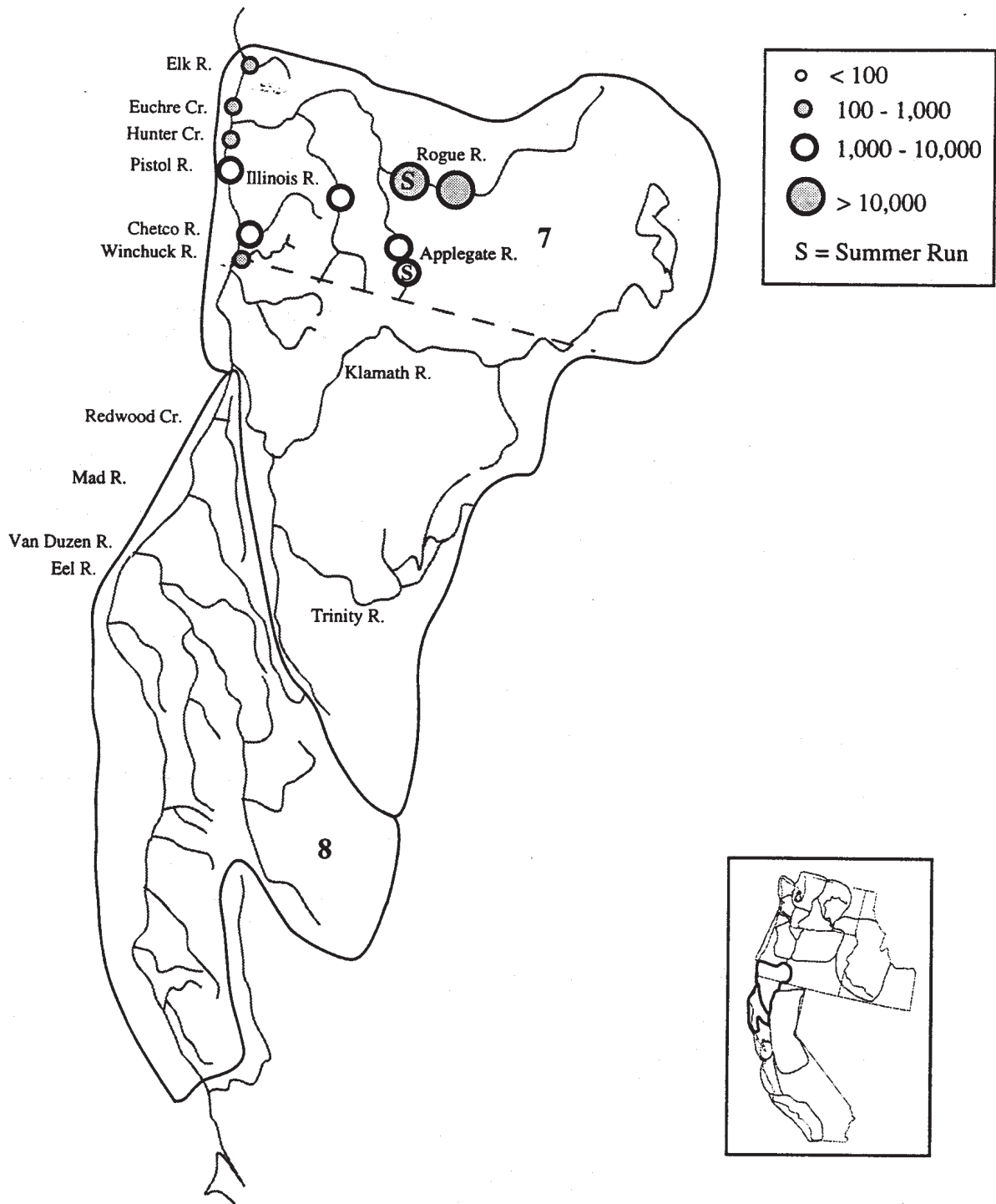


Figure 24. Recent total escapement for populations in steelhead ESU 7-Klamath Mountains Province. Where no total estimate is available, natural escapement is used. All data are for winter steelhead, except as noted (see Appendix E for details). Available abundance data for steelhead populations in ESU 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.



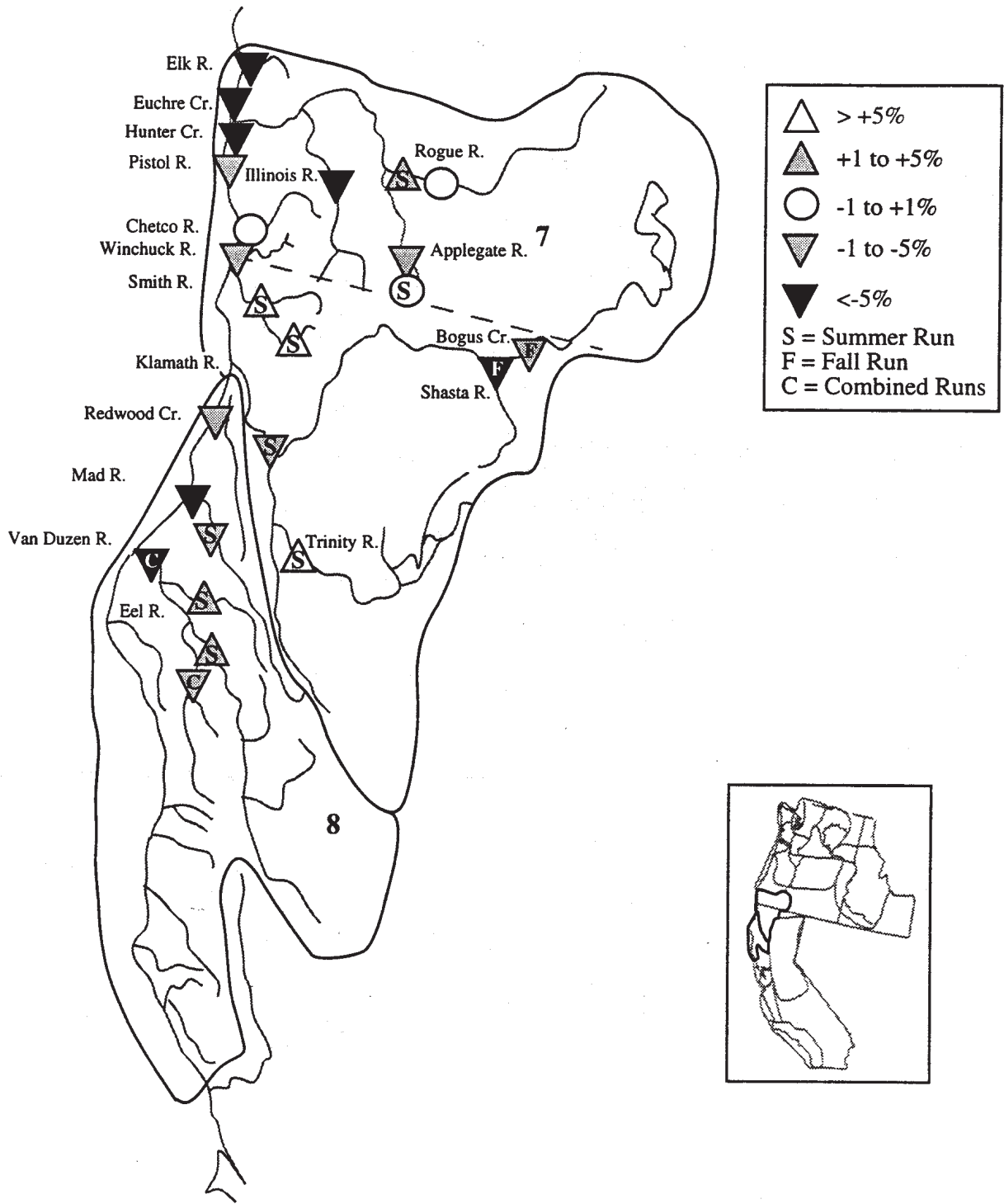


Figure 25. Trends (percent annual change) in total escapement for populations in steelhead ESUs 7-Klamath Mountains Province and 8-Northern California. All data are for winter steelhead, except as noted (see Appendix E for details).

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				

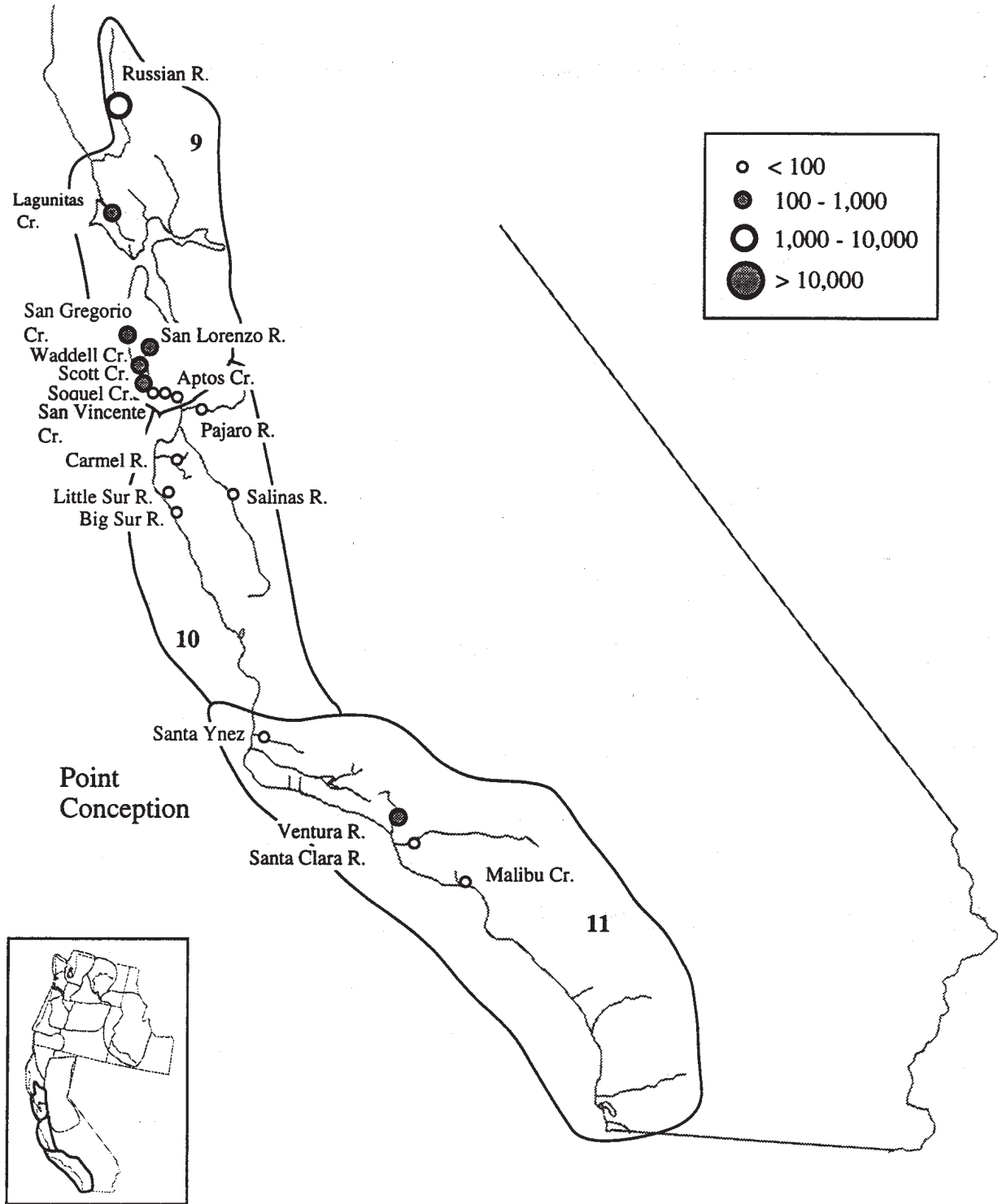


Figure 26. Recent total escapement for populations in steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California. Where no total estimate is available, natural escapement is used. All data are for winter steelhead (see Appendix E for details).

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<sup>18</sup>, Smith<sup>19</sup>).

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

---

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

<sup>19</sup> J. Smith, Department of Biological Sciences, San Jose State University, San Jose, CA 95192. Pers. commun., September 1994.

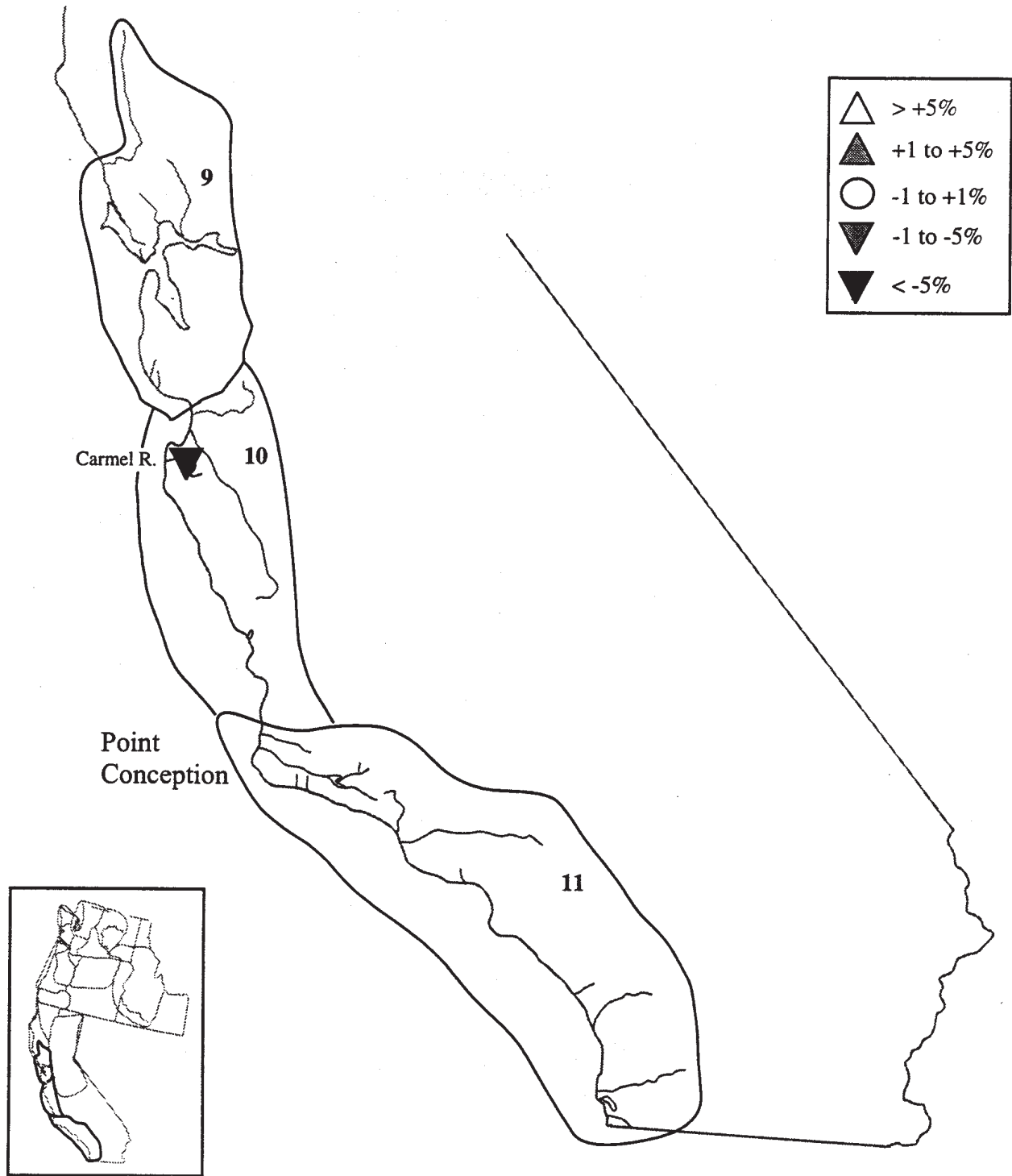


Figure 27. Trends (percent annual change) in total escapement for populations in steelhead ESUs 9-Central California Coast, 10-South-Central California Coast, and 11-Southern California. All data are for winter steelhead (see Appendix E for details).

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
	<100	1991	Reavis 1991
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	

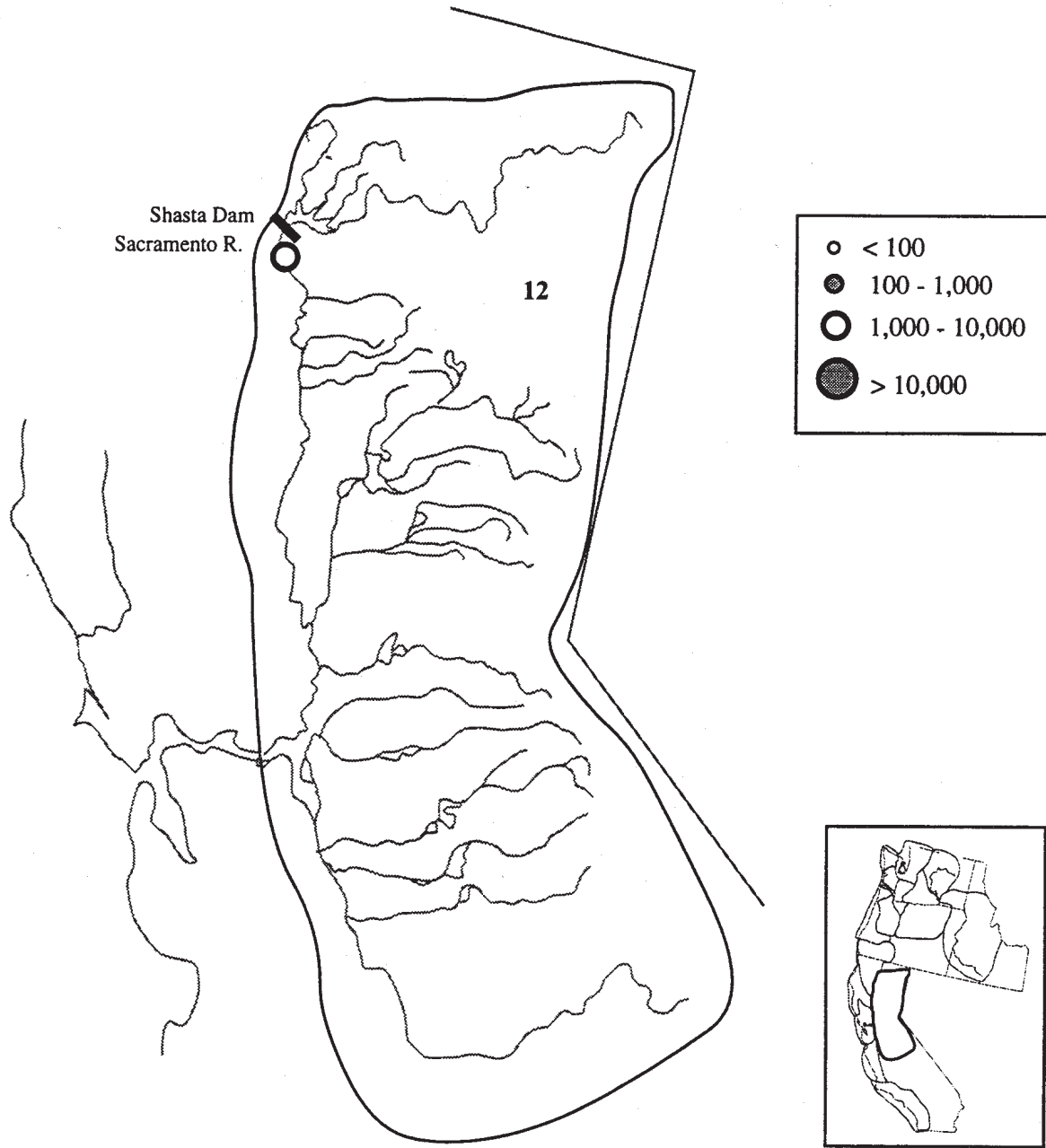


Figure 28. Recent total escapement for populations in steelhead ESU 12-Central Valley. Where no total estimate is available, natural escapement is used. All data are for winter steelhead (see Appendix E for details).

