
NOAA-NWFSC Tech Memo-19: Status Review for Klamath Mountains Province Steelhead

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NOAA Technical Memorandum NMFS-NWFSC-19

Status Review for Klamath Mountains Province Steelhead

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SUMMARY

The Endangered Species Act (ESA) allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. The policy of the National Marine Fisheries Service (NMFS) on this issue for Pacific salmon and steelhead is that a population will be considered "distinct" for purposes of the ESA if it represents an Evolutionarily Significant Unit (ESU) of the species as a whole. To be considered an ESU, a population or group of populations must 1) be substantially reproductively isolated from other populations, and 2) contribute substantially to ecological/genetic diversity of the biological species. Once an ESU is identified, a variety of factors related to population abundance are considered in determining whether a listing is warranted. NMFS received a petition in May 1992 asking that winter steelhead of Oregon's Illinois River be listed as a threatened or endangered species under the ESA. In May 1993, NMFS published a Federal Register notice concluding that Illinois River winter steelhead did not by themselves constitute a species as defined by the Endangered Species Act (ESA). At the same time, NMFS indicated that it would undertake a broader status review to determine the boundaries of the Evolutionarily Significant Unit (ESU) that contains Illinois River winter steelhead and determine whether this broader group was threatened or endangered. This report summarizes biological and environmental information gathered in that status review

Based on genetic, life history, zoogeographic, geologic, and environmental information, we conclude that the ESU that contains Illinois River winter steelhead extends from the vicinity of Cape Blanco in southern Oregon to the Klamath River Basin (inclusive) in northern California. These are essentially the boundaries of a prominent geologic feature known as the Klamath Mountains Province. Both winter- and summer-run steelhead are included in this ESU, as well as populations sometimes referred to as "fall-run" in California. Within this geographic area, most steelhead populations show a declining trend in abundance, and 10 stocks have been identified in independent stock assessment reports as being at moderate or high risk of extinction. Furthermore, the declines are even more dramatic when only natural fish (progeny of naturally spawning fish) are considered. We conclude that steelhead within this ESU are likely to become endangered in the foreseeable future.

ACKNOWLEDGMENTS

This review was conducted, in effect, as a continuation of the status review for Illinois River winter steelhead (Busby et al. 1993). Although the legal requirements for responding to the Illinois River winter steelhead petition were fulfilled by the initial status review, which concluded that the petitioned population was not a "species" under the Endangered Species Act, the National Marine Fisheries Service Directorate initiated this extended status review, and the authors of this Technical Memorandum would like to acknowledge their support.

As with all ESA status reviews, information submitted by agencies, organizations, and individuals was invaluable. The authors acknowledge the efforts of all who contributed to the Administrative Record.

The biological review team for this status review included: Peggy Busby, Dr. David Damkaer, Robert Emmett, Dr. Stephen Grabowski, Dr. Jeffrey Hard, Dr. Orlay Johnson, Dr. Conrad Mahnken, Gene Matthews, Dr. Michael Schiewe, Dr. Thomas Wainwright, William Waknitz, Dr. Robin Waples, Laurie Weitkamp, Dr. John Williams, and Dr. Gary Winans.

INTRODUCTION

In May 1992, the National Marine Fisheries Service (NMFS) received a petition (ONRC et al. 1992) to list southwest Oregon's Illinois River winter steelhead (Oncorhynchus mykiss) as a threatened or endangered "species" under the U.S. Endangered Species Act (ESA) of 1973 as amended (U.S.C. 1531 et seq.). A status review completed in May 1993 (Busby et al. 1993, NMFS 1993) concluded that winter steelhead of the Illinois River, a tributary to the Rogue River (Fig. 1), did not by itself constitute a species under the ESA. However, it was also concluded that steelhead from the Illinois River are part of a larger Evolutionarily Significant Unit (ESU) whose boundaries remained to be determined. Whether the larger ESU that contains Illinois River winter steelhead would merit protection under the ESA could not be determined until the nature and extent of the ESU were identified and additional information about patterns of abundance in coastal steelhead was compiled.

On 20 May 1993, NMFS published a Federal Register notice (NMFS 1993) initiating a status review of coastal steelhead populations in California, Oregon, and Washington for the purpose of identifying ESU(s) in these areas and determining whether listing under the ESA was warranted for any identified ESU. The present report summarizes information considered in this status review relative to the ESU that includes Illinois River winter steelhead.

The biological species *Oncorhynchus mykiss* includes several forms of nonanadromous and anadromous trout, including rainbow trout, redband trout, and steelhead (the name applied to the anadromous form of the species). Taxonomy of *O. mykiss*, and the relationship between the various forms, has been well studied, yet remains challenging (e.g., Kendall 1920, Snyder 1940, Behnke 1992). Behnke (1992) proposed that there are seven or eight subspecies within *O. mykiss* (Table 1).

Figure 1. Map showing the Illinois River and other key geographic locations discussed in this status review. See Figure 2 for detail.

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

Scientific name	Common name and comments
Rainbow trout of coastal basins	
O. mykiss irideus	Coastal rainbow trout from Alaska to California (anadromous form is called steelhead)

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

Two major genetic groups of *O. mykiss* are presently recognized: the inland and coastal groups, separated by 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 has only coastal steelhead. Based on Schreck et al. (1986), the demarcation between coastal and inland steelhead in the Columbia River Basin occurs between the Hood River and Fifteenmile Creek in Oregon and between the Klickitat River and Rock Creek in Washington (i.e., in the vicinity of The Dalles Dam). These genetic groups apply to both anadromous and nonanadromous forms of *O. mykiss*; that 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's (1992) terminology for subspecies of *O. mykiss* reflects this genetic difference. Coastal rainbow trout of North America, as well as coastal steelhead, are placed in the subspecies *O. m. irideus* (Behnke 1992). The inland Columbia redband trout of the Columbia and Fraser River Basins, as well as inland steelhead, are placed in the subspecies *O. m. gairdneri* (Behnke 1992). Illinois River winter steelhead fall within the coastal group, subspecies *O. m. irideus*.

Present distribution of coastal steelhead in Washington, Oregon, and California extends from the U.S.-Canada border south to Malibu Creek, California. Within this distribution are two major life-history types: summer-run (summer steelhead) and winter-run (winter steelhead). These run-types are primarily differentiated by time and duration of spawning migration and state of sexual maturity at the time of river entry. Summer steelhead enter fresh water between May and October, in a sexually immature condition. After several months in fresh water, summer steelhead mature and spawn. Winter steelhead enter fresh water between November and April with well-developed gonads and spawn shortly thereafter. Both summer and winter steelhead are found in some drainages, including the Rogue River Basin of southwest Oregon. The Illinois River is generally considered to have only winter-run steelhead.

Scope of Present Status Review

The environmental and biological information developed in the Illinois River winter steelhead status review (Busby et al. 1993) indicated that the ESU that contains that population might extend somewhat north of the Rogue River Basin and south into northern California. Therefore, the present status review concentrates on environmental and biological information for that geographic area.

KEY QUESTIONS IN ESA EVALUATIONS

Two key questions must be addressed in determining whether a listing under the ESA is warranted:

1) Is the entity in question a "species" as defined by the ESA?

2) If so, is the "species" threatened or endangered?

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 provided no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991). A more detailed description of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991). 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 in the evolutionary legacy of the species. Information that can be useful in determining the degree of reproductive isolation includes incidence of straying, rates of recolonization, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance can be provided by data on genetic and life-history characteristics, habitat differences, and the effects of stock transfers or supplementation efforts.

Hatchery Fish and Natural Fish

Because artificial propagation of Pacific salmonids has been widespread for many years, the influence of hatchery fish needs to be considered in most ESA status reviews. NMFS policy stipulates that in determining whether a population is distinct for purposes of the ESA, attention should focus on "natural" fish, which are defined as the progeny of naturally spawning fish (Waples 1991). 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.

The decision to focus on natural fish is based entirely on ecosystem considerations; the question of the relative merits of hatchery vs. natural fish is a separate issue. Fish are not excluded from ESA consideration simply because some of their direct ancestors may have spent time in a fish hatchery, nor does identifying a group of fish as "natural" as defined here automatically mean that they are part of a listed ESU. For a discussion of artificial propagation of Pacific salmon under the ESA, see Hard et al. (1992).

Thresholds for Threatened or Endangered Status

The ESA (sec. 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." Neither NMFS nor the U.S. Fish and Wildlife Service (USFWS), which share authority for administering the ESA, has an official policy interpreting these definitions in terms of thresholds for considering ESA "species" as threatened or endangered. An information document on this topic (Thompson 1991) published by NMFS suggests that conventional rules of thumb, analytical approaches, and simulations may all be useful in making this determination. There is considerable interest in incorporating the concepts of population viability analysis (PVA) into ESA threshold considerations for Pacific salmon. However, available PVA models generally require substantial life-history information that is not available for most Pacific salmon populations, so quantitative PVA is not practical at this time.

Therefore, NMFS considers a variety of information in evaluating the level of risk faced by an ESU. Important factors include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., selective fisheries and interactions between hatchery and natural fish); and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the ESU.

In evaluating these factors, the role of artificial propagation is an important issue. Because of the ESA's emphasis on conserving species in their native ecosystems, threshold determinations must focus on the status of natural fish.

Artificial production may have direct or indirect impacts on the status of a population through direct supplementation of numbers, by altering the genetic composition of the population, or through ecological interactions (competition, predation, disease transmission, etc.) between artificially-produced and natural fish. A mixture of artificially-produced and natural fish in a population also makes assessment of the natural fish difficult: abundance and viability of the natural stock is difficult to estimate unless artificially-produced fish are clearly marked, and trends in the natural stock can be obscured by the infusion of artificially-produced fish and their progeny into the natural population. An important question for many natural populations is the following: Is natural production sufficient to maintain the population without the constant infusion of artificially-produced fish?

According to the ESA, the determination whether a species is threatened or endangered should be made on the basis of the best scientific information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In this review, we did 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").

SUMMARY OF 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 the ESU that includes Illinois River winter steelhead. Information presented in this section forms the basis for conclusions regarding the species and threshold questions, which are addressed in the following section.

Environmental Features

Ecoregions and Zoogeography

Many efforts have been made to describe and classify the distributions of the Earth's plant and animal species and their habitats. These have resulted in the development of several classification schemes for continental and marine environments.

Bailey (1976, 1980), Omernik and Gallant (1986), and Omernik (1987) used geologic, edaphic, climatic, and vegetational patterns to delineate ecoregions for the United States. Franklin and Dyrness (1973) used similar information to delineate physiographic provinces for Oregon and Washington. Most recently, the Forest Ecosystem Management Assessment Team (FEMAT) delineated aquatic and terrestrial physiographic provinces for the northern spotted owl region (USFS and BLM 1994).

Zoogeographic regions and provinces in the marine environment have been described using climate and faunal distribution. Allen and Smith (1988) discussed the marine zoogeographic literature and presented zoogeographic regions and provinces and marine life zones for the North Pacific Ocean and Bering Sea. Within the Oregonian Province, Allen and Smith (1988, p. 144) found that Cape Mendocino, California "is an important southern limit (at least in abundance) of many northern species" of marine fish.

Ichthyogeography--Snyder (1907) may have been the first to attempt to categorize the freshwater ichthyofauna of Oregon and California into geographic groups. Based on phenotypic characteristics and assemblages of fluvial fish species, Snyder (1907) identified three ichthyofaunal groups for the coastal area between the Columbia and Sacramento Rivers: Columbia River Fauna, Klamath River Fauna, and Sacramento River Fauna. The Columbia River faunal group included basins north of the Rogue River. The Klamath River faunal group included the Rogue and Klamath River Basins. The Sacramento River faunal group included rivers south of the Klamath Basin.

Moyle (1976) discussed the zoogeography of inland fish of California. He noted that the Klamath smallscale sucker (Catostomus rimiculus) is common to both the Rogue and Klamath Rivers, yet the Rogue River "lacks other Klamath fishes, such as speckled dace [Rhinichthys osculus] and marbled sculpin [Cottus klamathensis], and contains reticulate sculpin [C. perplexus], a species abundant in coastal streams further north" (Moyle 1976, p. 15). Moyle considered coastal streams of northern California (south of the Klamath River) to be part of the Sacramento River inland fish fauna, as did Snyder (1907). Moyle specifically noted that "the Mad, Eel, Bear, Navarro, Gualala, and Russian rivers, as well as three tributaries to Tomales Bay (Walker, Papermill, and Olema creeks) all contain freshwater fishes derived from the Sacramento-San Joaquin River system" (p. 17).

Hughes et al. (1987) described ichthyogeographic regions in Oregon based on the distribution of 68 native fish species. They found a similarity between these ichthyogeographic regions and the physiographic provinces of Franklin and Dyrness (1973) and the aquatic ecoregions of Omernik (1987). Hughes et al. concluded that seven ichthyogeographic regions could be delineated in Oregon. Coastal steelhead are known from all of these regions except the Blue Mountains region, which contains inland steelhead, and the Endorheic Lakes region of eastern Oregon, which contains redband trout.

Physiographic and zoogeographic classification of southwest Oregon--With respect to the above, the Illinois River (Rogue River Basin) of southwest Oregon falls within the Coast Range and Sierra Nevada ecoregions of Omernik (1987) and the Klamath Mountains physiographic region of Franklin and Dyrness (1973) and FEMAT (USFS and BLM 1994). The Rogue River Basin is within the Rogue River/Sierra Nevada ichthyogeographic region of Hughes et al. (1987) and the Klamath/Siskiyou and Franciscan aquatic ecosystems physiographic provinces of FEMAT (USFS and BLM 1994). The Rogue River Basin shares some inland ichthyofaunal commonalities with the Klamath River to the south, as well as with some streams to the north (Snyder 1907, Moyle 1976, Behnke 1992). Each of the studies cited above has consistently delineated an ecoregion, that includes the Illinois River, that largely corresponds with a geological feature known as the Klamath Mountains Geological Province.

Klamath Mountains Geological Province

The Klamath Mountains Geological Province includes a complex of mountain ranges in southwest Oregon and northwest California (Fig. 2). Collectively, these are called the Klamath Mountains; they include the Trinity Alps, Salmon Mountains, Marble Mountains, and Siskiyou Mountains (Wallace 1983). Ecologically, the region is classified in the Marine Division of the Humid Temperate Domain (Bailey 1980); however, it exhibits influence from the warmer, drier Mediterranean Division (Atzet - footnote 1). This region includes diverse localized climates including cool, wet coastal areas and hot, dry interior valleys that receive less precipitation than any other location in the Pacific Northwest west of the Cascade Range (Franklin and Dyrness 1973). For example, average annual precipitation in the interior Rogue River valley ranges between 30 and 94 cm (Oregon Water Resources Committee 1955), while at Cave Junction in the middle Illinois Valley it is 152 cm, and Gold Beach at the mouth of the Rogue River receives 229 cm (USFS 1989).

The Siskiyou Mountains include northern extensions of geological formations typical of those found in the California Coast Ranges and the Sierra Nevada (Franklin and Dyrness 1973). The unusual geology and climate result in vegetation which "combines elements of the California, north coast, and eastern Oregon floras, with a large number of species indigenous only to the Klamath Mountains region" (Franklin and Dyrness 1973, p. 130).

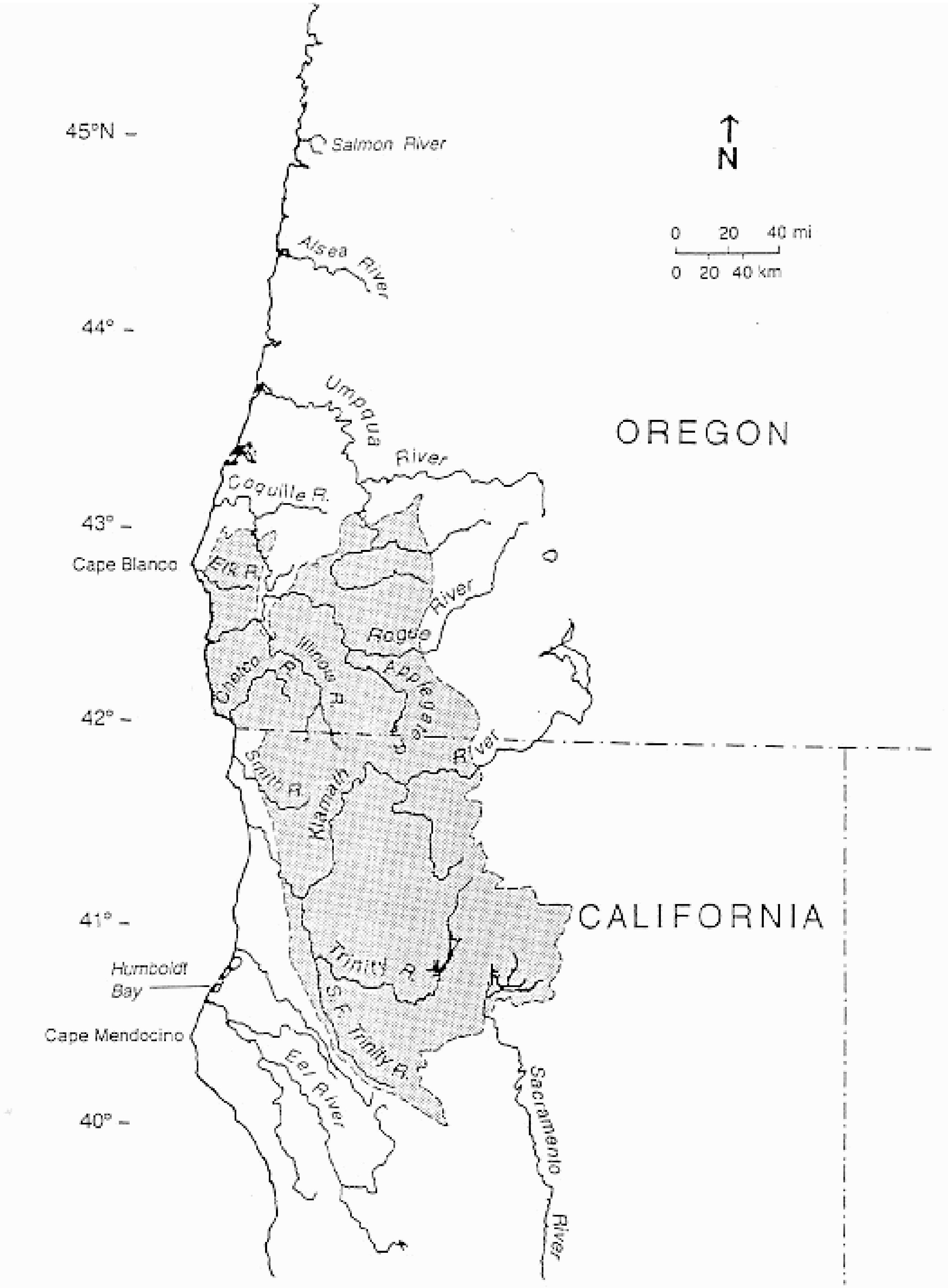

Figure 2. Map of the southern Oregon-northern California area. Shaded area is the Klamath Mountains

Geologic Province (modified from Irwin 1966 and Walker and MacLeod 1991).

California Current System

The rivers and streams of California, Oregon, and Washington drain into the California Current system of the eastern North Pacific Ocean. This current system includes the California Current, the California Undercurrent, and the Davidson Current (Hickey 1989). The prevailing California Current has a southerly flow. The California Undercurrent (or Countercurrent) flows northward on the continental slope. Both the California Current and California Undercurrent are strongest in summer (Hickey 1989). The Davidson Current is a north-flowing seasonal surface current, existing in winter and early spring (Doyle 1992).

Upwelling--Upwelling occurs when warm, nutrient poor surface waters are driven offshore by wind stress and are replaced by cold, nutrient-rich subsurface water. On the Oregon coast, prevailing winds from September through March are from the southwest. At the end of March, wind direction shifts, typically coming from the northwest, and Ekman transport causes surface water to move offshore and deep water moves up to replace it (Ingmanson and Wallace 1973, Neshyba 1987). These wind patterns result in summer upwelling and winter downwelling.

The strength and consistency of upwelling south of Cape Blanco yields highly productive waters. This is demonstrated in satellite imagery, described by Pearcy (1992), that shows chlorophyll-rich water extending several hundred kilometers offshore south of Cape Blanco to approximately 33øN latitude (Thomas and Strub 1989).

In-Stream Water Temperature

Data from the U.S. Geological Survey for coastal streams in Oregon and northern California demonstrate that with decreasing latitude there is an upward trend in water temperature (Table 2). There appears to be a geographical break-point in the average high water temperature south of the Mad River, California.

Table 2. Average daily high water-temperatures (°C), by month, recorded by U.S. Geological Survey for selected coastal streams in Oregon and California. Streams are listed from north to south (Hydrosphere 1993).

Stream	Recording location	Month (January-June)	Month (July-December)	Year*	Years of record	Number of years recorded
Oregon						
Siuslaw River	Mapleton	Jan: 6.7 Feb: 7.5 Mar: 8.9 Apr: 10.5 May:14.8 Jun: 18.8	Jul: 22.5 Aug: 22.6 Sep: 18.7 Oct: 13.5 Nov: 9.1 Dec: 7.5	13.4	1970-82	11

Umpqua River	Elkton	Jan: 5.9 Feb: 6.9 Mar: 9.0 Apr: 11.6 May: 15.6 Jun: 19.9	Jul: 23.7 Aug: 23.4 Sep: 19.9 Oct: 14.4 Nov: 9.1 Dec: 6.3	13.8	1971-91	21
Rogue River	Agness	Jan: 5.9 Feb: 7.2 Mar: 8.8 Apr: 11.2 May: 15.1 Jun: 19.4	Jul: 22.7 Aug: 22.3 Sep: 18.7 Oct: 13.5 Nov: 9.0 Dec: 6.7	13.4	1961-88	28
California						
Smith River	Crescent City	Jan: 7.5 Feb: 8.2 Mar: 9.0 Apr: 10.6 May: 13.7 Jun: 17.6	Jul: 20.4 Aug: 20.4 Sep: 17.9 Oct: 13.6 Nov: 10.2 Dec: 8.0	13.1	1966-81	16
Klamath River	Klamath	Jan: 6.8 Feb: 7.7 Mar: 9.0 Apr: 11.5 May: 14.4 Jun: 18.6	Jul: 22.4 Aug: 22.2 Sep: 20.1 Oct: 16.2 Nov: 11.4 Dec: 7.5	14.0	1966-81	16
Redwood Creek	Orick	Jan: 7.5 Feb: 8.8 Mar: 9.6 Apr: 11.6 May: 15.8 Jun: 20.5	Jul: 22.2 Aug: 21.4 Sep: 19.6 Oct: 14.9 Nov: 9.9 Dec: 8.1	14.2	1966-79	14
Mad River	Arcata	Jan: 7.8 Feb: 9.3 Mar: 10.2 Apr: 12.6 May: 16.2 Jun: 18.8	Jul: 21.5 Aug: 21.2 Sep: 19.6 Oct: 16.0 Nov: 11.6 Dec: 8.7	14.5	1962-79	16
Eel River	Scotia	Jan: 8.2 Feb: 9.0 Mar: 10.5 Apr: 12.8 May:16.8 Jun: 19.9	Jul: 21.7 Aug: 21.6 Sep: 20.5 Oct: 16.9 Nov: 12.5 Dec: 9.1	15.0	1962-82	20

Mattole River	Petrolia	Jan: 8.7 Feb: 10.0 Mar: 11.7 Apr: 14.0 May: 17.8 Jun: 22.1	Jul: 23.4 Aug: 22.5 Sep: 21.1 Oct: 16.7 Nov: 12.3 Dec: 9.9	15.9	1966-79	13
Noyo River	Fort Bragg	Jan: 8.5 Feb: 9.6 Mar: 10.8 Apr: 12.8 May: 16.4 Jun: 18.8	Jul: 20.3 Aug: 19.8 Sep: 18.3 Oct: 14.2 Nov: 11.2 Dec: 8.9	14.1	1966-79	14
Navarro River	Navarro	Jan: 8.7 Feb: 10.1 Mar: 11.7 Apr: 13.8 May: 18.4 Jun: 21.5	Jul: 22.4 Aug: 21.7 Sep: 20.0 Oct: 16.2 Nov: 11.9 Dec: 8.9	15.4	1966-79	13
Garcia River	Point Arena	Jan: 10.6 Feb: 11.4 Mar: 12.6 Apr: 14.5 May: 17.1 Jun: 18.7	Jul: 19.6 Aug: 19.6 Sep: 18.8 Oct: 16.7 Nov: 13.6 Dec: 11.2	15.4	1964-79	16
Russian River	Guerneville	Jan: 9.9 Feb: 11.6 Mar: 13.3 Apr: 16.2 May: 20.3 Jun: 23.6	Jul: 25.6 Aug: 24.6 Sep: 22.3 Oct: 18.2 Nov: 13.6 Dec: 10.3	17.5	1964-82	19

*The average of the monthly values.

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Life History

Except where specifically noted, the life-history information presented below applies to coastal steelhead and does not include inland steelhead of the Columbia and Fraser River Basins.