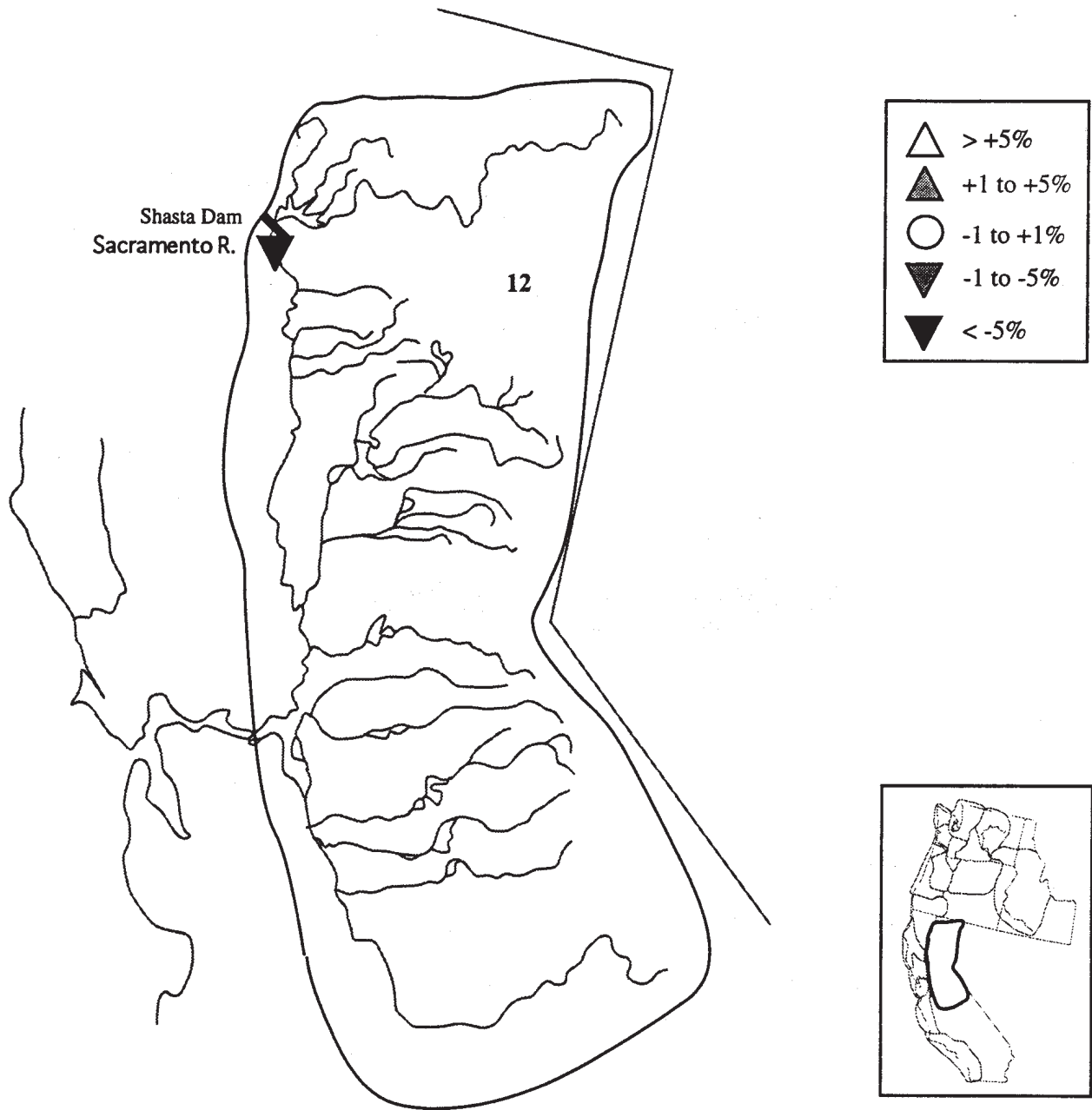


Figure 29. Trends (percent annual change) in total escapement for populations in steelhead ESU 12-Central Valley. All data are for winter steelhead (see Appendix E for details).

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

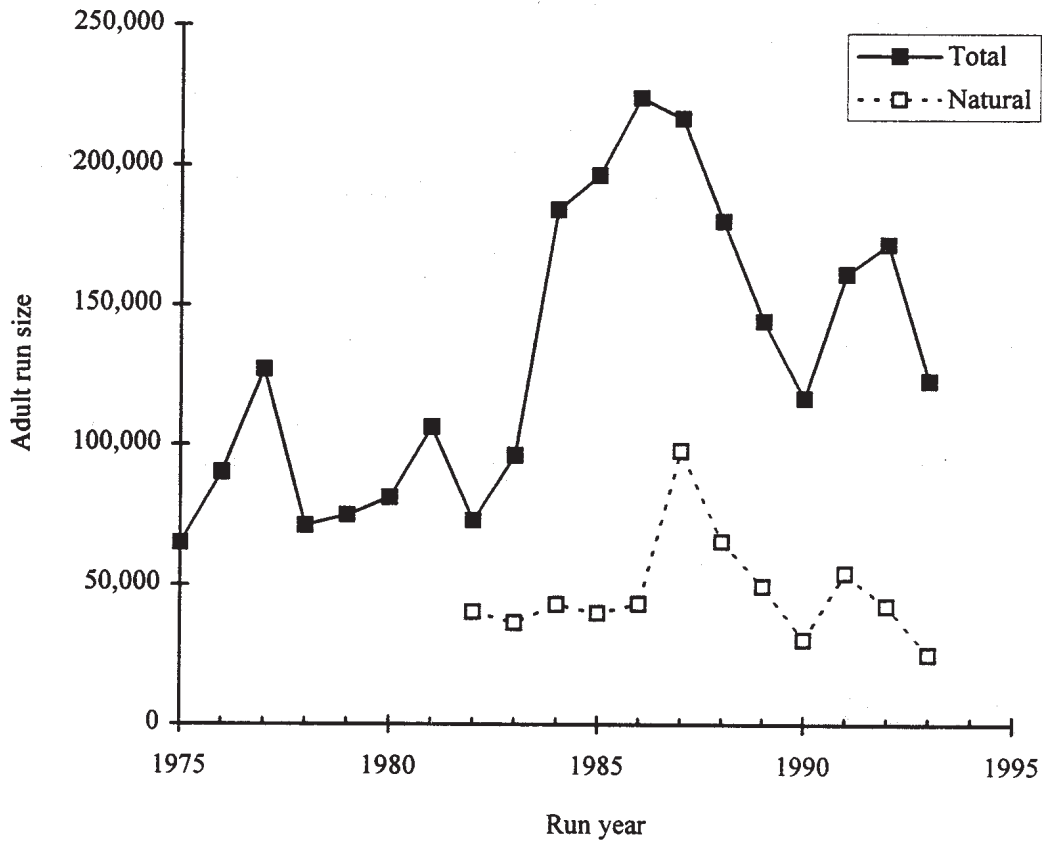


Figure 30. Estimated adult run size for steelhead ESU 13-Middle Columbia River, based on the difference between the count of steelhead passing Bonneville Dam and those passing Lower Granite Dam (Snake River) and Priest Rapids Dam (upper Columbia River), i.e. [Bonneville - (Lower Granite + Priest Rapids)]. 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

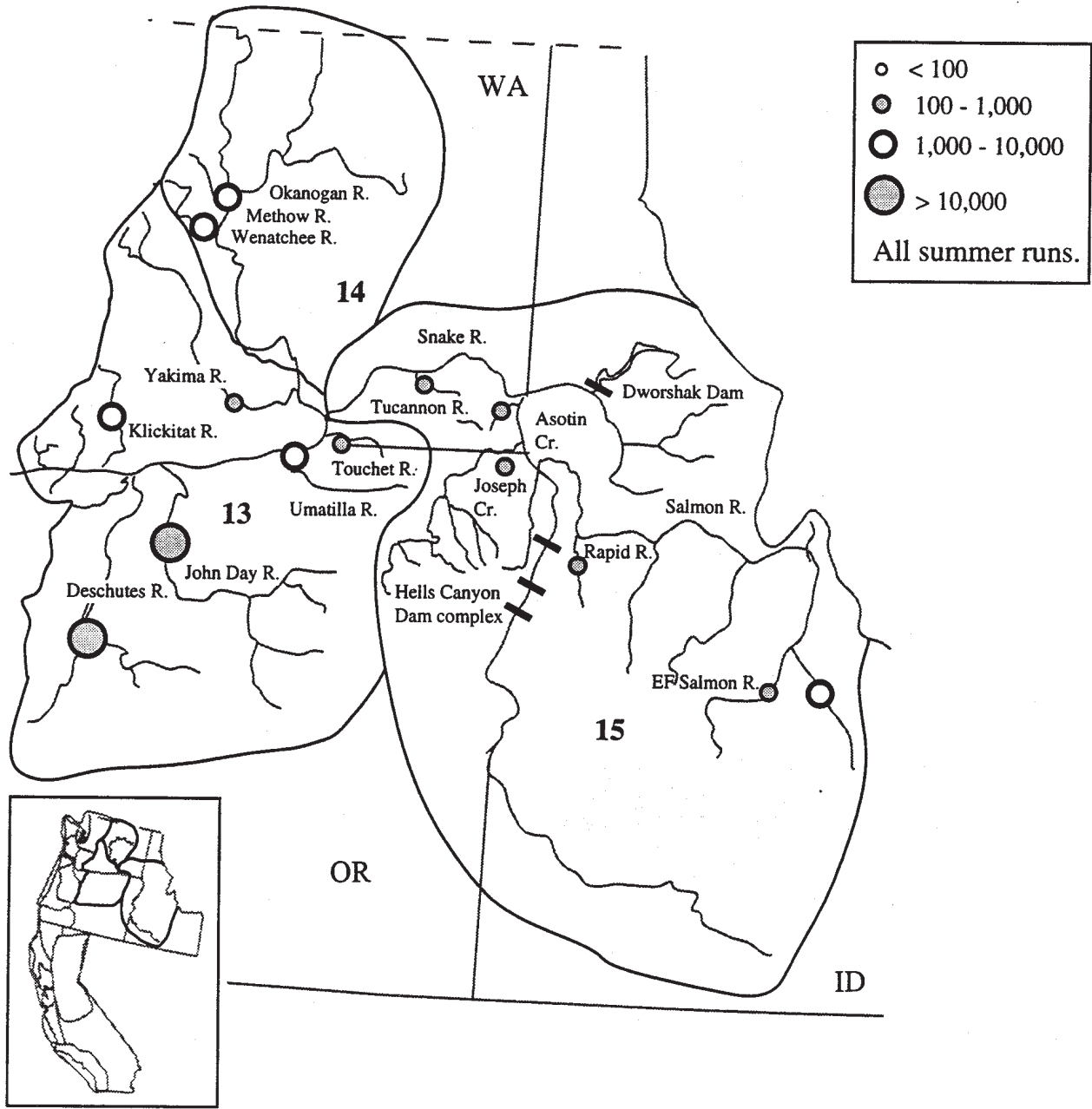


Figure 31. Recent total escapement for populations in steelhead ESUs 13-Middle Columbia River, 14-Upper Columbia River, and 15-Snake River Basin. Where no total estimate is available, natural escapement is used. All data are for summer steelhead (see Appendix E for details).



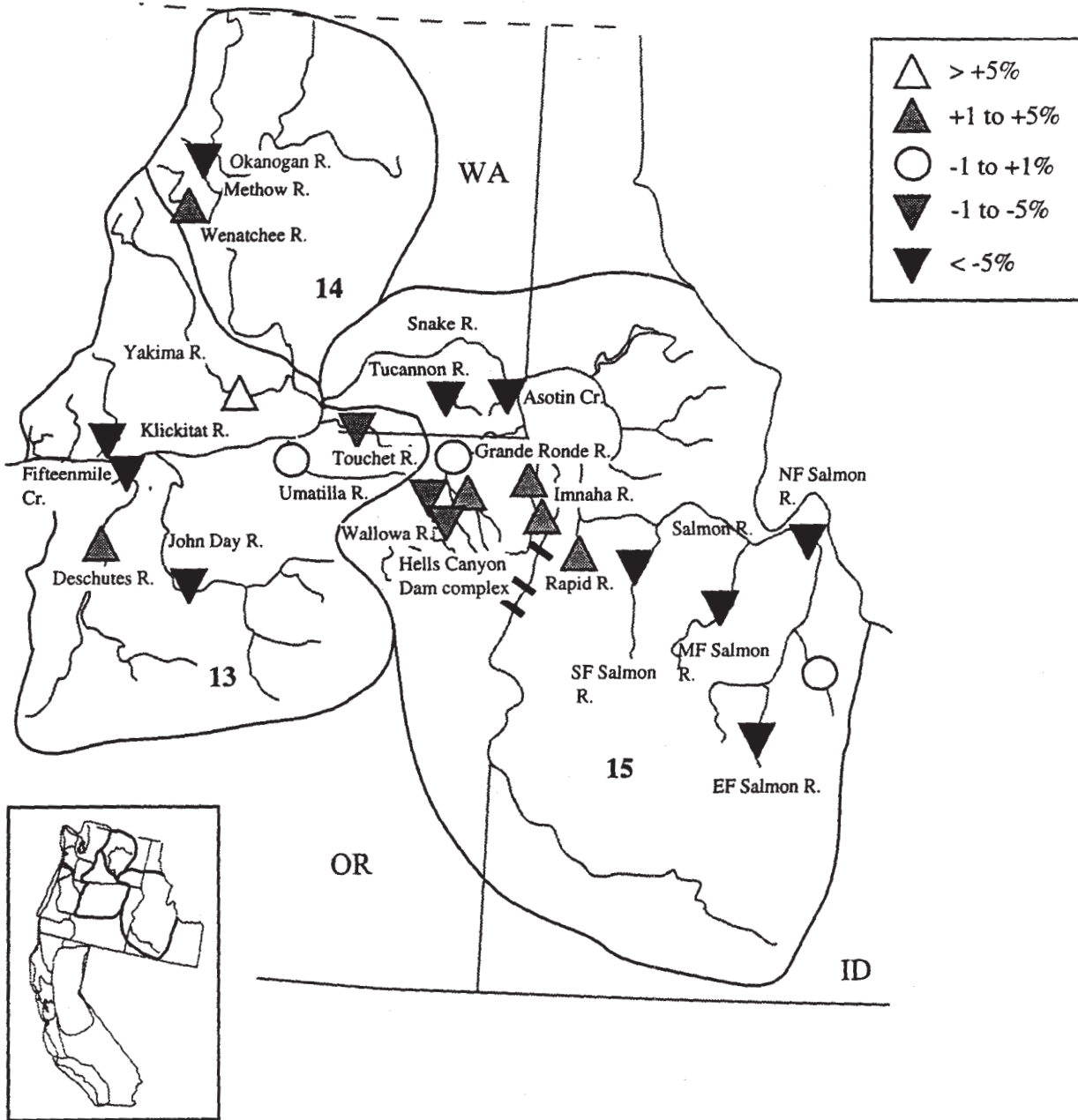


Figure 32. Trends (percent annual change) in total escapement for populations in steelhead ESUs 13-Middle Columbia River, 14-Upper Columbia River, and 15-Snake River Basin. All data are for summer steelhead (see Appendix E for details).

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.

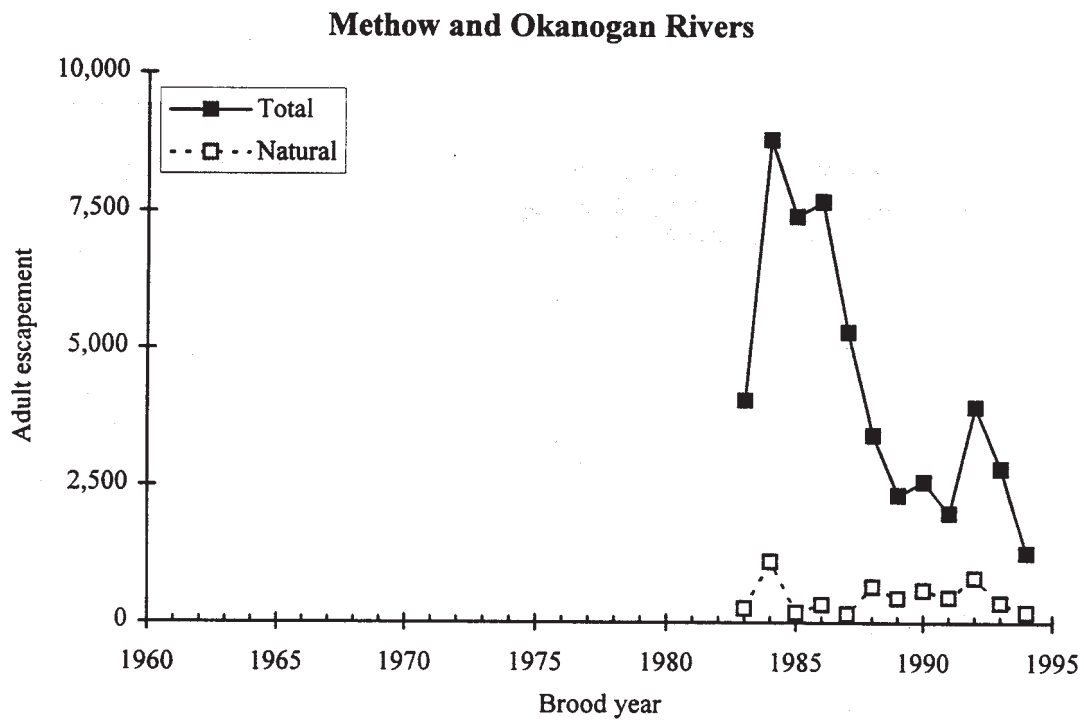
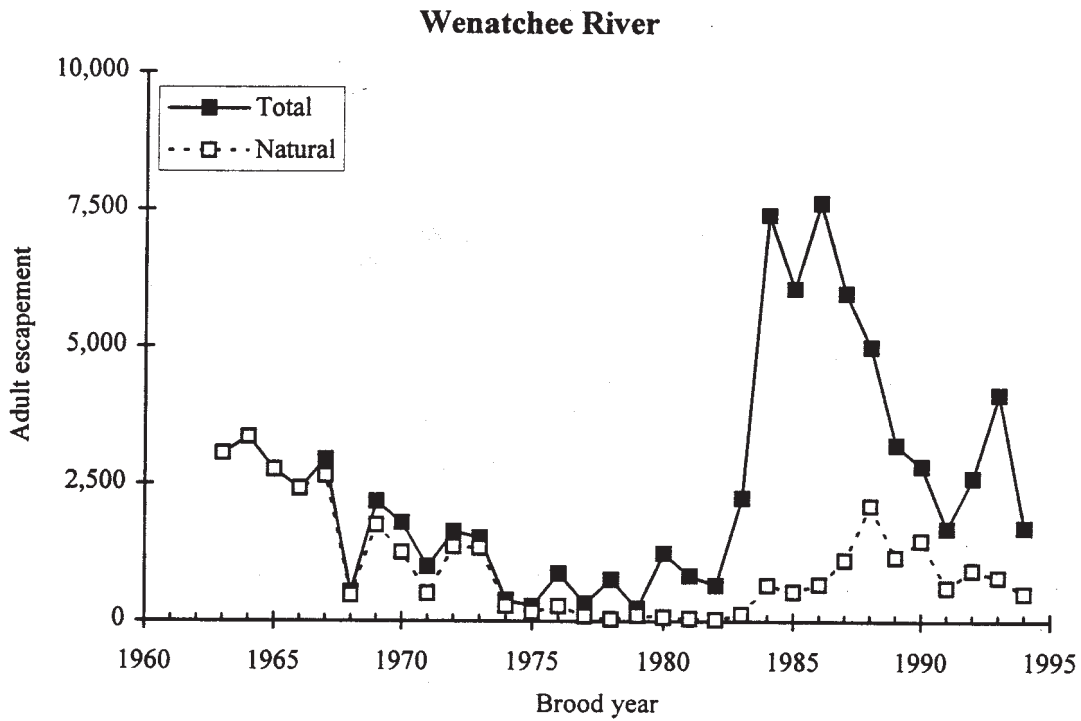


Figure 33. Estimated spawning escapement for Wenatchee and Methow/Okanogan summer steelhead stocks. Data from WDFW (1994b).

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	

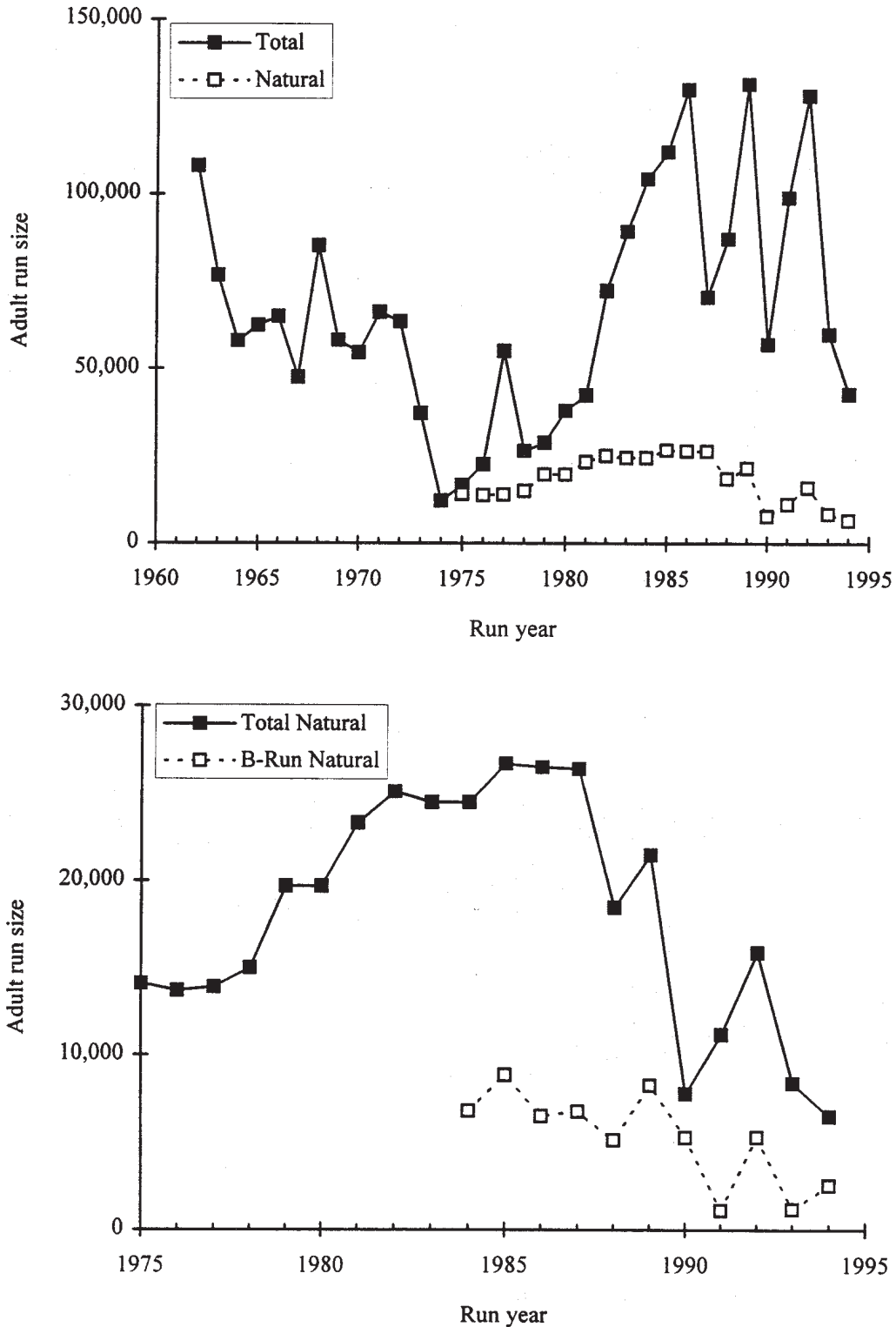


Figure 34. Estimated abundance of adult Snake River summer steelhead. Upper panel: total run size with natural run broken out beginning in 1975. Lower panel: natural run size, with natural B-run broken out beginning in 1984. Based on counts of fish passing above Lower Granite Dam (1975-94) or Ice Harbor 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.