Anadromy-Nonanadromy

The question of the relationship between anadromous and nonanadromous forms of salmonid species has been widely examined, perhaps most intensively for sockeye and kokanee salmon (*O. nerka*). Foote and Larkin (1988) examined assortative mating between sockeye and kokanee salmon and found that male mate choice was dominated by form; that is, kokanee males demonstrated preference to spawn with kokanee females rather than sockeye females. Neave (1944) determined that anadromous and nonanadromous *O. mykiss* of the Cowichan River, Vancouver Island, constituted distinct "races" based on scale counts and migration behavior.

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. Most 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, some protein electrophoretic studies that have reported data only for "rainbow trout" probably included samples of steelhead as well (Currens - footnote 2). 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 than between presumed steelhead and rainbow trout from below the falls.

In a study of mitochondrial DNA (mtDNA) in *O. mykiss*, Wilson et al. (1985) found that coastal populations of steelhead and rainbow trout were distinct from each other, even when sampled from the same river basin. However, steelhead and rainbow trout from interior British Columbia clustered in the same clonal line as rainbow trout from Alberta. Interpretation of these results is difficult because of the small sample sizes and dispersed sampling that included rainbow trout from California and Alberta whereas all steelhead samples were from British Columbia. Furthermore, Buroker (footnote 3) found that a mtDNA marker Wilson et al. (1985) reported as characteristic of rainbow trout was the most common marker in Buroker's study of North American steelhead.

Steelhead Run-Types

Across their distribution, steelhead return to fresh water throughout the year, with seasonal peaks in migration activity. These seasonal peaks are used to name and describe various runs. In Alaska, the runs are called fall and spring; in British Columbia, Washington, Oregon, and California, the runs are usually called summer and winter. Large rivers, such as the Klamath and Rogue Rivers, may have adult steelhead migrating throughout the year (Shapovalov and Taft 1954, Rivers 1957, Barnhart 1986), with several vernacular run names. For example, what is now known as summer steelhead in the Rogue River was historically divided into spring and fall steelhead (Rivers 1963). Run-type designation for steelhead in the Klamath and Trinity Rivers continues to be perplexing, particularly with respect to what is historically called fall-run steelhead. Everest (1973) and Roelofs (1983) contend that spring and fall steelhead of the Rogue, Klamath, Mad, and Eel Rivers are in fact summer steelhead based on lack of segregation at spawning, and the observation that sport fisheries for fall steelhead are limited to rivers with summer steelhead. However, other biologists classify fall steelhead separately (e.g., Heubach 1992) or as winter steelhead. Roelofs (1983) identified the need for research to identify the relationship between fall-run and summer-run steelhead of the Klamath and Eel Rivers. In this document, spring- and fall-run steelhead of the Klamath Basin are considered summer steelhead.

Biologically, steelhead can be divided into two basic run-types, 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 (fall-run in Alaska, summer-run elsewhere) enters fresh water in a sexually immature condition and requires several months in fresh water to mature and spawn. The ocean-maturing type (spring-run in Alaska, winter-run elsewhere) enters fresh water with well-developed gonads and spawns shortly thereafter. This document uses the terms summer-run or summer steelhead to refer to the stream-maturing type and winter-run or 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-run, and steelhead that enter fresh water between November and April are considered winter-run. Variations in migration timing exist between populations. Some river basins have both summer and winter steelhead, while others have only one run-type.

Distribution of coastal steelhead run-types--It is difficult to accurately describe the historical distribution of coastal steelhead run-types due to the muddled history of *O. mykiss* taxonomy and local vernacular terms for steelhead of various run-times. Current distribution of coastal steelhead run-types is described in varying detail by several authors (Roelofs 1983, Barnhart 1986, Pauley et al. 1986, Burgner et al. 1992). Winter steelhead utilize coastal streams from Yakutat, Alaska to Malibu, California (Burgner et al. 1992). Summer steelhead are discontinuously distributed across the same range, presently extending as far south as the Middle Fork of the Eel River (Roelofs 1983). California Department of Fish and Game records indicate summer steelhead may have existed in the Sacramento Basin prior to the construction of several dams in the 1940s-1960s (McEwan and Jackson in prep.). Table 3 shows the river basins in Washington, Oregon, and California that support natural runs of coastal summer steelhead alone and co-ocurring coastal summer and winter steelhead.

Temporal and spatial separation of spawning--Although time of stream entry is generally well documented for summer and winter steelhead, there is relatively little information on time and location of spawning. Both summer and winter steelhead spawn in the winter to early spring. Difficult field conditions at that time of year and the remoteness of spawning grounds contribute to the lack of specific information on steelhead spawning (USFWS 1956, Roelofs 1983).

In drainages with both summer and winter steelhead, there may or may not be temporal separation of spawning between the two run-types. Based on tagging upstream migrating steelhead and surveying spawning areas, Everest (1973) described spawning for Rogue River summer steelhead as December-March and for winter steelhead as March-June; thus, there is some overlap. However, Everest stated that peak spawning activity for the run-types was separated by about 60 days. Neave (1949) stated that the two run-types of steelhead in the Cowichan River, Vancouver Island, British Columbia, spawn in January-March and April-May, respectively; this indicates temporal segregation of these spawning populations.

Table 3. Distribution of summer-run coastal steelhead and co-occuring summer-run and winter-run coastal steelhead in Washington, Oregon, and California (Chilcote et al. 1992, WDF et al. 1993, McEwan and Jackson in prep.). Runs of summer steelhead known to be introduced are not listed.

State	**Basin**	**Location**	**Summer-run only**	**Summer-run and winter-run**
Washington	Nooksack	South Fork Nooksack River		†
	Skagit	Cascade River		†[a]
		Sauk River		†
		Finney Creek		†
	Stillaguamish	Deer Creek	†	
		Canyon Creek		†
	Snohomish	North Fork Skykomish River		†
		Tolt River		†[a]
	Hood Canal	Skokomish River		†[a]
		Duckabush River		†[a]
		Dosewallips River		†[a]
	Strait of Juan de Fuca	Dungeness River		†[a]
		Elwha River		†[a]
	Quillayute	Sol Duc River		†[a]
		Calawah River		†[a]
		Bogachiel River		†[a]
	Hoh	Hoh River		†
	Queets	Clearwater River		†
		Queets River		†
	Quinault	Quinault River		†
	Grays Harbor	Humptulips River		†
		Chehalis River		†[a]
	Columbia	Kalama River		†
		East Fork Lewis River		†
		North Fork Lewis River		†
		Washougal River		†
		West Fork Washougal River		†
		Klickitat River[b]		†
Oregon	Columbia	Hood River		†

	Siletz	Siletz River	†
	Rogue	Rogue River	†
		Applegate River	†
	Umpqua	North Umpqua River	†
		South Umpqua River	
California	Smith	Smith River	†
	Klamath	Klamath River	†
		Salmon River	†
		Scott River	†
		Shasta River	†
		Ukanom River	†
		Trinity River	†
		New River	†
	Redwood	Redwood Creek	†
	Mad	Mad River	†
	Eel	Eel River	

[a] Stock origin of these summer steelhead has not been determined.

[b] Classification of Klickitat River steelhead as coastal or inland has not been fully resolved.

Everest (1973) found that in the Rogue River Basin, winter steelhead spawned in larger streams than summer steelhead. Withler (1966) and Smith (1969) described waterfalls on the Coquihalla and San Juan Rivers in British Columbia that are barriers to winter steelhead but not summer steelhead. Burgner et al. (1992) reported that while marine distribution of summer and winter steelhead overlaps, they do exhibit some run-type specific differences. These differences probably reflect the difference in time of freshwater entry for the two run-types (Burgner et al. 1992); however, it is also possible that these are differences between coastal steelhead, which are primarily winter-run, and inland steelhead of the Columbia Basin, which are almost entirely summer-run.

Phenotypic characteristics--Smith (1969) conducted meristic counts of vertebrae, gill rakers, and lateral-line scales on summer and winter steelhead from eight coastal streams in British Columbia and Washington. Smith found no significant difference in these features between populations of the same run-type. When the data for populations of the same run-type were pooled, significant differences between run-types for all features except lateral-line scale count were found. Smith (1960, 1969) also artificially spawned wild summer and winter steelhead collected from the Capilano River, British Columbia to compare meristic and morphometric characteristics among and between their progeny; "crosses were not made between summer and winter fish" (Smith 1969, p. 23 and 24). Smith found that some meristic and morphometric characteristics, such as number of parr marks and relative quantity of visceral fat, were different between juveniles of the two run-types. Smith stated that no intergrades were found between the run-types for fat storage in yearling fish, gonad development in salt water, and quantity of fat relative to gonad development at stream entry. However, some characteristics were either not significantly different between run-types or were ambiguous. Smith concluded that the results of this study suggest recent reproductive isolation between summer and winter steelhead in the Capilano River.

Summer steelhead undergo morphological changes during their extended spawning migrations, developing red coloration on their opercula and lateral line similar to those found in rainbow trout; males also develop a kype (Snyder 1940; Smith 1960, 1969). Smith (1969) suggested that among sympatric populations of spawning summer and winter steelhead, these morphological characteristics may provide visual cues to prevent interbreeding between the run-types. Upon examination, Smith (1960) found that spawning summer steelhead in the Capilano River had flattened and bifurcated gill rakers. Capilano River winter steelhead demonstrated little development of rainbow coloration and lacked the flattened and bifurcated appearance of the gill rakers observed in summer steelead (Smith 1960).

Heritability of run-timing--Smith (1960) found that artificially spawned and reared offspring of wild summer and winter steelhead from the same river basin maintained the run-timing characteristics of their parents.

Genetic information on 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 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 sampled fish.

Thorgaard (1983) analyzed chromosomal variability in winter-run 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.

Run-timing of Illinois River steelhead--The Illinois River is generally considered to have only winter steelhead (Jennings - footnote 4). Historically, there may have been a weak run of summer steelhead in the Illinois River (Rivers 1957). Recent Forest Service records describe the occurrence of one apparent summer steelhead in the Illinois Basin in 1990 (USFS 1992, Busby et al. 1993). Whether the Illinois River at one time had its own run of summer steelhead, or whether summer steelhead observed in the river are actually migrants from the Rogue River, is not certain. Everest (1973) stated that prior to the construction of the flow-regulating Lost Creek Dam, summer steelhead from the Rogue River sought thermal refuge in the lower Illinois River; Everest (footnote 5) believes these may have been the summer steelhead that Rivers (1957) described in the Illinois River.

Age Structure

Steelhead exhibit a diverse array of life-history patterns with variations in smolt age, saltwater residence, and spawning activity. As a case in point, Oregon Department of Fish and Wildlife (ODFW) has identified 15 life-history patterns among wild summer steelhead in the Rogue River (ODFW 1994). The different life-history patterns are found at different frequencies among steelhead populations. The most common pattern for wild coastal steelhead south of Alaska is to smolt after 2 years in fresh water, then return to spawn after 2 years in salt water (Table 4 and 5), whereas steelhead reared in hatcheries usually smolt at 1 year (Chapman 1958, Lindsay et al. 1991). In Alaska, wild steelhead usually smolt at 3 years (Sanders 1985). There may be a latitudinal cline to these life-history patterns (Withler 1966), with increases in age at smolting and spawning at higher latitudes (Table 4 and 5). Titus et al. (in press) found no statistical evidence for a latitudinal cline in steelhead smolt age from California to British Columbia; however, they did find that saltwater age at spawning (and mean adult length) did increase with increasing latitude.

Table 4. Comparison of smolt age frequency for selected steelhead populations. Populations are arranged from north to south.

	Run-	Sample	Freshwater age				
Population	**type[a]**	**size**	**1**	**2**	**3**	**4**	**Reference**
Karluk River, AK	S	101	--	0.36	0.63	0.01	Sanders 1985
Anchor River, AK	S	90	--	0.12	0.85	0.03	Sanders 1985
Upper Copper River, AK	S	35	--	0.08	0.89	0.03	Sanders 1985
Situk River, AK	S/O	295	--	0.13	0.71	0.16	Sanders 1985
Sitkoh Creek, AK	O	678	--	0.04	0.66	0.30	Sanders 1985
Karta River, AK	O	817	--	0.18	0.69	0.13	Sanders 1985
Chilliwack River, BC	O	770	0.02	0.62	0.35	0.01	Maher and Larkin 1955
Kalama River, WA	O	3,114	--	0.88	0.11	<0.01	Leider et al. 1986
Kalama River, WA	S	2,841	--	0.91	0.09	<0.01	Leider et al. 1986
Sand Creek, OR	O	170	--	0.74	0.26	--	Bali 1959
Alsea River, OR	O	978	0.01	0.80	0.18	<0.01	Chapman 1958
Siuslaw River, OR	O	125	--	0.83	0.17	--	Lindsay et al. 1991
Coquille River, OR	O	81	--	0.54	0.45	0.01	Bali 1959
Rogue River, OR[b]	O	714	0.12	0.66	0.21	0.01	ODFW 1990
Illinois River, OR	O	125	0.01	0.59	0.38	0.02	ODFW 1992b
Chetco River, OR	O	90	0.01	0.39	0.55	0.05	Bali 1959
Mad River, CA	O	35	--	0.97	0.03	--	Forsgren 1979
Jacoby Creek, CA	O	109	0.11	0.78	0.11	--	Harper 1980
Waddell Creek, CA	O	3,220	0.10	0.69	0.19	0.02	Shapovalov and Taft 1954

[a] O = Ocean maturing; S = Stream maturing (see Glossary, Appendix A).

[b] These data are from adult fish collected in the lower Rogue River and therefore may include steelhead from the Illinois and Applegate Rivers.

Table 5. Saltwater age frequency for selected steelhead populations. Populations are arranged from north to south.

	Run-	Sample	Saltwater age at first spawning				
Population	**type[a]**	**size**	**1**	**2**	**3**	**4**	**Reference**

Karluk River, AK	S	62	0.18	0.79	0.03	--	Sanders 1985
Anchor River, AK	S	80	0.26	0.74	--	--	Sanders 1985
Upper Copper River, AK	S	30	0.17	0.77	0.06	--	Sanders 1985
Situk River, AK	S/O	211	--	0.57	0.43	--	Sanders 1985
Sitkoh Creek, AK	O	497	--	0.59	0.41	--	Sanders 1985
Karta River, AK	O	542	<0.01	0.72	0.27	--	Sanders 1985
Sand Creek, OR	O	170	0.25	0.73	0.02	--	Bali 1959
Alsea River, OR	O	978	0.05	0.66	0.26	0.03	Chapman 1958
Siuslaw River, OR	O	125	--	0.82	0.17	0.01	Lindsay et al. 1991
Coquille River, OR	O	81	0.51	0.44	0.05	--	Bali 1959
Rogue River, OR[b]	O	547	0.14	0.86	--	--	ODFW 1990
Illinois River, OR	O	122	0.07	0.83	0.10	--	ODFW 1992b
Chetco River, OR	O	90	0.89	0.11	--	--	Bali 1959
Mad River, CA	O	35	0.28	0.69	0.03	--	Forsgren 1979
Jacoby Creek, CA	O	109	0.37	0.61	0.02	--	Harper 1980
Waddell Creek, CA	O	3,220	0.60	0.40	<0.01	--	Shapovalov and Taft 1954

[a] O = Ocean maturing; S = Stream maturing (see Glossary, Appendix A).

[b] These data are from adult fish collected in the lower Rogue River and therefore may include steelhead from the Illinois and Applegate Rivers.

Steelhead may survive spawning, return to the ocean, and spawn again in subsequent years. Up to five spawning migrations have been recorded for individual steelhead (Bali 1959, Lindsay et al. 1991); however, more than two is unusual. Columbia River steelhead are essentially semelparous (Long and Griffin 1937, ODFW 1986), typically completing only one spawning migration. Repeat spawners are predominately female due to higher post-spawningmortality among males (Shapovalov and Taft 1954, Maher and Larkin 1955, Chapman 1958, Withler 1966, ODFW 1986, Burgner et al. 1992). Incidence of repeat spawning tends to decrease from south to north (Withler 1966), with much variation among populations (Table 6).

Half-Pounders

Steelhead with the life-history pattern called "half-pounder" (Snyder 1925) are steelhead that return from their first ocean season to fresh water from July through September, after only 2 to 4 months of saltwater residence. They generally overwinter in fresh water before outmigrating again in the spring. There is some variability in criteria for defining half-pounders. Kesner and Barnhart (1972) described Klamath River half-pounders as being 250-349 mm. Everest (1973) used 406 mm as the upper limit of half-pounder body length on the Rogue River.

The half-pounder migration has been termed a "false spawning run" because few half-pounders are believed to be sexually mature. However, Everest (1973) found some spawning activity by male half-pounders that were 355-406 mm in length.

Half-pounders are reported in the scientific literature from the Rogue, Klamath, Mad, and Eel River drainages of southern Oregon and northern California (Snyder 1925, Kesner and Barnhart 1972, Everest 1973, Barnhart 1986). Anecdotal accounts suggest that the half-pounder life history may also occur outside of these basins. However, the lack of either a half-pounder fishery outside the Rogue, Klamath, Mad, and Eel Rivers or scientific documentation suggests that if it occurs in other locations, the half-pounder strategy is less successful than in the basins named above and occurs at a much lower frequency.

Table 6. 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 arranged from north to south.

	Sample	**Spawning runs**					
Population	**size**	**1**	**2**	**3**	**4**	**5**	**Reference**
Kalama River, WA							
winter-run, wild	3,114	0.89	0.09	0.02	<0.01	--	Leider et al. 1986
winter-run, hatchery	2,200	0.95	0.05	<0.01	<0.01	--	Leider et al. 1986
summer-run, wild	2,841	0.94	0.06	<0.01	<0.01	--	Leider et al. 1986
summer-run, hatchery	7,441	0.97	0.03	<0.01	--	--	Leider et al. 1986
Sand Creek, OR	196	0.77	0.18	0.04	0.01	--	Bali 1959
Alsea River, OR	1,223	0.89	0.09	0.02	--	--	Chapman 1958
Siuslaw River, OR							
wild	125	0.86	0.11	0.02	--	0.01	Lindsay et al. 1991
hatchery	230	0.86	0.14	--	--	--	Lindsay et al. 1991
Coquille River, OR	79	0.61	0.32	0.05	0.02	--	Bali 1959
Rogue River, OR							
summer-run, wild	922	0.79	0.17	0.04	--	--	ODFW 1994
Waddell Creek, CA	3,888	0.83	0.15	0.02	<0.01	--	Shapovalov and Taft 1954

Half-pounders can migrate significant distances; for example, half-pounders of Klamath River origin have been found in the Rogue River (Everest 1973). It is apparently common for steelhead to make their half-pounder run into a nonnatal stream and then return to their natal stream to spawn as mature adults (Everest 1973, Satterthwaite 1988). A popular sport fishery has developed around the half-pounder runs in the Klamath and Rogue Rivers.

Half-pounders are generally associated with summer-run steelhead populations. However, this trait has also been identified in winter-run steelhead, albeit at a lower frequency. For example, Hopelain (1987) found a half-pounder frequency of 23.2% among lower Klamath River winter-run steelhead, as compared to a mean frequency of 95.2% among fall-run (summer) steelhead from six Klamath River tributaries. Scale analysis of Rogue River winter steelhead initially collected for Cole Rivers Hatchery broodstock indicated a half- pounder frequency of approximately 30% (Evenson - footnote 6).

Presumably, the half-pounder life history occurs either to avoid a deleterious condition in the ocean or to exploit a beneficial condition inland. However, since half-pounders were first described in the literature (Snyder 1925), little additional information has been published, and no convincing theories to explain half-pounders have been advanced. It is not known to what degree this trait is due to genetic as opposed to environmental factors. In initiating the winter-run steelhead broodstock at Cole Rivers Hatchery (on the Rogue River), scale patterns were used to select fish that lacked the half-pounder life history (Evenson footnote 6). Recently, however, there is evidence of half-pounders among winter-run steelhead returning to the hatchery. Cramer et al. (1985, p. 112) stated that the "occurrence of the half-pounder life history has increased among winter steelhead released from Cole Rivers Hatchery since the time that growth rates of parr in the hatchery have been accelerated in order to produce age 1 smolts." These findings suggest that the incidence of the half-pounder life history can be influenced by environmental conditions.

Illinois River steelhead scale data from ODFW (1992b) indicate that of 163 steelhead angled between January 1982 and February 1990, 158 were mature adults and 5 (3%) were half-pounders. It is possible that the few half-pounders had roamed from their natal stream and were not of Illinois River origin. The ODFW data do not indicate whether any of the mature adults had scale patterns indicative of previous half-pounder runs. Anglers have reported to NMFS that half-pounders are indeed present, and caught, in the Illinois River (Beyerlin 1992, Leseman 1993).

Although half-pounders occur at a much lower frequency among Illinois River steelhead than Rogue River steelhead, the Illinois River is not unique among coastal steelhead streams in not having half-pounders. In fact, most steelhead populations coastwide do not have this life-history trait. We were unable to determine whether other river basins besides the Rogue River that have half-pounders (i.e., the Klamath, Mad, and Eel Rivers) have tributaries, like the Illinois River, in which the trait is rare or absent.

Oceanic Migration Patterns

Anadromous salmonids are known to demonstrate stock-specific differences in oceanic migrations. Examples of this are seen in data from coded-wire-tag recoveries of hatchery reared salmon (Table 7). Chinook (*O. tshawytscha*) and coho (*O. kisutch*) salmon released from ODFW hatcheries north of the Rogue River are recovered in the ocean off Alaska, British Columbia, and Washington at greater frequencies than are salmon from the Rogue and Chetco Rivers. Conversely, southern Oregon stocks of salmon are recovered in the ocean fishery off California at greater frequencies than are the northern stocks. Nicholas and Hankin (1988) found that chinook salmon from Oregon rivers south of Cape Blanco (e.g., the Rogue and Chetco Rivers) generally rear in the ocean off southern Oregon and northern California, while chinook salmon from Elk River and basins to the north generally rear in the ocean as far north as Alaska; these stocks are termed "south-migrating" and "north-migrating," respectively. An anomaly in this pattern is spring-run chinook salmon from the Umpqua River; Nicholas and Hankin refer to this as a "north-and-south-migrating" stock because they rear in the ocean from northern California to Alaska (Table 8).

Table 7. Geographic distribution of recovery of selected coded-wire-tagged (CWT) chinook and coho salmon stocks originating from ODFW hatcheries (Garrison et al. 1992). Numbers are proportion of total CWT recoveries for each stock by recovery location*. AK = Alaska, BC = British Columbia, WA = Washington, OR = Oregon, CA = California.

Species	Stock origin and release site	Latitude	Saltwater recovery location AK	BC	WA	OR	CA
Chinook salmon (fall)							
	Trask River	45°27 N	0.49	0.42	0.01	0.04	<0.01
	Alsea River	44°25 N	0.35	0.51	0.03	0.08	--
	Coos River	43°20 N	0.11	0.32	0.07	0.46	0.03
	Coquille River	43°08 N	0.11	0.41	0.03	0.43	0.02
	Elk River	42°42 N	0.06	0.25	0.04	0.60	0.02
	Rogue River	42°24 N	--	<0.01	<0.01	0.48	0.51
	Chetco River	42°04 N	--	<0.01	0.01	0.65	0.31
Chinook salmon (spring)							
	Trask River	45°27 N	0.20	0.29	0.15	0.29	0.02
	Umpqua River	43°36 N	<0.01	0.05	0.05	0.80	0.09
	Coquille River	43°08 N	<0.01	0.05	0.03	0.69	0.23
	Rogue River	42°24 N	--	--	<0.01	0.51	0.49
Coho salmon							
	Nehalem River	45°43 N	--	0.05	0.06	0.62	0.25
	Trask River	45°27 N	--	0.04	0.07	0.60	0.26
	Siletz River	44°52 N	--	0.05	0.05	0.60	0.30
	Alsea River	44°25 N	--	0.04	0.04	0.67	0.23
	Umpqua River	43°36 N	--	0.01	0.02	0.65	0.29
	Coos River	43°20 N	--	0.04	0.03	0.39	0.48
	Coquille River	43°08 N	--	0.02	0.01	0.49	0.46
	Rogue River	42°24 N	--	--	--	0.30	0.66

*Difference between total recoveries for a given stock and 1.0 is the proportion recovered in freshwater sport and gill-net fisheries, which ranged between 0.0 and 0.05.

Steelhead--There are several published reports on the distribution and abundance of steelhead during their saltwater phase (e.g., Sutherland 1973, Hartt and Dell 1986, Light et al. 1989, Pearcy et al. 1990). One might conclude that a great deal is known of the ocean ecology of steelhead. However, the appearance is deceptive because many of these reports utilize the same data set, that of the International North Pacific Fisheries Commission. These data are concentrated north of latitude 42°N and are collected primarily between April and October each year. Conclusions on the movements of steelhead are commonly drawn from very small sample sizes; for example, Pearcy and Masuda (1982) reported steelhead migration behavior based on 13 fish collected over 2 years. With these caveats, the published assumptions concerning steelhead behavior in the ocean are given below.

Several authors have concluded that juvenile steelhead move directly offshore after ocean entry (e.g., Pearcy and Masuda 1982, Miller et al. 1983, Hartt and Dell 1986, Pearcy et al. 1990). Steelhead have been collected at longitude 145°W during their first summer in salt water; in their second ocean summer, steelhead have been collected at longitude 180° (Pearcy and Masuda 1982). Other species of salmonids, notably chinook and coho salmon, tend to remain along the coast during their ocean migrations (Pearcy 1992).

Table 8. Direction of ocean migration patterns for coastal Oregon chinook salmon (Nicholas and Hankin 1988). Rivers are listed from north to south.

Run-type	North migrating	North and south migrating	South migrating
Spring-run	Trask River	Umpqua River	Rogue River[a]
	Nestucca River		
Fall-run	Nehalem River[b]		Rogue River[a]
	Miami River[b]		Hunter Creeka, b
	Kilchis River[b]		Pistol River[a], b
	Wilson River[b]		Chetco River[a]
	Trask River		Winchuck River[a], b
	Tillamook River[b]		
	Nestucca River		
	Salmon River		
	Siletz River[b]		
	Yaquina River		
	Alsea River		
	Siuslaw River		
	Umpqua River[b]		
	Coos River[b]		
	Coquille River[b]		
	Floras Creekb		
	Sixes River[b]		
	Elk River[a]		

[a] River is located south of Cape Blanco, Oregon.

[b] Provisional classification based on geographic location, limited data, or both (Nicholas and Hankin 1988).

Pearcy et al. (1990) observed that steelhead originating south of Cape Blanco are rarely recovered north of Cape Blanco in high seas and nearshore collections. Pearcy (1992) stated that southern stocks of coho salmon and steelhead "may not be highly migratory and may feed in the strong upwelling areas off northern California and southern Oregon rather than migrate long distances into productive subarctic waters" (p. 13).

Everest (1973) found evidence of summer steelhead straying between the Rogue and Klamath River Basins. Based on recapture data from summer steelhead tagged in the Rogue River, Everest (1973, p. 32) reported that "the primary offshore rearing areas of Rogue summer steelhead lie to the south, off the northern California coast. The area could be shared coincidentally with Klamath River stocks, which could explain the exchange of fish between the two river systems."

Summary of ocean information--Steelhead (also, coho and chinook salmon) from rivers south of Cape Blanco, Oregon, generally exhibit different ocean migration patterns than their conspecifics from rivers north of that geographic feature. Whereas the northern populations migrate north (e.g., to the Gulf of Alaska), populations south of Cape Blanco generally do not. One factor in this pattern may be the strong summer upwelling in the ocean south of Cape Blanco which provides highly productive ocean waters.

Straying

Based on tag returns, Everest (1973) found evidence of straying by summer steelhead between the Rogue and Klamath River Basins. Some of this straying was by half-pounders, but adults also strayed. According to Everest (1973, p. 31), "[s]trong physical and behavioral similarities exist between summer steelhead populations in the two systems and strays from the Rogue probably reproduce successfully with Klamath stocks."

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4. M. Jennings, Steelhead Program Leader, Oregon Department of Fish and Wildlife, 2501 SW First Avenue, P.O. Box 59, Portland, OR 97207. Pers. commun., January 1993.

5. F. Everest, U.S. Forest Service Pacific Northwest Research Station, Forestry Sciences Laboratory, 2270 Sherwood Lane, Suite 2A, Juneau, AK 99801-8545. Pers. commun., January 1994.

6. 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.

7. S. Phelps, Washington Department of Fisheries, P.O. Box 43151, Olympia, WA 98504, Pers. commun., April 1994.

8. These numbers, including the total, are taken from Sheppard (1972, p. 549). The discrepancy between the sum of the component numbers (1,518,100) and the given total (1,528,800) is not explained.

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History of Hatchery Stocks and Outplantings

Steelhead Hatcheries

Annual hatchery production of steelhead on the west coast of North America increased from about 3 million juvenile steelhead in 1960 to almost 30 million in 1987 (Light 1989). The majority of hatchery produced steelhead (89%) are from the Pacific Northwest states of Idaho, Washington, and Oregon (Table 9), and this figure is dominated by steelhead from hatcheries concentrated in the Columbia River Basin (Light 1989).

Oregon Hatchery Stocks

The State of Oregon produces 22 hatchery stocks of coastal steelhead (ODFW 1986). Of these, we found that five stocks have a substantial history of production and/or stocking within the Klamath Mountains Province. As named by ODFW (1986), these five stocks are Alsea Winter-Run 43, Applegate Winter-Run 62, Chetco Winter-Run 96, Rogue Winter-Run 52, and Rogue Summer-Run 52.

Alsea Winter-Run 43--Steelhead originating from the Alsea River were planted in streams along Oregon's coast from the late 1930s through the 1960s; liberations of this stock since then have been limited to the coast between the Coquille and Salmon Rivers (ODFW 1986). Although specific information is not available regarding stocking locations of Alsea steelhead prior to 1980, it is likely that some introductions occurred in streams considered here.

Table 9. 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

Applegate Winter-Run 62--This Cole Rivers Hatchery stock began in 1979; broodstock are collected from the Applegate River (ODFW 1986). The stock is propagated primarily to mitigate habitat loss due to Applegate Dam, and most of the plantings from this stock have been into the Applegate River (ODFW 1993a). From 1983 through 1993, an average of 126,000 steelhead from Applegate Winter-Run 62 were stocked in the Applegate Basin annually, at an average size of about 18 cm; occasionally, Applegate steelhead have been planted in a variety of lakes and ponds in southern Oregon (ODFW 1993a).

Chetco Winter-Run 96--Chetco Winter-Run 96 hatchery stock was established in 1970; broodstock are collected from steelhead returning to the Chetco River (ODFW 1986). As the Chetco River was stocked with Alsea Winter-Run 43 prior to 1970, the present stock may have some Alsea stock influence (ODFW 1986). Chetco Winter-Run 96 is reared at the Elk River Hatchery, then released into the Chetco River at an average length of 18 cm; from 1980 through 1993, an average of 62,000 Chetco Winter-Run 96 were released annually (ODFW 1993a).

Rogue Winter-Run 52--Culture of Rogue River winter steelhead at Cole Rivers Hatchery began in 1974 to mitigate loss of habitat due to Lost Creek Dam (ODFW 1986). Most of this stock is planted in the Rogue River; an annual average of 132,000 fish were planted from 1980 through 1993, at an average length of

20 cm (ODFW 1993a). Fish from this stock that are not used in the Rogue River are usually planted in local ponds and reservoirs to supplement the trout fishery (ODFW 1986). Most of these fish have gone to Lost Creek Reservoir, just upstream from the hatchery, and to Emigrant Reservoir on Bear Creek, in the Rogue River Basin near Ashland, Oregon (ODFW 1993a).

Rogue Summer-Run 52--This stock was established in 1962 with broodstock collected at Gold Ray Dam (ODFW 1986). Initially, Rogue Summer-Run 52 was reared at Butte Falls and Bandon Hatcheries, then released into the Rogue River. Since 1974, broodstock collection and smolt production have been conducted at Cole Rivers Hatchery, below Lost Creek Dam (ODFW 1986). From 1980 through 1993, an average of 181,000 Rogue Summer-Run 52 steelhead were released annually in the Rogue River, at an average length of 18 cm (ODFW 1993a). In addition, from 1990 through 1993 an average of 109,000 steelhead were released in Lost Creek Reservoir, at an average length of 10 cm; other plantings of this stock have occasionally occurred in other southern Oregon reservoirs and ponds (ODFW 1993a).

Applegate Summer-Run 62--Data from ODFW (1993a) indicate that in 1981 and 1982, a stock of Applegate summer-run steelhead was produced at Cole Rivers Hatchery. These fish were released primarily in the Applegate and Rogue River Basins (ODFW 1993a). These may actually have been winter steelhead (Evenson - footnote 6); ODFW (1986) does not mention this stock.

California Hatchery Stocks

California Department of Fish and Game produces steelhead at seven hatcheries, of which two (Iron Gate and Trinity River Hatcheries) are within the Klamath Mountains Province and another (Mad River Hatchery) is nearby. Iron Gate and Trinity River Hatcheries are mitigation hatcheries for habitat lost to power generating and water diversion dams; Mad River Hatchery is an enhancement hatchery (McEwan and Jackson in prep.). California Department of Fish and Game also administers several community-based steelhead rearing projects throughout northern California (McEwan and Jackson in prep.). Additionally, there is one USFWS hatchery in northern California (Coleman National Fish Hatchery, Sacramento River) and two locally operated hatcheries, Rowdy Creek (Smith River) and Prairie Creek (Redwood Creek), that also produce steelhead.

Iron Gate Hatchery--Iron Gate Hatchery is on the Klamath River near Hornbrook, California. Steelhead have been reared at this hatchery since 1966 (CDFG 1994a). Most broodstock are taken from steelhead returning to the hatchery; however, some eggs were imported from Trinity River Hatchery and from Cowlitz Trout Hatchery (Washington) in the late 1960s (CDFG 1994a). Steelhead releases from Iron Gate Hatchery have primarily been into the Klamath River. There have been several transfers of eggs from Iron Gate to Trinity River Hatchery, and occasionally Iron Gate Hatchery has supplied eggs or fingerlings to various other facilities within the Klamath Mountains Province (e.g., Humboldt State University, Six Rivers National Forest, and Tribal facilities; CDFG 1994a). Iron Gate Hatchery produces 200,000 steelhead smolts annually (McEwan and Jackson in prep.). Between 1972 and 1982, hatchery steelhead comprised an average of 7.8% of the steelhead runs on the Klamath River (McEwan and Jackson in prep.).

Trinity River Hatchery--The Trinity River Hatchery program began in 1958. To supplement steelhead returning to the hatchery, eggs and fingerlings have been imported from other facilities (CDFG 1994b). The most common source of eggs has been Iron Gate Hatchery, with annual transfers since 1974 (CDFG 1994b). Trinity River Hatchery has also received eggs and fingerlings from the Sacramento and Eel River Basins in California, Willamette River in Oregon (Roaring River Hatchery), and Washougal River in Washington (Skamania Hatchery). These latter transfers have been few and infrequent and apparently ceased after 1973 (CDFG 1994b). Most of the steelhead produced at Trinity River Hatchery are released into the Trinity River. Some transfer of eggs and fingerlings to Iron Gate and Mad River Hatcheries has occurred (CDFG 1994b). Trinity River Hatchery produces 800,000 steelhead smolts annually; hatchery contribution to the steelhead runs on the Trinity River was 20-34% for the run years 1980-83 (McEwan and Jackson in prep.).

Mad River Hatchery--Mad River Hatchery is outside of the Klamath Mountains Province; however, as a fishery enhancement facility, Mad River Hatchery has received steelhead eggs from a variety of locations, and steelhead from Mad River Hatchery have been stocked into numerous waters. Mad River Hatchery has received steelhead eggs from the following river basins: Trinity (CA), Eel (CA), San Lorenzo (CA), Smith (CA), Dry Creek (CA), and Washougal (WA). In 1978 and 1979, 284,000 steelhead eggs were transferred from Rowdy Creek Hatchery on the Smith River to Mad River Hatchery (CDFG 1994c).

Steelhead from Mad River Hatchery have been transferred to several facilities, including some within the Klamath Mountains Province. Most of these have involved the Smith River; between 1971 and 1981, 410,000 smolts and 41,000 fry were planted in the Smith River Basin from Mad River Hatchery (CDFG 1994c). Of these, 37% were of Smith River stock (CDFG 1994c).

Population Genetic Structure

Previous Studies

Numerous protein electrophoretic studies of population structure in coastal *O. mykiss* have been published since the mid-1970s. Allendorf (1975) first distinguished two major groups of *O. mykiss* in Washington, Oregon, and Idaho, separated geographically by the Cascade Crest; Allendorf termed these 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).

Parkinson (1984) found substantial genetic differences among steelhead populations from adjacent drainages in British Columbia. Studies from Washington (Allendorf 1975, Reisenbichler and Phelps 1989) and Oregon (Hatch 1990, Reisenbichler et al. 1992) reported smaller differences between populations. 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 single within-state sources (the Green River in Washington and the Alsea River in Oregon).

Allozyme studies on Oregon steelhead, including some populations from the Rogue River Basin, 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 systems larger than 350 km2. Hatch also reported that "the area south of the Coos River was marked by sharp transition in four different enzymes..." (p. 17) and that "the pattern of several alleles ending their detectable Oregon 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 from 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. Genetic differences between naturally spawning populations in separate drainages within clusters were not statistically significant and were similar in magnitude to those reported in coastal Washington (Allendorf 1975, Reisenbichler and Phelps 1989) and less than reported in British Columbia (Parkinson 1984). However, pair-wise comparisons revealed significant differences within drainages between hatchery fish and naturally spawning populations, including Cole Rivers Hatchery fish and Rogue River natural stocks.

In recent years, genetic methods that analyze DNA variation directly have seen increasing use with salmonids, and we are aware of two studies of mtDNA that address population structure in steelhead. In a study that remains unpublished, Buroker (footnote 3) 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 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) sequenced part of the D-loop section of mtDNA of steelhead and rainbow trout in California and found that a different allele was the most common in each of three geographic regions: north coast, central coast, and south coast. The boundary between the central and south coast regions corresponds to a natural biogeographic boundary near Point Conception. All of the samples, however, including those from the north coast area, were from south of Humboldt Bay.

Chromosome 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).

New Data

As part of the status review of Illinois River winter steelhead, NMFS biologists analyzed 15 new samples of coastal steelhead, focusing on the Illinois and Rogue River drainages but including samples from as far south as the Smith and Klamath Rivers in northern California (Busby et al. 1993). Genetic distance values (Nei 1978) were computed between each pair of populations based on 39 gene loci that were variable (polymorphic) in at least one sample. Busby et al. (1993) found that the three samples from north of Cape Blanco (Bandon Hatchery, Nehalem River, and Yaquina River), as a group, were genetically distinct from the more southerly populations. This is consistent with results reported by Hatch (1990) and Reisenbichler et al. (1992), who found evidence for some genetic differentiation between populations in northern and southern Oregon. In contrast, little geographic pattern was evident in samples from the area between Cape Blanco and the Klamath River. The four samples from the Illinois River did not form a coherent genetic group; in fact, three of the four samples were genetically more similar to samples from outside the Rogue River drainage than they were to other Illinois River samples.

For this expanded status review, we analyzed an additional five samples of steelhead collected from streams in northern California (Table 10). Collection and laboratory procedures were as described in Busby et al. (1993), and data were again gathered for 39 polymorphic gene loci. Results of unweighted pair-group method (UPGMA) clustering of pairwise genetic distance values are shown in the dendrogram in Figure 3. One of the new samples was from the Trinity River, and this sample showed a clear genetic affinity with the other steelhead from the Klamath River Basin as well as with those north to Cape Blanco. In contrast, the four samples from south of the Klamath River (Redwood Creek, Mad River wild and hatchery, and Eel River) were distinct genetically. In fact, genetic differences between steelhead populations from south of the Klamath River and areas to the north are considerably larger than the differences between steelhead from southern and northern Oregon.

Table 10. Steelhead populations examined in the genetic analysis. For run timing, W = winter, S = summer, and W/S = uncertain or a mixture of both forms.

Location **Population**	**Run timing**	**Sample size**	**Population number (see Figure 4)**
North of Cape Blanco			
Nehalem River	W	40	1
Yaquina River	W	40	2
Bandon Hatchery (Coquille R. stock)	W	40	3
Cape Blanco to Klamath River Basin			
Elk River	W	40	4
Rogue River			

Lobster Creek	W/S	40	5
Little Butte Creek	W/S	40	6
Cole Rivers Hatchery	W	40	7
Illinois River			
Grayback Creek	W	40	8
Briggs Creek	W	40	9
Lawson Creek	W/S	40	10
Indigo Creek	W/S	30	11
Pistol River	W	40	12
Winchuck River	W	40	13
Smith River	W	40	14
Klamath River	W/S	40	15
Trinity River	W/S	39	16
South of Klamath River Basin			
Redwood Creek	W/S	40	17
Mad River (hatchery)	W	40	18
Mad River (wild)	W/S	40	19
Van Duzen River	W/S	40	20

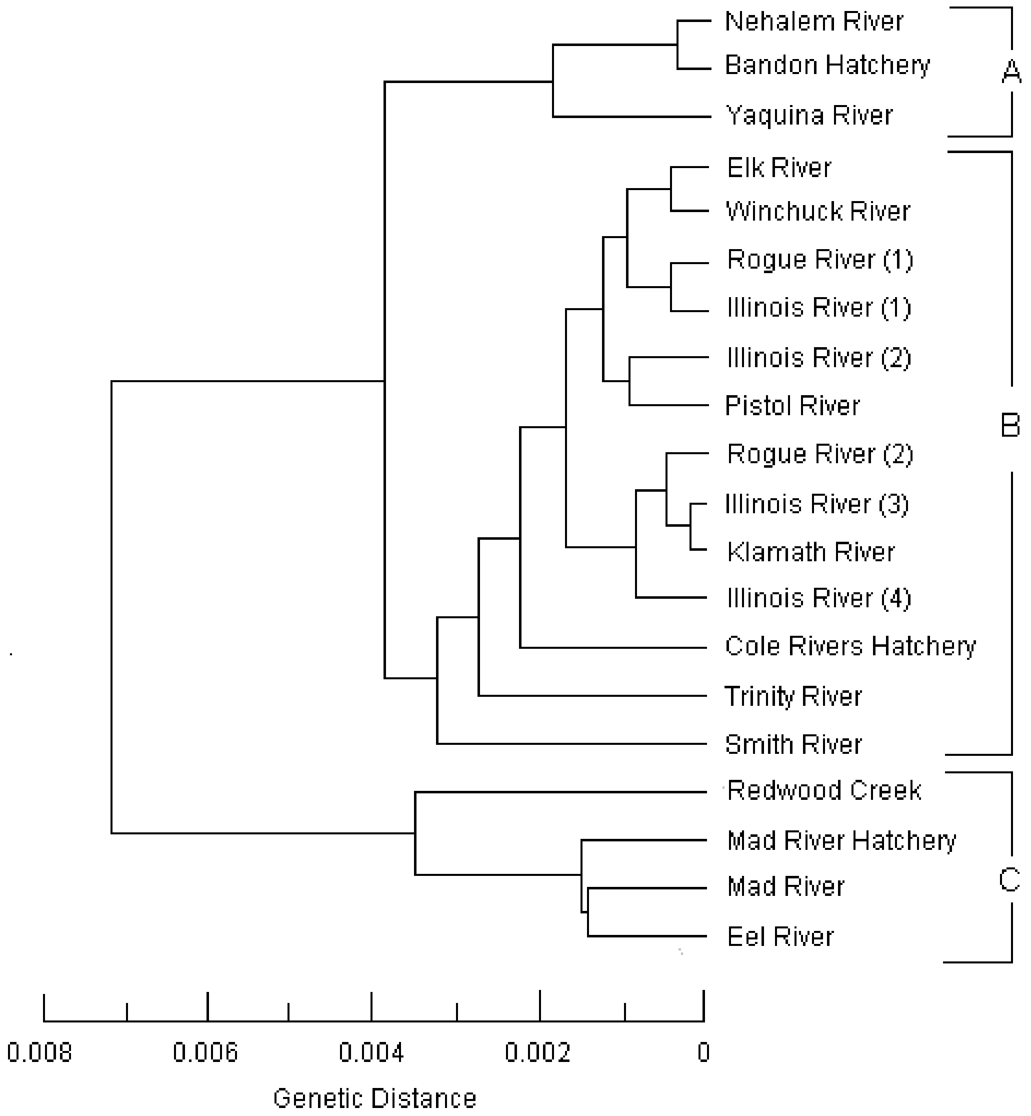

Figure 3. Dendrogram depicting genetic relationships among 20 coastal steelhead populations analyzed for this study. The figure was constructed by clustering of Nei's (1978) unbiased, pairwise genetic distance values based on data for 39 polymorphic gene loci. Rogue River: 1 = Lobster Creek, 2 = Little Butte Creek; Illinois River: 1 = Indigo Creek, 2 = Briggs Creek, 3 = Lawson Creek, 4 = Grayback Creek. Letters identify three geographic regions: A = north of Cape Blanco; B = Cape Blanco through the Klamath River Basin (i.e., the Klamath Mountains Province); C = south of the Klamath River Basin.

As a group, the samples from south of the Klamath River Basin are characterized by divergent allele frequencies at the loci *FBALD-3, *GPIA, *LDHB-1, *NTP, *PGM-2, and *sSOD-1 (Fig. 4a-b). Based on the genetic data, Redwood Creek, the basin immediately south of the Klamath River, appears to be in a transitional zone; the sample from this stream falls out with the southern group but also has some genetic affinity with samples from the Klamath River and areas to the north. For the three loci shown in Figure 4b (*NTP, *PGM-2, and *sSOD-1), there is some evidence for north-south clines in allele frequency. The *sSOD-1 locus was one for which Hatch (1990) reported a cline in steelhead from Oregon rivers with basins larger than 350 km2. However, closer examination of Figure 4b indicates that the clines, if they exist, are not monotonic; in fact, there is little evidence of a cline within the Klamath Mountains Province for any of these three loci. Trends are apparent for these loci because allele frequencies for samples from within the Klamath Mountains Province are intermediate to frequencies for samples taken north or south of this area.

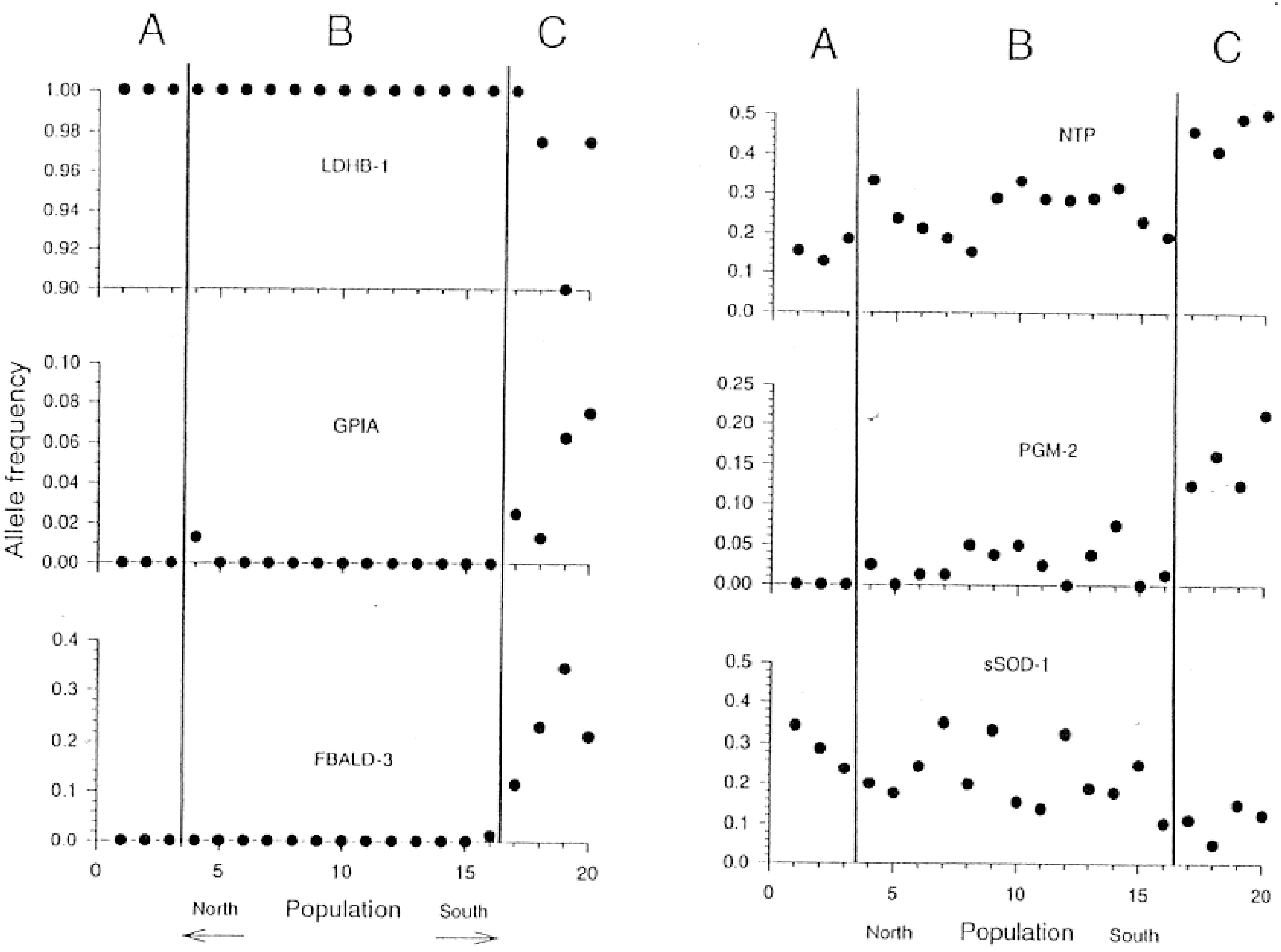

Figure 4a

Figure 4a

Figure 4b

Figure 4. Allele frequencies at selected gene loci in 20 coastal steelhead populations. Populations are arranged from north to south along the X-axis, and population numbers correspond to those shown in Table 10. Letters identify three geographic regions: A = north of Cape Blanco; B = Cape Blanco through the Klamath River Basin (i.e. the Klamath Mountains Province); C = south of the Klamath River Basin.