## CITATIONS

- Aebersold, P. B., G. A. Winans, D. J. Teel, G. B. Milner, and F. M. Utter. 1987. Manual for starch gel electrophoresis: A method for the detection of genetic variation. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 61, 19 p.
- Allen, J. E., M. Burns, and S. C. Sargent. 1986. Cataclysms on the Columbia. Timber Press, Portland, OR, 213 p.
- Allen, M. J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 66, 151 p.
- Allendorf, F. W. 1975. Genetic variability in a species possessing extensive gene duplication: Genetic interpretation of duplicate loci and examination of genetic variation in populations of rainbow trout. Ph.D. Dissertation, Univ. Washington, Seattle, 98 p.
- Allendorf, F. W., and N. Ryman. 1987. Genetic management of hatchery stocks. *In* N. Ryman and F. Utter (editors), Population genetics & fishery management, p. 141-159. University of Washington Press, Seattle.
- American Fisheries Society (AFS). 1991. Minutes of southern California steelhead meeting, U.S. Fish and Wildlife Service Office, Ventura, California, January 22, 1991. Am. Fish. Soc., California-Nevada Chapter, Environmental Concerns Committee, 9 p. (Available from Trout Unlimited of California, 2530 San Pablo Ave., Suite D, Berkeley, CA 94702.)
- Bali, J. M. 1959. Scale analyses of steelhead trout, *Salmo gairdnerii gairdnerii* Richardson, from various coastal watersheds of Oregon. M.S. Thesis, Oregon State College, Corvallis, 189 p.
- Barnhart, R. A. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)--steelhead. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.60), 21 p.
- Beamish, R. J., and D. R. Bouillon. 1993. Pacific salmon production trends in relation to climate. *Can. J. Fish. Aquat. Sci.* 50:1005-1016.
- Behnke, R. J. 1992. Native trout of western North America. *Am. Fish. Soc. Monog.* 6, 275 p. American Fisheries Society, Bethesda, MD.
- Bennett, D. E. 1987. 1986 Willamette River spring chinook salmon run. ODFW Columbia River Management, 35 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

- Berg, W. J., and G. A. E. Gall. 1988. Gene flow and genetic differentiation among California coastal rainbow trout populations. *Can. J. Fish. Aquat. Sci.* 45:122-131.
- Bjornn, T. C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. *Univ. Idaho, Coll. For., Wildl. Range Sci. Bull.* 27, 57 p.
- Bonneville Power Administration (BPA). 1992. Stock summary reports for Columbia River anadromous salmonids, 5 volumes. Columbia River Coordinated Information System (CIS). (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR 97208-3621.)
- Bottom, D. L., P. J. Howell, and J. D. Rodgers. 1985. The effects of stream alterations on salmon and trout habitat in Oregon. Oregon Department of Fish and Wildlife, 70 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Briggs, J. C. 1974. *Marine zoogeography*. McGraw-Hill, New York, 475 p.
- Briggs, J. C. 1986. Introduction to the zoogeography of North American fishes. In C. H. Hocutt and E. O. Wiley (editors), *The zoogeography of North American freshwater fishes*, p. 1-16. John Wiley and Sons, New York, 866 p.
- Brown, L., and P. Moyle. 1991. Eel River survey: Final report. Calif. Dep. Fish Game Contract F-46-R-2, 74p. + App. (Available from University of California, Davis, Department of Wildlife and Fisheries Biology, Davis, CA 95616.)
- Bryant, G. 1994. Status review of coho salmon populations in Scott Creek and Waddell Creeks, Santa Cruz County, California. *Natl. Mar. Fish. Serv.*, unpublished report, dated April 1994, 102 p. (Available from Southwest Region, *Natl. Mar. Fish. Serv.*, 501 W. Ocean Blvd., Suite 4200, Long Beach, CA 90802.)
- Burgner, R. L., J. T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and origins of steelhead trout (*Oncorhynchus mykiss*) in offshore waters of the North Pacific Ocean. *Int. North Pac. Fish. Comm. Bull.* 51, 92 p.
- Busby, P. J., O. W. Johnson, T. C. Wainwright, F. W. Waknitz, and R. S. Waples. 1993. Status review for Oregon's Illinois River winter steelhead. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-10, 85 p.
- Busby, P. J., T. C. Wainwright, and R. S. Waples. 1994. Status review for Klamath Mountains Province steelhead. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-19, 130 p.
- California Advisory Committee on Salmon and Steelhead (CACSS). 1988. Restoring the balance. Calif. Dep. Fish Game, Sacramento, CA. 84 p.

- California Coastal Commission (CCC). 1994. Letter to M. Tuttle, dated 25 July 1994, re: comments on petition to list steelhead, 4 p. plus attachments. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- California Department of Fish and Game (CDFG). 1965. California Fish and Wildlife Plan. Three volumes. Sacramento, CA.
- California Department of Fish and Game (CDFG). 1982. 1982 Status report of California wild and scenic rivers salmon and steelhead fisheries. Calif. Dep. Fish Game, Sacramento, CA, 159 p.
- California Department of Fish and Game (CDFG). 1991. Sport fishing for anadromous salmonid fishes. Calif. Dep. Fish Game, Sacramento, CA, 69 p.
- California Department of Fish and Game (CDFG). 1994. Documents submitted to the ESA Administrative Record for coastal steelhead: Annual reports for salmon and steelhead hatcheries. Feather River Salmon and Steelhead Hatchery, 1963-64 through 1991-92, 29 volumes; Iron Gate Salmon and Steelhead Hatchery, 1965-66 through 1991-92, 27 volumes; Lewiston Fish Trapping Facility and Trinity River Salmon and Steelhead Hatchery, 1958-59 through 1991-92, 33 volumes; Mad River Salmon and Steelhead Hatchery, 1970-71 through 1990-91, 21 volumes; Nimbus Salmon and Steelhead Hatchery, 1955-56 through 1991-92, 37 volumes; Van Arsdale Fisheries Station, Mendocino County, 1966-67 through 1991-92, 15 volumes; Warm Springs Salmon and Steelhead Hatchery, 1980-81 through 1990-91, 11 volumes. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- California Department of Fish and Game (CDFG). 1995. Letter to M. Schiewe for the ESA Administrative Record for west coast steelhead, dated 30 March 1995, 10 p. plus attachments. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Campton, D. E., and J. M. Johnston. 1985. Electrophoretic evidence for a genetic admixture of native and nonnative rainbow trout in the Yakima River, Washington. *Trans. Am. Fish. Soc.* 114:782-793.
- Caughley, G. 1994. Directions in conservation biology. *J. Anim. Ecol.* 63:215-244.
- Cavalli-Sforza, L. L., and A. W. F. Edwards. 1967. Phylogenetic analysis: Models and estimation procedures. *Am. J. Human Genet.* 19:233-257.
- Chapman, D. W. 1958. Studies on the life history of Alsea River steelhead. *J. Wildl. Manage.* 22(2):123-134.

- Chapman, D., C. Peven, T. Hillman, A. Giorgi, and F. Utter. 1994. Status of summer steelhead in the mid-Columbia River. Don Chapman Consultants, Inc, 318 p. plus appendices. (Available from Don Chapman Consultants, Inc., 3653 Rickenbacker, Suite 200, Boise, ID 83705.)
- Chilcote, M. N., B. A. Crawford, and S. A. Leider. 1980. A genetic comparison of sympatric populations of summer and winter steelheads. *Trans. Am. Fish. Soc.* 109:203-208.
- Chilcote, M. C., C. Dale, K. Kostow, H. Schaller, and H. Weeks. 1992. Wild fish management policy. Oregon Department of Fish and Wildlife (ODFW), Biennial Progress Report, 31 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Christianson, C. 1993. Operations plan for anadromous fish production facilities in the Columbia River Basin: Volume III, Oregon Department of Fish and Wildlife hatcheries. 1992 Annual Report to the Bonneville Power Administration, Portland, Oregon, Project 92-043, 324 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Clanton, D. A., and J. F. Jarvis. 1946. Memorandum to Bureau of Fish Conservation re: field inspection trip to the Matilija-Ventura watershed in relation to the construction of the proposed Matilija Dam, dated 8 May 1946. *Calif. Dep. Nat. Resour., Div. Fish Game*, 3 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Columbia Basin Fish and Wildlife Authority (CBFWA). 1990. Integrated system plan for salmon and steelhead production in the Columbia River Basin. Columbia Basin System Planning, 449 p. and 40 subbasin volumes. (Available from Northwest Power Planning Council, 851 S.W. Sixth, Suite 1100, Portland, OR 97204-1348.)
- Columbia River Fisheries Management Plan Technical Advisory Committee (CRFMP TAC). 1991. Summer steelhead. *In* Columbia River fish management plan: 1991 All species review. Technical Advisory Committee, *U.S. v. Oregon*. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Comstock, R. 1992. Santa Clara River steelhead restoration assessment. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington, 10 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Cook, R. R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Natural Sciences, National Museums of Canada, Ottawa, 200 p.

- Cooper, R., and T. H. Johnson. 1992. Trends in steelhead abundance in Washington and along the Pacific coast of North America. Wash. Dep. Wildlife, Fish. Manage. Div., Report 92-20, 90 p. (Available from Washington Department of Wildlife, 600 Capital Way N., Olympia, WA 98501-1091.)
- Coots, M. 1973. A study of juvenile steelhead, *Salmo gairdnerii gairdnerii*, Richardson, in San Gregorio Creek lagoon, San Mateo County, March through August 1971. Calif. Dep. Fish Game Rep. 78-4, 21 p.
- Cramer, S. P., and 12 co-authors. 1995. The status of steelhead populations in California in regards to the Endangered Species Act. Document prepared for Association of California Water Agencies, 167 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Crawford, B. A. 1979. The origin and history of the trout brood stocks of the Washington Department of Game. Washington State Game Dep., Fishery Research Report, 76 p. (Available from Washington Department of Fish and Wildlife, 600 Capital Way N., Olympia, WA 98501.)
- Currens, K. P. and C. B. Schreck. 1993. Genetic analysis of Umatilla River rainbow trout. Final Report. Project No. 90-005, Bonneville Power Administration, Portland, OR, 40 p. plus appendix.
- Currens, K. P., C. B. Schreck, and H. W. Li. 1990. Allozyme and morphological divergence of rainbow trout (*Oncorhynchus mykiss*) above and below waterfalls in the Deschutes River, Oregon. *Copeia* 1990:730-746.
- Currens, K. P., S. L. Stone, and C. B. Schreck. 1987. A genetic comparison of rainbow trout (*Salmo gairdneri*) above and below Izee Falls in the John Day River, Oregon. Oregon Coop. Fish. Res. Unit Genet. Lab. Rep. 87(2), 34 p. (Available from Oregon Cooperative Fishery Research Unit, Oregon State University, Corvallis, OR 97331.)
- Delarm, M. R., and R. Z. Smith. 1990a. Assessment of present anadromous fish production facilities in the Columbia River Basin, Volume 1: U.S. Fish and Wildlife hatcheries. Report to U.S. Department of Energy, Contract DE-AI79-89BP98379, Project 89-045, 106 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Delarm, M. R., and R. Z. Smith. 1990b. Assessment of present anadromous fish production facilities in the Columbia River Basin, Volume 2: Idaho Department of Fish and Game hatcheries. Report to U.S. Department of Energy, Contract DE-AI79-89BP98379, Project 89-045, 77 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)

- Delarm, M. R., and R. Z. Smith. 1990c. Assessment of present anadromous fish production facilities in the Columbia River Basin, Volume 3: Oregon Department of Fish and Wildlife hatcheries. Report to U.S. Department of Energy, Contract DE-AI79-89BP98379, Project 89-045, 177 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Delarm, M. R., and R. Z. Smith. 1990d. Assessment of present anadromous fish production facilities in the Columbia River Basin, Volume 5: Washington Department of Wildlife hatcheries. Report to U.S. Department of Energy, Contract DE-AI79-89BP98379, Project 89-045, 122 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Donley, M. W., S. Allan, P. Caro, and C. P. Patton. 1979. Atlas of California. Pacific Book Center, Culver City, CA, 191 p.
- Everest, F. H. 1973. Ecology and management of summer steelhead in the Rogue River. Oregon State Game Comm., Fishery Research Report 7, Corvallis, 48 p.
- Fagen, R., and W. W. Smoker. 1989. How large-capacity hatcheries can alter interannual variability of salmon production. Fish. Res. 8:1-11.
- Fish, F. F., and M. G. Hanavan. 1948. A report on the Grand Coulee Fish Maintenance Project 1938-1947. U.S. Fish Wildl. Serv. Spec. Sci. Rep. 55.
- Foott, J. S., R. L. Walker, J. D. Williamson, and K. C. True. 1994. Health and physiology monitoring of chinook and steelhead smolts in the Trinity and Klamath Rivers. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, unpubl. rep., 12 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Forsgren, H. L. 1979. Age, growth, origin and repeat spawning of winter steelhead (*Salmo gairdneri*) in Mad River, California. M.S. Thesis, Humboldt State Univ., Arcata, CA, 56 p.
- Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-8, 417 p. (Available from U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station, P.O. Box 3890, Portland, OR 97208.)
- Freese, J. L. 1982. Selected aspects of the ecology of adult summer steelhead in the Trinity River, California. M.S. Thesis, Humboldt State University, Arcata, CA.
- Frenkel, R. E. 1993. Vegetation. In P. L. Jackson and A. J. Kimerling (editors), Atlas of the Pacific Northwest, p. 58-65. Oregon State University Press, Corvallis.



- Fulton, L. A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River Basin--past and present. U.S. Dep. Commer., Natl. Mar. Fish Serv., Spec. Sci. Rep. Fish. 618, 37 p.
- Gall, G. A. E., B. Bentley, and R. C. Nuzum. 1990. Genetic isolation of steelhead rainbow trout in Kaiser and Redwood Creeks, California. Calif. Fish Game 76(4):216-223.
- Gilpin, M. E., and M. E. Soulé. 1986. Minimum viable populations: Processes of species extinction. In M. E. Soulé (editor), Conservation biology: The science of scarcity and diversity, p. 19-34. Sinauer Associates, Sunderland, MA.
- Graves, D. S., and J. W. Burns. 1970. Comparison of yields of downstream migrant salmonids before and after logging road construction on the South Fork Casper Creek, Mendocino County. Calif. Dep. Fish Game Inland Fisheries Admin. Rep. 70-3, 12 p.
- Hallock, R. J. 1989. Upper Sacramento River steelhead, *Oncorhynchus mykiss*, 1952-1988. A report prepared for the U.S. Fish and Wildlife Service, Red Bluff, CA, 86 p.
- Hallock, R. J., W. F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River system. Calif. Fish Game Fish Bull. 114, 73 p.
- Hard, J. J., R. P. Jones, Jr., M. R. Delarm, and R. S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-2, 56 p.
- Harper, W. G. 1980. Age, growth, and migration of coho salmon and steelhead trout in Jacoby Creek, California. M.S. Thesis, Humboldt State Univ., Arcata, CA, 104 p.
- Hassemer, P. F. 1992. Run composition of 1991-92 run-year Snake River summer steelhead measured at Lower Granite Dam. Report to the National Oceanic and Atmospheric Administration, Award NA90AA-D-IJ718, 4 p. (Available from Idaho Fish and Game, 600 South Walnut, Box 25, Boise, ID 83707-0025.)
- Hatch, K. M. 1990. A phenotypic comparison of thirty-eight steelhead (*Oncorhynchus mykiss*) populations from coastal Oregon. M.S. Thesis, Oregon State Univ., Corvallis, 55 p.
- Healey, M. C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. In W. J. McNeil and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific, p. 203-229. Oregon State University Press and Oregon State University Sea Grant College Program, Corvallis.

- Henke, E. 1994. Letters to G. Bryant re: information on steelhead for the Administrative Record for west coast steelhead. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Hershberger, W. K., and D. Dole. 1987. Genetic identification of salmon and steelhead stocks in the mid-Columbia River. Report for Don Chapman Consultants, Inc. (Available from Don Chapman Consultants, Inc., 3653 Rickenbacker, Suite 200, Boise, ID 83705.)
- Higgins, P. 1991. Southern California steelhead recovery assessment. Report to the South Coast Chapter, Trout Unlimited, 26 p. (Available from Trout Unlimited of California, 2530 San Pablo Ave., Suite D, Berkeley, CA 94702.)
- Higgins, P., S. Dobush, and D. Fuller. 1992. Factors in northern California threatening stocks with extinction. Humboldt Chapter of the American Fisheries Society, Arcata, CA. 24 p. (Available from Humboldt Chapter of the American Fisheries Society, P.O. Box 210, Arcata, CA 95521.)
- Howell, P., K. Jones, D. Scarnecchia, L. LaVoy, W. Kendra, and D. Ortmann. 1985. Stock assessment of Columbia River anadromous salmonids Volume II: Steelhead stock summaries stock transfer guidelines—information needs. Final Report to Bonneville Power Administration, Contract DE-AI79-84BP12737, Project 83-335, 1032 p. (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR 97208.)
- Huew, T., L. Dingwall, and R. Rathvon. 1990. Progress report for Whitehorse, Skykomish and Barnaby Slough rearing ponds, July 1, 1989 - June 30, 1990. Wash. Dep. Wildl. Fish. Manage. Div. Rep. 90-15, 25 p. (Available from Washington Department of Fish and Wildlife, Fisheries Management Program, 600 Capitol Way N, Olympia, WA 98501-1091.)
- Hunt, L. E., P. E. Lehman, and M. H. Capelli. 1992. Vertebrate resources at Emma Wood State Park and the Ventura River estuary, Ventura County, California: Inventory and management. Calif. Dep. Parks Rec., document dated 6 November 1992, 107 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Hutchison, B. 1993. Operation plans for anadromous fish production facilities in the Columbia River Basin, Volume II: Idaho Department of Fish and Game hatcheries. 1992 Annual Report to the Bonneville Power Administration, Contract DE-BJ79-91BP60629, 92 p. (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR 97208.)

- Huzyk, L., and H. Tsuyuki. 1974. Distribution of LDH-B" gene in resident and anadromous rainbow trout (*Salmo gairdneri*) from streams in British Columbia. J. Fish. Res. Board Can. 31:106-108.
- Hydrosphere. 1993. Hydrodata USGS daily values: West 1 and West 2. CD-ROM data bases. Hydrosphere Data Products, Inc., 1002 Walnut, Suite 200, Boulder, CO 80302.
- Idaho Department of Fish and Game (IDFG). 1994. Documents submitted to the ESA Administrative Record for west coast steelhead by E. Leitzinger, 18 October 1994. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Idaho Department of Fish and Game (IDFG). 1995. Correspondence to P. Busby for submission to the ESA Administrative Record for west coast steelhead, and enclosures, dated 2 and 29 March 1995. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Jackson, P. L. 1993. Climate. In P. L. Jackson and A. J. Kimerling (editors), Atlas of the Pacific Northwest, p. 48-57. Oregon State Univ. Press, Corvallis.
- Johnson, M. L. 1964. San Lorenzo River System, Santa Cruz County. Calif. Dep. Fish Game, Region 3, unpubl. file rep, 8 p. (Available from the Administrative Record for coho salmon in Scott and Waddell Creeks, Natl. Mar. Fish. Ser., Southwest Region, 501 W. Ocean Boulevard, Suite 4200, Long Beach, CA 90802-4213.)
- Kenaston, K. R. 1989. Estimated run size of winter steelhead in Oregon coastal streams, 1980-85. Info. Rep. 89-1, 18 p. Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.
- Kesner, W. D., and R. A. Barnhart. 1972. Characteristics of the fall-run steelhead trout (*Salmo gairdneri gairdneri*) of the Klamath River system with emphasis on the half-pounder. Calif. Fish Game 58(3):204-220.
- Koski, R. O. 1963. Salmon and steelhead catch data, 1953-62. Oregon State Game Commission, Fishery Division. Unpublished data tables. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Kostow, K. (editor). 1995. 1994 Biennial report of the status of wild fish in Oregon. Oregon Dep. Fish Wildl., Portland. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Landry, M. R., and B. M. Hickey. 1989. Coastal Oceanography of Washington and Oregon. Elsevier Oceanog. Ser. 47.

- Larson, R. W., and J. M. Ward. 1954. Management of steelhead trout in the state of Washington. *Trans. Am. Fish. Soc.* 84:261-274.
- Lawson, P. W. 1993. Cycles in ocean productivity, trends in habitat quality, and the restoration of salmon runs in Oregon. *Fisheries* 18(8):6-10.
- Leider, S. A., P. L. Hulett, and T. H. Johnson. 1994. Preliminary assessment of genetic conservation management units for Washington steelhead: Implications for WDFWs draft steelhead management plan and the federal ESA. Washington Dep. Fish Wildl. Rep. 94-15, 42 p. (Available from Washington Department of Fish and Wildlife, Fisheries Management Program, 600 Capitol Way N, Olympia, WA 98501-1091.)
- Leider, S. A., S. R. Phelps, and P. L. Hulett. 1995. Genetic analysis of Washington steelhead: Implications for revision of genetic conservation management units. Wash. Dep. Fish Wildl. Prog. Rep., 21 p. (Available from Washington Department of Fish and Wildlife, Fish Management Program, 600 Capitol Way N, Olympia, WA 98501-1091.)
- Leitzinger, E. J., and C. E. Petrosky. In press. Idaho natural production monitoring: Part I. General monitoring subproject Annual Report for 1993, prepared for Bonneville Power Administration, Project 91-73, 14 p. (Available from Idaho Fish and Game, 600 South Walnut, Box 25, Boise, ID 83707-0025.)
- Leonard, W. P., H. A. Brown, L. L. Jones, K. R. McAllister, and R. M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, 168 p.
- Light, J. T. 1987. Coastwide abundance of North American steelhead trout. (Document submitted to the annual meeting of the INPFC, 1987.) Fisheries Research Institute Report FRI-UW-8710. Univ. Washington, Seattle, 18 p.
- Light, J. T. 1989. The magnitude of artificial production of steelhead trout along the Pacific coast of North America. Fisheries Research Institute Report FRI-UW-8913. Univ. Washington, Seattle, 11 p.
- Lindsay, R. B., K. R. Kenaston, and R. K. Schroeder. 1991. Steelhead production factors. Oregon Dep. Fish Wildl., Annual Prog. Rep., 19 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Maher, F. P., and P. A. Larkin. 1955. Life history of the steelhead trout of the Chilliwack River, British Columbia. *Trans. Am. Fish. Soc.* 84:27-38.
- Matthews, G. M., and R. S. Waples. 1991. Status review for Snake River spring and summer chinook salmon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-200, 75 p.

- McEwan, D., and T. A. Jackson. 1996. Steelhead restoration and management plan for California. California Dep. Fish Game, 234 p. (Available from California Department of Fish and Game, Inland Fisheries Division, 1416 Ninth Street, Sacramento, CA 95814.)
- McPhail, J. D., and C. C. Lindsey. 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north to the Stikine). *In* C. H. Hocutt and E. O. Wiley (editors), The zoogeography of North American freshwater fishes, p. 615-637. John Wiley and Sons, New York, 866 p.
- Meyer Resources. 1988. Benefits from present and future salmon and steelhead production in California. Report to the California Advisory Committee on Salmon and Steelhead, 78 p. (Available from California Advisory Committee on Salmon and Steelhead Trout, 120 Schoonmaker Point, Foot of Spring Street, Sausalito, CA 94965.)
- Milner, G. 1977. Biochemical genetic variation: Its use in mixed fishery analysis. *In* T. J. Hassler and R. R. Van Kirk (editors), Genetic implications of steelhead management, p. 10-15. Calif. Coop. Fish. Res. Unit, Spec. Rep. 77-1. (Available from California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA 95521.)
- Milner, G. B., and D. J. Teel. 1985. Genetic Variation in Steelhead Populations of the Snake River. Final Report to the Nez Perce Tribe Fisheries Department. Northwest and Alaska Fisheries Center, National Marine Fisheries Service. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.)
- Minckley, W. L., D. A. Hendrickson, and C. A. Bond. 1986. Geography of western North American freshwater fishes: Description and relationships to intracontinental tectonism. *In* C. H. Hocutt and E. O. Wiley (editors), The zoogeography of North American freshwater fishes, p. 519-613. John Wiley and Sons, New York, 866 p.
- Monaco, M. E., T. A. Lowery, and R. L. Emmett. 1992. Assemblages of U.S. west coast estuaries based on the distribution of fishes. *J. Biogeogr.* 19:251-267.
- Moore, M. M. 1980. Factors influencing the survival of juvenile steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Ventura River. M.S. Thesis, Humboldt State Univ., Arcata, CA, 82 p.
- Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley, 405 p.
- Moyle, P. B., and R. M. Yoshiyama. 1992. Fishes, aquatic diversity management areas, and endangered species: A plan to protect California's native aquatic biota. California Policy Seminar Report, California Policy Seminar, Univ. Cal., Berkeley, 22 p. (Available from The California Policy Seminar, University of California, 2020 Milvia Street, Suite 412, Berkeley, CA 94720.)

- Mullan, J. W., K. R. Williams, G. Rhodus, T. W. Hillman, and J. D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. Monograph I, U.S. Fish and Wildlife Service, Box 549, Leavenworth, WA 98826, 489 p.
- Murphy, G. I., and L. Shapovalov. 1951. A preliminary analysis of northern California salmon and steelhead runs. *Calif. Fish Game* 37(4):497-507.
- Narver, D. W. 1969. Age and size of steelhead trout in the Babine River, British Columbia. *J. Fish. Res. Board Can.* 26(10):2754-2760.
- Narver, D. W. 1974. Age and size of Nahmint River summer steelhead in anglers' catches, 1973. *Fish. Res. Board Can., Nanaimo Biol. Sta. Circ.* 97, 15 p.
- Narver, D. W., and F. C. Withler. 1974. Steelhead of the Nanaimo River—Aspects of their biology and the fishery from 3 years of anglers' catches. *Fish. Res. Board Can., Nanaimo Biol. Sta. Circ.* 99, 25 p.
- Nash, L. 1993. Environment and drought in California, 1987-1992: Impacts and implications for aquatic and riparian resources. Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, July 1993, 96 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- National Marine Fisheries Service (NMFS). In press a. Factors for decline: A supplement to the notice of determination for west coast steelhead under the Endangered Species Act. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- National Marine Fisheries Service (NMFS). In press b. Steelhead conservation efforts: A supplement to the notice of determination for west coast steelhead under the Endangered Species Act. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- National Marine Fisheries Service (NMFS). 1991. Notice of policy: Policy on applying the definition of species under the Endangered Species Act to Pacific salmon. *Federal Register* [Docket 910248-1255, 20 November 1991] 56(224):58612-58618.
- National Marine Fisheries Service (NMFS). 1993a. Endangered and threatened species; Illinois River winter steelhead in Oregon. *Federal Register* [Docket 930517-3117, 20 May 1993] 58(96):29390-29392.
- National Marine Fisheries Service (NMFS). 1993b. Interim policy on artificial propagation of Pacific salmon under the Endangered Species Act. *Federal Register* [Docket 921186-2286, 5 April 1993] 58(63):17573-17576.

- National Marine Fisheries Service. 1994a. Conclusions of the Northwest Fisheries Science Center's review of the status of coho salmon from California, Oregon, and Washington under the U.S. Endangered Species Act. NMFS Northwest Fisheries Science Center, Seattle, WA, 2 September 1994.
- National Marine Fisheries Service (NMFS). 1994b. Endangered and threatened species; Deer Creek summer steelhead. Federal Register [Docket 941095-4295, 21 November 1994] 59(223):59981-59983.
- National Marine Fisheries Service (NMFS). 1995. Endangered and threatened species; proposed threatened status for southern Oregon and northern California steelhead. Federal Register [Docket 941084-4284, 16 March 1995] 60(51):14253-14261.
- Neeley, D. 1995. A statistical evaluation of coastal California steelhead genetic data gathered by J. L. Nielsen et al. and by Trihey and Associates. Unpubl. rep. prepared under subcontract to Trihey & Associates for S. P. Cramer & Associates, 25 p. IntSTATS, Oregon City, Oregon. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21.
- Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583-590.
- Nelson, J. 1994. Coho salmon and steelhead habitat and population surveys of Scott Creek, Santa Cruz, California, 1993. Calif. Dep. Fish Game Annual Rep., 52 p.
- Nicholas, J. W., and D. G. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins: Description of life histories and assessment of recent trends in run strengths. Oregon Dep. Fish Wildl. Info. Rep. 88-1, 359 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Nickelson, T. E., J. W. Nicholas, A. M. McGie, R. B. Lindsay, D. L. Bottom, R. J. Kaiser, and S. E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Oregon Department of Fish and Wildlife, Research and Development Section and Ocean Salmon Management. Unpubl. manuscr., 83 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Nielsen, J. L. 1994. Molecular genetics and stock identification in Pacific salmon (*Oncorhynchus* spp.). Ph.D. Dissertation, Univ. California, Berkeley, 167 p.
- Nielsen, J. L., C. A. Gan, J. M. Wright, D. B. Morris, and W. K. Thomas. 1994. Biogeographic distribution of mitochondrial and nuclear markers for southern steelhead. Mol. Mar. Biol. Biotech. 3(5):281-293.

- Northwest Indian Fisheries Commission (NWIFC). 1994. Summary of tribal steelhead releases. Letter submitted to the ESA Administrative Record for west coast steelhead, dated 16 September 1994. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Okazaki, T. 1984. Genetic divergence and its zoogeographical implications in closely related species *Salmo gairdneri* and *Salmo mykiss*. Japanese J. Ichthyol. 31:297-310.
- Omernik, J. M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Am. Geogr. 77:118-125.
- Oregon Department of Fish and Wildlife (ODFW). 1980. Oregon Salmon and Steelhead Catch Data, 1969-79, submitted to the ESA Administrative Record for Illinois River winter steelhead. Unpublished data tables. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Oregon Department of Fish and Wildlife (ODFW). 1986. Steelhead management plan 1986-1992, 146 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Oregon Department of Fish and Wildlife (ODFW). 1990. Effects of Lost Creek Dam on winter steelhead in the Rogue River. Phase II Completion Report. Rogue Basin Fisheries Evaluation Project. U.S. Army Corps of Engineers, Contract DACW57-77-C-0033, 82 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Oregon Department of Fish and Wildlife (ODFW). 1992. Oregon Salmon and Steelhead Catch Data, 1979-91, submitted to ESA Administrative Record for Illinois River winter steelhead, 1 December 1992. Unpublished data tables. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Oregon Department of Fish and Wildlife (ODFW). 1993. Oregon Salmon and Steelhead Catch Data, 1980-92. Unpublished data tables. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Oregon Department of Fish and Wildlife (ODFW). 1994a. 1994 Biennial report on the status of wild fish in Oregon and the implementation of fish conservation policies. The Natural Production Program, Ore. Dep. Fish. Wildl., 165 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)



- Oregon Department of Fish and Wildlife (ODFW). 1994b. 1995 Statewide smolt releases: Steelhead fin marks. *Oreg. Dep. Fish Wild. Intradepartmental Memorandum* dated 28 June 1994, submitted to the ESA Administrative Record for west coast steelhead. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Oregon Department of Fish and Wildlife (ODFW). 1994c. Data for hatchery steelhead releases, 1980 to 1994. Electronic data submitted to the ESA Administrative Record for west coast steelhead, September 1994. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Oregon Department of Fish and Wildlife (ODFW). 1994d. Effects of Lost Creek Dam on summer steelhead in the Rogue River. Phase II Completion Report. Rogue Basin Fisheries Evaluation Project. U.S. Army Corps of Engineers, Contract DACW57-77-C-0033, 235 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Oregon Department of Fish and Wildlife (ODFW). 1995a. Comprehensive plan for production and management of Oregon's anadromous salmon and trout, part III: Steelhead. Draft document dated 10 March 1995, *Oreg. Dep. Fish Wildl.*, 85 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Oregon Department of Fish and Wildlife (ODFW). 1995b. Letter to M. Schiewe, dated 1 April 1994, regarding assessment of steelhead abundance in Oregon. 2 p. plus enclosures. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Oregon Natural Resources Council (ONRC), 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 Inc., Siskiyou Audubon Society, Siskiyou Regional Education Project, Trout Unlimited of Oregon, University of Oregon Survival Center, and Western Ancient Forest Campaign. 1994. Petition for a rule to list steelhead trout as threatened or endangered under the Endangered Species Act and to designate critical habitat. Unpubl. manusc., 133 p. (Document submitted to the USDOC NOAA NMFS Northwest Region, Seattle, Washington, February 1994.) (Available from Oregon Natural Resources Council, Joy Belsky, 522 S.W. 5th, No. 1050, Portland, OR 97204.)

- Oregon Natural Resources Council (ONRC), Siskiyou Regional Education Project, Federation of Fly Fishers, Kalmiopsis Audubon Society, Siskiyou Audubon Society, Klamath/Siskiyou Coalition, Headwaters, The Wilderness Society, North Coast Environmental Center, Oregon Chapter of The Sierra Club, and The National Wildlife Federation. 1992. Petition for a rule to list the Illinois River winter steelhead as threatened or endangered under the Endangered Species Act and to designate critical habitat. Unpubl. manuscript, 16 p. (Document submitted to the USDOC NOAA NMFS Northwest Region, Seattle, Washington, May 1992.) (Available from Oregon Natural Resources Council, Western Regional Office, 1161 Lincoln Street, Eugene, OR 97401.)
- Ostberg, C. O., and G. H. Thorgaard. 1994. Karyotypes of *Oncorhynchus mykiss* from three Puget Sound rivers. Washington State University, Unpubl. rep. to Washington Department of Fish and Wildlife, 10 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Pacific States Marine Fisheries Commission (PSMFC). 1994. Columbia River Basin Coordinated Information System (CIS) Computerized Distributed System. PSMFC, 45 S.E. 82nd Drive, Suite 100, Gladstone, OR 97027.
- Parkinson, E. A. 1984. Genetic variation in populations of steelhead trout (*Salmo gairdneri*) in British Columbia. Can. J. Fish. Aquat. Sci. 41:1412-1420.
- Pautzke, C. F., and R. C. Meigs. 1941. Studies on the life history of the Puget Sound steelhead trout (*Salmo gairdnerii*). Trans. Am. Fish. Soc. 70:209-220.
- Pearcy, W. G. 1992. Ocean ecology of North Pacific salmonids. University of Washington Press, Seattle, WA, 179 p.
- Pearcy, W. G., R. D. Brodeur, and J. P. Fisher. 1990. Distribution and biology of juvenile cutthroat trout *Oncorhynchus clarki clarki* and steelhead *O. mykiss* in coastal waters off Oregon and Washington. Fish. Bull., U.S. 88(4):697-711.
- Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, M. Fischer, and S. A. Leider. 1994. Yakima species interactions studies. Annual report for 1993. Project 89-105, Bonneville Power Administration, Portland, OR, 247 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Peven, C. M. 1990. The life history of naturally produced steelhead trout from the mid-Columbia River Basin. M.S. Thesis, Univ. Washington, Seattle, 96 p.
- Phelps, J. V. 1973. Salmon and Steelhead Catch Data, 1963-72. Oregon State Game Commission, Fishery Division. Unpublished data tables. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)

- Phelps, S. R., B. M. Baker, P. L. Hulett, and S. A. Leider. 1994. Genetic analysis of Washington steelhead: Initial electrophoretic analysis of wild and hatchery steelhead and rainbow trout. Washington Dep. Fish and Wildlife, Fisheries Management Program Report 94-9. (Available from Washington Department of Fish and Wildlife, Fisheries Management Program, 600 Capitol Way N., Olympia, WA 98501-1091.)
- Phelps, S. R., N. Switzler, and B. Ingram. 1990. Electrophoretic characterization of five rainbow trout collections from the White Salmon River, Washington and determination of their genetic similarities to four hatchery strains. Unpublished report to the Pacific Power and Light Company from the Washington Department of Fisheries, Olympia. 28 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Porter, S. C. 1983. Late-Quaternary environments of the United States, volume 1: The late Pleistocene. Univ. Minnesota Press, Minneapolis, 407 p.
- Portland General Electric (PGE). 1994. Fish Runs: Willamette Falls, Sandy River, Clackamas River, Deschutes River, 38 p. (Available from Portland General Electric, 121 S.W. Salmon Street, Portland, OR 97204.)
- Puckett, L. K. 1975. The status of spring-run (*Salmo gairdnerii*) of the Eel River system. Calif. Dep. Water Res. and Calif. Dep. Fish Game, Memo. Rep., 22 p. (Available from California Department of Fish and Game, Inland Fisheries Division, 1416 Ninth Street, Sacramento, CA 95814.)
- Puckett, L. K., and N. A. Villa. 1985. Lower Santa Clara River steelhead study. Calif. Dep. Fish Game, report prepared under Interagency Agreement B54179 with the Calif. Dep. Water Res., 31 p. (Available from California Department of Fish and Game, Inland Fisheries Division, 1416 Ninth Street, Sacramento, CA 95814.)
- Quinalt Fisheries Division (QFD) and Washington Department of Fish and Wildlife (WDFW). 1994a. Stock status and harvest management plan for steelhead returning to the Humptulips River in the winter of 1994-95. Joint report dated 13 December 1994, 7 p. plus appendices. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Quinalt Fisheries Division (QFD) and Washington Department of Fish and Wildlife (WDFW). 1994b. Stock status and harvest management plan for steelhead returning to the Queets River in winter 1994-95. Joint report dated 12 December 1994, 8 p. plus appendices. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)

- Quinalt Fisheries Division (QFD) and Washington Department of Fish and Wildlife (WDFW). 1995a. Stock status and harvest management plan for steelhead returning to the Chehalis River in the winter of 1994-95. Joint report dated 8 February 1995, 8 p. plus appendices. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Quinalt Fisheries Division (QFD) and Washington Department of Fish and Wildlife (WDFW). 1995b. Stock status and harvest management plan for steelhead returning to the Quinalt River in winter 1994-95. Joint report dated 9 January 1995, 8 p. plus appendices. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Reavis, B. 1991. Status of California steelhead stocks. *In* Pacific States Marine Fisheries Commission and Association of Northwest Steelheaders (organizers), International Symposium on Steelhead Trout Management, January 3-5, 1991, Portland, OR, p. 57-63. (Available from Pacific States Marine Fisheries Commission, 45 S.E. 82nd Drive, Suite 100, Gladstone, OR 97027-2522.)
- Reisenbichler, R. R., J. D. McIntyre, M. F. Solazzi, and S. W. Landino. 1992. Genetic variation in steelhead of Oregon and northern California. *Trans. Am. Fish. Soc.* 121:158-169.
- Reisenbichler, R. R., and S. R. Phelps. 1989. Genetic variation in steelhead (*Salmo gairdneri*) from the north coast of Washington. *Can. J. Fish. Aquat. Sci.* 46:66-73.
- Reynolds, F. L., T. J. Mills, R. Benthin, and A. Low. 1993. Restoring Central Valley streams: A plan for action. California Department of Fish and Game, Sacramento, CA, 184 p.
- Ricker, J., and T. Butler. 1979. San Lorenzo River watershed management plan: Fishery habitat and the aquatic ecosystem technical section. County of Santa Cruz Community Resources Agency and Calif. Dep. Fish Game, 26 p. plus references. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Ricker, W. E. 1938. "Residual" and kokanee salmon in Cultus lake. *J. Fish. Res. Bd. Can.* 4(3):192-218.
- Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. *In* R. C. Simon and P. A. Larkin (editors), *The stock concept in Pacific salmon*, p. 27-160. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

- Riggs, L. A. 1990. Principles for genetic conservation and production quality. Report to Northwest Power Planning Council. GENREC/Genetic Resource Consulting, Berkeley, CA, 20 p. plus appendices. (Available from Northwest Power Planning Council, 851 S.W. Sixth Ave., Suite 1100, Portland, OR 97204-1348.)
- Roelofs, T. D. 1983. Current status of California summer steelhead (*Salmo gairdneri*) stocks and habitat, and recommendations for their management. Submitted to USDA Forest Service, Region 5, 77 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Rosenfeld, C. L. 1993. Landforms and geology. In P. L. Jackson and A. J. Kimerling (editors), Atlas of the Pacific Northwest, p. 40-47. Oregon State University Press, Corvallis.
- Sanders, G. 1985. Summary of age, sex, run timing, and length-weight characteristics of Alaska steelhead, p. 29-49. In Alaska Dep. Fish Game, Alaska Steelhead Workshop 1985, unpubl. manusc., 134 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Schreck, C. B., H. W. Li, R. C. Hjort, and C. S. Sharpe. 1986. Stock identification of Columbia River chinook salmon and steelhead trout. Final Report to Bonneville Power Administration, Contract DE-A179-83BP13499, Project 83-451, 184 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dep. Fish Game Fish Bull. 98, 375 p.
- Shelldrake, T. 1993. Operation plans for anadromous fish production facilities in the Columbia River Basin, Volume I: U. S. Fish and Wildlife Service hatcheries. 1992 Annual Report to the Bonneville Power Administration, Contract DE-BJ79-91BP60629, 158 p. (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR 97208.)
- Sheppard, D. 1972. The present status of the steelhead trout stocks along the Pacific coast. In D. H. Rosenberg (editor), A review of the oceanography and renewable resources of the northern Gulf of Alaska, p. 519-556. IMS Report R72-23, Sea Grant Report 73-3. Institute of Marine Science, University of Alaska, Fairbanks.

- Shuman, T. 1994. Letter to the ESA Administrative Record for west coast steelhead from the Steelhead Listing Project, Santa Cruz, California, dated 5 May 1994, re: steelhead return estimates for Santa Cruz County, 2 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Simon, R. C., J. D. McIntyre, and A. R. Hemmingsen. 1986. Family size and effective population size in a hatchery stock of coho salmon (*Oncorhynchus kisutch*). *Can. J. Fish. Aquat. Sci.* 43:2434- 2442.
- Snider, W. M. 1983. Reconnaissance of the steelhead resource of the Carmel River drainage, Monterey County. Calif. Dep. Fish Game, Environmental Services Branch Admin. Rep. 83-3., 41 p. (Available from California Department of Fish and Game, Inland Fisheries Division, 1416 Ninth Street, Sacramento, CA 95814.)
- Snyder, J. O. 1907. The fishes of the coastal streams of Oregon and northern California. *U.S. Bur. Fish., Bull.* 27:155-189.
- Snyder, J. O. 1925. The half-pounder of Eel River, a steelhead trout. *Calif. Fish Game* 11(2):49-55.
- Stanley, J. R. 1976. American River steelhead, *Salmo gairdnerii gairdnerii*, management, 1956-1974. Calif. Dep. Fish Game Anadromous Fisheries Branch Admin. Rep. 76-2, 41 p. (Available from California Department of Fish and Game, Inland Fisheries Division, 1416 Ninth Street, Sacramento, CA 95814.)
- State Water Resources Control Board, California (SWRCB). 1982. Draft staff report for fact-finding hearing: Zayante Creek/lower San Lorenzo River and the upper San Lorenzo River instream beneficial use protection program. State Water Res. Control Board, Sacramento, CA, draft report dated 28 September 1992, 11 p. plus appendices. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Stebbins, R. C. 1966. A field guide to western reptiles and amphibians. The Peterson Field Guide Series, Houghton Mifflin, Boston, 279 p.
- Swift, C. C., T. R. Haglund, M. Ruiz, and R. N. Fisher. 1993. The status and distribution of the freshwater fishes of southern California. *Bull. South. Calif. Acad. Sci.* 92(3):101-167.
- Taylor, E. B. 1991. A review of local adaptation in Salmonidae, with particular reference to Pacific and Atlantic salmon. *Aquaculture* 98:185-207.
- Thompson, G. G. 1991. Determining minimum viable populations under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-198, 78 p.