Because several out-of-basin steelhead stocks, including some from Washington State, have been used at the Mad River Hatchery, we considered the possibility that the genetic differences we saw in steelhead populations from south of the Klamath River were an artifact of stock transfers. Although we cannot discount genetic effects of these stock transfers on natural populations, they do not explain the observed genetic differences. We find substantial allele frequency differences between our sample of steelhead from the Mad River Hatchery and samples from the Skamania and Washougal Hatchery stocks (Phelps-footnote 7), which are among those that have been used in the Mad River Hatchery.

Discussion and Conclusions on the Species Question

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

Reproductive Isolation

Steelhead in general are believed to have strong tendencies to home to their natal stream, but there are few studies directly relevant to the area under consideration. There is evidence that some adult steelhead move between the Klamath, Rogue, and Smith Rivers, but it is not clear whether this "wandering" results in spawning in nonnatal streams.

Genetic information presented in the Illinois River winter steelhead status review (Busby et al. 1993) supported earlier findings that there is a genetic discontinuity (or at least a transition) between steelhead from coastal streams in southern and northern Oregon. The discontinuity/transition appears to occur in the vicinity of Cape Blanco, but sampling has not been sufficiently fine-scaled to precisely define the boundary.

For the present status review, we collected genetic data for five additional samples from northern California, including four from streams south of the Klamath River Basin. Whereas steelhead from the Klamath River and the Trinity River (a tributary to the Klamath River) do not differ substantially from steelhead populations to the north, there are large allele frequency differences between samples from the Klamath River Basin and those taken from rivers to the south. Genetic differences between steelhead from these two areas are larger than those found between southern and northern Oregon populations.

Within the area bounded by Cape Blanco and the Klamath River Basin (inclusive), there is evidence for genetic heterogeneity, suggesting a reasonable degree of reproductive isolation of individual populations. However, there is no clear geographic pattern to the genetic structuring that would allow us to identify major subgroups within this area.

Two seasonal run-types of steelhead are widely recognized in North America: summer-run and winter-run. These terms refer to the time of year at which adults enter fresh water to commence their spawning migration. In the Pacific Northwest, steelhead that enter fresh water between May and October are usually considered summer run, and steelhead that enter fresh water between November and April are usually considered winter run. In the Klamath River Basin, some biologists refer to fall-run steelhead; disagreement exists as to whether fall-run steelhead should be considered as summer-run, winter-run, or as a separate entity. In this status review, we consider fall-run steelhead from the Klamath River Basin to be part of the summer run.

Because the Illinois River winter steelhead petition focussed only on winter-run steelhead, and because the few summer-run steelhead populations in the area are depressed and difficult to sample, our genetic study also focussed on winter-run steelhead. However, genetic studies that considered both winter and summer steelhead from other areas have failed to find consistent genetic differences between run-types within a region. Although there are behavioral and ecological differences between summer and winter steelhead, sufficient evidence of reproductive isolation between these ecotypes within the geographical range of an ESU is lacking. Genetic evidence clearly supports a polyphyletic origin for coastal summer steelhead.

Patterns of ocean migration of salmon and steelhead may reflect reproductive isolation of spawning populations. Chinook salmon populations from south of Cape Blanco are generally considered south migrating (e.g., to ocean areas off southern Oregon and California), while most stocks from north of Cape Blanco are considered north migrating. Other studies suggest that coho salmon and steelhead from south of Cape Blanco may not be highly migratory, remaining instead in the highly productive oceanic waters off southern Oregon and California.

Ecological/Genetic Diversity

The Klamath Mountains Province extends from the vicinity of Cape Blanco in the north to the Klamath River Basin in the south. Geologically, the province is distinctive in that it includes northern extensions of formations typical of the California Coastal Ranges and the Sierra Nevada. Ecologically, the province includes areas that are warmer and drier than coastal regions to the north and south; interior valleys receive less precipitation than any other location in the Pacific Northwest west of the Cascade Range. The vegetation combines elements from California, the northern coast, and eastern Oregon, as well as a large number of endemic species (Whittaker 1960).

The nearshore ocean environment in this region is strongly affected by seasonal upwelling. The strength and consistency of upwelling south of Cape Blanco yields highly productive waters. The area of increased upwelling extends, with some local variations, as far south as 33°N latitude.

Studies of the zoogeography of freshwater fishes have consistently identified differences between the Rogue River Basin and streams to the north. A number of authors have also noted affinities between freshwater fish of the Klamath and Rogue River Basins. Ichthyofauna of coastal streams south of the Klamath River Basin are generally considered to be allied with the Sacramento River Basin. For marine fishes, Cape Mendocino has been identified as an important southern limit to the abundance of many northern species.

The half-pounder life history form of steelhead appears to be restricted to southern Oregon and northern California, having been described from the Rogue, Klamath, Eel, and Mad Rivers. The advantages of the half-pounder strategy are poorly understood; presumably, the fish are either seeking refuge from adverse conditions in the ocean or taking advantage of favorable conditions in fresh water. It is likely that expression of this life history strategy is due to a combination of genetic and environmental factors.

Conclusions

Several lines of evidence suggest Cape Blanco as the northern boundary for the ESU that contains Illinois River winter steelhead. Genetic and ocean distribution data suggest that there is substantial reproductive isolation between steelhead populations from north and south of Cape Blanco. Cape Blanco is also an approximate northern boundary for the Klamath Mountains Province, a local area of intense upwelling, the distribution of the half-pounder life history, and the Klamath-Rogue freshwater zoogeographic zone. To the south, Cape Mendocino is a natural landmark associated with changes in ocean currents and also represents the approximate southern limit of the half-pounder life history strategy. However, the Klamath River Basin forms the southern boundary of the Klamath Mountains Province as well as the Klamath-Rogue freshwater zoogeographic zone. Furthermore, genetic data show a sharp discontinuity between steelhead populations from the Klamath River Basin and those farther south. Therefore, we conclude that the geographic boundaries of the ESU that contains Illinois River winter steelhead extend from Cape Blanco in the north and include the Klamath River Basin in the south.

There is no question that diversity in run-timing is an important component of the overall diversity of steelhead within this ESU, and this diversity may be in part genetically based. However, we have little direct information about the degree of reproductive isolation of the different steelhead runs in any stream within the proposed ESU. Furthermore, previous genetic studies suggest that summer- and winter-run steelhead are not independent, monophyletic groups over broad geographic regions. Based on available evidence, therefore, we conclude that all runs of steelhead (those termed summer-, fall-, and winter-run) within these geographic boundaries should be considered part of the same ESU.

We have found no direct evidence regarding the relationship between anadromous and nonanadromous *O. mykiss* within the geographic area of this status review. Studies from other geographic areas indicate that the two forms within an area can be genetically more similar to each other than either is to the similar form from outside the area. On the other hand, studies of a number of species of salmonids (including *O. mykiss*) have repeatedly found evidence for reproductive isolation between anadromous and nonanadromous forms from the same geographic area (reviewed by Johnson et al. 1994). We therefore conclude that, until information specifically for *O. mykiss* populations within the Klamath Mountains Province becomes available, only anadromous fish should be considered part of the ESU. Nevertheless, we recognize the possibility that some resident populations within the geographic boundaries of the ESU may have a close affinity with anadromous populations, and such resident populations could be considered part of the ESU if information becomes available demonstrating that the two forms share a common gene pool.

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ABUNDANCE AND THRESHOLD DETERMINATION

Population Trends

Coastwide Overview of Steelhead Abundance

Three substantial reviews of North American steelhead abundance have been undertaken: Sheppard (1972), Light (1987), and Cooper and Johnson (1992).

Sheppard (1972) reviewed historical commercial catch records from the 1890s through the 1960s. Total U.S. commercial steelhead catch declined sevenfold from an average of 2,700,000 kg in the 1890s to an average of 370,000 kg in the 1960s. Sheppard attributed most of this decline to restrictions on the fisheries rather than decline in abundance. For the period from 1945 to 1962, however, the Oregon coastal fishery was primarily an Indian gill-net fishery with relatively stable effort, so statistics for that fishery provide an index of abundance. This fishery declined from an average of 38,100 kg in 1945-49 to an average of 1,500 kg in 1958-62. The fishery was discontinued in 1962 due to declining stocks.

Sheppard (1972) also reviewed trends in sport catch of steelhead. Steelhead sport fishing statistics were first formally collected after World War II, when Washington and Oregon instituted punchcard systems in 1948 and 1952, respectively. California began using questionnaires to estimate steelhead catch in 1953 but discontinued regular reporting after 1956. In both Washington and Oregon, the number of anglers and total steelhead sport catch increased roughly twofold from 1953 to 1969, the last year included in Sheppard's study.

Finally, Sheppard (1972) provided rough estimates of total regional average adult steelhead runs in the early 1970s: California, 400,000; Oregon, 357,200; Washington, 606,400; Idaho, 42,500; British Columbia, 112,000; total, 1,528,000 (footnote 8). (This estimate for California can be compared with an estimate of 600,000 in the early 1960s; CDFG 1965.) These estimates were based on an expansion of total sport and commercial catch, assuming a 50% catch rate. Sheppard's overall assessment was that North American steelhead abundance remained relatively constant from the 1890s through the 1960s, although there had been significant replacement of natural production with hatchery production in California, Oregon, and Washington.

Light (1987) attempted to estimate total average run size for the mid-1980s based on sport harvest data, dam counts, and other resource agency information (Table 11). His coastwide total of 1.6 million was similar to Sheppard's estimate 15 years earlier.

Cooper and Johnson (1992) focussed on recent regional trends in steelhead abundance, using catch and hatchery returns as indices. They did not attempt an overall abundance estimate; however, they noted a recent (1985 to 1991) decline in steelhead returns (both hatchery and wild) in British Columbia, Washington, and Oregon. Cooper and Johnson suggested common factors that might be responsible for declines in steelhead returns, including a combination of low ocean productivity in the Gulf of Alaska, competition for food due to increased salmonid hatchery smolt releases and increased pink and sockeye salmon stocks, and catch of steelhead in high-seas driftnet fisheries.

Table 11. Estimates of average annual steelhead runs in the mid-1980s (Light 1987).

Region	**Adults (thousands)** **Hatchery**	 **Wild**	 **Total**	**Percent** **wild**
Alaska	2	73	75	97
British Columbia	34	190	224	85
Washington Coast/Puget Sound	151	64	215	30
Columbia Basin	330	122	452	27
Oregon Coast	222	108	330	33
California	60	215	275	78
Regions combined	799	772	1,571	49

McEwan and Jackson (in prep.) provide an overview of steelhead abundance and trends in California. Despite the lack of any reliable abundance estimates, they note that angler catch rates, fishway counts, and survey estimates show substantial recent declines throughout the state. They also note widespread habitat loss and extirpation of several runs (especially in southern California) over the last two decades.

Historical Abundance in Southern Oregon and Northern California

Information on steelhead abundance in southern Oregon before the 1950s is sketchy, coming primarily from Rivers' (1957, 1963) studies of Rogue River Basin steelhead. Regarding late 19th-century fisheries in the Rogue River Basin, Rivers (1963, p. 56) reported that

> cutthroat and downstream migrant steelhead were abundant and easily caught by the hundreds from streams all through the settled portions of the basin.... The headwaters of the Applegate River, the Illinois River, Jumpoff Joe Creek, and Grave Creek were sections of the basin preferred for trout fishing because of the easy access afforded by mining roads.

Historical information for northern California is even more scarce, although Snyder (1925) noted that trout (including steelhead) were declining in the Klamath River Basin at that time.

The Threshold Question

In considering whether the ESU containing Illinois River winter steelhead is threatened or endangered according to the ESA, we evaluated both qualitative and quantitative information. Recent information regarding steelhead stock abundance and trends are summarized at a river-basin level in Appendix B. In compiling that summary, we sought to include all available assessments, both qualitative and quantitative, of steelhead populations in the region.

Qualitative assessments--Qualitative evaluations considered recent published assessments by agencies or conservation groups of the status of steelhead stocks from Cape Blanco to the Klamath River Basin (Nehlsen et al. 1991; Nickelson et al. 1992; USFS 1993a,b; McEwan and Jackson in prep.). Results of these assessments are summarized in Table 12; more detail can be found in Appendix B. Most winter steelhead stocks in the region are considered to be depressed and/or declining. Of the exceptions (those from the Rogue, Winchuck, Smith, and some subbasins of the Klamath and Trinity Rivers), most are heavily influenced by hatchery production. Only the Smith River appears to have healthy and largely natural production of winter-run steelhead in this region. For summer steelhead, the best assessment for any stock in this region is "depressed," and most are considered to be at moderate or high risk of extinction by the above authors.

Quantitative assessments--Historical abundance information for the geographic area of the ESU is largely anecdotal. Within this area, time series data are available for most populations only since 1970. We compiled and analyzed this information to provide several summary statistics of natural spawning abundance, including recent total spawning run size, percent annual change in total run size, recent naturally-produced spawning run size, and average natural return ratio (described below). Complete methods and results are given in Appendix B.

Because the ESA (and NMFS policy) mandates that we focus on viability of natural populations, we attempted to distinguish naturally produced fish from hatchery produced fish in compiling these summary statistics. All statistics are based on data for adults that spawn in natural habitat ("naturally spawning fish"). The total of all naturally spawning fish ("total run size") is divided into two components (Fig. 5): "Hatchery produced" fish are reared as juveniles in a hatchery but return as adults to spawn naturally; "naturally produced" fish are progeny of naturally spawning fish.

Table 12. Summary of recent qualitative assessments of steelhead abundance for all river basins reviewed. Blanks indicate that a particular run was not evaluated.

River basin	Run-type	Nehlsen et al. risk level[a]	ODFW/CDFG assessment[b]	USFS assessment[c]
Oregon				
Elk River	Winter			Healthy
Euchre Creek	Winter			
Rogue River	Winter		Healthy	Healthy
	Summer	Moderate	Depressed	Depressed
Applegate River	Winter			
	Summer			
Illinois River	Winter	Moderate	Depressed	Depressed
Hunter Creek	Winter			
Pistol River	Winter		Depressed	
Chetco River	Winter		Depressed	Depressed
Winchuck River	Winter		Healthy	Healthy
California				
Smith River	Winter		Healthy	Low abundance
	Summer	High		Depressed
Klamath River	Winter			Low abundance, insufficient information

	Summer	Moderate	Depressed, moderate to high risk
Trinity River	Winter		Stable, depressed
	Summer		Stable, high risk

a - Risk of local extinction, as defined in Nehlsen et al. (1991).
b - Assessments in state agency documents: Oregon, Nickelson et al. (1992); California, McEwan and Jackson (in prep.).
c - General assessments of condition of portions of runs on U.S. Forest Service lands (USFS 1993a,b).

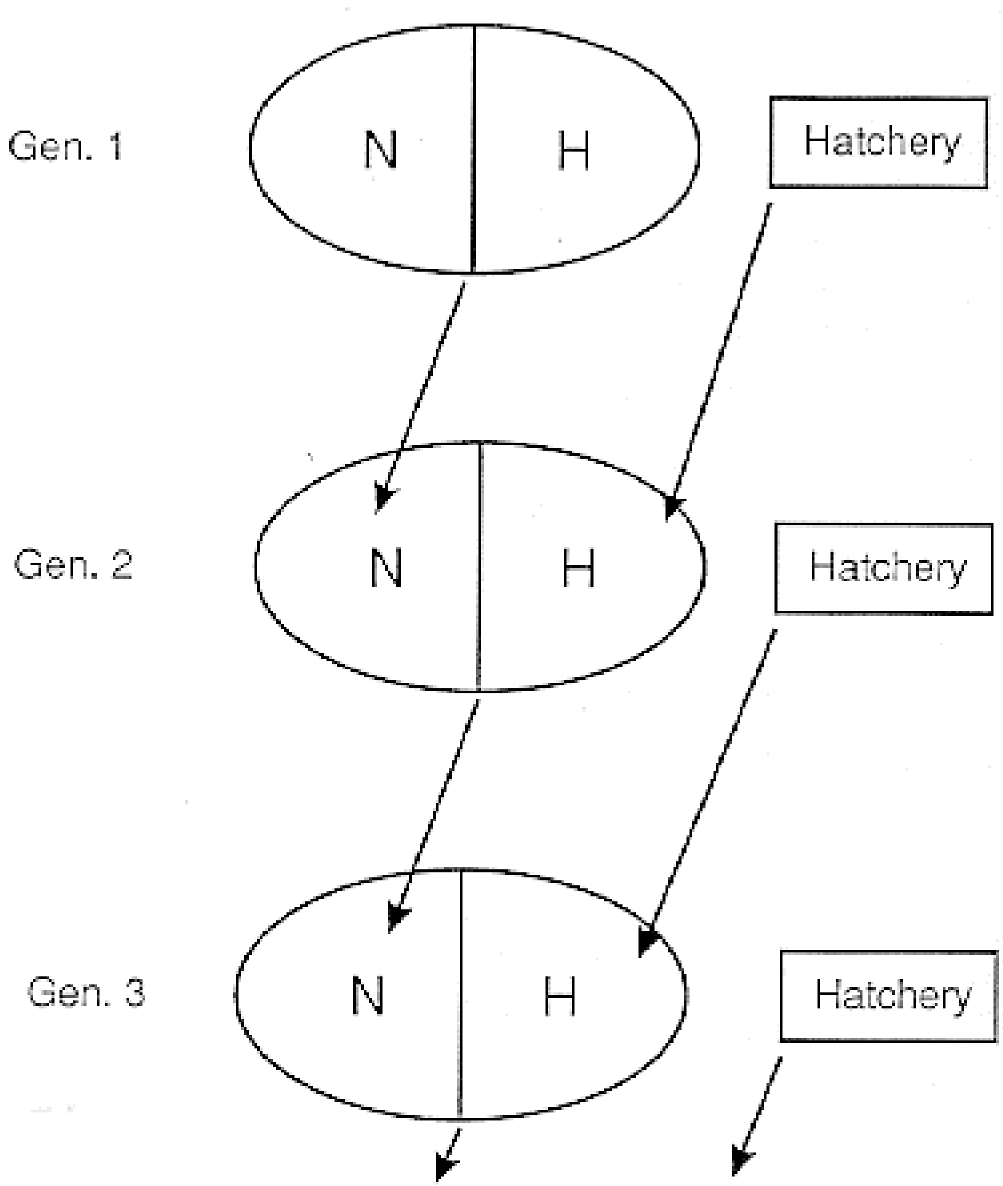

Figure 5. Schematic diagram of mixing of naturally and hatchery produced fish in natural habitat. Ovals represent the total spawning in natural habitat each generation. This total is composed of naturally produced (N) and hatchery produced (H) individuals in the previous generation.

The natural return ratio is used here as an indicator of the production of natural fish in the natural environment. This ratio is an estimate of the ratio of naturally produced spawners in one generation to total natural spawners (both naturally and hatchery produced) in the previous generation. This provides a rough index of natural production with the current-year contribution of hatchery spawners removed. As an example, the upper Rogue River summer steelhead run, counted at Gold Ray Dam, has been increasing at an average rate of 2% per year since 1971. However, it is estimated that between 11 and 73% of these have been hatchery fish, and the estimated average natural return ratio (based on a 4-year life cycle) for this period is only 0.68, indicating that natural production is not maintaining the population.

Results of these quantitative evaluations are summarized in Table 13. Most of the stocks in the region are in significant decline, even with hatchery production included. Natural production appears to be below replacement for all stocks for which we have this information; given the qualitative assessments, there is little reason to believe that other stocks are in better condition (with the possible exception of the Smith River winter run mentioned above). We are unable to demonstrate that any steelhead stocks in this region are naturally self-sustaining.

Total abundance varies widely among populations within the proposed ESU, with several populations having run sizes of 10,000 or more fish. The heavily hatchery influenced summer/fall run from the Klamath River may total 100,000 or more fish. At the other extreme, there are a number of populations with less than 1,000 spawners per year.

Table 13. Summary of recent steelhead population status for all river basins reviewed. Ranges in estimates reflect either multiple data sources or variation in estimates of percent hatchery composition. Question marks (?) indicate insufficient information. See individual stock summaries for details and data sources.

River basin	Run-type	Approximate total run size	Data years	Annual change (%)	Approximate natural run size	Average NRR[a]	Average percent hatchery
Oregon							
Elk River							
	Winter	850	1970-91	-8	540	0.44	36
Euchre Creek							
	Winter	140	1970-91	-5	90	?	?
Rogue River, upper							
	Winter	5,300-11,000	1943-91	-5 to 0	8,500	0.16-0.79	47-81
	Summer	8,900-14,000	1942-91	+2 to +3	7,000	0.68	18-49
Applegate River							
	Winter	5,300	1970-91	-2	1,900	0.18-0.49	47-81
	Summer	1,600	1970-91	0	1,300	?	?
Illinois River							
	Winter	5,900	1970-91	-10	5,500	0.60	7
Hunter Creek							

	Winter	380	1970-91	-6	130	0.17	67
Pistol River							
	Winter	1,500	1970-91	-3	910	0.53	38
Chetco River							
	Winter	5,100	1970-91	0	2,600	0.47	49
Winchuck River							
	Winter	540	1970-91	-4	350	0.44-0.60	25-45
California							
Smith River							
	Winter	?		?	?	?	?
	Summer	50	1981-91	+9 to +38	?	?	?
Klamath River							
	Winter	20,000		?	?	?	?
	Summer[b]	110,000	1977-91	-15 to +4	?	?	?
Trinity River							
	Winter	?		?	?	?	?
	Summer[b]	15,000	1977-91	+5 to +16	?	?	?

a - NRR: Natural Return Ratio (see Glossary, Appendix A).

b - "Summer-run" estimates for Klamath and Trinity River Basins include "fall-run" steelhead.

Estimates of percent annual change indicate that most of the populations in the region are in significant decline, even with hatchery production included. We considered that this assessment may be influenced by the recent coastwide decreases in survival noted above. However, excluding these recent years (1987-present) from the trend analysis did not substantially change overall conclusions for the stocks considered here. Of those populations that are not declining, most have a large (ca. 20-80% of the run) hatchery produced component, so the apparent stability of these populations cannot be directly attributed to natural production.

Although this quantitative evaluation used the best data available, interpreting these results requires consideration of several complicating factors related to data reliability, analytic methods, and natural factors which may affect population abundance and trends. These problems are discussed in Appendix B and are only briefly mentioned here. Much of the quantitative analysis is based on either angler catch or instream adult survey data, which may not accurately reflect trends in population abundance. The methods used to derive natural return ratios from mixed-stock information require several assumptions about population regulation, which may lead to over- or underestimating potential natural production.

Reductions in Available Steelhead Habitat

In this section, we briefly discuss human activities that may have affected anadromous salmonid distribution and abundance within the geographical area of the proposed ESU. This is not meant to be a comprehensive analysis; rather, it is intended to briefly outline the nature and scope of activities that have occurred.

The effects of human activities on salmonids in the Klamath River Basin have been recognized to the extent that in 1986 Congress passed the Klamath River Basin Fishery Resources Restoration Act (16 U.S.C. 460ss-460ss-6, Public Law 99-552) to restore and maintain anadromous fish populations. The Klamath Act (p. 592) states in part:

> ...floods, the construction and operation of dams, diversions and hydroelectric projects, past mining, timber harvest practices, and roadbuilding have all contributed to sedimentation, reduced flows, and degraded water quality which has significantly reduced the anadromous fish habitat in the Klamath-Trinity River System.

Dams

A number of dams and diversions have been constructed within the Klamath Mountains Province during the past century. Dams have been installed for the purposes of flood control, hydropower, recreation, and domestic, industrial, and agricultural water supply. Not all of the dams have survived to the present time. Rivers (1963) and the Klamath River Basin Fisheries Task Force (KRBFTF 1991) chronicled the history of dams and diversions in the Rogue and Klamath River Basins, respectively. This document will discuss only those dams which have had a substantial impact on salmonid distribution and abundance.

Rogue River Basin--Gold Ray Dam (RKm 203) was originally completed in 1905 and rebuilt in 1940 (Rivers 1963). Fish ladders of various types and effectiveness have been installed at Gold Ray since 1906 (Rivers 1963). The Oregon Department of Fish and Wildlife has used the present ladder as a counting station for anadromous fish since 1968 (Evenson et al. 1982). Savage Rapids Dam (RKm 173) was completed in 1922 and has been laddered since 1923 (Rivers 1963). Construction of Lost Creek Dam on the Rogue River (RKm 254) was completed in February 1977; the primary purpose of this dam is flood control (ODFW 1994). Approximately 13% of the Rogue River Basin is located above Lost Creek Dam (ODFW 1994), which has no provision for fish passage (Cramer et al. 1985). Cole Rivers Hatchery operates as a mitigation hatchery for Lost Creek Dam; summer and winter steelhead as well as coho and spring chinook salmon are reared there (Evenson et al. 1982). Applegate Dam began operation in November 1980 at RKm 75 of the Applegate River (a tributary to the Rogue River at RKm 154) (ODFW 1994). Applegate Dam has no fish passage facility. Adult steelhead broodstock are collected below Applegate Dam, and eggs are cultured at Cole Rivers Hatchery.