- Thorgaard, G. H. 1977. Chromosome studies of steelhead. *In* T. J. Hassler and R. R. VanKirk (editors), Proceedings of the Genetic Implications of Steelhead Management Symposium, May 20-21, 1977, Arcata, CA, p. 20-25. Special Report 77-1. Calif. Coop. Fish. Res. Unit.
- Thorgaard, G. H. 1983. Chromosomal differences among rainbow trout populations. *Copeia* 1983(3):650-662.
- Titus, R. G., D. C. Erman, and W. N. Snider. In press. History and status of steelhead in California coastal drainages south of San Francisco Bay. *Hilgardia*.
- U.S. Forest Service (USFS). 1993a. Letter from Hugh Black, Jr., to Merritt Tuttle, 19 July 1993, 2 p. plus enclosures. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- U.S. Forest Service (USFS). 1993b. Letter from Hugh Black, Jr., to Merritt Tuttle, 4 August 1993, 2 p. plus enclosures. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Utter, F. M., P. Aebersold, and G. Winans. 1987. Interpreting genetic variation detected by electrophoresis. *In* N. Ryman and F. Utter (editors), Population genetics & fishery management, p. 21-45. Univ. Washington Press, Seattle.
- Utter, F. M., and F. W. Allendorf. 1977. Determination of the breeding structure of steelhead populations through gene frequency analysis. *In* T. J. Hassler and R. R. VanKirk (editors), Proceedings of the Genetic Implications of Steelhead Management Symposium, May 20-21, 1977, Arcata, CA, p. 44-54. Special Report 77-1. Calif. Coop. Fish. Res. Unit.
- Wahle, R. J., and R. Z. Smith. 1979. A historical and descriptive account of Pacific coast anadromous salmonid rearing facilities and a summary of their releases by region, 1960-76. NOAA Tech. Rep. NMFS SSRF-736, 40 p.
- Waples, R. S. 1991a. Genetic interactions between hatchery and wild salmonids: Lessons from the Pacific Northwest. *Can. J. Fish. Aquat. Sci.* 48 (Suppl. 1):124-133.
- Waples, R. S. 1991b. Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. *U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev.* 53(3):11-22.
- Waples, R. S. 1995. Genetic analysis of Idaho steelhead. Memorandum to Pat Bigelo, USFWS, and Ed Bowles, IDFG, dated 5 April 1995, 5 p. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)

- Waples, R. S., O. W. Johnson, P. B. Aebersold, C. K. Shiflett, D. M. VanDoornik, D. J. Teel, and A. E. Cook. 1993. A genetic monitoring and evaluation program for supplemented populations of salmon and steelhead in the Snake River Basin. Report to the U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, contract DE-A179-89BP00911. (Available from Northwest Fish. Science Cent., 2725 Montlake Blvd. E., Seattle, WA 98112.)
- Waples, R. S., and D. J. Teel. 1990. Conservation genetics of Pacific salmon. I. Temporal changes in allele frequency. *Conserv. Biol.* 4: 144-156.
- Ward, B. R., and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. *Can. J. Fish. Aquat. Sci.* 45:1110-1122.
- Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), and Western Washington Treaty Indian Tribes (WWTIT). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Wash. Dep. Fish Wildlife, Olympia, 212 p. and 5 regional volumes. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N, Olympia, WA 98501-1091.)
- Washington Department of Fish and Wildlife (WDFW). 1994a. Hatchery release data for steelhead, 1982 to 1994. Electronic data submitted to the ESA Administrative Record for coastal steelhead, August 1994. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N, Olympia, WA 98501-1091.)
- Washington Department of Fish and Wildlife (WDFW). 1994b. Letter to the ESA Administrative Record for west coast steelhead, 27 July 1994, enclosure 15, WDFW Steelhead Resource Inventory Tables (tables updated by WDFW in 1995). (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Ser., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Washington Department of Fish and Wildlife (WDFW). 1995. Correspondence and submissions to the ESA Administrative Record for west coast steelhead from Thom Johnson, WDFW Biologist, regarding Washington steelhead life history, abundance, and artificial propagation. Items dated 27, 29, and 31 March 1995; 7 April 1995; and 3 May 1995. (Available from Environmental and Technical Services Division, Natl. Mar. Fish. Ser., 525 N.E. Oregon Street, Suite 500, Portland, OR 97232.)
- Washington Trout. 1993. Petition for a rule to list the Deer Creek summer steelhead under the Endangered Species Act and to designate critical habitat. Unpubl. manuscript, 18 p. (Document submitted to the USDOC NOAA NMFS Northwest Region, Seattle, WA, September 1993.) Washington Trout 15635 N.E. Main Street, P.O. Box 402, Duvall, WA 98019.



- Weber, W., and W. Knispel. 1977. Nehalem River winter steelhead study. Oreg. Dep. Fish. Wild., Anadromous Fish Conservation Project Final Report AFS 65, 101 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97207.)
- Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-24, 258 p.
- Whitt, C. R. 1954. The age, growth, and migration of steelhead trout in the Clearwater River, Idaho. M.S. Thesis, Univ. Idaho, Moscow, 67 p.
- Williams, R. W., R. M. Laramie, and J. J. Ames. 1975. A catalog of Washington streams and salmon utilization, Volume 1: Puget Sound region. Washington Department of Fisheries, 704 p. plus appendices.
- Wilson, G. M., W. K. Thomas, and A. T. Beckenbach. 1985. Intra- and inter-specific mitochondrial DNA sequence divergence in *Salmo*: Rainbow, steelhead, and cutthroat trouts. *Can. J. Zool.* 63:2088-2094.
- Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. *J. Fish. Res. Board Can.* 23(3):365-393.
- Withler, R. E. 1988. Genetic consequences of fertilizing chinook salmon (*Oncorhynchus tshawytscha*) eggs with pooled milt. *Aquaculture* 68: 15-25.
- Wold, E. 1993. Operations plan for anadromous fish production facilities in the Columbia River Basin: Volume V, Washington Department of Wildlife hatcheries. 1992. Annual Report to the Bonneville Power Administration, Portland, Oregon, Project 92-043, 131 p. (Available from Bonneville Power Administration, P.O. Box 351, Portland, OR 97208.)
- Wright, S. G. 1968. Origin and migration of Washington's chinook and coho salmon. Information Booklet No. 1, 25 p. State of Washington Department of Fisheries. (Available from Washington Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091.)



**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 <sup>a</sup>	Location sampled	State	Sample size	Year collected	Genetics laboratory
<b>Puget Sound Region</b>						
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 <sup>a</sup>	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
<b>Hood Canal Region</b>						
21	Tahuya	Tahuya River	WA	111	1994	WDFW
22	Skokomish	Skokomish River	WA	111	1994	WDFW
23	Dosewallips	Dosewallips River	WA	53	1994	WDFW
<b>Strait of Juan de Fuca Region</b>						
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 <sup>a</sup>	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
<b>Coastal Washington Region</b>						
33	Quillayute	Sol Duc River <sup>b</sup>	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	Humtuplups	Humtuplups River	WA	49	1994	WDFW
38	Humtuplups	East Fork Humtuplups River	WA	50	1994	WDFW
39	Humtuplups	West Fork Humtuplups 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 <sup>a</sup>	Location sampled	State	Sample size	Year collected	Genetics laboratory
<b>Coastal Columbia River Basin</b>						
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
<b>Coastal Oregon Region</b>						
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 <sup>a</sup>	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
<b>Northern California Region</b>						
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 <sup>a</sup>	Location sampled	State	Sample size	Year collected	Genetics laboratory
<b>Sacramento River Basin and San Francisco Bay</b>						
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
<b>South of San Francisco Bay</b>						
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
<b>Washington state rainbow trout hatcheries</b>						
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.

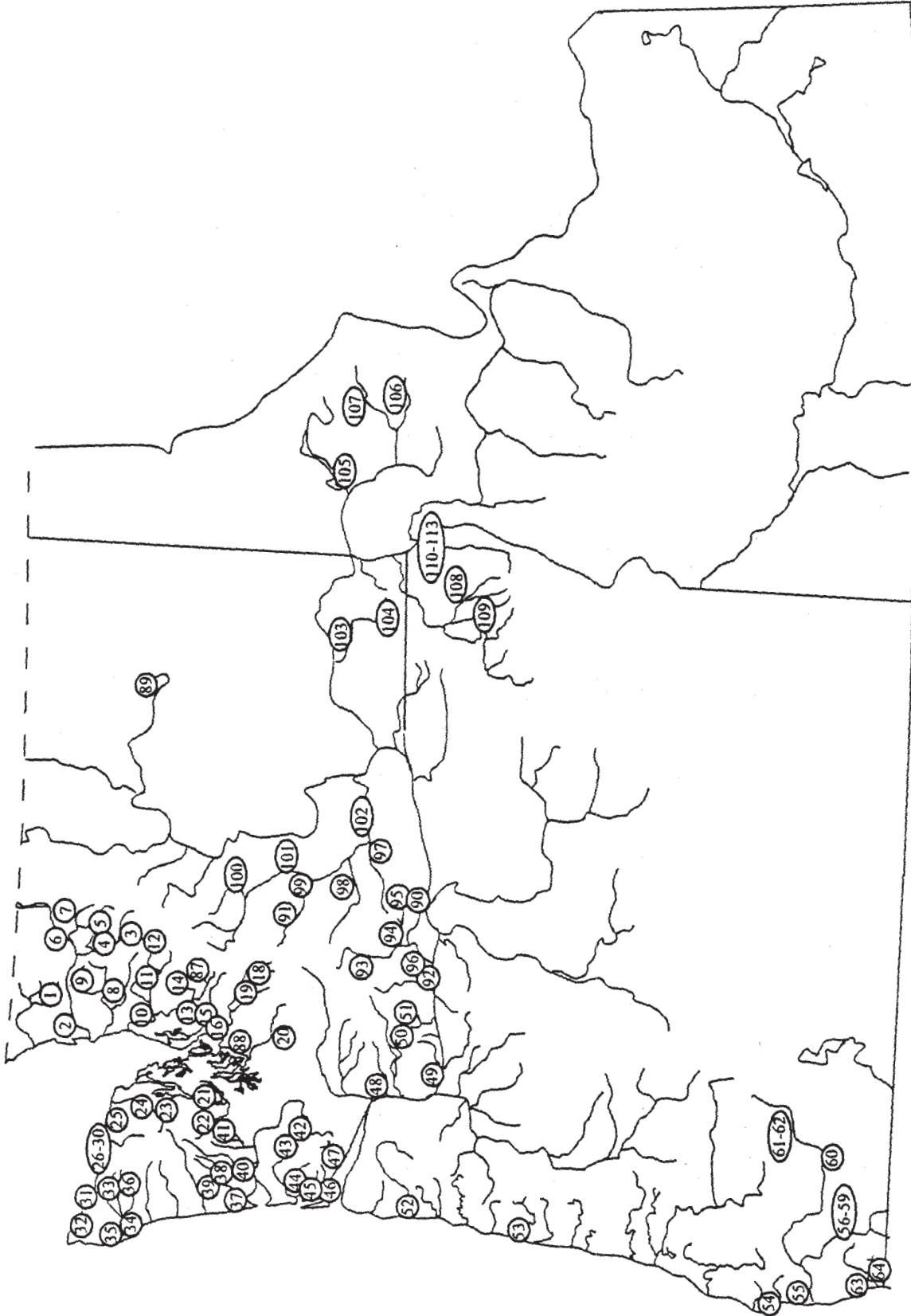
Sample code	Sample name <sup>a</sup>	Location sampled	State	Sample size	Year collected	Genetics laboratory
91	Goldendale-RT-H	Goldendale Hatchery rainbow trout collected from Naches rearing pond	WA	53	1990	WDFW
<b>Inland Columbia River Basin</b>						
92	Big White Salmon	Big White Salmon River	WA	302	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
<b>Snake River Basin</b>						
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 <sup>a</sup>	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

<sup>a</sup>Samples of rainbow trout are indicated by the suffix "RT;" samples from hatchery fish are indicated by the suffix "H."

<sup>b</sup>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.



Appendix A-2. Mapped locations of samples of *Oncorhynchus mykiss* used in the genetic analyses for this report. Numeric sample codes are listed in Appendix A-1.



Appendix A-2. Mapped locations of samples of *Oncorhynchus mykiss* used in the genetic analyses for this report. Continued.

**Appendix B**

**Petitioned Steelhead Populations Listed by Evolutionarily Significant Unit**





Appendix B. Steelhead stocks specified in petition by ONRC et al. (1994), listed by evolutionarily significant unit (ESU).

ESU	Petitioned population name	Population No. from petition
<b>1-Puget Sound</b>		
	South Fork Nooksack River summer steelhead	15
	Samish River winter steelhead	16
	Skagit River Basin	
	Sauk River summer steelhead	17
	Cascade River summer steelhead	1
	Stillaguamish River Basin	
	Deer Creek summer steelhead	2
	Snohomish River Basin	
	North Fork Skykomish River summer steelhead	20
	Lake Washington winter steelhead	13
	Hood Canal	
	Dewatto River winter steelhead	3
	Tahuya River winter steelhead	21
	Skokomish River winter steelhead	18
	Skokomish River summer steelhead	19
	Duckabush River winter steelhead	7
	Duckabush River summer steelhead	8
	Dosewallips River winter steelhead	5
	Dosewallips River summer steelhead	6
	Strait of Juan de Fuca	
	Discovery Bay winter steelhead	4
	Dungeness River winter steelhead	9
	Dungeness River summer steelhead	10
	Morse, Siebert, and McDonald Creeks winter steelhead	14
	Elwha River winter steelhead	11
<b>2-Olympic Peninsula</b>		
	Quillayute River Basin	
	Sol Duc River* summer steelhead	27
	Calawah River summer steelhead	22
	Queets River Basin	
	Clearwater River summer steelhead	24
<b>3-Southwest Washington</b>		
	Grays Harbor	
	Humptulips River summer steelhead	25

## Appendix B. Steelhead stocks specified in petition. Continued.

ESU	Petitioned population name	Population No. from petition
	Chehalis River summer steelhead	23
	Skookumchuck/Newaukum winter steelhead	26
	South Grays Harbor winter steelhead	28
	Columbia River winter steelhead (below Willamette River)	29
	Elochoman River winter steelhead	31
<b>4-Lower Columbia River</b>		
	Cowlitz River Basin	
	Cowlitz River winter steelhead	30
	Toutle River, Mainstem/North Fork winter steelhead	39
	Green River winter steelhead (Toutle River Basin)	32
	Kalama River summer steelhead	33
	Lewis River Basin	
	East Fork Lewis River winter steelhead	34
	East Fork Lewis River summer steelhead	35
	North Fork Lewis River winter steelhead	37
	North Fork Lewis River summer steelhead	36
	Salmon Creek winter steelhead	38
	Washougal River Basin	
	Washougal River (mainstem) winter steelhead	41
	Washougal River (mainstem) summer steelhead	40
	West (North) Fork Washougal River winter steelhead	43
	West (North) Fork Washougal River summer steelhead	42
	Wind River Basin	
	Wind River winter steelhead	64
	Wind River (mainstem) summer steelhead	63
	Panther Creek summer steelhead	54
	Trout Creek summer steelhead	57
	Willamette River winter steelhead (below Willamette Falls)	44
	Hood River winter steelhead	49
	Hood River summer steelhead	48
<b>5-Upper Willamette River</b>		
	Willamette River steelhead (above Willamette Falls)	44
<b>6-Oregon Coast</b>		
	Necanicum River winter steelhead	81
	Nehalem River winter steelhead	81

## Appendix B. Steelhead stocks specified in petition. Continued.

ESU	Petitioned population name	Population No. from petition
	Salmonberry River winter steelhead (Nehalem River)	87
	Tillamook Bay	
	Miami River winter steelhead	80
	Kilchis River winter steelhead	79
	Wilson River winter steelhead	95
	Trask River winter steelhead	94
	Nestucca River winter steelhead	83
	Salmon River winter steelhead	86
	Siletz River winter steelhead	88
	Siletz River summer steelhead	89
	Alsea River winter steelhead	75
	Yachats River winter steelhead	96
	Tenmile Creek winter steelhead	93
	Siuslaw River winter steelhead	90
	Smith River winter steelhead (Umpqua River Basin)	92
	Coos River winter steelhead	77
	Sixes River winter steelhead	91
	<b>7-Klamath Mountains Province</b>	
	Rogue River summer steelhead	85
	Illinois River winter steelhead	78
	Pistol River winter steelhead	84
	Chetco River winter steelhead	76
	Smith River summer steelhead	102
	Klamath River summer steelhead	99
	<b>8-Northern California</b>	
	Redwood Creek summer steelhead	101
	Mad River summer steelhead	100
	Eel River winter steelhead	98
	Eel River summer steelhead	97
	Van Duzen River summer steelhead (Eel River Basin)	103
	<b>9-Central California Coast</b>	
	Petaluma River winter steelhead	105
	Sonoma Creek winter steelhead	108
	Napa River winter steelhead	104
	Wildcat Creek winter steelhead	109

## Appendix B. Steelhead stocks specified in petition. Continued.

ESU	Petitioned population name	Population No. from petition
	San Pedro Creek winter steelhead	119
	Denniston Creek winter steelhead	111
	Frenchman's Creek winter steelhead	112
	Pilarcitos Creek winter steelhead	116
	Lobitos Creek winter steelhead	114
	Tunitas Creek winter steelhead	120
	San Gregorio Creek winter steelhead	118
	Pomponio Creek winter steelhead	117
	Pescadero and Butano Creeks winter steelhead	115
	Gazos Creek winter steelhead	113
	Whitehouse Creek winter steelhead	121
	Año Nuevo Creek winter steelhead	110
	Finny Creek winter steelhead	126
	Waddell Creek winter steelhead	137
	Scott Creek winter steelhead	135
	San Vincente Creek winter steelhead	134
	Liddel Creek winter steelhead	128
	Laguna Creek winter steelhead	127
	Majors Creek winter steelhead	129
	Medler Creek winter steelhead	130
	Baldwin Creek winter steelhead	124
	San Lorenzo River winter steelhead	133
	Arana Gulch winter steelhead	123
	Soquel Creek winter steelhead	136
	Aptos Creek winter steelhead	122
	Coja Creek winter steelhead	125
	Respini Creek winter steelhead	132
<b>10-South-Central California Coast</b>		
	Pajaro River winter steelhead	131
	Salinas River winter steelhead	146
	Carmel River winter steelhead	142
	San Jose Creek winter steelhead	147
	Garrapata Creek winter steelhead	143
	Rocky Creek winter steelhead	145
	Little Sur River winter steelhead	144

## Appendix B. Steelhead stocks specified in petition. Continued.

ESU	Petitioned population name	Population No. from petition
	Bixby Creek winter steelhead	141
	Big Sur River winter steelhead	140
	Big Creek winter steelhead	139
	Alder Creek winter steelhead	138
	San Carpojo Creek winter steelhead	159
	Arroyo de la Cruz winter steelhead	148
	Little Pico Creek winter steelhead	154
	Pico Creek winter steelhead	157
	San Simeon Creek winter steelhead	161
	Santa Rosa Creek winter steelhead	162
	Cayucos Creek winter steelhead	150
	Old Creek winter steelhead	156
	Toro Creek winter steelhead	163
	Morro Creek winter steelhead	155
	Chorro Creek winter steelhead	151
	Islay Creek winter steelhead	153
	Coon Creek winter steelhead	152
	San Luis Obispo Creek winter steelhead	160
	Pismo Creek winter steelhead	158
	Arroyo Grande Creek winter steelhead	149
<b>11-Southern California</b>		
	Santa Ynez River winter steelhead	171
	Cañada Honda Creek winter steelhead	165
	Cañada del Corral Creek winter steelhead	164
	Refugio Creek winter steelhead	169
	Dos Pueblos Canyon Creek winter steelhead	167
	Tecolote Creek winter steelhead	172
	San Jose Creek winter steelhead	170
	Mission Creek winter steelhead	168
	Carpinteria Creek winter steelhead	166
	Ventura River winter steelhead	175
	Santa Clara River winter steelhead	174
	Big Sycamore Canyon Creek winter steelhead	173
	Arroyo Sequit winter steelhead	176
	Malibu Creek winter steelhead	177

## Appendix B. Steelhead stocks specified in petition. Continued.

ESU	Petitioned population name	Population No. from petition
	Topanga Creek winter steelhead	178
<b>12-Central Valley</b>		
	Sacramento River winter steelhead	106
	San Joaquin River winter steelhead	107
<b>13-Middle Columbia River</b>		
	White Salmon River winter steelhead	62
	White Salmon River summer steelhead	61
	Klickitat River winter steelhead	51
	Klickitat River summer steelhead	50
	Fifteenmile Creek winter steelhead	47
	Deschutes River summer steelhead	45
	Rock Creek summer steelhead	55
	Umatilla River summer steelhead	58
	Walla Walla River summer steelhead	59
	Touchet River summer steelhead (Walla Walla River Basin)	56
	Yakima River summer steelhead	65
<b>14-Upper Columbia River</b>		
	Wenatchee River summer steelhead	60
	Entiat River summer steelhead	46
	Methow River summer steelhead	52
	Okanogan River summer steelhead	53
<b>15-Snake River Basin</b>		
	Snake River (mainstem) summer steelhead	73
	Tucannon River summer steelhead	74
	Asotin Creek summer steelhead	66
	Clearwater River summer steelhead A-run	67
	Clearwater River summer steelhead B-run	68
	Grande Ronde summer steelhead	69
	Imnaha River summer steelhead	70
	Salmon River summer steelhead A-run	71
	Salmon River summer steelhead B-run	72

\*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.

**Appendix C**

**Steelhead Artificial Propagation Facilities**





Appendix C. Major Federal, State, and Tribal steelhead production facilities currently operating in Washington, Idaho, Oregon, and California, organized by evolutionarily significant unit (ESU). Operators: WDFW=Washington Department of Fish and Wildlife, Tribe=Tribal Agency, USFWS=U.S. Fish and Wildlife Service, ODFW=Oregon Department of Fish and Wildlife, CDFG=California Department of Fish and Game, and IDFG=Idaho Department of Fish and Game. Type: SP=smolt production, ET=egg taking station (Crawford 1979, Wahle and Smith 1979, Delarm and Smith 1990a-d, Christianson 1993, Hutchison 1993, Shelldrake 1993, Wold 1993, NWIFC 1994).

ESU	River Basin	Facility name	Facility type	Operator	Year of start-up <sup>a</sup>
<b>1-Puget Sound</b>					
	Skagit River	Barnaby Slough Pond	SP	WDFW	1960
		Upper Skagit Hatchery	SP	Upper Skagit Tribe	1986
	Stillaguamish River	Stillaguamish Hatchery	SP	Stillaguamish Tribe	1991
		Whitehorse Ponds	SP	WDFW	1962
	Skykomish River	Skykomish Ponds	SP	WDFW	1974
	Snoqualmie River	Tokul Creek Hatchery	SP	WDFW	1951
	Green River	Keta Creek Hatchery	SP	WDFW	1969
		Muckleshoot Hatchery	SP	Muckleshoot Tribe	1981
	Puyallup River	Puyallup Tribal Hatchery	SP	Puyallup Tribe	1980
		Puyallup Hatchery	SP	WDFW	1947
	Chambers Creek	Chambers Creek Hatchery	ET/SP	WDFW	1945
		South Tacoma Hatchery	ET	WDFW	1984
	Elson Creek	Elson Creek Hatchery	SP	Squaxin Island Tribe	1982
	Skokomish River	Shelton Hatchery	SP	WDFW	1947
	Elwha River	Lower Elwha Hatchery	SP	Lower Elwha Tribe	1977
<b>2-Olympic Peninsula</b>					
	Hoko River	Hoko River Hatchery	SP	Makah Tribe	1986
	Sooes River	Makah NFH <sup>b</sup>	SP	USFWS	1986
	Sol Duc River <sup>c</sup>	Sol Duc Pond	SP	WDFW	1977
	Bogachiel River	Bogachiel Pond	SP	WDFW	1967
	Quillayute River	Quileute Hatchery	SP	Quileute Tribe	1982
	Hoh River	Chalaat Creek Hatchery	SP	Hoh Tribe	1978

## Appendix C. Major Federal, State, and Tribal steelhead production facilities. Continued.

ESU	River Basin	Facility name	Facility type	Operator	Year of start-up <sup>a</sup>
	Quinault River	Lake Quinault Hatchery	SP	Quinault Tribe	1974
		Quinault NFH	SP	USFWS	1968
<b>3-Southwest Washington</b>					
	Chehalis River	Aberdeen Hatchery	SP	WDFW	1951
		Skookumchuck Pond	SP	WDFW	1973
	Columbia River	Klaskanine Hatchery	SP	ODFW	1911
		Big Creek Hatchery	ET/SP	ODFW	1941
		Gnat Creek Hatchery	SP	ODFW	1911
		Beaver Creek Hatchery	SP	WDFW	1957
<b>4-Lower Columbia River</b>					
	Cowlitz River	Cowlitz Hatchery	SP	WDFW	1967
	Kalama River	Gobar Pond	SP	WDFW	1975
	Clackamas River	Clackamas Hatchery	SP	ODFW	1979
		Eagle Creek NFH	SP	USFWS	1957
	Columbia River	Vancouver Hatchery	SP	WDFW	1936
	Washougal River	Skamania Hatchery	SP	WDFW	1956
<b>5-Upper Willamette River</b>					
	Willamette River	Willamette Hatchery	SP	ODFW	1922
	Santiam River	Marion Forks Hatchery	SP	ODFW	1951
		Roaring River Hatchery	SP	ODFW	1925
		South Santiam Hatchery	SP	ODFW	1923
	McKenzie River	Leaburg Hatchery	SP	ODFW	1953
		McKenzie Hatchery	SP	ODFW	1975
<b>6-Oregon Coast</b>					
	Nehalem River	Nehalem Hatchery	SP	ODFW	1968
	Nestucca River	Cedar Creek Hatchery	SP	ODFW	1935
	Alsea River	Alsea Hatchery	SP	ODFW	1937
	North Umpqua River	Rock Creek Hatchery	SP	ODFW	1922
	Coquille River	Bandon Hatchery	SP	ODFW	1924

## Appendix C. Major Federal, State, and Tribal steelhead production facilities. Continued.

ESU	River Basin	Facility name	Facility type	Operator	Year of start-up <sup>a</sup>
<b>7-Klamath Mountains Province</b>					
	Elk River	Elk River Hatchery	SP	ODFW	1969
	Rogue River	Cole Rivers Hatchery	SP	ODFW	1972
	Klamath River	Iron Gate Hatchery	SP	CDFG	1966
	Trinity River	Trinity Hatchery	SP	CDFG	1963
<b>8-Northern California</b>					
	Mad River	Mad River Hatchery	SP	CDFG	1971
	Eel River	Van Arsdale Fisheries Station	ET	CDFG	1907
<b>9-Central California Coast</b>					
	Russian River	Warm Springs Hatchery	ET	CDFG	1980
<b>10-South-Central California Coast</b>					
	-none-				
<b>11-Southern California</b>					
	-none-				
<b>12-Central Valley</b>					
	Sacramento River	Coleman NFH	SP	USFWS	1942
	American River	Nimbus Hatchery	SP	CDFG	1955
	Feather River	Feather River Hatchery	SP	CDFG	1967
	Mokelumne River	Mokelumne River Fish Installation	SP	CDFG	1964
<b>13-Middle Columbia River</b>					
	Deschutes River	Oak Springs Hatchery	SP	ODFW	1923
		Round Butte Hatchery	SP	ODFW	1974
	Columbia River	Irrigon Hatchery	SP	ODFW	1984
		Ringold Hatchery	ET/SP	WDFW	1962
	Touchet River	Dayton Pond	SP	WDFW	1987
	Yakima River	Nelson Hatchery	SP	WDFW	1958
		Yakima Hatchery	SP	WDFW	1937
	Naches River	Naches Hatchery	SP	WDFW	1922
<b>14-Upper Columbia River</b>					

## Appendix C. Major Federal, State, and Tribal steelhead production facilities. Continued.

ESU	River Basin	Facility name	Facility type	Operator	Year of start-up <sup>a</sup>
	Columbia River	Chelan Hatchery	SP	WDFW	1965
		Eastbank Pond	SP	WDFW	1989
		Turtle Rock Pond	SP	WDFW	1990
		Wells Hatchery	ET/SP	WDFW	1967
	Wenatchee River	Leavenworth NFH	SP	USFWS	1941
<b>15-Snake River Basin</b>					
	Clearwater River	Clearwater Hatchery	SP	IDFG	1992
		Dworshak NFH	ET/SP	USFWS	1969
	Grande Ronde River	Cottonwood Pond	SP	WDFW	1984
	Pahsimeroi River	Pahsimeroi Hatchery	ET	IDFG	1969
	Salmon River	Salmon River Hatchery	ET	IDFG	1984
	Snake River	Hagerman NFH	SP	USFWS	1933
		Lyons Ferry Hatchery	ET/SP	WDFW	1982
		Magic Valley Hatchery	SP	IDFG	1987
		Niagara Springs Hatchery	SP	IDFG	1966
		Oxbow Hatchery	ET	IDFG	1962
	Tucannon River	Curl Lake Hatchery	SP	WDFW	1984
	Wallowa River	Big Canyon Pond	SP	ODFW	1987
		Wallowa Hatchery	ET/SP	ODFW	1985

<sup>a</sup>Discrepancies in start-up date were found in the literature for several of the listed facilities. Additionally, some facilities began as trout hatcheries, then shifted to steelhead production; where this occurred, the date given is the beginning of the steelhead program.

<sup>b</sup>NFH = National Fish Hatchery.

<sup>c</sup>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.

**Appendix D**

**Releases of Hatchery Steelhead**



Appendix D. Hatchery steelhead releases, listed by evolutionarily significant unit (ESU). The period of record indicates the time frame of available data; actual releases during that period did not necessarily occur annually.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
<b>1-Puget Sound</b>						
	Nooksack River	W	Chambers Creek	1981-94	1,603,290	WDF et al. 1993, WDFW 1994a
	Lummi Bay	W	Quinault	1983-86	71,274	WDF et al. 1993, NWIFC 1994
	Samish River	W	Chambers Creek	1981-94	445,149	WDF et al. 1993, WDFW 1994a
	Skagit River	S	Skamania	1981-94	273,800	WDF et al. 1993, WDFW 1994a
		W	Chambers Creek and local stock	1981-94	3,904,374	Huew et al. 1990, WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Stillaguamish River	S	Skamania	1981-94	820,268	Huew et al. 1990, WDF et al. 1993, WDFW 1994a
		W	Chambers Creek	1981-94	1,575,648	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Snohomish River	S	Skamania	1981-94	2,007,939	WDF et al. 1993, WDFW 1994a
		W	Chambers Creek and local stock	1981-94	4,585,274	WDF et al. 1993, WDFW 1994a
	Lake Washington	W	Chambers Creek	1981-94	759,701	WDF et al. 1993, WDFW 1994a
	Green River	S	Skamania	1981-94	821,034	WDF et al. 1993, WDFW 1994a
		W	Chambers Creek and Green River	1981-94	3,100,354	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Puyallup River	W	Chambers Creek	1981-94	2,269,127	WDF et al. 1993, NWIFC 1994, WDFW 1994a
		W	Quinault	1981-94	514,322	WDF et al. 1993, NWIFC 1994, WDFW 1994a

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Chambers Creek	W	Chambers Creek	1981-94	2,369,580	WDF et al. 1993, WDFW 1994a
	Nisqually River	S	Skamania	1982-93	225,369	WDF et al. 1993, WDFW 1994a
	Deschutes River	S	Skamania	1982-92	198,348	WDF et al. 1993, WDFW 1994a
		W	Chambers Creek	1981-94	348,594	WDF et al. 1993, WDFW 1994a
	South Sound streams	W	Chambers Creek and Quinault	1981-94	945,750	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Dewatto River	W	Chambers Creek	1982-90	99,770	WDF et al. 1993, WDFW 1994a
	Tahuya River	W	Chambers Creek	1982-93	119,166	WDF et al. 1993, WDFW 1994a
	Union River	W	Chambers Creek	1981-94	115,788	WDF et al. 1993, WDFW 1994a
	Skokomish River	W	Chambers Creek and Quinault	1981-94	877,581	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Duckabush River	W	Chambers Creek	1981-94	192,509	WDF et al. 1993, WDFW 1994a
	Dosewallips River	W	Chambers Creek	1981-94	225,830	WDF et al. 1993, WDFW 1994a
	Quilcene River	W	Chambers Creek and Bogachiel/Chambers Creek	1982-90	86,260	WDF et al. 1993, WDFW 1994a
	Snow Creek	W	Chambers Creek	1991-93	3,498	WDF et al. 1993, WDFW 1994a
	Dungeness River	S	Skamania	1981-94	97,317	WDF et al. 1993, WDFW 1994a
		W	Chambers Creek	1981-94	203,077	WDF et al. 1993, WDFW 1994a
	Morse Creek	W	Bogachiel/Chambers Creek	1981-94	177,899	WDF et al. 1993, WDFW 1994a
	Elwha River	S	Skamania	1982-90	221,679	WDF et al. 1993, NWIFC 1994, WDFW 1994a



## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
		W	Bogachiel/Chambers Creek and Eltwha	1981-94	1,002,519	WDF et al. 1993, NWIFC 1994, WDFW 1994a
<b>2-Olympic Peninsula</b>						
	Lyre River	S	Skamania	1981-94	96,133	WDF et al. 1993, WDFW 1994a
		W	Bogachiel/Chambers Creek	1981-94	268,788	WDF et al. 1993, WDFW 1994a
	Pysht River	W	Hoko River	1981-94	122,802	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Clallam River	W	Hoko River	1981-94	74,715	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Hoko River	W	Hoko River and Bogachiel/Chambers Creek	1981-94	167,631	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Sekiu River	W	Hoko River and Bogachiel/Chambers Creek	1989-92	19,817	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Sail River	W	Hoko River	1989-92	38,133	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Waatch River	W	Hoko River and Sooes River	1985-92	394,548	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Sooes River	W	Sooes River	1983-92	808,945	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Quillayute River	S	Skamania	1981-94	453,497	WDF et al. 1993, NWIFC 1994, WDFW 1994a
		W	Bogachiel/Chambers Creek and Quinault	1981-94	1,505,918	WDF et al. 1993, NWIFC 1994, WDFW 1994a

Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Hoh River	W	Hoh River and Quinault	1981-94	1,635,774	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Queets River	W	Quinault	1980-92	1,416,125	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Quinault River	W	Quinault	1980-94	13,949,904	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Raft River	W	Quinault	1981-92	566,075	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Moclips River	W	Quinault	1981-91	143,226	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Copalis River	W	Quinault	1985	50,000	WDF et al. 1993, NWIFC 1994, WDFW 1994a
<b>3-Southwest Washington</b>						
	Lewis and Clark River	W	Big Creek	1980-94	647,287	ODFW 1994c
	Humtulsips River	S	Skamania	1981-94	268,095	WDF et al. 1993, WDFW 1994a
	Hoquiam River	W	Bogachiel/Chambers Creek, Chambers Creek, and Quinault	1981-94	2,634,641	WDF et al. 1993, NWIFC 1994, WDFW 1994a
	Wynoochee River	W	Wishkah River	1981-94	113,970	WDF et al. 1993, WDFW 1994a
	North River	S	Skamania	1981-94	1,073,949	WDF et al. 1993, WDFW 1994a
	Willapa River	W	Chambers Creek	1981-94	3,985,971	WDF et al. 1993, WDFW 1994a
		W	Shelton	1981-94	313,746	WDF et al. 1993, WDFW 1994a
		S	Skamania	1986-91	49,518	WDF et al. 1993, WDFW 1994a
		W	Shelton	1981-94	780,101	WDF et al. 1993, WDFW 1994a

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Nemah River	W	Shelton	1981-94	125,899	WDF et al. 1993, WDFW 1994a
	Naselle River	W	Shelton	1981-94	392,842	WDF et al. 1993, WDFW 1994a
	Klaskanine River	W	Big Creek	1981-94	830,316	ODFW 1994c
	Grays River	W	Grays River	1981-94	540,341	WDF et al. 1993, WDFW 1994a
	Big Creek	W	Big Creek	1980-94	944,484	ODFW 1994c
	Rock Creek	W	Washougal	1989-91	27,784	ODFW 1994c
	Gnat Creek	S	South Santiam River	1980-91	85,786	ODFW 1994c
	Skamokawa Creek	W	Beaver Creek	1980-94	107,397	ODFW 1994c
	Elochoman River	S	Skamania	1980-94	382,049	ODFW 1994c
	Clatskanie River	W	Beaver Creek	1980-94	1,538,318	ODFW 1994c
		S	South Santiam River	1981	5,010	ODFW 1994c
		W	Big Creek	1980-94	441,704	ODFW 1994c
	Germany Creek	W	Beaver Creek	1981-94	164,170	WDF et al. 1993, WDFW 1994a
	Abernathy Creek	W	Beaver Creek	1981-94	73,052	WDF et al. 1993, WDFW 1994a
	Coal Creek	W	Beaver Creek	1984-93	20,250	WDF et al. 1993, WDFW 1994a
	Lower Columbia River	S	South Santiam River	1980-89	435,597	ODFW 1994c
		S	Columbia Basin	1981-94	3,738,769	WDF et al. 1993, WDFW 1994a
		W	Big Creek	1980-94	704,493	ODFW 1994c
		W	Eagle Creek	1984	245,342	ODFW 1994c
		W	Beaver Creek	1981-94	424,572	WDF et al. 1993, WDFW 1994a

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
<b>4-Lower Columbia River</b>						
	Cowlitz River	S	Skamania	1981-94	4,567,732	WDF et al. 1993, WDFW 1994a
		W	Cowlitz River	1981-94	12,953,071	WDF et al. 1993, WDFW 1994a
	Kalama River	S	Skamania	1981-94	1,032,217	WDF et al. 1993, WDFW 1994a
		W	Beaver Creek	1981-94	1,172,695	WDF et al. 1993, WDFW 1994a
	Lewis River	S	Skamania	1981-94	2,270,253	WDF et al. 1993, WDFW 1994a
		W	Vancouver	1981-94	2,657,105	WDF et al. 1993, WDFW 1994a
	Salmon Creek	W	Vancouver	1981-94	237,129	WDF et al. 1993, WDFW 1994a
	Clackamas River	S	South Santiam River	1980-94	2,625,792	ODFW 1994c
		W	Big Creek	1980-94	2,108,308	ODFW 1994c
		W	Clackamas River early	1983-88	1,270,841	ODFW 1994c
		W	Clackamas River late	1986-94	388,847	ODFW 1994c
		W	Faraday Hatchery	1992-94	121,246	ODFW 1994c
		W	Eagle Creek	1980-94	2,241,156	ODFW 1994c
	Sandy River	S	South Santiam River	1980-94	256,710	ODFW 1994c
		W	Big Creek	1980-94	2,860,053	ODFW 1994c
		W	Clackamas River late	1986-94	260,330	ODFW 1994c
	Washougal River	S	Skamania	1981-94	1,853,917	WDF et al. 1993, WDFW 1994a
		W	Skamania	1981-94	1,794,553	WDF et al. 1993, WDFW 1994a
	Hamilton Creek	W	Washougal	1988-91	24,624	WDF et al. 1993, WDFW 1994a

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Wind River	S	Skamania	1981-94	353,832	WDF et al. 1993, WDFW 1994a
	Hood River	S	South Santiam River	1980-94	1,399,343	ODFW 1994c
		W	Big Creek	1985-91	188,620	ODFW 1994c
		W	Hood River	1992-94	91,359	ODFW 1994c
	<b>5-Upper Willamette River</b>					
	Tualatin River	W	Big Creek	1980-94	464,544	ODFW 1994c
	Molalla River	S	South Santiam River	1980-94	692,589	ODFW 1994c
		W	Big Creek	1980-94	861,832	ODFW 1994c
		W	Klaskanine River	1985-88	219,763	ODFW 1994c
		W	North Santiam River	1982	23,492	ODFW 1994c
	Yamhill River	W	Big Creek	1980-82	101,355	ODFW 1994c
	Willamina Creek	W	Big Creek	1980-82	53,919	ODFW 1994c
	Santiam River	S	McKenzie River	1989	119,339	ODFW 1994c
		S	South Santiam River	1980-94	5,595,712	ODFW 1994c
		W	Big Creek	1980	58,632	ODFW 1994c
		W	North Santiam River	1980-94	2,423,260	ODFW 1994c
		W	South Santiam River	1982-86	150,356	ODFW 1994c
	McKenzie River	S	McKenzie River	1980-94	1,391,280	ODFW 1994c
		S	South Santiam River	1980-85	615,390	ODFW 1994c
		W	Big Creek	1985-86	28,320	ODFW 1994c

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Willamette River	S	McKenzie River	1980-94	1,205,381	ODFW 1994c
		S	South Santiam River	1980-94	622,425	ODFW 1994c
		W	Big Creek	1981	5,025	ODFW 1994c
		W	North Santiam River	1980-85	204,110	ODFW 1994c
	<b>6-Oregon Coast</b>					
	Necanicum River	W	North Nehalem River	1980-94	509,738	ODFW 1994c
		W	Nestucca River	1982-86	163,384	ODFW 1994c
	Nehalem River	W	Fish Hawk Creek	1980-94	768,050	ODFW 1994c
		W	North Nehalem River	1980-94	2,120,228	ODFW 1994c
	Miami River	W	Alsea River	1980-90	29,794	ODFW 1994c
		W	Nestucca River	1980-94	395,611	ODFW 1994c
	Kilchis River	S	Siletz River	1980-94	148,856	ODFW 1994c
		S	Nestucca River	1982-84	31,558	ODFW 1994c
		W	Alsea River	1980-81	90,974	ODFW 1994c
		W	Nestucca River	1980-94	459,835	ODFW 1994c
	Wilson River	S	Siletz River	1980-94	42,814	ODFW 1994c
		S	Nestucca River	1988-94	141,251	ODFW 1994c
		W	Alsea River	1980-90	372,781	ODFW 1994c
		W	Nestucca River	1980-94	1,537,962	ODFW 1994c
	Tillamook River	W	Alsea River	1980-90	68,726	ODFW 1994c

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Nestucca River	W	Nestucca River	1980-94	389,138	ODFW 1994c
		S	Siletz River	1980-94	1,226,760	ODFW 1994c
		S	Nestucca River	1988-94	322,100	ODFW 1994c
		W	Alsea River	1980-90	407,133	ODFW 1994c
		W	Nestucca River	1980-94	2,010,088	ODFW 1994c
	Salmon River	S	South Santiam River	1980-94	940,954	ODFW 1994c
		W	Alsea River	1980-94	380,463	ODFW 1994c
		W	Nestucca River	1983-86	183,397	ODFW 1994c
	Siletz River	S	Siletz River	1980-94	1,308,905	ODFW 1994c
		W	Alsea River	1980-94	1,337,505	ODFW 1994c
		W	Nestucca River	1984	10,177	ODFW 1994c
	Yaquina River	W	Alsea River	1980-94	494,353	ODFW 1994c
	Alsea River	W	Alsea River	1980-94	2,190,441	ODFW 1994c
	Tenmile Creek	W	Alsea River	1980-94	316,864	ODFW 1994c
		W	Coos River	1990-92	52,026	ODFW 1994c
	Siuslaw River	W	Siuslaw River	1990-92	101,568	ODFW 1994c
		W	Alsea River	1980-94	2,756,507	ODFW 1994c
	Smith River	W	Alsea River	1980-94	975,260	ODFW 1994c
	North Umpqua River	S	North Umpqua River	1980-94	2,963,045	ODFW 1994c
		W	North Umpqua River	1990	22,535	ODFW 1994c