Lost Creek and Applegate Dams are part of a three-dam flood control project in the Rogue River Basin (Fustish et al. 1989). The third dam, Elk Creek, has not yet been constructed. Elk Creek enters the Rogue River at RKm 244, and the proposed dam would be at RKm 2.7 on Elk Creek (Flesher et al. 1990).

Klamath River Basin--Anadromous fish passage to the upper Klamath River has been blocked at Klamath Falls, Oregon since the construction of the Link River hydroelectric dam in 1895 (KRBFTF 1991). Two hydroelectric dams were built by the California Oregon Power Company (Copco) northeast of Yreka, California in the early 1900s: Copco 1 in 1917 and Copco 2 in 1925 (KRBFTF 1991). No fish passage was provided, but a mitigation hatchery operated downstream on Fall Creek until 1948 (KRBFTF 1991). In 1958, Copco completed another dam below Keno, Oregon, presently called the J. C. Boyle Dam. Iron Gate Dam, completed in 1962, was ostensibly constructed to regulate the adverse flow regimes caused by Copco 1 and 2; however, it is also used for hydropower production (KRBFTF 1991). The dams described above block anadromous fish access to 120 km of mainstem habitat in the Klamath River and tributaries to that part of the river; it is estimated that this could provide spawning habitat to 9,000 chinook salmon and 7,500 steelhead (KRBFTF 1991).

The Trinity River is the largest tributary to the Klamath River; two diversion dams, Trinity and Lewiston Dams, were built on the upper Trinity River in 1964 to divert water to the Sacramento Basin as part of the Central Valley Project (KRBFTF 1991). The Trinity River Fish Hatchery was constructed at Lewiston Dam to mitigate the loss of fish passage.

Other Activities

It is relatively simple to quantify habitat loss due to dam construction; however, other activities that may effectively render habitat unusable for steelhead (e.g., through sedimentation, gravel mining, or water withdrawal) are more difficult to quantify.

Timber harvesting and associated road building activities occur throughout the Klamath Province on Federal, State, private, and tribal lands. These activities may increase sedimentation and debris flows and reduce cover and shade, resulting in aggradation, embedded spawning gravel, and increased water temperatures. The majority of forest lands in the Klamath Basin are managed by the U.S. Forest Service (KRBFTF 1991). The Klamath Mountains Province includes holdings of the Klamath, Rogue River, Shasta-Trinity, Siskiyou, and Six Rivers National Forests. According to the Forest Ecosystem Management Assessment Team, FEMAT (USFS and BLM 1994), 56% of the land in the Klamath Province is owned by the U.S. Forest Service, and 9% is owned by the Bureau of Land Management. Recognition of the importance of timber management activities on aquatic habitat is demonstrated in the provisions for riparian reserves and key watersheds described in FEMAT (USFS and BLM 1994).

The Rogue and Klamath Basins have been sites of active mining, primarily for gold, since the mid-1800s (Rivers 1963, KRBFTF 1991). Suction dredge mining results in sedimentation, which affects viability of salmonid eggs and juveniles, reduces holding habitat for adult salmonids, and reduces the standing crop of aquatic insects that salmonids prey upon (Rivers 1963, KRBFTF 1991). Suction dredging in the region continues to the present day (KRBFTF 1991). Dry rock (lode) mining introduces cyanide to the water and may cause fish kills (Rivers 1963, KRBFTF 1991). Lode mining for gold, copper, and chromite in the Klamath River Basin continued as recently as 1987 (KRBFTF 1991).

Irrigation in the Rogue Basin began in the late 1880s (Rivers 1963). Loss of salmon and steelhead to unscreened irrigation diversions was recognized as early as 1901 (Rivers 1963); however, the significance of these losses was not generally accepted. Loss of salmonids to unscreened irrigation diversions continues to the present day and is estimated at 1 million juvenile salmonids per year in the Rogue Basin (Palmisano 1992).

Discussion and Conclusions on the Status of the ESU

Threshold Assessment

Our quantitative and qualitative analyses revealed the following:

1. Although historical trends in overall abundance within the ESU are not clearly understood, there has been a substantial replacement of natural fish with hatchery produced fish.
2. Since about 1970, trends in abundance have been downward in most steelhead populations within the ESU, and a number of populations are considered by various agencies and groups to be at moderate to high risk of extinction.
3. Declines in summer steelhead populations are of particular concern.
4. Most 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 are unable to identify any steelhead populations that are naturally self-sustaining.

5. Total abundance of adult steelhead remains fairly large (above 10,000 individuals) in several river basins within the region, but several basins have natural runs below 1,000 adults per year.

Conclusion

The Klamath Mountains Province steelhead ESU is not now at risk of extinction, but if present trends continue, it is likely to become so in the forseeable future. Although steelhead populations within the ESU share many ecological, life-history, and genetic characteristics, they are by no means homogeneous. The ESU contains populations from small streams as well as large rivers, and includes fish with a wide range of run-timing. Conserving existing diversity within this ESU should be a key component of recovery planning, just as it is for the ESU that contains Snake River spring/summer chinook salmon.

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APPENDIX B
STOCK ABUNDANCE AND TRENDS

STOCK ABUNDANCE AND TRENDS

This appendix contains stock abundance and trend summaries for coastal steelhead trout (anadromous *Oncorhynchus mykiss*) spawning in coastal streams from Cape Blanco, Oregon, to, and including, the Klamath River Basin, California. Stocks are aggregated within major coastal drainage basins, listed from north to south. Minor drainages for which we have little information are not considered.

The goal of this summary is to provide sufficient information to assess the viability of natural steelhead populations in this region. While there are several quantitative techniques used for population viability (or vulnerability) analysis (PVA), such analyses for Pacific salmon are not sufficiently well developed to serve as a basis for ESA listing decisions. Instead, we consider a variety of information in evaluating the level of risk faced by a species. Important factors include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and current carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., from strays or outplants from hatchery programs); and 6) recent events (e.g., a drought or changes in management) that have predictable short-term consequences for abundance of the species. All of these factors need to be considered in terms of populations in the natural environment.

Information presented here includes estimates of historical and recent levels and trends in adult spawner populations and adult abundance indices derived from adult counts at dams or weirs, sport catch records, and spawner surveys. No consistent data for other life-history stages are available.

Historical abundance information for this geographic area is largely anecdotal, as is information relating to habitat capacity. This information is summarized in the main report and is not repeated here. Time-series data for adult abundance are available for most populations only since 1970. We compiled and analyzed this recent information to provide several summary statistics of natural spawning abundance, including recent total spawning run size, percent annual change in total run size, recent natural run size, and average natural return ratio.

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 compiling these summary statistics. All statistics are based on data for adults that spawn in natural habitat ("naturally spawning fish"). The total of all naturally spawning fish ("total run size") is divided into two components (Fig. 5): "Hatchery produced" fish are reared as juveniles in a hatchery but return as adults to spawn naturally; "natural" fish are progeny of naturally spawning fish.

Although the quantitative evaluations presented here 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 based on catch (which itself may not always have been measured accurately) or on limited survey data. In many cases, there were also limited data to separate hatchery production from natural production.

Methods

Data Sources

Information was compiled from a variety of state and federal agency records. We believe it to be complete in terms of long-term adult abundance records for steelhead in the region covered. Principal data sources were angler catch estimates, dam or weir counts, and stream surveys. None of these provides a complete measure of adult spawner abundance for any of the streams. Specific data sources and problems are discussed below for each data type.

Angler catch--Availability of sport harvest information differs between Oregon and California. 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, so earlier data are not directly comparable to those since 1970. Our analyses for Oregon river basins focusses on data for the 1970 to 1992 run years (ODFW 1980, 1992c, 1993b). California began using questionnaires to estimate steelhead catch in 1953 but discontinued regular reporting after 1956, so no time-series of catch data are available for California river basins.

Interpreting population abundance from angler catch data presents several problems. First, numbers of fish caught do not directly represent abundance, which must be estimated from catch 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 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 (Fig. B-1), and winter steelhead catch rates (calculated by comparing catch estimates with dam passage counts) for the upper Rogue and upper North Umpqua Rivers have shown only small variation over the last several years (Fig. B-2).

The following analysis assumes that catch trends reflect trends in overall population abundance. We recognize that variations in effort and effectiveness introduce a certain amount of error, and that the index may not precisely represent trends in the total population in a river basin, but we believe that changes in catch still provide a useful indication of trends in population abundance.

Dam and weir counts--Dam and weir counts are available in two river basins: at Gold Ray Dam on the upper Rogue River, and at Bogus Creek and Shasta River weirs in the Klamath River Basin. These counts are probably the most accurate estimates available of total spawning run abundance, but they only represent small portions of the total population in each river basin. As with angler catch, these counts represent a combination of hatchery produced and natural fish, and these types are counted separately only at Gold Ray Dam.

Stream surveys--The California Department of Fish and Game and the U.S. Forest Service have conducted multiyear summer surveys for steelhead in several streams in northern California. For most of these streams, these are the only observations of steelhead abundance available. Unfortunately, these surveys count only fish that are "holding" in the streams during the summer, and so reflect only the early summer run, not the late summer (fall) run or the winter run. In addition, methods were not standardized in early surveys, and many streams were not surveyed each year, so analysis of these data is limited. The Oregon Department of Fish and Wildlife has conducted seine surveys for summer steelhead since 1976 at Huntley Park near the mouth of the Rogue River, from which total run size for the entire Rogue River Basin (including the Applegate River) has been estimated (ODFW 1994). The accuracy of these estimates is unknown.

Population Abundance Estimates

Historical abundance information is not available for individual river basins. Recent natural run-size estimates were compiled from various sources, including dam or weir counts and expansions of angler catch estimates, as described below.

Kenaston (1989) estimated average run sizes for Oregon winter steelhead returning to coastal streams from 1980 to 1985. These estimates were calculated by dividing estimated angler catch in each stream by an assumed exploitation rate based on classifying the local fishery as high, moderate, or low intensity. Kenaston also divided total run size into hatchery and "wild" components based on historical scale-analysis for individual streams or aggregate averages (when individual stream information was unavailable). We calculated similar estimates for the 1987 to 1991 run years including summer as well as winter steelhead. For winter steelhead, we used the exploitation rates used by Kenaston (1989, appendix A); for summer steelhead, we assumed the rates reported for moderate intensity fisheries (Kenaston 1989, Table 2). To estimate natural and hatchery components of the total run-size estimates, we applied average estimates of hatchery composition in the fishery from Chilcote et al. (1992), supplemented with estimates made by ODFW at Gold Ray Dam (summer and winter runs) and Huntley Park (summer run only). Resulting estimates of total and natural run sizes are of course only approximate, and should be interpreted only as approximate indicators of true population abundance.

Population Trend Estimates

As an indication of overall trend in steelhead populations in individual streams, we calculated average (over the available data series) percent annual change in adult spawner indices within each river basin. Trend estimates were calculated using exponential regression of spawner abundance indices against time with a generalized linear model (GLIM) (McCullagh and Nelder 1983) technique assuming Poisson observation errors. The GLIM technique was used rather than simple log-linear least squares regression because it is robust to zero counts in the population index and reflects the tendency of variance in population observations to be related to abundance. The regressions provided direct estimates of mean instantaneous rates of population change (r); these values were subsequently converted to percent annual change, calculated as $100(e^r-1)$. 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.

Natural Production Estimates

The important role of artificial propagation (in the form of hatcheries) for Pacific salmon requires careful consideration in ESA evaluations. Waples (1991) and Hard et al. (1992) discuss the role of artificial propagation in ESU determination and emphasize the need to focus on natural production in the threatened or endangered status determination. However, they do not address the specific methods for evaluating natural production in the threatened or endangered status determination. This second problem is addressed here.

Because of the ESA's emphasis on ecosystem conservation, the threshold determination focuses on naturally reproducing salmon. An important question in the threshold determination is thus: Is natural production sufficient to maintain the population without the constant infusion of artificially produced fish? To answer this question, we need a method of estimating natural production with the contribution of hatchery reared fish removed. The natural return ratio (NRR) described below provides a rough measure of this.

Terminology--It is important to carefully distinguish stock components in populations that are derived from a mixture of natural and artificial production (Fig. 5). The natural component consists of fish that complete their entire life cycle in essentially natural habitat; the artificial component consists of fish that spend part of their early life cycle under artificial conditions. Note that these definitions refer only to the conditions under which fish live, not their heritage; natural fish may be the progeny of artificially produced parents, and vice versa. The two components will mix across generations: naturally spawning fish in one generation may be derived from both natural and artificially produced parents, and natural fish may be removed from natural habitat as broodstock for artificial propagation.

Production of a population is defined here in terms of return ratios (lambda$t$) per generation and the closely related annual instantaneous rates of change (*rt*), both of which typically vary across brood years (*t*). Return ratios are simply the ratio of returning adult spawners to adult spawners the previous generation; an average ratio of 1 indicates a stable population. Annual instantaneous rates of change are calculated as

$$r_t = \ln(\lambda_t)/\alpha$$

where alpha is the mean age of spawning in the population. A value of 0 for the mean instantaneous rate of change indicates a stable population.

Approach--The general approach to estimating NRR consists of three steps:
1) identifying natural stock abundance through time,
2) estimating the returning offspring from natural spawners, and
3) calculating return ratios and instantaneous rates of change for each brood year (or set of time-averaged brood years).

The average return ratio serves as an index of trend in the natural stock component, and variation about the average indicates the degree of variation in natural stock production.

Estimating return ratios--Because we rarely have age information on returning adults, we have estimated NRR by using returns at a fixed time-lag corresponding to the most common spawning age for the stock (assumed to be age 4 for these steelhead stocks; this assumption has little influence on the estimated average values). Because we have no direct counts of naturally spawning adults, we have used the best available index of natural spawning: dam counts, spawner survey counts, or angler catch estimates.

Estimation of return ratios depends on the type of information available for the population. Here, we consider only two typical scenarios: high information, with separate annual counts of natural fish and artificially produced fish on the spawning grounds, and minimal information, with only an annual index of total run size and an estimate of the average proportion of artificially produced fish in the spawning population. Estimates for the second scenario are of course more approximate. Among stocks considered in this review, the high-information scenario applied only to adult counts at Gold Ray Dam on the Rogue River; the minimal-information methods were used for other Oregon stocks. No California stocks had even the minimal information needed for this analysis.

Under the high-information scenario, the calculation proceeds as follows. Define T_t as the total (hatchery produced plus naturally produced) natural spawners in year *t* and N_t as the naturally produced natural spawners in year *t*. Then, assuming a 4-year life cycle, average NRR may be calculated as the geometric mean of N_{t+4}/T_t. For the minimal-information scenario, we have data for only T_t and the average proportion of the run that is hatchery produced (*h*). We note that, on average, $N_t = (1\text{-h})T_t$, so average NRR may be approximated as the geometric mean of $(1\text{-h})T_{t+4}/T_t$.

Assumptions--In interpreting average NRR as a quantitative indicator of population status, a number of simplifying assumptions need to be recognized. These include:
1) The population consists of a single unit, closed to all migration and immigration except for interaction with the included artificial stock.
2) Per capita contribution of artificially produced natural spawners to future generations is equal to

that of naturally produced natural spawners.

3) Density dependence is not important.

4) Artificially produced fish have no effect on the production of natural fish.

Departures of real populations from these assumptions will of course affect the utility of NRR as an indicator of population status. The effect of the first assumption (closure to migration) could be either positive or negative, depending on whether emigration or immigration is larger for a particular population. The second assumption (equal reproductive success of natural and hatchery fish) is intentionally conservative (i.e., leading to a lower estimate of NRR than would other assumptions). There is some evidence for steelhead that artificially produced fish may have lower per capita contribution to future generations than do natural fish (Reisenbichler and McIntyre 1977), but the extent to which such effects depend on specific stocks or hatchery practices is unknown. The effect of the third assumption (lack of density dependence) is also conservative in that, if a mixed stock is near carrying capacity, the apparent NRR may be substantially lower than would be observed for the same stock at lower abundance levels (or if there were no hatchery). The final assumption (no effect of hatchery fish on natural fish) is also probably in a sense conservative: if the effect of hatchery fish is negative (e.g., through competition, disease transmission, or lowered hybrid fitness), then the observed NRR would be lower than return ratios for the natural stock in the absence of hatchery fish. Considering all the assumptions together, it is likely that average NRR provides a somewhat conservative estimate of natural stock production.

Finally, it must be recognized that these estimates of NRR are only approximate. Especially for estimates derived from angler catch data, there is a potentially high level of error in estimates of both spawner numbers and hatchery proportions. Because of these errors and the various assumptions in interpreting return ratios, these ratios should not be viewed as formal statistical estimates of true population parameters, and we have not tried to provide error estimates or confidence intervals for them.

Trend and Production Estimates

Results of the quantitative analyses are summarized in Table B-1. Other information, including qualitative assessments of population status, are given in the individual stock summaries that follow.

Table B-1. Summary of estimated abundance statistics for individual data series, listed by state and river basin. Recent run size estimates reflect an average of the most recent 5 years of data, or the most recent published estimate. Blanks (--) indicate lack of information. Where ranges are given, these reflect ranges in estimates of the hatchery produced proportion of spawning stocks. Sources of information are given in the individual stock summaries.

River basin	Run-type	Data type[a]	Data years	Recent total run	Annual change (%) (mean(s.e.))	Percent hatchery	Recent natural run	Average NRR[b]
Oregon								
Elk River	winter	AC	1970-91	850	-8.4(0.1)	36	540	0.44
Euchre Creek	winter	AC	1970-91	140	-4.7(0.5)	-	90	--
Rogue River, upper[c]	winter	AC	1970-91	5,300	-5.3(0.0)	47-81	1,900	0.16-0.45
	winter	DC	1942-91	11,000	+0.3(0.0)	47-81	8,500	0.79
	summer	AC	1970-91	8,900	+1.5(0.0)	18-49	5,200	--
	summer	DC	1942-91	14,000	+3.2(0.0)	18-49	6,900	0.68

Rogue River, lower[c]	winter	AC	1970-91	14,400	--	--	5,200	--
	summer	AC	1970-91	13,200	--	--	10,300	--
	summer	BS	1976-91	18,000	-2.5(0.0)	22	14,000	0.57
Applegate River	winter	AC	1970-91	5,300	-1.7(0.1)	47-81	1,900	0.18-0.49
	summer	AC	1970-91	1,600	-0.1(0.1)	--	1,300	--
Illinois River	winter	AC	1970-91	5,900	-10.2(0.1)	7	5,500	0.60
Hunter Creek	winter	AC	1970-91	380	-5.8(0.3)	67	130	0.17
Pistol River	winter	AC	1970-91	1,500	-3.2(0.3)	38	910	0.53
Chetco River	winter	AC	1970-91	5,100	-0.2(0.1)	49	2,600	0.47
Winchuck River	winter	AC	1970-91	540	-3.9(0.2)	25-45	350	0.44-0.60

River basin	Run-type	Data type[a]	Data years	Recent total run	Annual change (%) (mean(s.e.))	Percent hatchery	Recent natural run	Average NRR[b]
California								
Smith River								
Middle Fork	summer	SS	1982-91	--	+38.0(10.6)	--	--	--
South Fork	summer	SS	1981-91	--	+9.4(2.3)	--	--	--
Klamath River								
	winter	UK	1980s	20,000	--	--	--	--
	summer and fall	UK	1980s	110,000	--	--	--	--
Salmon River, North Fork	summer	SS	1980-91	--	-12.8(1.5)	--	--	--
Salmon River, South Fork	summer	SS	1980-91	--	-9.0(0.9)	--	--	--
Wooley Creek	summer	SS	1980-91	--	-2.6(0.6)	--	--	--
Bluff Creek	summer	SS	1980-91	--	+3.7(1.1)	--	--	--
Redcap Creek	summer	SS	1980-91	--	-1.8(2.0)	--	--	--
Dillon Creek	summer	SS	1980-91	--	-8.2(0.6)	--	--	--
Clear Creek	summer	SS	1980-91	--	+2.2(0.4)	--	--	--
Elk Creek	summer	SS	1980-91	--	-3.9(0.9)	--	--	--
Combined Klamath River Basin	summer	SS	1980-91	--	-3.3(0.3)	--	--	--
Shasta River	fall	DC	1977-92	--	-14.9(0.5)	--	--	--
Bogus Creek	fall	DC	1984-92	--	-1.1(4.6)	--	--	--
Iron Gate Hatchery	fall and winter	HR	1963-91	--	+1.5(0.1)	--	--	--
Trinity River								
above Willow Creek		RR	1980-91	15,000	--	--	--	--

Trinity River, South Fork	summer	SS	1982-91	--	+5.3(1.9)	--	--	--
Trinity River, upper	summer	SS	1980-91	--	+16.4(3.6)	--	--	--
New River	summer	SS	1980-91	--	+5.5(0.4)	--	--	--
Trinity River, North Fork	summer	SS	1980-89	--	+11.4(0.6)	--	--	--
Canyon Creek	summer	SS	1980-91	--	+4.7(2.5)	--	--	--
Combined Trinity River Basin	summer	SS	1980-89	--	+7.6(0.4)	--	--	--
Trinity River Hatchery	summer and winter	HR	1958-90	-- -	1.5(0.0)	--	--	--

a - AC--angler catch; BS--beach seine; DC--dam or weir count; HR--hatchery return; RR--run reconstruction; SS--stream survey; UK--unknown method (see stock summary).

b - NRR: Natural Return Ratio (see Glossary, Appendix A).

c - Includes some upper Rogue, Applegate, and Illinois River steelhead.

STOCK SUMMARIES

Elk River, OR

The Elk River has only winter-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Elk River. Recent abundance estimates are derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run size of ca. 1,400 total and 800 natural fish; updated run-size estimates (1987-91 average) are 850 total and 540 natural fish. Angler catch declined at an average rate of ca. 8% per year between 1970 and 1991 (Fig. B-3). Hatchery fish have recently averaged 36% of the angler catch (Chilcote et al. 1992), and average NRR based on angler catch is ca. 0.44. (Chilcote et al. estimate that less than 10% of fish on spawning grounds are of hatchery origin, so actual NRR may be higher than that estimated from angler catch.) Biologists with the U.S. Forest Service (USFS) report that this steelhead population appears healthy (USFS 1993a,b).

Euchre Creek, OR

Euchre Creek has only winter-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to Euchre Creek. Recent abundance estimates are derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run size of ca. 300 total and 200 natural fish; updated run-size estimates (1987-91 average) are 140 total and 90 natural fish. Angler catch declined at an average rate of ca. 5% per year between 1970 and 1991 (Fig. B-4). No estimate of the proportion of hatchery fish in the run is available (Chilcote et al. 1992), so we cannot estimate NRR.

Rogue River, OR

The Rogue River has both winter- and summer-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Rogue River. Recent abundance estimates are derived from angler catch estimates (ODFW 1980, 1992c, 1993b), adult passage counts at Gold Ray Dam on the upper Rogue (ODFW 1990, 1994), and summer steelhead surveys at Huntley Park near the river mouth (ODFW 1994). From angler catch data, Kenaston (1989) estimated average 1980-85 winter steelhead run sizes of ca. 7,400 total and 3,200 natural fish in the lower Rogue, and 4,000 total/1,500 natural fish in the upper Rogue; corresponding updated run-size estimates (1987-91 average) are 14,400 total/5,200 natural fish in the lower Rogue and 5,300 total/1,900 natural fish in the upper Rogue. For summer steelhead, estimated average 1987-91 run sizes were 13,200 total/10,300 natural fish in the lower Rogue and 8,900 total/5,200 natural fish in the upper Rogue. Recent (1981-91) counts at Gold Ray Dam had the following ranges: 4,300-16,200 total and 2,900-12,700 natural winter-run steelhead; 4,400-26,300 total and 3,200-13,000 natural summer-run steelhead. Between 1970 and 1991, angler catch of winter-run steelhead declined at an average rate of ca. 5% per year while catch of summer-run steelhead increased ca. 2% per year (Fig. B-5). Over a similar period, counts at Gold Ray Dam increased by less than 1% (winter run) and ca. 3% (summer run) per year (Fig. B-6), while estimates of adult summer-run steelhead passing Huntley Park declined by ca. 3% per year (Fig. B-7). Estimated average return ratios (see Table B-1) have shown similar variation among the data sets. Nehlsen et al. (1991) listed summer-run steelhead in the Rogue as at "moderate risk of extinction." The ODFW described Rogue River winter steelhead as "healthy" and summer steelhead as "depressed" (Nickelson et al. 1992); USFS biologists concurred with this assessment (USFS 1993a,b).