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	South Umpqua River	W	Cow Creek	1988-93	86,154	ODFW 1994c
		W	Alsea River	1980-94	772,874	ODFW 1994c
		W	North Umpqua River	1992-94	50,658	ODFW 1994c
	Coos River	W	Alsea River	1980-94	535,801	ODFW 1994c
		W	Coos River	1992-93	75,334	ODFW 1994c
		W	Coquille River	1987-90	42,357	ODFW 1994c
	Millicoma River	W	Coos River	1992-94	250,829	ODFW 1994c
		W	Alsea River	1980-86	422,662	ODFW 1994c
		W	Coquille River	1987-91	301,268	ODFW 1994c
	Coquille River	W	Alsea River	1980-88	580,379	ODFW 1994c
		W	Coquille River	1980-94	2,116,150	ODFW 1994c
		W	South Coquille River	1994	21,809	ODFW 1994c
<b>7-Klamath Mountains Province</b>						
	Rogue River	S	Applegate River	1981-92	201,968	ODFW 1994c
		S	Cole Rivers	1980-94	3,253,994	ODFW 1994c
		W	Applegate River	1980-94	2,009,604	ODFW 1994c
		W	Cole Rivers	1980-94	2,713,481	ODFW 1994c
	Chetco River	W	Chetco River	1980-94	970,789	ODFW 1994c
	Smith River	W	Eel River	1972-73	98,255	CDFG 1994
		W	San Lorenzo River	1973	57,265	CDFG 1994



## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
		W	Mad River	1975-76	41,861	CDFG 1994
		W	Smith River	1980-81	102,100	CDFG 1994
	Klamath River	W	Mad River	1975	172,419	CDFG 1994
		W	Cowlitz River	1970	134,000	CDFG 1994
		W	Klamath River	1968-91	8,953,376	CDFG 1994
	<b>8-Northern California</b>					
	Mad River	S	Skamania	1972-81	349,880	CDFG 1994
		S	Mad River	1968-91	909,311	CDFG 1994
		W	Eel River	1972-74	292,210	CDFG 1994
		W	Mad River	1968-91	3,986,235	CDFG 1994
		W	Mad River (fry)	1982-85	720,330	CDFG 1994
		W	Russian River	1989-90	22,320	CDFG 1994
		W	Russian River (fry)	1989	64,180	CDFG 1994
		W	San Lorenzo River	1973	100,800	CDFG 1994
	Eel River	W	Eel River	1968-91	1,395,956	CDFG 1994
		W	Mad River	1975-85	743,163	CDFG 1994
	Willits Creek	W	Mad River	1979-83	41,619	CDFG 1994
	Davis Creek	W	Mad River	1979-83	40,222	CDFG 1994
	Mattole River	W	Eel River	1972	30,065	CDFG 1994
		W	San Lorenzo River	1973	19,067	CDFG 1994

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Noyo River	W	Mad River	1975	30,012	CDFG 1994
	Navarro River	W	San Lorenzo River	1973	40,100	CDFG 1994
		W	Eel River	1972	40,950	CDFG 1994
		W	San Lorenzo River	1973	40,057	CDFG 1994
	Garcia River	W	Mad River	1975-81	99,013	CDFG 1994
		W	Mad River	1975-76	20,333	CDFG 1994
	Gualala River	W	Eel River	1972-74	48,750	CDFG 1994
		W	San Lorenzo River	1973	20,345	CDFG 1994
		W	Mad River	1975-82	30,830	CDFG 1994
<b>9-Central California Coast</b>						
	Russian River	S	Skamania	1980-81	270,410	CDFG 1994
		W	Eel River	1972	85,140	CDFG 1994
		W	San Lorenzo River	1973	83,350	CDFG 1994
		W	Mad River	1975-81	483,954	CDFG 1994
		W	Russian River	1968-91	2,199,000	CDFG 1994
	Papermill Creek	W	Eel River	1972	10,080	CDFG 1994
		W	San Lorenzo River	1973	4,500	CDFG 1994
		W	Mad River	1976	10,010	CDFG 1994
	Lagunitas Creek	W	Mad River	1981	30,000	CDFG 1994
	Nicasio Creek	W	Mad River	1979-81	15,600	CDFG 1994

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Chorro Creek	W	Mad River	1979-83	16,585	CDFG 1994
	Napa River	W	Eel River	1972	20,200	CDFG 1994
		W	Mad River	1979-80	20,165	CDFG 1994
		W	San Lorenzo River	1973	14,400	CDFG 1994
	Pinole Creek	W	Mad River	1979	3,153	CDFG 1994
	Uvas Creek	W	Mad River	1975-81	30,063	CDFG 1994
	Marsh Creek	W	Mad River	1979-83	3,743	CDFG 1994
	Grapewine Creek	W	Mad River	1979-83	4,337	CDFG 1994
	Pescadero Creek	W	Eel River	1972	7,650	CDFG 1994
		W	San Lorenzo River	1973	9,000	CDFG 1994
	San Lorenzo River	W	Mad River	1975-81	44,659	CDFG 1994
		W	Eel River	1972	20,250	CDFG 1994
		W	San Lorenzo River	1973	97,150	CDFG 1994
		W	Mad River	1975-81	149,090	CDFG 1994
<b>10-South-Central California Coast</b>						
	Arroyo Seco Creek	W	Mad River	1981	10,450	CDFG 1994
	Carmel River	W	Mad River	1980	8,400	CDFG 1994
	San Luis Obispo Creek	W	Mad River	1979-81	7,635	CDFG 1994
<b>11-Southern California</b>						
	Ventura River	W	Mad River (fry)	1976-79	41,020	CDFG 1994

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
<b>12-Central Valley</b>						
	Sacramento River	S	Skamania	1968-81	736,000	CDFG 1994, Cramer et al. 1995
		W	Nimbus Hatchery (Nimbus and Eel River stocks)	1958-90	13,469,000	CDFG 1994
		W	Feather River Hatchery (Feather River and Nimbus stocks)	1971-90	5,915,000	CDFG 1994
		W	Mokolunne Hatchery (Mokolunne River and Nimbus stocks)	1965-81	1,198,000	CDFG 1994
		W	Coleman NFH	1965-90	9,876,000	CDFG 1994
<b>13-Middle Columbia River</b>						
	Little White Salmon River	S	Skamania	1984	68,852	WDF et al. 1993, WDFW 1994a
	White Salmon River	S	Skamania	1982-91	428,714	WDF et al. 1993, WDFW 1994a
		W	Vancouver	1982-94	300,315	WDF et al. 1993, WDFW 1994a
	Klickitat River	S	Skamania	1981-94	1,175,229	WDF et al. 1993, WDFW 1994a
	Mill Creek	S	Lyons Ferry	1981-94	292,390	WDF et al. 1993, WDFW 1994a
	Deschutes River	S	Deschutes River	1980-94	6,112,635	ODFW 1994c
	Umatilla River	S	Umatilla River	1980-94	1,059,859	ODFW 1994c
	Walla Walla River	S	Lyons Ferry, Wells, and Wallowa River	1981-94	3,119,645	WDF et al. 1993, WDFW 1994a

Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Yakima River	S	Ringold, Wells, Lyons Ferry, Klickitat River, and Yakima River	1981-94	1,268,617	Howell et al. 1985, WDFW et al. 1993, WDFW 1994a
	Columbia River	S	Walla Walla River	1991	8,400	ODFW 1994c
		S	Deschutes River	1980	27,280	ODFW 1994c
		S	Ringold	1981-94	2,303,462	WDF et al. 1993, WDFW 1994a
	<b>14-Upper Columbia River</b>					
	Wenatchee River	S	Wells	1981-94	3,571,670	Chapman et al. 1994, WDFW 1994a
		S	Skamania	1982-87	744,000	Chapman et al. 1994, WDFW 1994a
		S	Ringold	1983-89	621,000	Chapman et al. 1994, WDFW 1994a
	Entiat River	S	Wells and Priest Rapids	1981-94	407,133	Chapman et al. 1994, WDFW 1994a
		S	Skamania	1982-83	45,000	Chapman et al. 1994, WDFW 1994a
		S	Ringold	1984-90	120,000	Chapman et al. 1994, WDFW 1994a
	Methow River	S	Wells and Priest Rapids	1981-94	6,024,112	Chapman et al. 1994, WDFW 1994a
	Okanogan River	S	Wells and Priest Rapids	1981-94	1,546,708	Chapman et al. 1994, WDFW 1994a
	Columbia River	S	Wells	1980-85	359,000	Chapman et al. 1994, WDFW 1994a
		S	Skamania	1986	202,000	Chapman et al. 1994, WDFW 1994a
	<b>15-Snake River</b>					
	Lower Snake River	S	Imnaha River	1987-90	176,289	
		S	Walla Walla River	1987-91	782,858	
		S	Lyons Ferry Hatchery	1981-94	2,443,671	WDF et al. 1993, WDFW 1994a

## Appendix D. Hatchery steelhead releases. Continued.

ESU	Receiving water body	Run*	Released stock	Period of record	Total released	References
	Tucannon River	S	Tucannon River	1981-94	1,631,888	WDF et al. 1993, WDFW 1994a
	Clearwater River Basin	S	Clearwater Hatchery	1992	annual goal 2,300,000	Hutchison 1993
	Salmon River Basin	S	Dworshak Hatchery	1970-92	55,200,000	Shelldrake 1993
		S	Magic Valley Hatchery	1987-92	10,778,500	Hutchison 1993
		S	Niagara Springs Hatchery	1987-92	22,230,000	Hutchison 1993
	Snake River	S	Hagerman NFH	1984-92	6,565,500	Shelldrake 1993
		S	Niagara Springs Hatchery	1987-92	22,230,000	Hutchison 1993
	Asotin Creek	S	Hagerman NFH	1984-92	6,565,500	Shelldrake 1993
		S	Lyons Ferry Hatchery	1985-94	462,357	WDFW et al. 1993, WDFW 1994a
	Grande Ronde River	S	Imnaha River	1990	3,212	ODFW 1994c
		S	Wallowa River	1986-94	5,324,996	ODFW 1994c
	Wallowa River	S	Imnaha River	1990	21,760	ODFW 1994c
		S	Wallowa River	1980-94	15,074,518	ODFW 1994c
	Imnaha River	S	Lyons Ferry Hatchery	1983-84	682,858	ODFW 1994c
		S	Imnaha River	1980-94	2,707,265	ODFW 1994c

\*Runs: S = summer steelhead; W = winter steelhead.

**Appendix E**

**Steelhead Abundance Data**









Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>					Data type <sup>c</sup>	Data years	Recent total		Percent annual change <sup>d</sup>		Recent natural run	Recent natural esc.	Percent hatchery esc.	Notes <sup>e</sup>	Data references
			A	B	C	D	E			run	esc.	S.E.	run					
Moclips R	Up Quinault R	W	MWH				RR	1978-94	450	400	-2.6*	1.2	300	1,900				PSMFC 1994, WDFW 1995
		W	MWH				RR	1978-94			+1.8	1.7		1,400				PSMFC 1994, WDFW 1995
		W	NWH				RR	1988-93			+13.6	7.5		250				WDFW 1994b, 1995
Copalis R		W	NWU															
<b>3-Southwest Washington</b>																		
Humphilips R		W	NWH				RR	1979-94	4,100	2,500	-3.5*	1.7	3,000	2,300				QFD & WDFW 1994a, WDFW 1994b
		S	NWU															
Hoquiam R	Basinwide	W	NWH				RR	1984-94			-4.2*	1.5		600				WDFW 1994b, 1995
		W	NWH				RR	1981-94	13,600	8,500	-1.1	2.6	9,900	7,700				QFD & WDFW 1995a, WDFW 1994b
Wishkah R	Wynoochee R	W	NWH				RR	1984-94			-7.3*	2.6		650				WDFW 1994b, 1995
		W	MCH				RR	1984-94			+0.4	4.3		2,000				WDFW 1994b, 1995
Satsop R	Cloquallam Cr	W	NWD				RR	1984-94			-5.1	3.2		2,300				WDFW 1994b, 1995
		W	NWD				RR	1984-93			-5.9	5.5		400				WDFW 1994b
Skookunchuck/ Newaukum R	Mainstem & tribs	W	MCD				RR	1984-94			-7.2	2.6		500				WDFW 1994b, 1995
		W	NWU				RR	1984-94			-6.5*	1.5		2,000				WDFW 1994b, 1995
Grays Harbor	North R/Smith Cr	W	NWU				RR	1993										WDFW 1995
		W	NWU															
Willapa Bay	Palix R	W	NWH				RR	1993										WDFW 1995
		W	NWU															
Nemah R	Naselle R	W	NWU				RR	1993-94						650				WDFW 1995
		W	NWU				RR	1993										WDFW 1995
Bear Cr	Bear Cr	W	NWU															
		W	NWU															
Grays R	Skamokawa Cr	W	C NWD				RR	1991-94		1,200				900		23		WDFW 1994b, 1995
		W	B? NWU				RR	1992-94		300				250		6		WDFW 1994b, 1995
Elochoman R	Mill Cr	W	C NWD				RR	1991-94		900				250		72		WDFW 1994b, 1995
		W	B? NWD															
Abernathy Cr	Germany Cr	W	B? NWD				RR	1991-94		200				150		25		WDFW 1994b, 1995
		W	B? NWD				RR	1993-94		200				150		23		WDFW 1995
Youngs Bay	Lewis and Clark R	W	B?				AC	1977-92			-1.7	1.4				50		Chilcote et al. 1992, ODFW 1992, 1993, 1994c
		W	B?				AC	1977-92			-5.2*	1.9				55		Chilcote et al. 1992, ODFW 1992, 1993
Big Cr	Gnat Cr	W	B?				AC	1977-92			-5.2*	1.9						ODFW 1992, 1993, 1994c
		W	B?				AC	1977-92			-0.3	2.3						ODFW 1992, 1993, 1994c
Clatskanie Bay	Clatskanie R	W	B?															Chilcote et al. 1992, ODFW 1994c
		W	B?															
<b>4-Lower Columbia</b>																		
Cowlitz R	Coweman R	W	B MWD				RR	1988-94		800	-11.7*	4.7		500		35		WDFW 1994b, 1995
		W	C NWD				RR	1989-94		100	+47.9	29.2		100		0		WDFW 1995
Toulet R & N Fk	Toulet R, S Fk	W	C NWD				RR	1984-94		1,000	-5.2	3.4		950		9		WDFW 1994b, 1995
		W	C NWH				RR	1987-94			-16.5*	7.5		90				WDFW 1994b, 1995
Kalama R	Green R	W	C NWD				RR	1978-94		2,300	+0.1	2.2		1,100		32		WDFW 1994b, 1995
		W	C NWH				RR	1978-94		6,600	-1.2	3.1		1,200		66		WDFW 1994b, 1995

Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

ESU	River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>					Data type <sup>c</sup>	Data years	Recent total run	Recent total esc.	Percent annual change <sup>d</sup>	S.E.	Recent natural run	Recent natural esc.	Percent hatchery esc.	Notes <sup>e</sup>	Data references
				A	B	C	D	E											
	Lewis R	East Fork	W	C	NWD				RR	1986-94		-15.7 *	2.7		90			WDFW 1994b, 1995	
		North Fork	S	A	NWD														
	Salmon Cr		W	B?	NWD				RR	1989								WDFW 1995	
	Wahougal R		W	B	NWU				RR	1991-93				100				WDFW 1994b, 1995	
		West Fork	S	A	NWU														
			W	B	NWU														
			S		NWU														
	Hamilton Cr		W	B?	NWU														
	Wind R		W	A	NWU														
		Total	W	A	NWU														
		Mainstem	S	B	NWD				RR	1984-94	600	-7.8 *	3.4	300		53		WDFW 1994b, 1995	
		Panther Cr	S	B?	NWD				RR	1985-94		-3.0	4.4	150			WDFW 1995		
		Trout Cr	S	B?	NWD				RR	1985-94		-1.0	5.4	40			WDFW 1995		
	White Salmon R		W	A	UWD				RR	1985-94		-23.7 *	4.0	50			WDFW 1995		
			S	A+	UWD														
	Sandy R		W	B?					AC	1977-92		-0.4	1.9			>30	Chilcote et al. 1992, ODFW 1992, 1993, 1994c		
			S	X					AC	1978-92	>300	+3.4	2.8			>30	ODFW 1992, 1993		
	Tanner Cr		W	B?					AC	1977-92		+2.5	1.7				ODFW 1995a		
	Willamette R	Lower	W						AC	1977-92		+9.3 *	3.6				ODFW 1992, 1993		
			S						DC	1958-93	1,300	-0.4	0.7				ODFW 1992, 1993		
		Clackamas R	W	B					AC	1977-92		-0.2	1.9			70	PSMFC 1994		
			S						DC	1972-93	3,500	+10.8 *	3.5				ODFW 1992, 1993, 1995a		
			W	A					AC	1977-92		+5.2 *	2.6				PSMFC 1994		
	Hood R		W	A					AC	1977-92	750	-7.3 *	2.3			>40	ODFW 1992, 1993		
			S	B					AC	1977-92	1,500	+4.2 *	2.1			80	ODFW 1992, 1993		
		Lower tribs below Bonneville Dam	W	B													ODFW 1995a		
		Lower tribs above Bonneville Dam	W	A															
			S	A															
	5-Upper Willamette		W						DC	1955-93	6,300	-3.7 *	1.5				PSMFC 1994		
	Willamette R	Basinwide	(Early)						DC	1971-93	1,900	-4.5 *	1.6					PSMFC 1994	
			(Late)						DC	1971-93	4,200	-3.5 *	1.7					PSMFC 1994	
			S						AC	1977-92	11,400	-3.9	2.5					Chilcote et al. 1992, ODFW 1992, 1993	
									DC	1970-93	9700	+13.5 *	3.3					PSMFC 1994	
			W	B?					AC	1977-92	17,800	+4.0	3.8					Chilcote et al. 1992, ODFW 1992, 1993	
		Molalla R	W	B?					AC	1977-92	2,900	-4.9	2.6			0		ODFW 1992, 1993, 1994c, 1995a	
									SS	1979-93		-4.4 *	2.1					PSMFC 1994	

Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

ESU River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>			Data type <sup>c</sup>	Data years	Recent total run	Recent total esc.	Percent annual change <sup>d</sup>	S.E.	Recent natural run	Recent natural esc.	Percent hatchery	Notes <sup>e</sup>	Data references	
			A	B	C												D
6-Oregon Coast	Santiam R	W				DC	1971-87	20								PSMFC 1994	
		S				DC	1970-78	100								PSMFC 1994	
	North Fork	W	B?			AC	1977-92	2,500	2,000	-4.0	3.0			54		ODFW 1992, 1993, 1995a	
	South Fork	W	B?			AC	1977-92	700	550	+2.4	7.3					ODFW 1992, 1993	
	Calapooya R	W	C				700							<g>	Howell et al. 1985, Kostow 1995		
Necanicum R	Lower	W	S			AC	1977-92	3,600	2,100	-2.4	2.2			63		ODFW 1992, 1993, 1994a,b,c	
		W	D			AC	1977-92	2,500	1,500	-3.1	2.9			24		ODFW 1992, 1993, 1994a	
	North Fork	W	D			AC	1977-92	4,000	2,400	-0.5	2.7			37		ODFW 1992, 1993, 1994a	
		W	D											26		ODFW 1994a	
	Upper	W	D			SS	1973-93			-6.0	3.1					PSMFC 1994	
	Salmonberry R	W	D			AC	1977-92	1,400	1,100	-6.4*	2.6			48		ODFW 1992, 1993, 1994a,b,c	
	Miami R	W	C			AC	1977-92	2,300	1,800	-7.6*	1.8			66		ODFW 1992, 1993, 1994a,b,c	
	Kitchis R	W	C			AC	1977-92	300	200	-5.8*	2.6					ODFW 1992, 1993	
	Wilson R	W	C			AC	1977-92	14,900	12,000	-6.7*	1.2			51		ODFW 1992, 1993, 1994a,b,c	
		W	S			AC	1977-92	2,900	2,100	-5.4*	1.7					ODFW 1994a,b,c	
		C				AC	1953-92			+1.0	0.8					Koski 1963, Phelps 1973, ODFW 1980, 1992, 1993	
	Trask R	W	C			AC	1977-92	3,600	2,500	-8.2*	1.5			32-55		Chilcote et al. 1992, ODFW 1992, 1993	
	Nestucca Bay	Tillamook R	S	C			AC	1977-92	900	700	-6.7*	1.6			69		ODFW 1992, 1993
			W	C			AC	1977-92	900	700	-7.7*	2.5					ODFW 1992, 1993, 1994a,b,c
		Nestucca R	W	C			AC	1977-92	7,400	4,400	-8.9*	1.5			34		ODFW 1992, 1993, 1994a,b,c
		S				AC	1977-92	6,400	4,600	-5.6*	1.9					ODFW 1992, 1993, 1994a,b,c	
Little Nestucca R		C				AC	1953-92			+2.3*	0.7					Koski 1963, Phelps 1973, ODFW 1980, 1992, 1993	
		W	D			AC	1977-92	1,200	1,000	-11.8*	2.2			79		ODFW 1992, 1993, 1994a	
		W	D														
		W	C			AC	1977-92	4,400	3,500	-7.7*	1.9			70		ODFW 1992, 1993, 1994a,b,c	
Rock Cr./Devils Lk		S				AC	1977-92	500	350	-0.1	3.4					ODFW 1992, 1993	
		W	D														
	Siletz R	W	C			AC	1977-92	6,700	4,500	-7.6*	1.8			57		ODFW 1992, 1993, 1994a,b,c	
		S	B			AC	1977-92	4,400	3,200	-10.9*	2.1			90		ODFW 1992, 1993, 1994a,b,c	
Yaquina R	Drift Cr	W				AC	1977-92	1,100	900	-12.4*	2.7			58		ODFW 1992, 1993, 1994a	
	Total	C							+2.7*	0.8						Koski 1963, Phelps 1973, ODFW 1980, 1992, 1993	
	Big Elk Cr	W	C			AC	1977-92	1,800	1,400	-2.9	4.0			60		ODFW 1992, 1993, 1994a	
		W														ODFW 1992, 1993	
Theil Cr	Beaver Cr	W	D														
		W	D														
	Alesea Bay	W	C			AC	1977-92	6,500	4,000	-7.2*	2.5			50		ODFW 1992, 1993, 1994a,b,c	
	Drift Cr	W	D			AC	1977-92	700	600	-6.5	4.2			79-91		Chilcote et al. 1992, ODFW 1992, 1993	
Big Cr	Total	C				AC	1970-92			-6.4*	1.3					ODFW 1980, 1992, 1993	
		W	D														
	Yachats R	W	C			AC	1977-92	250	200	-4.1	4.0			>10		Chilcote et al. 1992, ODFW 1992, 1993	

Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

ESU	River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>				Data type <sup>c</sup>	Data years	Recent total run	Recent total esc.	Percent annual change <sup>d</sup>	S.E.	Recent natural run	Recent natural esc.	Percent hatchery esc.	Notes <sup>f</sup>	Data references
				A	B	C	D											
	Cummins Cr		W					D										
	Bob Cr		W					D										
	Tennite Cr		W	C	D	D	D	D	300	250	-3.6	3.5				27	Chilcote et al. 1992, ODFW 1992, 1993	
	Rock Cr		W					D										
	Big Cr		W	C	D	D	D	D	300	200	-7.0*	3.2				>10	Chilcote et al. 1992, ODFW 1992, 1993	
	Cape Cr		W					D										
	Sutton Cr		W					D										
	Siuslaw Bay	Siuslaw R	W	C	D	D	D	D	4,600	2,700	-4.9	2.7				56	ODFW 1992, 1993, 1994a,b,c	
		Siuslaw R, NF	W	C	D	D	D	D	700	600	+0.3	3.4				49	ODFW 1992, 1993, 1994a	
	Sillcoos R		W					S										
	Talkenitch Cr		W					S										
	Umpqua Bay	Smith R	W					D										
		Umpqua R	W					D										
			S						1,000	500	-3.5	2.8				48	ODFW 1992, 1993, 1994a,b,c	
			C						14,700	11,900	-3.4*	1.6				53-81	Chilcote et al. 1992, ODFW 1992, 1993	
									1,000	500	-3.5	2.8						
									AC 1953-92		-1.1	0.6						
			W					S	5,600	5,300	-0.5	0.3						
								H	DC 1946-93									
									AC 1977-92		-0.6	1.7						
			S						7,200							10	ODFW 1992, 1993	
									2,700		+1.0*	0.4				<g>	ODFW 1994a,b,c, PSMFC 1994	
									AC 1977-92		+0.9	2.9						
			C						9,300							62	ODFW 1995a	
											+7.6*	1.2				<g>	Koski 1963, Phelps 1973, ODFW 1980, 1992, 1993	
			W					S	4,300	3,500	-0.8	3.4				43-81	Chilcote et al. 1992, ODFW 1992, 1993, 1994a,b,c	
			S															
			W						800	400	+5.4	5.5				38	ODFW 1992, 1993, 1994a,b,c, 1995a	
			W						AC 1977-92		-2.5	4.3				80	ODFW 1992, 1993, 1994a,b,c	
			W						6,100	5,600	-1.3	1.2				70	Phelps 1973, ODFW 1980, 1992, 1993	
			W															
			W						3,800	3,100	-0.5	3.5				65	ODFW 1992, 1993, 1994a,b,c	
			W						AC 1977-92		-3.0	3.8				75	ODFW 1992, 1993, 1994a,b,c	
			W						5,000	3,000	+1.4	3.7				55	ODFW 1992, 1993, 1994a, 1995a	
			W						3,900	3,200	+16.0*	5.7						
			W						AC 1977-92		+7.9	4.4						
			W						2,100	1,700	-2.9	3.0				55	ODFW 1992, 1993, 1994a, 1995a	
			W						600	500	+2.6*	0.8						
			W															
			W						900	700	-1.4	2.8				32	Koski 1963, Phelps 1973, ODFW 1980, 1992, 1993, 1994a	
			W															
			W						1,000	800	-4.6*	2.3				36	Chilcote et al. 1992, ODFW 1992, 1993, 1994a,b,c	







Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

ESU	River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>					Data type <sup>c</sup>	Data years	Recent total run	Recent total esc.	Percent annual change <sup>d</sup>	S.E.	Recent natural run	Recent natural esc.	Percent hatchery esc.	Notes <sup>e</sup>	Data references
				A	B	C	D	E											
	Dos Pueblos Canyon Cr		W						?										
	Tecolote Cr		W						?										
	San Jose Cr	two stocks	W						?										
	Maria Ygnacio Cr		W	X															
	Mission Cr	two stocks	W						?										
	Carpinteria Cr		W						?										
	Rincon Cr		W	X					E										
	Ventura R	five stocks	W	A					E<7	C				<200				Higgins 1991, Nehlsen et al. 1991, Reavis 1991, Nash 1993, CCC 1994, McEwan and Jackson 1996	
	Santa Clara R	four stocks	W	A					E<	C				<100				Nehlsen et al. 1991, Reavis 1991, CCC 1994	
	Calleguas Cr		W						?										
	Big Sycamore Canyon Cr		W						?										
	Arroyo Sequit		W						X										
	Malibu Cr		W	A					<					<100				AFS 1991, Nehlsen et al. 1991, Reavis 1991, Nash 1993	
	Topanga Cr		W						X										
	Los Angeles R	three stocks	W	X					E										
	San Gabriel R	five stocks	W	X					E										
	Santa Ana R		W	X					E										
	San Juan Cr		W						E										
	San Mateo Cr		W	X					E										
	San Onofre Cr		W						E										
	Santa Margarita R		W	X					E										
	San Luis Key R		W	X					E										
	San Diego R		W	X					E										
	San Diego R		W	X					E										
	Sweetwater R		W	X					E										
	Olaj R		W						E										
	Tijuana R	two stocks	W						E										
	Santo Domingo R		W						?										
<b>12-Central Valley</b>																			
	Sacramento R		W	A															CDFG 1994
	Upper R		W							1,500	-9.0*	1.1							PSMFC 1994
										2,200									CDFG 1994
										10,000									CDFG 1994
<b>INLAND ESUs</b>																			
<b>13-Middle Columbia</b>																			
	Klickitat R		W	A	NWU									2,400	-9.2	5.2			WDFW 1994b
	Rock Cr		S	C	NWU														
	Yakima R		S	A?	NWU														
	Fifteenmile Cr	mainstem	W	B	NWD					1,000	850	+14.0*	5.9	850	800		5	<Δ>	WDFW 1994b, 1995
		mainstem & tribs	W	B?	NWD							-5.4*	2.1						ODFW 1994c, PSMFC 1994
												-37.4*	6.6						PSMFC 1994

Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

ESU	River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>				Data type <sup>c</sup>	Data years	Recent total run	Recent total esc.	Percent annual change <sup>d</sup>	S.E.	Recent natural run	Recent natural esc.	Percent hatchery	Notes <sup>e</sup>	Data references
				A	B	C	D											
	Deschutes R		S					DC	1978-93	11,300	+2.6	2.6		3,000			ODFW 1994c, PSMFC 1994	
								AC	1976-92		-0.1	2.2					ODFW 1992, 1993	
		Warm Springs R	S					DC	1978-94	150	-5.8 *	2.6			50	<g>	ODFW 1995a	
		Shitike Cr	S					SS	1976-94		-6.3 *	2.3					PSMFC 1994	
	John Day R	Total	S					AC	1976-92		+11.1 *	3.7					Howell et al. 1985, ODFW 1992, 1993, 1994c	
		Lower	S							>1000					11	<g>	Chilcote et al. 1992, ODFW 1995a	
		Upper	S							>1000						<g>	ODFW 1995a	
		John Day R	S					SS	1959-94		-2.2 *	0.8					PSMFC 1994	
		JDR & ms tribs	S					SS	1966-94		-1.4	1.8					PSMFC 1994	
		SF tributaries	S					SS	1969-94		-4.1 *	2.0					PSMFC 1994, WDFW 1995	
		NF tributaries	S					SS	1985-94		-20.2 *	7.6				<g>	ODFW 1995a	
		MF tributaries	S					SS	1968-94		-0.8	2.9				<g>	ODFW 1995a	
		Combined	S					SS	1985-94		-14.6 *	5.4				<g>	ODFW 1995a	
	Unatilla R		S					DC	1967-94	1,700	+0.7	1.2					PSMFC 1994	
			S					AC	1976-92		-3.0	3.6				<25	ODFW 1992, 1993, 1995a	
	Walla Walla R		S	C	MCD			AC	1976-92		+7.9 *	3.2		300-400			Howell et al. 1985, ODFW 1992, 1993	
			S					RR	1986-93	650	-2.7	8.2		300		5	<g>	ODFW 1995a
		Touchet R & Forks	S					MCD								7		WDFW 1994b, WDFW 1995
<b>14-Upper Columbia</b>																		
	Wenatchee R		S	C	MWD			RR	1962-93	2,700	+2.6	1.9		800		65		WDFW 1994b, 1995
	Entiat R		S	A	MWD													
	Methow R & Okanogan R	Combined	S	A	MWD			RR	1982-93	4,700	-12.0 *	2.8		450		81		WDFW 1994b, 1995
	Spokane R		S	X														
	Pend Oreille R		S	X														
<b>15-Snake River Basin</b>																		
	Tucannon R		S	C	MCD			RR	1986-93	700	-18.3 *	3.8		140		57		WDFW 1994b, 1995
	Snake R	above Lower Granite Dam	S					RR	1975-94	71,400	+6.9 *	2.0		9,500		86		WDFW 1994b, IDFG 1995
		Oregon	S					AC	1981-92		+22.2 *	8.2						ODFW 1993, 1994a
	Asotin Cr		S	B	MCD			RR	1985-93	200	-19.7 *	6.6				<4>	WDFW 1994b, 1995	
	Grande Ronde R	Total	S	A?	MCD			AC	1986-92		+160.6 *	56.7					ODFW 1993, 1994a	
		Lower GR	S					SS	1964-88		-0.5	2.2					PSMFC 1994	
		Upper GR	S					SS	1966-94		-3.5	2.1					PSMFC 1994	
		Joseph Cr & tribs	S					SS	1969-93		+3.9	3.3					PSMFC 1994	
		Wallowa R	S					AC	1987-92	>300	-6.1	47.6				0	<g>	Chilcote et al. 1992, ODFW 1995a
		Wallowa R & tribs	S					SS	1965-94		-3.0 *	1.4					Howell et al. 1985, ODFW 1993, 1994a	
	Salmon R		S	C													PSMFC 1994	
		Salmon R & tribs	S					SS	1990-94		-30.0	20.3					IDFG 1994	
		East Fork	S					DC	1985-94	150	-6.0	7.0				20		PSMFC 1994, IDFG 1995

Appendix E. Summary of steelhead abundance data considered, by evolutionarily significant unit (ESU) and river basin. Continued.

ESU River basin	Sub-basin	Run <sup>a</sup>	Previous assessments <sup>b</sup>				Data type <sup>c</sup>	Data years	Recent total run	Recent total esc.	Percent annual change <sup>d</sup>	S.E.	Recent natural run	Recent natural esc.	Percent hatchery esc.	Notes <sup>e</sup>	Data references
			A	B	C	D											
	Middle Fk. & tribs	S					SS 1990-94			-25.8 *	10.0					IDFG 1994	
	South Fk. & tribs	S					SS 1990-94			-8.0	12.8					IDFG 1994	
	Pashimetroi	S					DC 1986-94	1,400		+0.1	0.2		40			PSMFC 1994, IDFG 1995	
		S	C				AC 1988-92			+81.2 *	28.8				>50	Howell et al. 1985, CBFWA 1990, ODFW 1993, 1994a, 1995a	
	Camp Cr	S					SS 1965-94			+1.4	2.4					PSMFC 1994	
	Rapid R	S					DC 1975-85	80		+1.7	3.6					PSMFC 1994	
	Clearwater R	S	C														
	Powder R	S	X														
	Burnt R	S	X														
	Weiser R	S	X														
	Payette R	S	X														
	Malheur R	S	X														
	Boise R	S	X														
	Owyhee	S	X														
	Bruneau R	S	X														

<sup>a</sup>S--Summer, W--winter, F--Fall (may be stream or ocean maturing), C--Combined.

<sup>b</sup>Status summaries from the following sources:

A--Nehlsen et al. (1991); X, extinct; A+, possibly extinct; A, high extinction risk; B, moderate extinction risk; C, special concern.

B--WDF et al. (1993). Three characters represent stock origin, production type, and status, in that order. Origin: N, native; X, non-native; M, mixed; U, unknown; -, unresolved by state and tribes.

Production: W, wild; C, composite; U, unknown; -, unresolved. Status: H, healthy; D, depressed; C, critical; U, unknown. Dito marks (\*) indicate that stock was included with previous stock in the report.

C--Nickelson et al. (1992); H, Healthy; D, Depressed; S, Special concern.

D--Titus et al. (1994); X, steelhead present, no discernible change from historical levels; <, production reduced or likely so; ?, current presence/absence unknown; E, extinct population.

E--USFS (1993a,b); U, "unknown"; D, "depressed"; "declining"; "low", or "moderate risk of extinction"; S, "stable" or "healthy"; C, "critical"; "high risk of extinction", or "severely depressed";

X, "extinct"; N, "not present".

\*AC--angler catch; BS--beach seine; DC--dam or weir count; HR--hatchery return; RR--run reconstruction; SS--stream survey.

<sup>d</sup>Asterisk (\*) denotes annual change significantly different from zero (two-tailed t-test, p<0.05).

<sup>e</sup>Letter codes are:

<a> most recent 5 years not consecutive

<b> less than 5 years data available

<c> less than 5 years natural run size data available

<d> less than 5 years % hatchery escapement data available

<e> data from 1985-90 used for most recent 5 years

<f> data from 1988-92 used for most recent 5 years

<g> estimated annual run recorded in recent total run column.



**Appendix F**

**Glossary**



## Glossary

### ageing

Ageing and **backcalculated** length at age are based on counts and measurements of annual rings on scales or **otoliths** (a calcareous “**earstone**” found in the internal ear of fishes). The typically **anadromous** life history of **steelhead** and their ability to undergo multiple spawning migrations complicate the matter of reporting the age of fish of this species. Numerous authors have developed notation styles for this purpose. Original citations should be consulted for in-depth descriptions (e.g., **Shapovalov** and Taft 1954). Freshwater age is generally separated from saltwater age by either a slash (/) or period (.); for example, a fish which **smolted** after 2 years in fresh water and was caught after 3 years in the ocean could be represented by 2/3 or 2.3.

### allele

An **allele** is an alternate form of a gene (the basic unit of heredity passed from parent to offspring). By convention, the “**100 allele**” is the most common **allele** in a population and is the reference for the **electrophoretic** mobility of other **alleles** of the same gene. Other genetic terms used in this document include **allozymes** (alternate forms of an enzyme produced by different **alleles** and often detected by protein **electrophoresis**); gene locus (**pl. loci**; the site on a chromosome where a gene is, found); genetic distance (**D**) (a quantitative measure of genetic differences between a pair of samples); and **introgression**. (introduction of genes from one population or species into another). See also **DNA and electrophoresis**.

### artificial propagation

See hatchery.

### Cape Blanco

A geographic feature on the Oregon coast at **43°50'N**.

### Cape Mendocino

A geographic feature on the California coast at **40°25'N**.

## coastal steelhead

*Anadromous Oncorhynchus mykiss* that occur in rivers from Alaska to California, including tributaries to the Fraser and Columbia Rivers largely west of the Cascade Crest. Coastal steelhead are genetically distinct from inland steelhead that occur in the Fraser and Columbia River Basins largely east of the Cascade Crest. Behnke (1992) has proposed subspecies status for these two forms and applies the taxonomic name *O. m. irideus* to coastal steelhead. The resident form is commonly called rainbow trout.

## DNA (deoxyribonucleic acid)

DNA is a complex molecule that carries an organism's heritable information. The two types of DNA commonly used to examine genetic variation are mitochondrial DNA (mtDNA), a circular molecule that is maternally inherited, and nuclear DNA, which is organized into a set of chromosomes. See also allele and electrophoresis.

## electrophoresis

Electrophoresis refers to the movement of charged particles in an electric field. It has proven to be a very useful analytical tool for biochemical characters because molecules can be separated on the basis of differences in size or net charge. Protein electrophoresis, which measures differences in the amino acid composition of proteins from different individuals, has been used for over three decades to study natural populations, including all species of anadromous Pacific salmonids. Because the amino acid sequence of proteins is coded for by DNA, data provided by protein electrophoresis provide insight into levels of genetic variability within populations and the extent of genetic differentiation between them. Utter et al. (1987) provide a review of the technique using examples from Pacific salmon, and the laboratory manual of Aebersold et al. (1987) provides detailed descriptions of analytical procedures. Genetic techniques that focus directly on variation in DNA also routinely use electrophoresis to separate fragments formed by cutting DNA with special enzymes (restriction endonucleases).

Other genetic terms used in this document include allele (an alternate form of a gene); allozymes (alternate forms of an enzyme produced by different alleles and often detected by protein electrophoresis); chromosome (a thread-like structure containing many genes); dendrogram (a branching diagram, sometimes resembling a tree, that provides one way of visualizing similarities between different groups or samples); gene (the basic unit of heredity passed from parent to offspring); gene locus (pl. loci; the site on a chromosome where a gene is found); genetic distance (a quantitative measure of genetic differences between a pair of samples); introgression (introduction of genes from one population or species into another); and karyotype (the number, size, and morphology of the chromosome complement).



**ESA**

The U.S. Endangered Species Act.

**ESU**

Evolutionarily significant unit; a “distinct” population of Pacific salmon, and hence a species, under the Endangered Species Act.

**escapement**

The number of fish that survive to reach the spawning grounds or hatcheries. The escapement plus the number of fish removed by harvest form the **total run size**.

**half-pounder**

A life history trait of **steelhead** exhibited 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.

**hatchery**

Salmon hatcheries use artificial procedures to spawn adults and raise the resulting progeny in fresh water for release into the natural environment, either directly from the hatchery or by transfer into another area. In some cases, fertilized eggs are **outplanted** (usually in “hatch-boxes”), but it is more common to release fry (young juveniles) or **smolts** (Juveniles that are physiologically prepared to undergo the migration into salt water).

The **broodstock** of some hatcheries is based on the adults that return to the hatchery each year; others rely on fish or eggs from other hatcheries, or capture adults in the wild each year.

**inland steelhead**

*Anadromous Oncorhynchus mykiss* that occur in the Fraser and Columbia River Basins largely east of the Cascade Crest. Inland **steelhead** are genetically distinct from **coastal steelhead** that occur in rivers from Alaska to California, including tributaries to the Fraser and Columbia Rivers largely west of the Cascade Crest. Behnke (1992) has proposed subspecies status for these two forms and applies the taxonomic name *O. m. gairdneri* to inland **steelhead**. The resident form is commonly called **redband** trout.

**monophyletic**

Relating to, descended from, or derived from one stock or source. See **polyphyletic**.

**multidimensional scaling**

A **nonmetric** ordination technique used to visualize genetic relationships among populations in two or three dimensions.

**ocean-maturing**

**Steelhead** that enter fresh water with well-developed gonads and spawn shortly thereafter; commonly referred to as winter **steelhead**. See **stream-maturing**.

**phenotype**

The phenotype is the appearance, or other observable characteristic, of an organism resulting from the interaction of the genotype and the environment.

**polymorphic**

Having more than one form (e.g., **polymorphic** gene loci have more than one **allele**).

**polyphyletic**

Relating to or characterized by development from more than one ancestral type. See **monophyletic**.

**punchcard**

A card (alternatively called a tag or stamp) used by **steelhead** and salmon anglers to record catch information; it is returned to the management agency after the fishing season.

**redd counts**

Most **salmonids** deposit their eggs in nests called **redds**, which are dug in the **streambed** substrate by the female. Most **redds** occur in predictable areas and are easily identified by an experienced observer by their shape, size, and color (lighter than surrounding areas because silt has been cleaned away).

**Spawning surveys** utilize counts of **redds** and fish carcasses to estimate spawner escapement and identify habitat being used by spawning fish. Annual surveys can be used to compare the relative magnitude of spawning activity between years.

**river kilometer (RKm)**

Distance, in kilometers, from the mouth of the indicated river. Usually used to identify the location of a physical feature, such as a **confluence**, dam, or waterfall.

**smolt**

verb- The physiological process that prepares a juvenile **anadromous** fish to survive the transition from fresh water to salt water.

noun- A juvenile **anadromous** fish which has smelted.

**steelhead**

The **anadromous** form of the species *Oncorhynchus mykiss*. **Anadromous** fish spend their early life history in fresh water, then migrate to salt water, where they may spend up to several years before returning to fresh water to spawn. Rainbow trout is the **nonanadromous** form of *Oncorhynchus mykiss*.

**stream-maturing**

**Steelhead** that enter fresh water in a sexually immature condition and require several months in fresh water to mature and spawn, commonly referred to as summer **steelhead**. See **ocean-maturing**.