Applegate River, OR

The Applegate River has both winter- and summer-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Applegate River. Recent abundance estimates were derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run size of ca. 2,200 total and 800 natural fish; updated run-size estimates (1987-91 average) are 5,300 total and 1,900 natural fish. Recent (1987-91 average) run-size estimates for summer steelhead are 1,600 total and 1,300 natural fish. Summer-run angler catch showed no significant decline between 1970 and 1991, while winter-run catch declined at an average rate of ca. 2% per year (Fig. B-8). Hatchery fish have recently averaged 47-81% of the winter run (Chilcote et al. 1992), and average winter-run NRR is ca. 0.18-0.49. No hatchery composition estimate is available for summer-run steelhead.

Illinois River, OR

The Illinois River presently has only winter-run steelhead. Rivers (1957) noted a small summer run, but whether these summer fish actually spawned in the Illinois River is unknown. We have no historical (pre-1900s) abundance estimates specific to the Illinois River. Recent abundance estimates were derived from angler catch estimates (ODFW 1980, 1992c, 1993b), which reflect primarily the upper basin (above Illinois Falls). Kenaston (1989) estimated average 1980-85 winter steelhead run-size of ca. 10,300 total and 6,300 natural fish; updated run-size estimates (1987-91 average) are 5,900 total and 5,500 natural fish. Angler catch declined at an average rate of ca. 10% per year between 1970 and 1991 (Fig. B-9). Hatchery fish have recently averaged only 7% of the run (Chilcote et al. 1992), and average NRR is ca. 0.60. Nehlsen et al. (1991) listed winter-run steelhead in the Illinois River as at "moderate risk of extinction." ODFW described this population as "depressed" (Nickelson et al. 1992, ODFW 1992a);

USFS biologists concurred with this assessment (USFS 1993a,b).

Hunter Creek, OR

Hunter Creek has only winter-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to Hunter Creek. Recent abundance estimates were derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run-size of ca. 800 total and 500 natural fish; updated run-size estimates (1987-91 average) are 380 total and 130 natural fish. Angler catch declined at an average rate of ca. 6% per year between 1970 and 1991 (Fig. B-10). Hatchery fish have recently averaged 67% of the run (Chilcote et al. 1992), and average NRR is ca. 0.17.

Pistol River, OR

The Pistol River has only winter-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Pistol River. Recent abundance estimates were derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run-size of ca. 2,200 total and 1,200 natural fish; updated run-size estimates (1987-91 average) are 1,500 total and 900 natural fish. Angler catch declined at an average rate of ca. 3% per year between 1970 and 1991 (Fig. B-11). Hatchery fish have recently averaged 38% of the run (Chilcote et al. 1992), and average NRR is ca. 0.53.

Chetco River, OR

The Chetco River has only winter-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Chetco River. Recent abundance estimates were derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run-size of ca. 7,200 total and 3,200 natural fish; updated run-size estimates (1987-91 average) are 5,100 total and 2,600 natural fish. Angler catch declined at an average rate of less than 1% per year between 1970 and 1991 (Fig. B-12). Hatchery fish have recently averaged 49% of the run (Chilcote et al. 1992), and average NRR is ca. 0.47. ODFW described this population as "depressed" (Nickelson et al. 1992); USFS biologists concurred with this assessment (USFS 1993a,b).

Winchuck River, OR

The Winchuck River has only winter-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Winchuck River. Recent abundance estimates were derived from angler catch estimates (ODFW 1980, 1992c, 1993b). Kenaston (1989) estimated average 1980-85 winter steelhead run-size of ca. 800 total and 400 natural fish; updated run-size estimates (1987-91 average) are 540 total and 350 natural fish. Angler catch declined at an average rate of ca. 4% per year between 1970 and 1991 (Fig. B-13). Hatchery fish have recently averaged 25-45% of the run (Chilcote et al. 1992), and average NRR is ca. 0.44-0.60. ODFW described this population as "healthy" (Nickelson et al. 1992); USFS biologists concurred with this assessment (USFS 1993a,b).

Smith River, CA

The Smith River presently has both winter- and summer-run steelhead, although the historical presence of the summer run is questionable (USFS 1993a,b). We have no historical (pre-1900s) steelhead abundance estimates specific to the Smith River. Spawning escapement was estimated to be ca. 30,000 in the early 1960s (CDFG 1965, Vol. 3(B)), although this estimate is not based on direct observations and should be viewed as approximate. Recent abundance estimates were derived from summer diver surveys (Roelofs 1983; McEwan 1992; Pisano 1992) which index only early summer-run steelhead. Summer-run survey counts increased since 1980 (Fig. B-14), although the data are limited and estimates of the rate of increase have high standard errors (Table B-1). We have insufficient information to calculate a natural return ratio for this stock. Nehlsen et al. (1991) listed summer-run steelhead in the Smith River as at "high risk of extinction." USFS biologists described the Smith River winter- run steelhead population as low, but stable, and the summer-run population as depressed, of questionable viability (USFS 1993a,b). McEwan and Jackson (in prep.) describe this population (no runs differentiated) as healthy, with fully seeded juvenile habitat.

Klamath River, CA

The Klamath River has both winter- and summer-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Klamath River Basin. Spawning escapement (excluding the Trinity River) was estimated to be ca. 171,000 (150,000 mainstem, 21,000 tributaries) in the early 1960s (CDFG 1965, Vol. 3(B)), although this estimate is not based on direct observations and should be viewed as approximate. McEwan and Jackson (in prep.) cite total run-size estimates for the 1977-78 to 1982-83 run-years ranging from 87,000 to 181,000, with an average of 129,000. For the early 1980s, Hopelain (1987) estimated that winter-run steelhead abundance was between 10,000 and 30,000. Combining these estimates suggests that early 1980s summer-run (including fall-run) abundance was ca. 99,000-119,000. Recent abundance estimates were derived from weir counts at Shasta River and Bogus Creek (Pisano 1992), returns to the Iron Gate Hatchery (Pisano 1992), and summer diver surveys (Roelofs 1983, McEwan 1992, Pisano 1992) which index only early summer-run steelhead. Summer-run survey counts have been fluctuating with an average decline of 3% per year since 1980 (Fig. B-15). Weir counts (Fig. B-16) index natural fall-run steelhead. Shasta River weir counts showed a strong decline (average 15% per year) since 1977; Bogus Creek weir counts were low, possibly with a slight decline (ca. 1% per year, but not significantly different from zero). Returns to Iron Gate Hatchery had been increasing at ca. 2% per year since 1963, but exhibited a strong decline since 1987 (Fig. B-17). Barnhart (1994) noted that recent steelhead catch rates (fish per angler-hour) showed significant downward trends. We have insufficient information to calculate a natural return ratio for these stocks. Nehlsen et al. (1991) listed summer-run steelhead in the Klamath as at "moderate risk of extinction." USFS biologists described Klamath River winter-run steelhead stocks as low and possibly declining (but with insufficient information for a clear assessment), and the summer-run stocks as depressed, with possibly reduced range, and with moderate to high risk of extinction (USFS 1993a,b). Barnhart (1994) noted that "[w]ild stocks of Klamath River steelhead may be at all time low levels ...," and he cited declining total run sizes and increasing hatchery component of the run as evidence of the problem.

Trinity River, CA

The Trinity River has both winter- and summer-run steelhead. We have no historical (pre-1900s) steelhead abundance estimates specific to the Trinity River Basin. Spawning escapement was estimated to be ca. 50,000 in the early 1960s (CDFG 1965, Vol. 3(B)), although this estimate is not based on direct observations and should be viewed as approximate. Recent abundance estimates were for total fall-run steelhead run size and angler catch above Willow Creek in the lower Trinity River (Heubach 1992), returns to the Trinity River Hatchery (Pisano 1992), and summer diver surveys (Roelofs 1983, McEwan 1992, Pisano 1992) which index only early summer-run steelhead. Summer-run survey counts have been increasing at an average rate of 8% per year since 1980 (Fig. B-18), largely due to increases in the North Fork Trinity River and the New River. For fall-run steelhead, run-size estimates above Willow Creek (Fig. B-19) showed fluctuations since 1980 between about 5,000 and 37,000 adults, averaging ca. 15,000, but data are insufficient to estimate a trend. Returns of hatchery fish were quite low (less than 1,000 in all but 2 years) from 1965 to 1985, after which they recovered for a short time before declining again after a peak of 4,800 fish in 1989; average decline was ca. 2% per year between 1958 and 1990. USFS biologists described various Trinity River winter-run steelhead stocks as stable to depressed with heavy hatchery influence in the mainstem and North Fork, and the summer-run stocks as either low but stable or unknown, except for a drastic reduction and "high risk of extinction" in the South Fork (USFS 1993a,b).

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APPENDIX A

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 2/3 or 2.3.

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.

Cole Rivers Hatchery
An Oregon Department of Fish and Wildlife fish hatchery on the upper Rogue River, northeast of Medford, constructed by the U.S. Army Corps of Engineers in connection with Lost Creek Dam. Hatchery operations began in 1979. This hatchery was named for **Cole Rivers**, a long-time fish biologist for the State of Oregon, who spent much of his career on the Rogue River and is cited several times in this document.

Electrophoresis
Electrophoresis refers to the movement of charged particles in an electric field. It has proven to be a very useful analytical tool for biochemical characters because molecules can be separated on the basis of differences in size or net charge. Protein electrophoresis, which measures differences in the amino acid composition of proteins from different individuals, has been used for over two decades to study natural populations, including all species of anadromous Pacific salmonids. Because the amino acid sequence of proteins is coded for by DNA, data provided by protein electrophoresis provide insight into levels of genetic variability within populations and the extent of genetic differentiation between them. 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.

Fluvial
Of, relating to, or inhabiting a river or stream.

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.

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

Natural Return Ratio (NRR)
An estimate of the ratio of naturally produced spawners in one generation to total natural spawners (both naturally and hatchery produced) in the previous generation.

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 of an organism resulting from the interaction of the genotype and the

environment.

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 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 smolted.

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.

U.S. Dept Commerce/NOAA/NMFS/NWFSC/Publications

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Appendix Figures 1-6

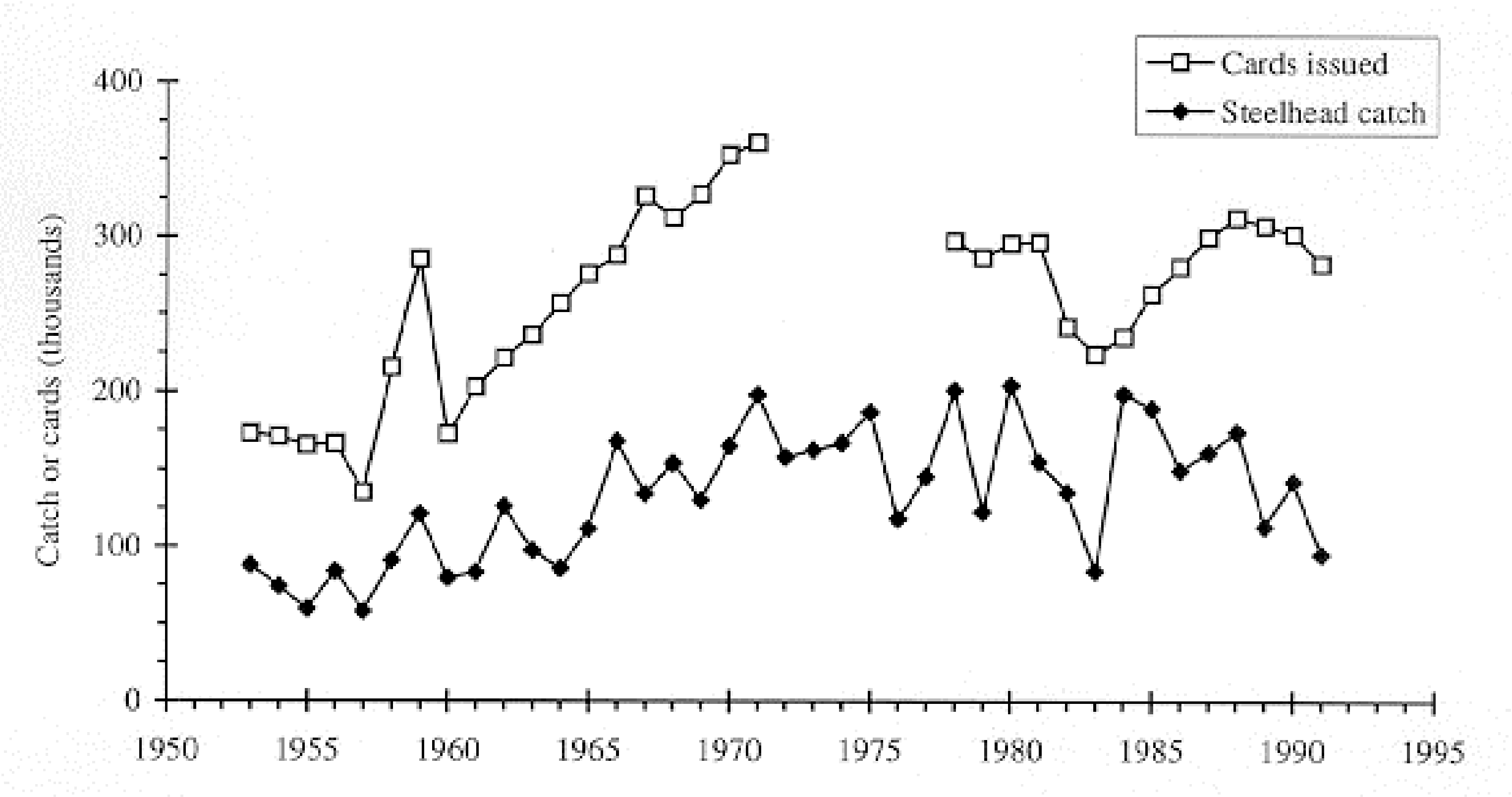

Figure B-1. Oregon statewide total angler fishing effort and steelhead catch. Effort is indexed by number of annual salmon-steelhead punchcards issued (squares). Catch (diamonds) is statewide total, all runs. Effort for 1972 to 1977 omitted because reported totals include daily punchcards in addition to annual punchcards. Based on data from Koski (1963), Phelps (1973), Berry (1983), and ODFW (1992c, 1993b).

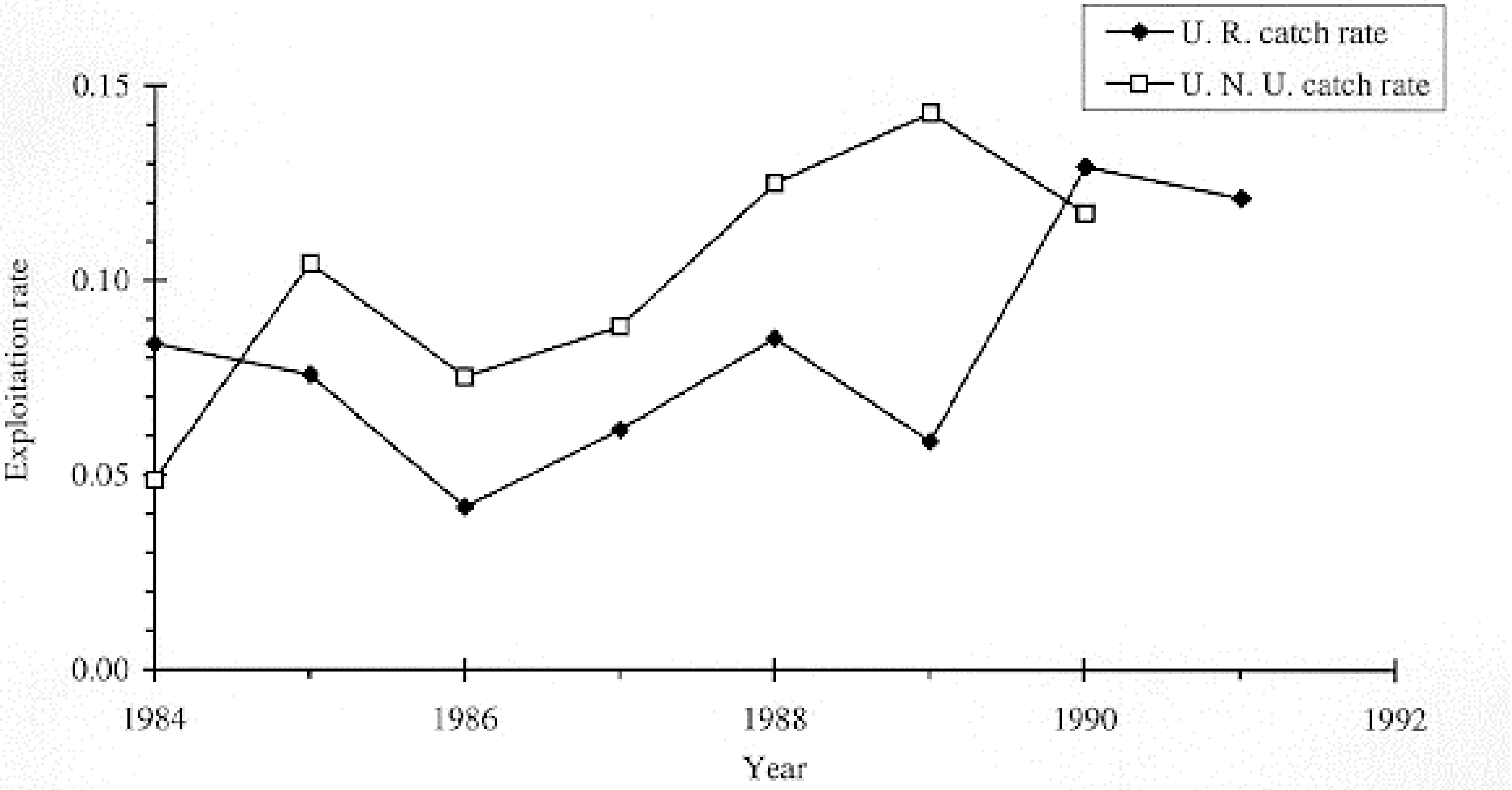

Figure B-2. Winter steelhead exploitation rates for the upper North Umpqua River (squares) and upper Rogue River (diamonds). Rates are calculated as the ratio of angler catch to total run size estimated from adult dam passage counts, as in Kenaston (1989). Catch data are from ODFW (1992c, 1993b); passage counts for Winchester Dam (North Umpqua River) are from Loomis and Liscia (1990); passage counts for Gold Ray Dam (Rogue River) are from ODFW (1990, 1994).

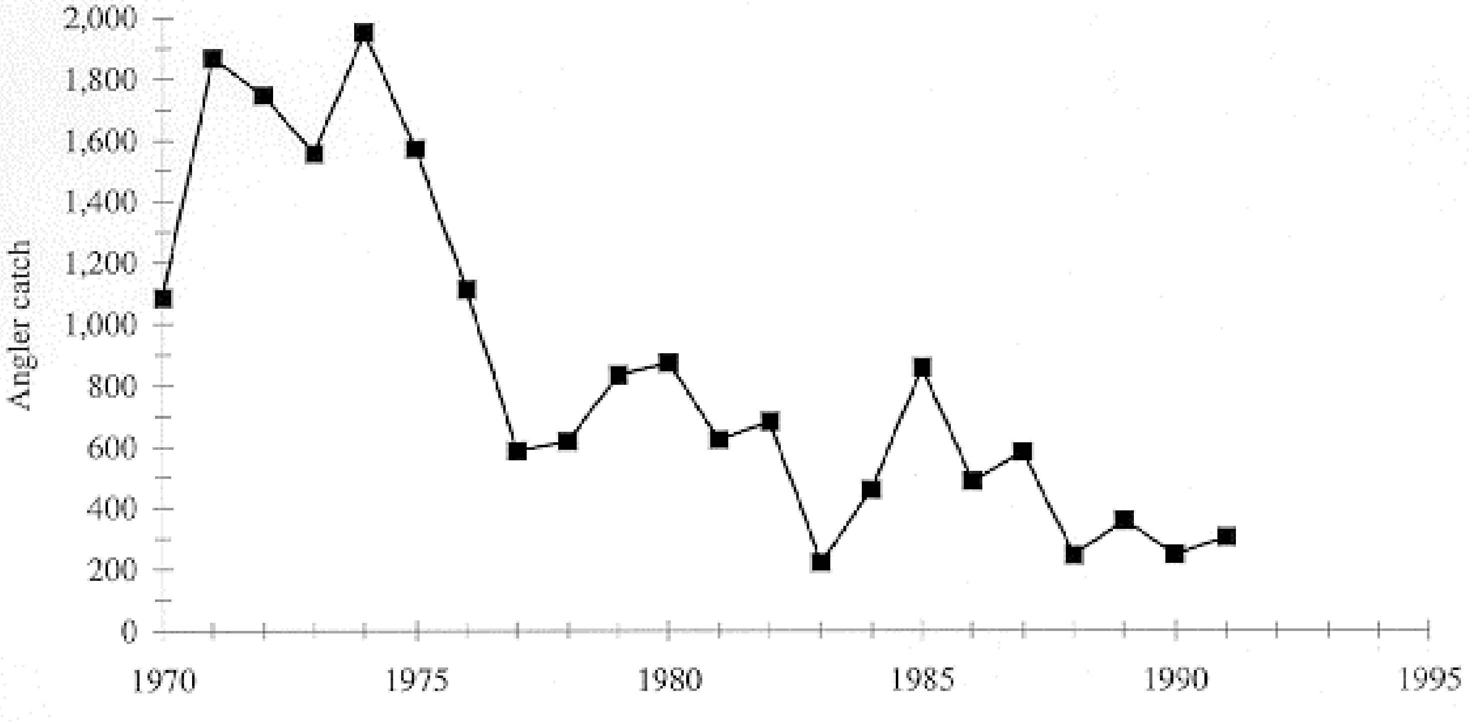

Figure B-3. Estimated angler catch for Elk River winter steelhead. Based on data from ODFW (1980, 1992c, 1993b).

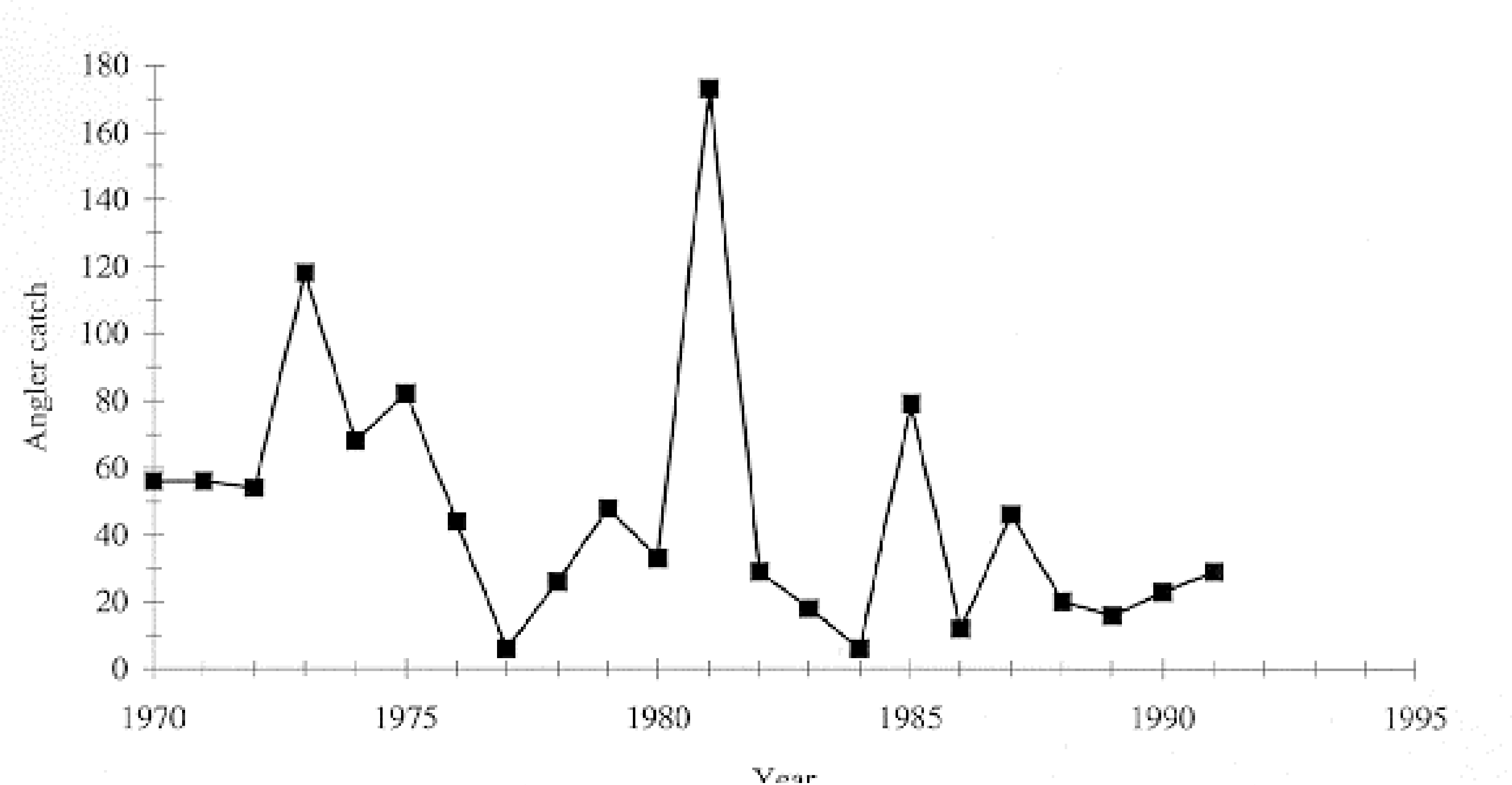

Figure B-4. Estimated angler catch for Euchre Creek winter steelhead. Based on data from ODFW (1980, 1992c, 1993b).

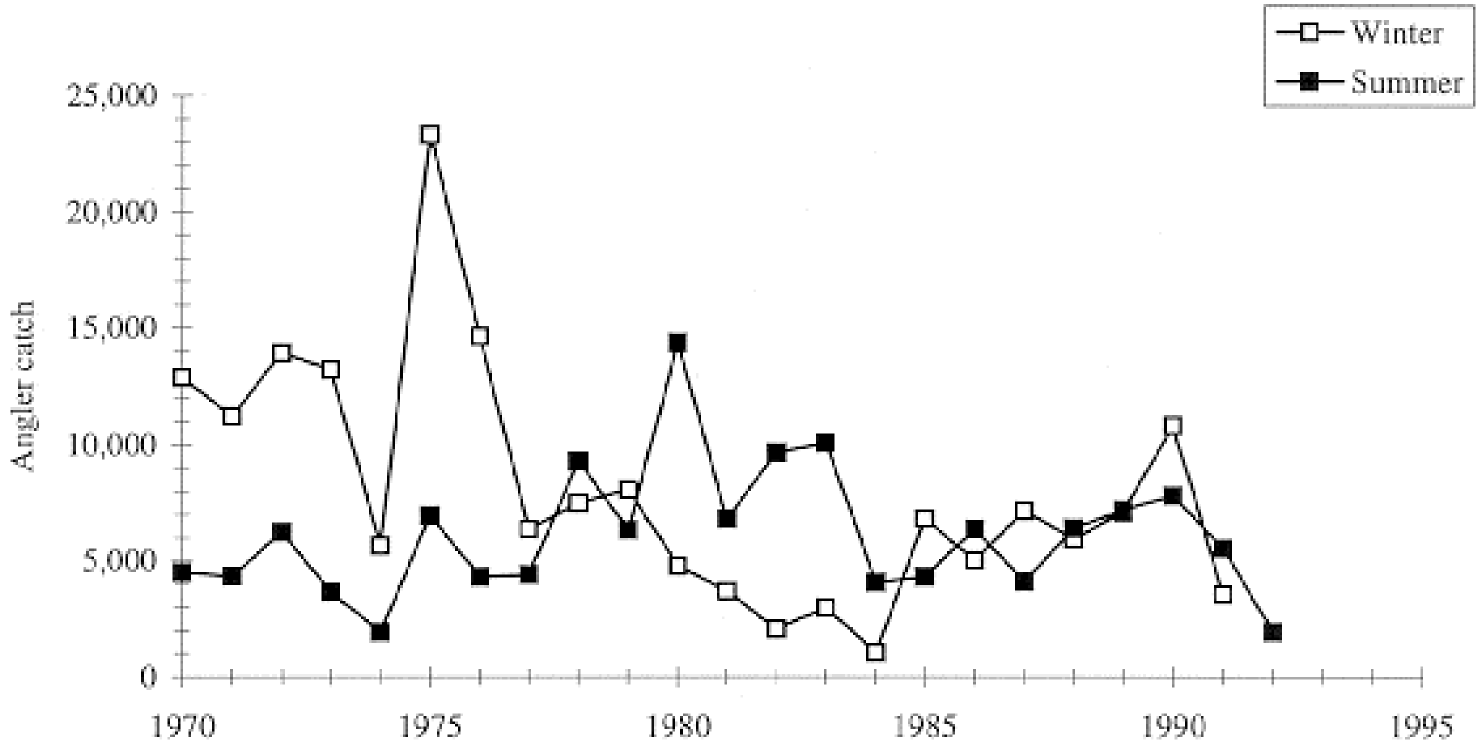

Figure B-5. Estimated angler catch for Rogue River (upper and lower river estimates comtined) winter and summer steelhead. Based on data from ODFW (1980, 1992c, 1993b).

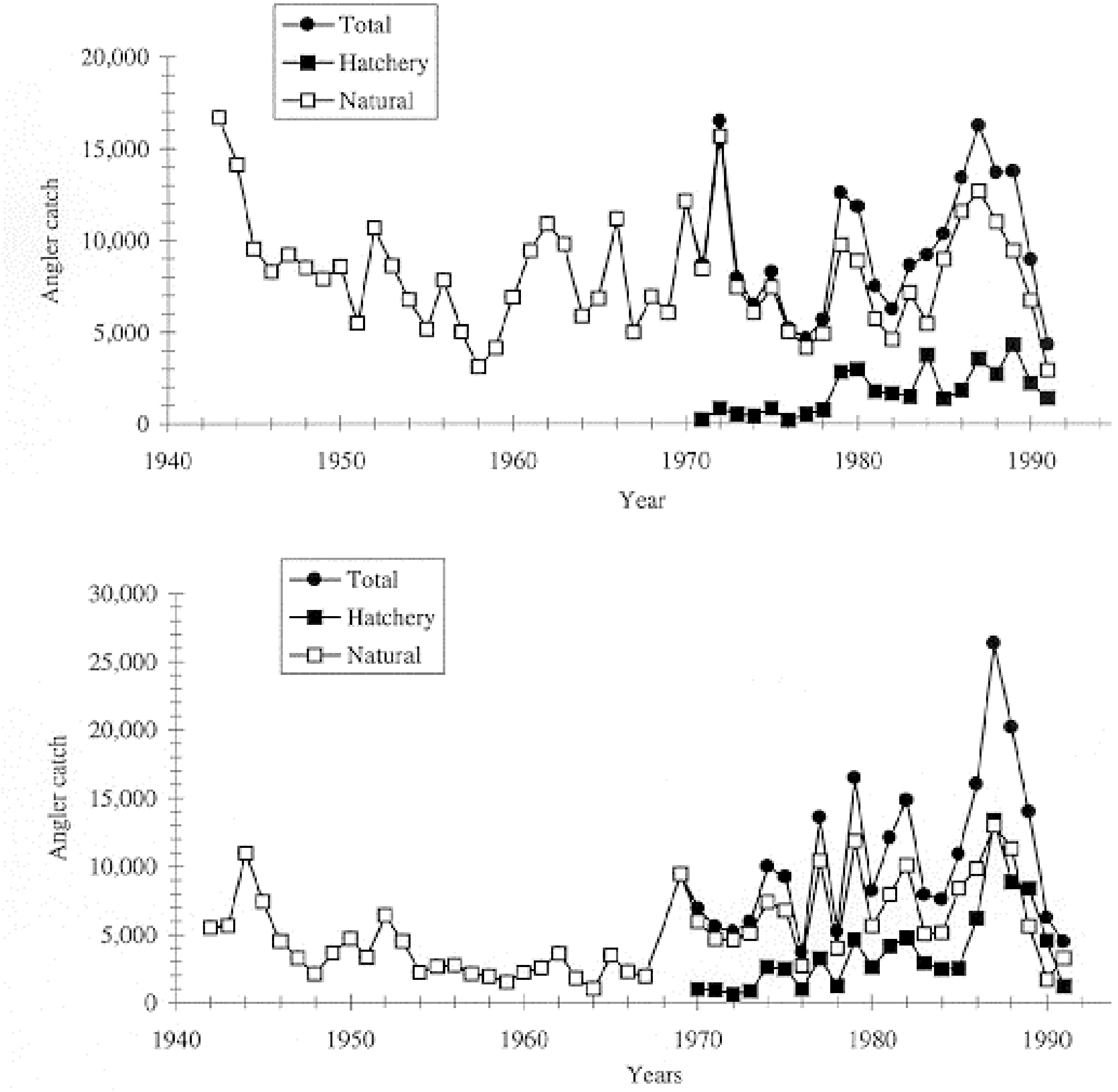

Figure B-6. Counts of adult winter (upper panel) and summer (lower panel) steelhead passing Gold Ray Dam on the Rogue River. Based on data from ODFW (1990, 1994).

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Appendix Figures 7-12

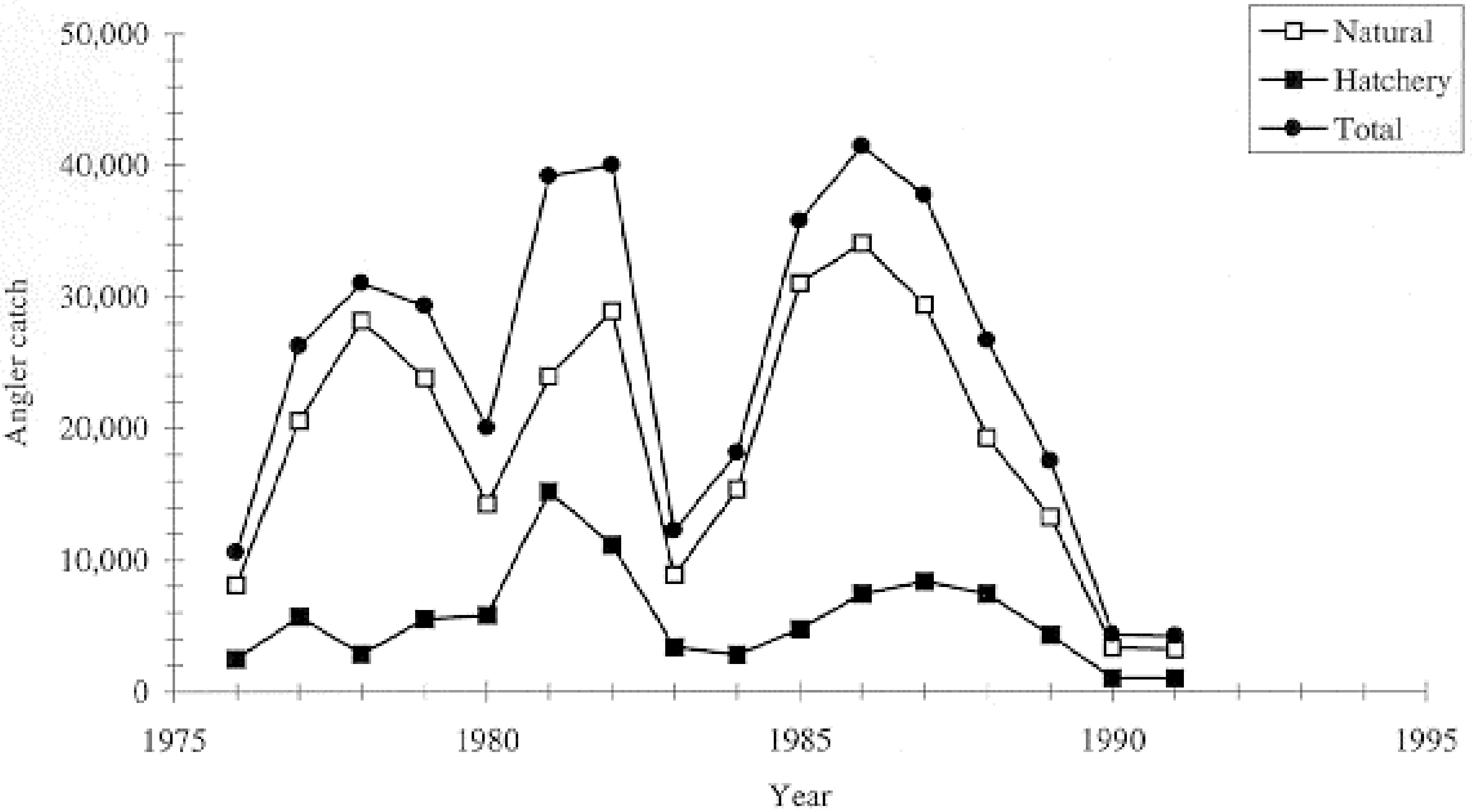

Figure B-7. Estimated summer steelhead run size at Huntley Park on the lower Rogue River. Based on data from ODFW (1994).

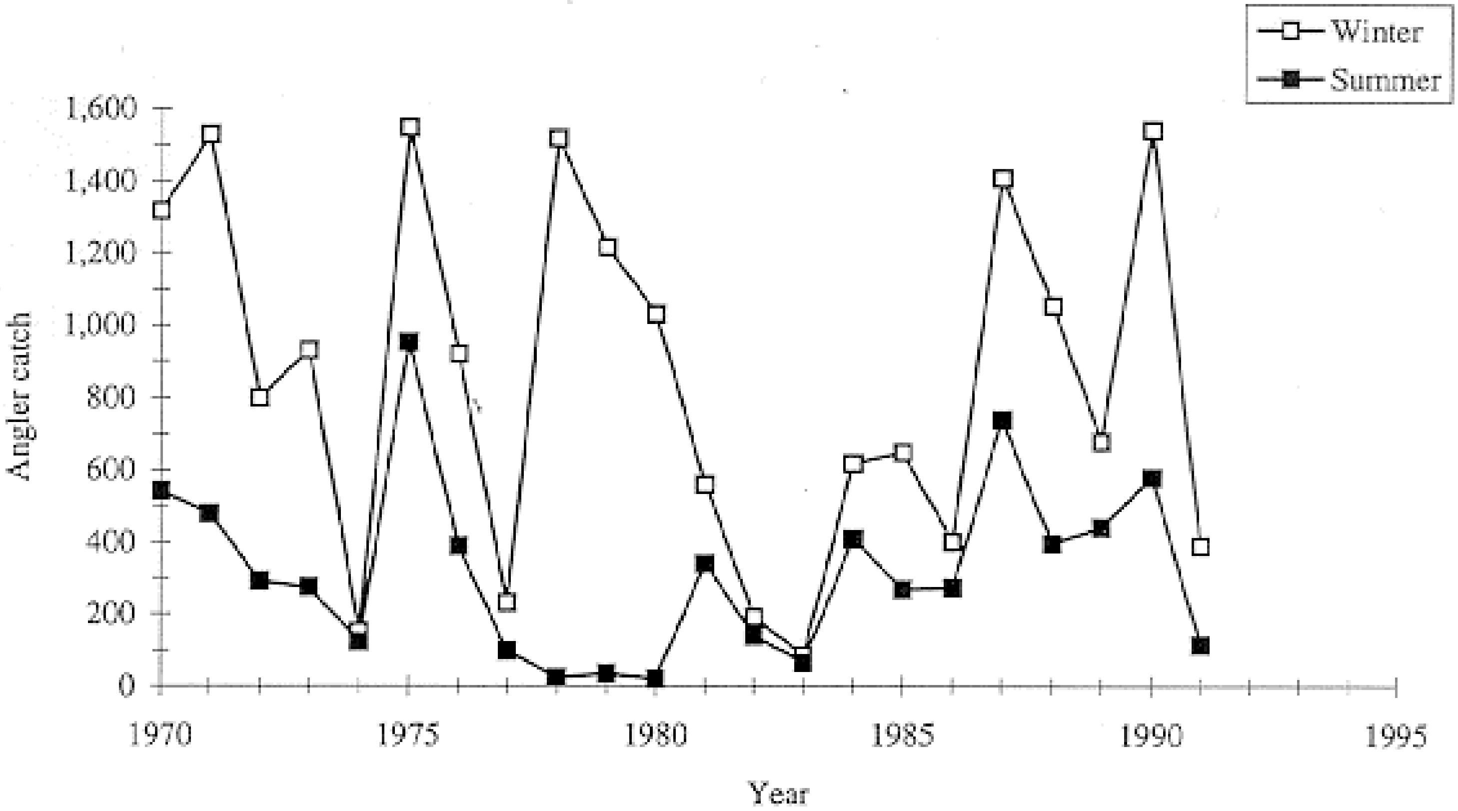

Figure B-8. Estimated angler catch for Applegate River winter and summer steelhead. Based on data from ODFW (1980, 1992c, 1993b).

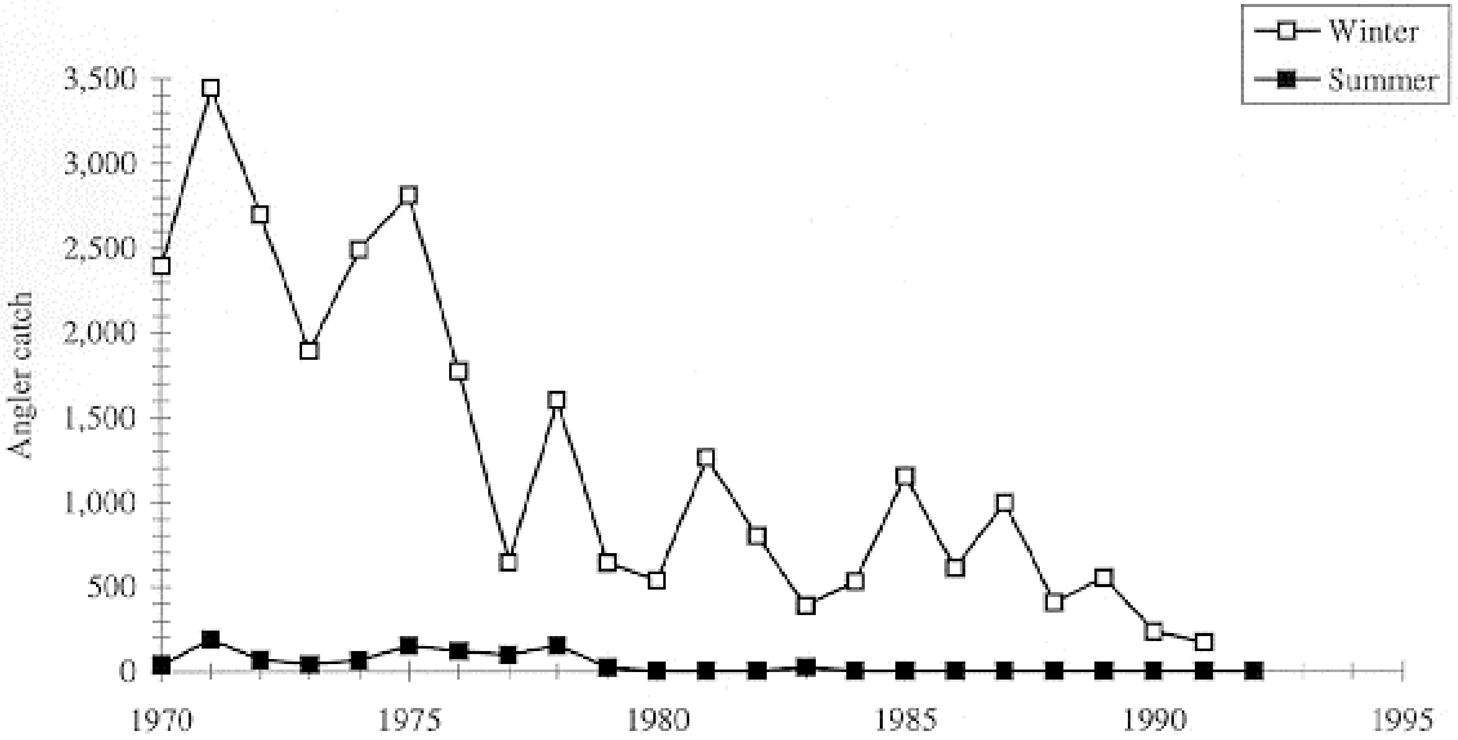

Figure B-9. Estimated angler catch for Illinois River winter and summer steelhead. Based on data from ODFW (1980, 1992c, 1993b).

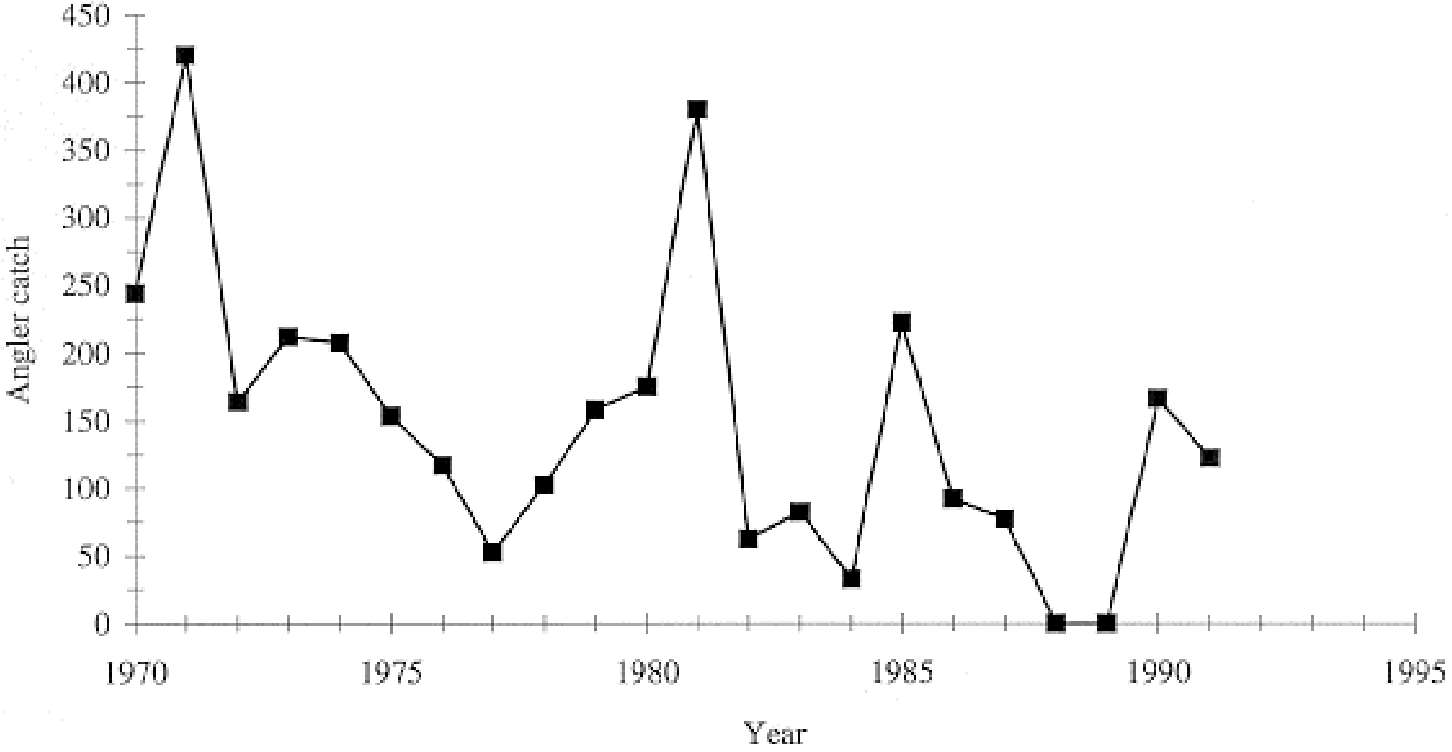

Figure B-10. Estimated angler catch for Hunter Creek winter steelhead. Based on data from ODFW (1980, 1992c, 1993b).

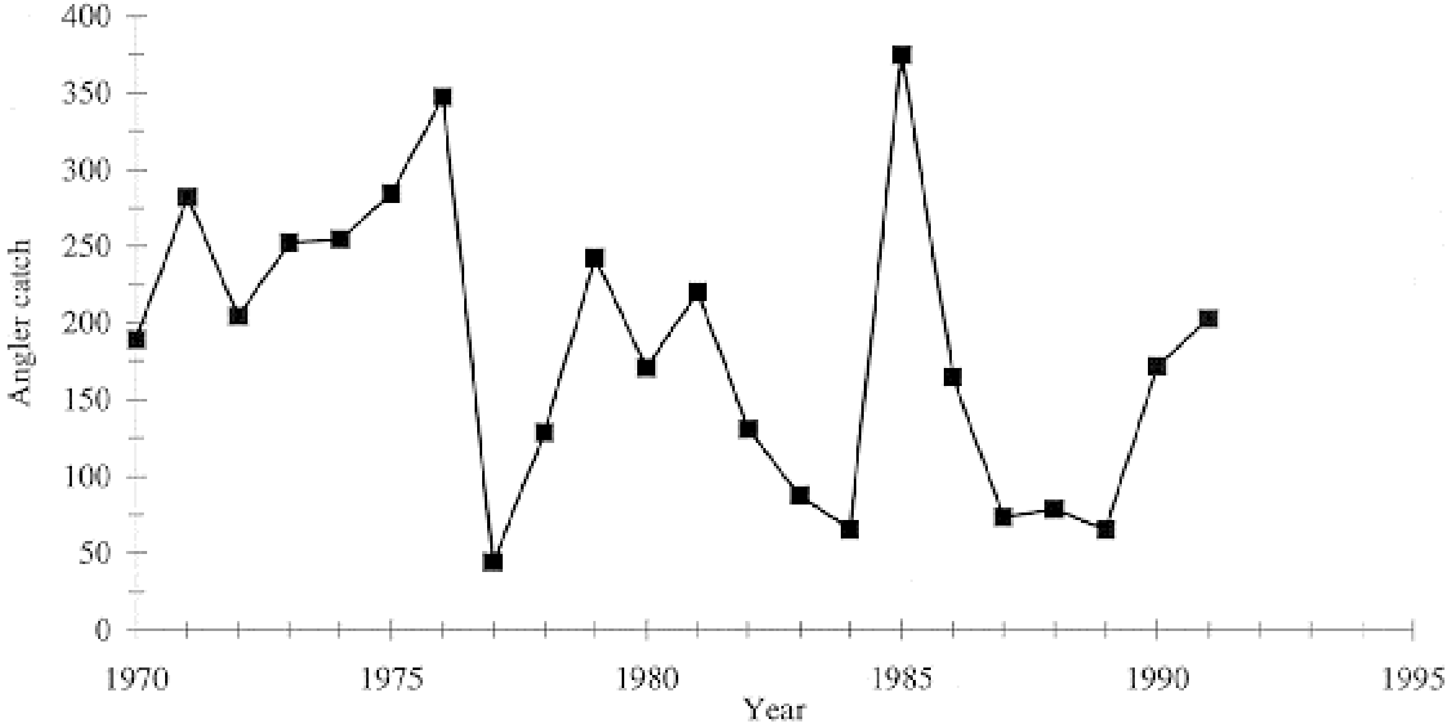

Figure B-11. Estimated angler catch for Pistol River winter steelhead. Based on data from ODFW (1980, 1992c, 1993b).

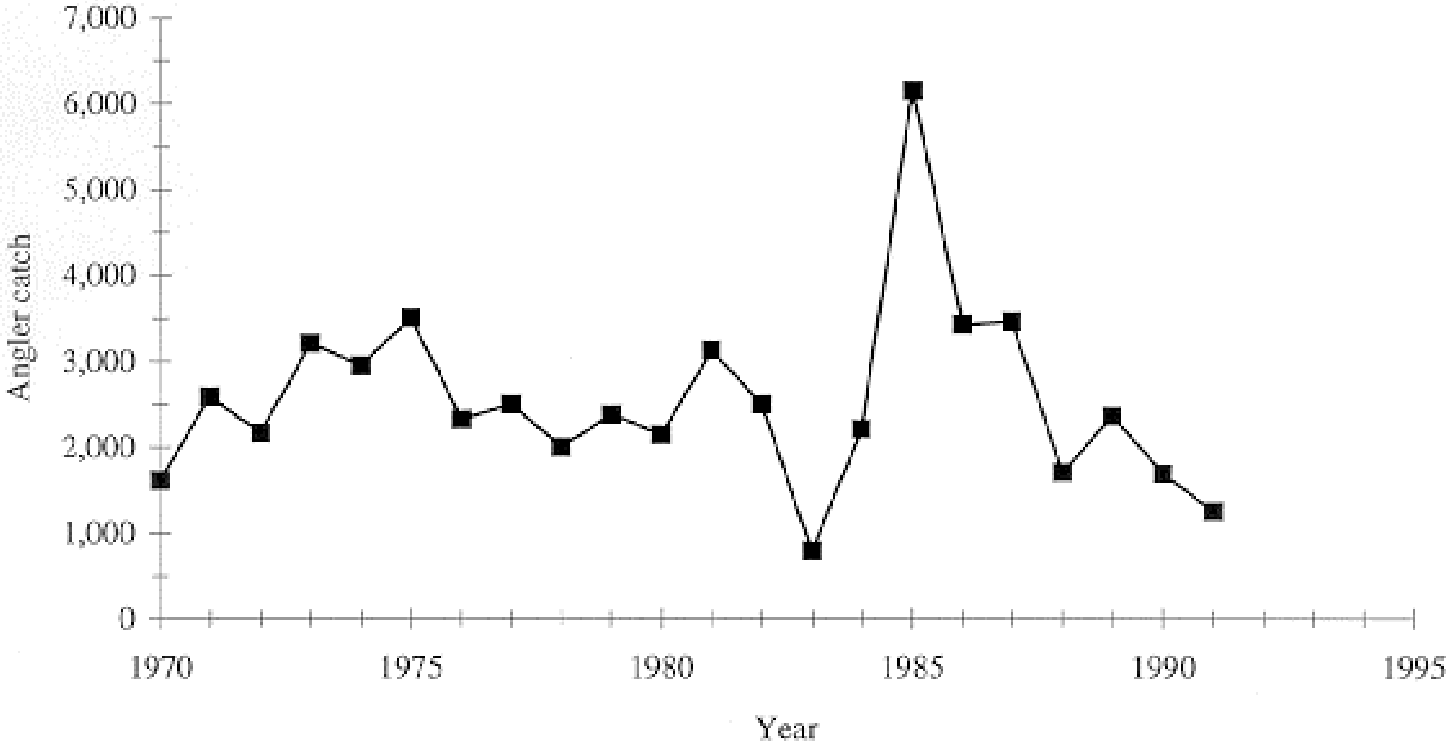

Figure B-12. Estimated angler catch for Chetco River winter steelhead. Based on data from ODFW (1980, 1992c, 1993b).

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Appendix Figures 13-19

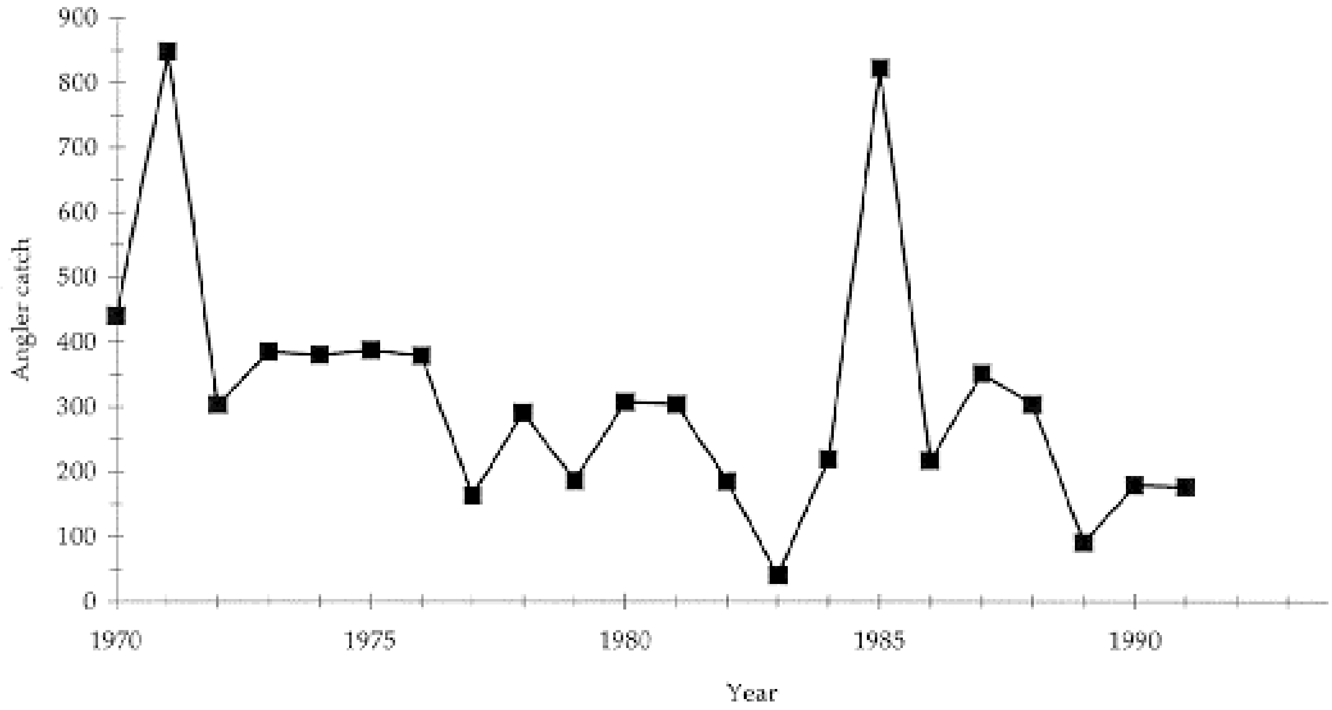


Figure B-13. Estimated angler catch for Winchuck River winter steelhead. Based on data from ODFW (1980, 1992c, 1993b).

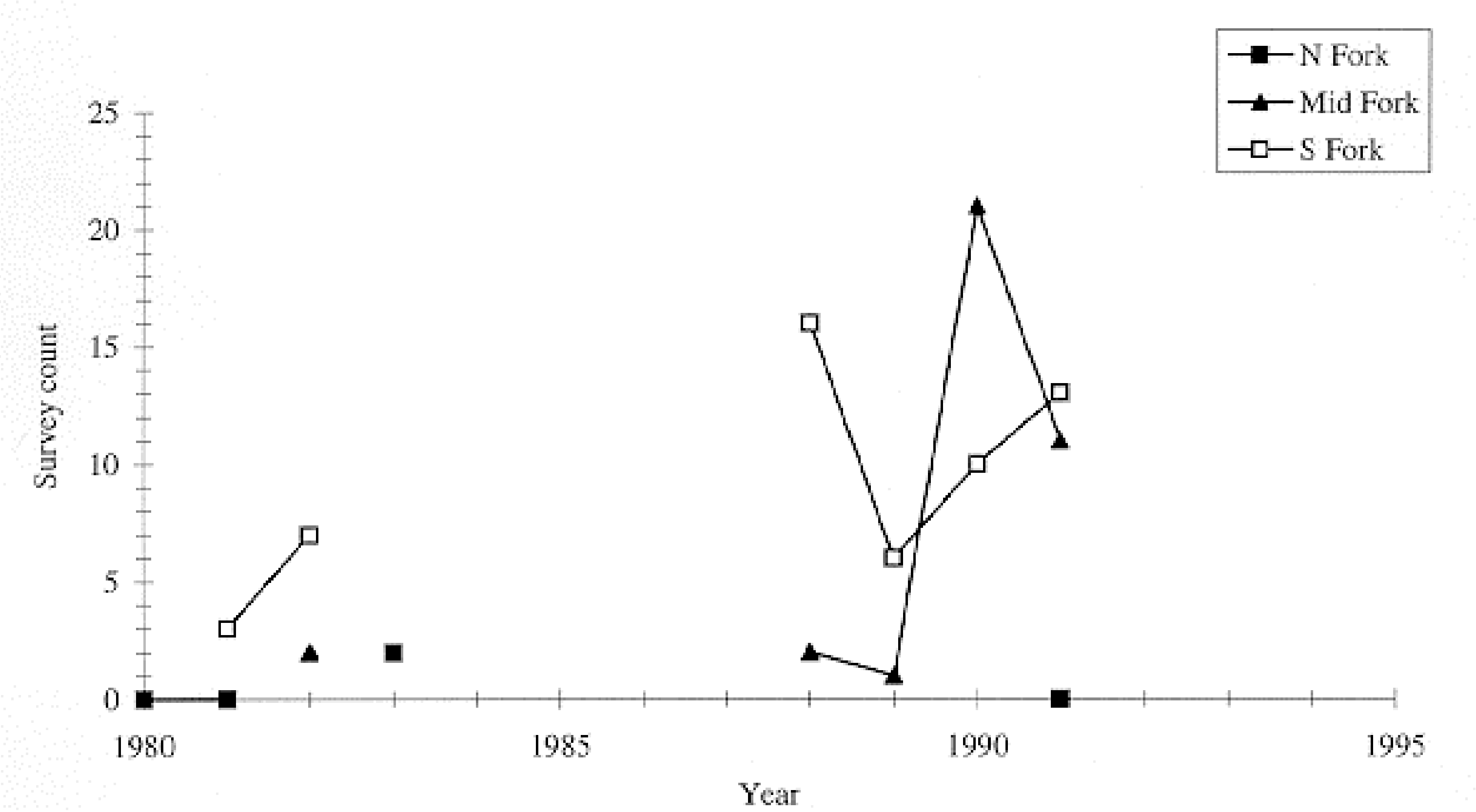
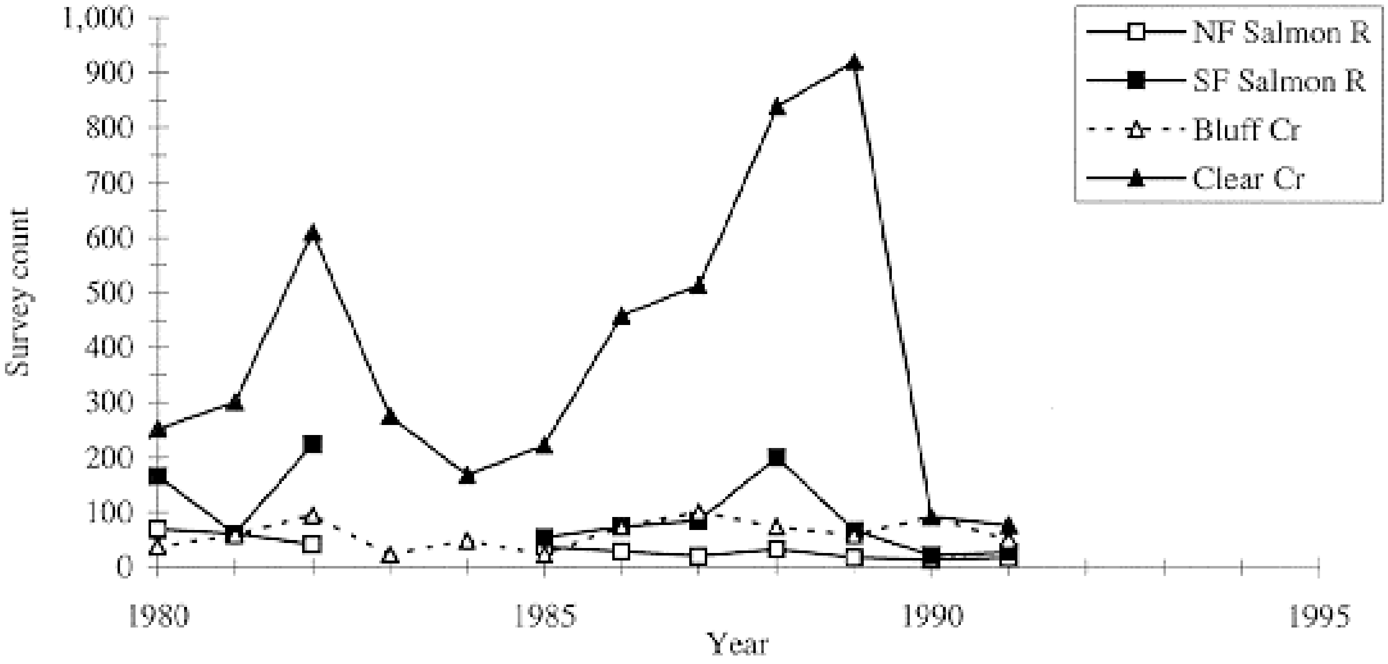


Figure B-14. Summer steelhead survey counts for three tributaries of the Smith River, California. Based on data from Roelofs (1983), McEwan (1992), and Pisano (1992).



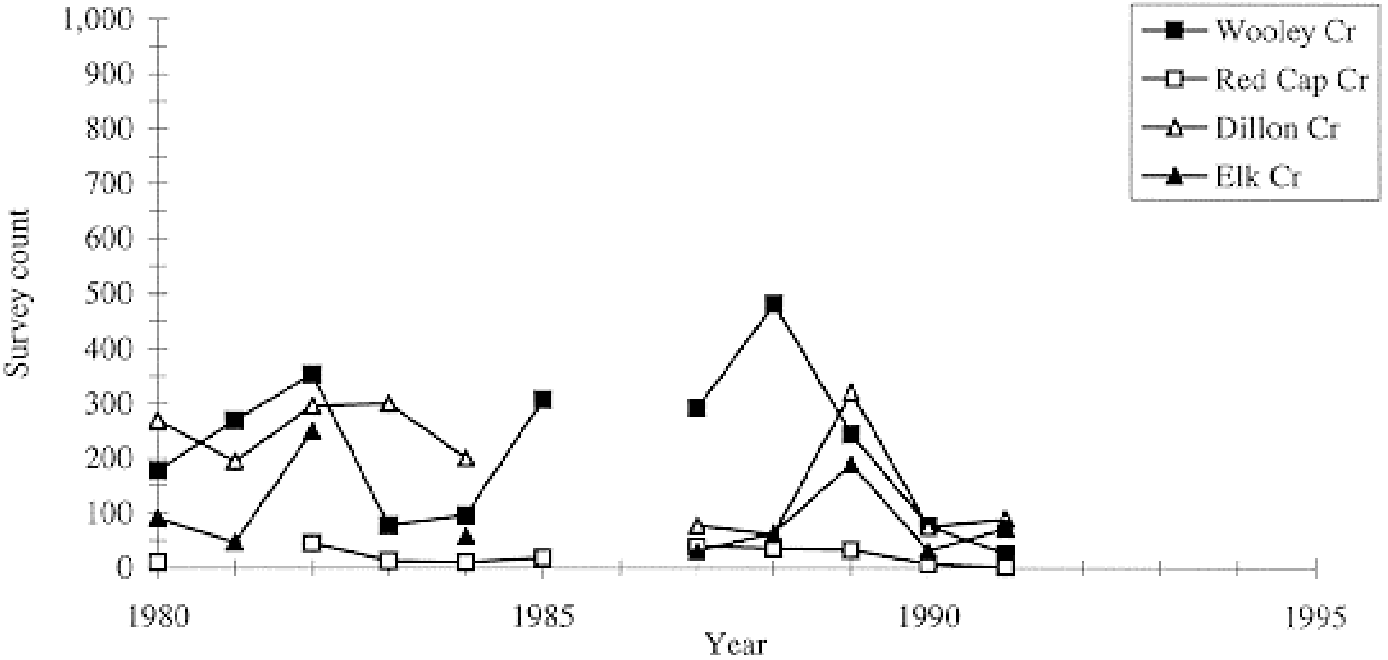


Figure B-15. Summer steelhead survey counts for eight tributaries of the Klamath River. Based on data from Roelofs (1983), McEwan (1992), and Pisano (1992).

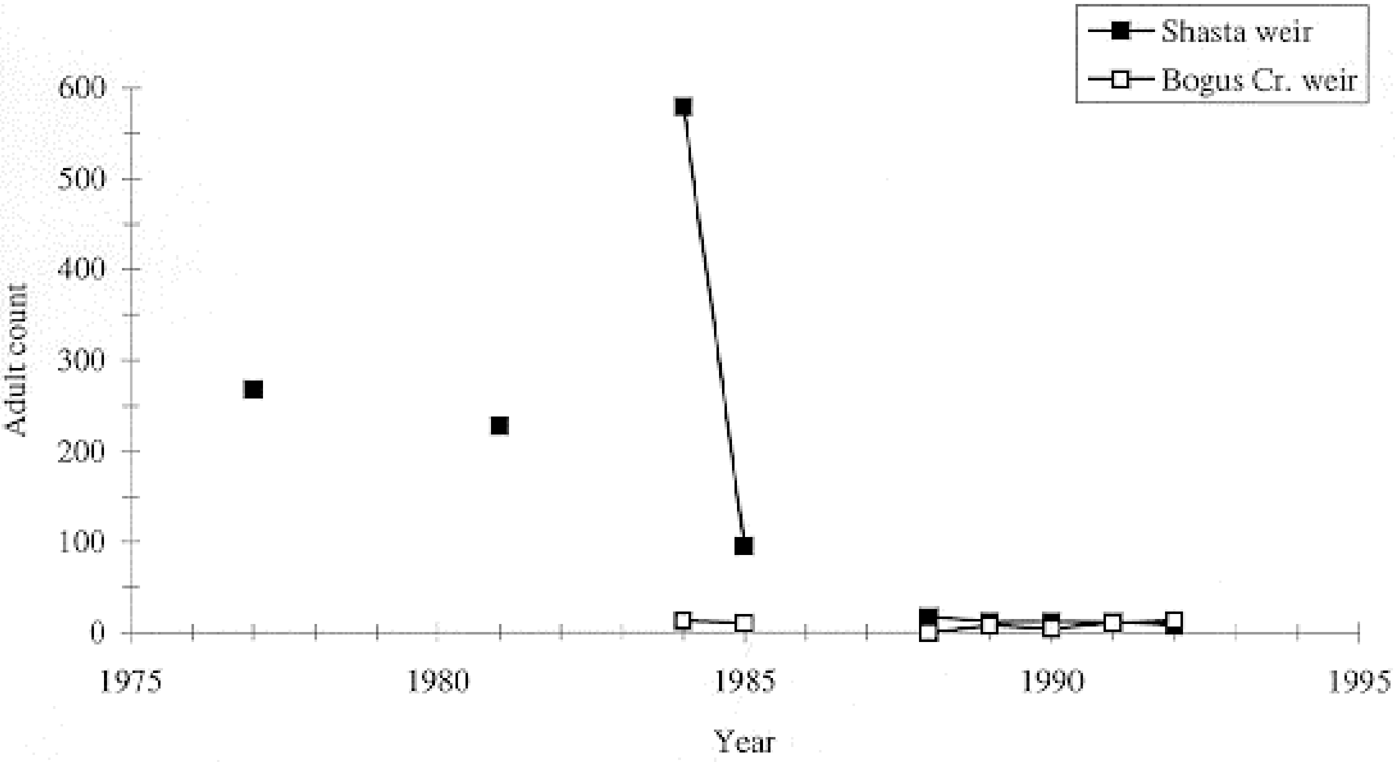


Figure B-16. Counts of adult fall steelhead at two weirs on Klamath River tributaries. Based on data from Pisano (1992).

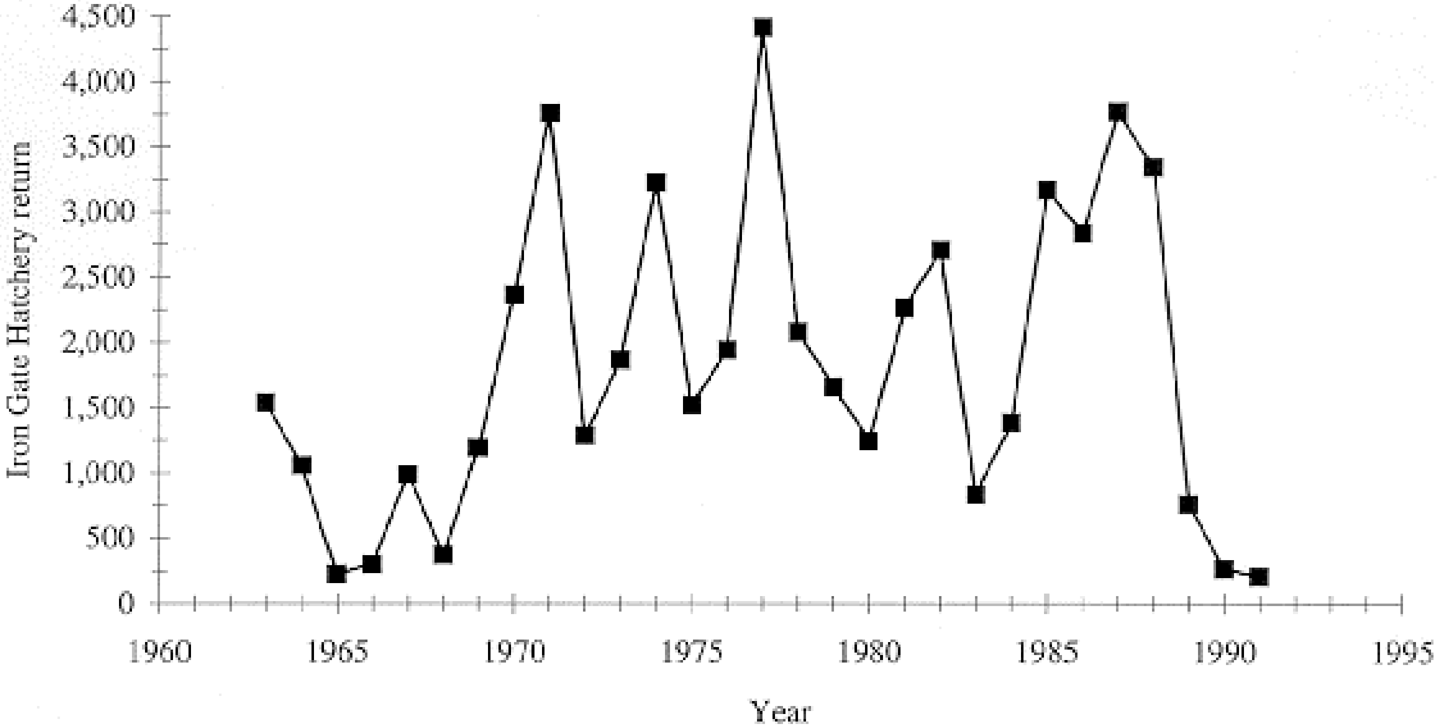


Figure B-17. Returns of adult steelhead to Iron Gate Hatchery on the Klamath River. Based on data from Pisano (1992).

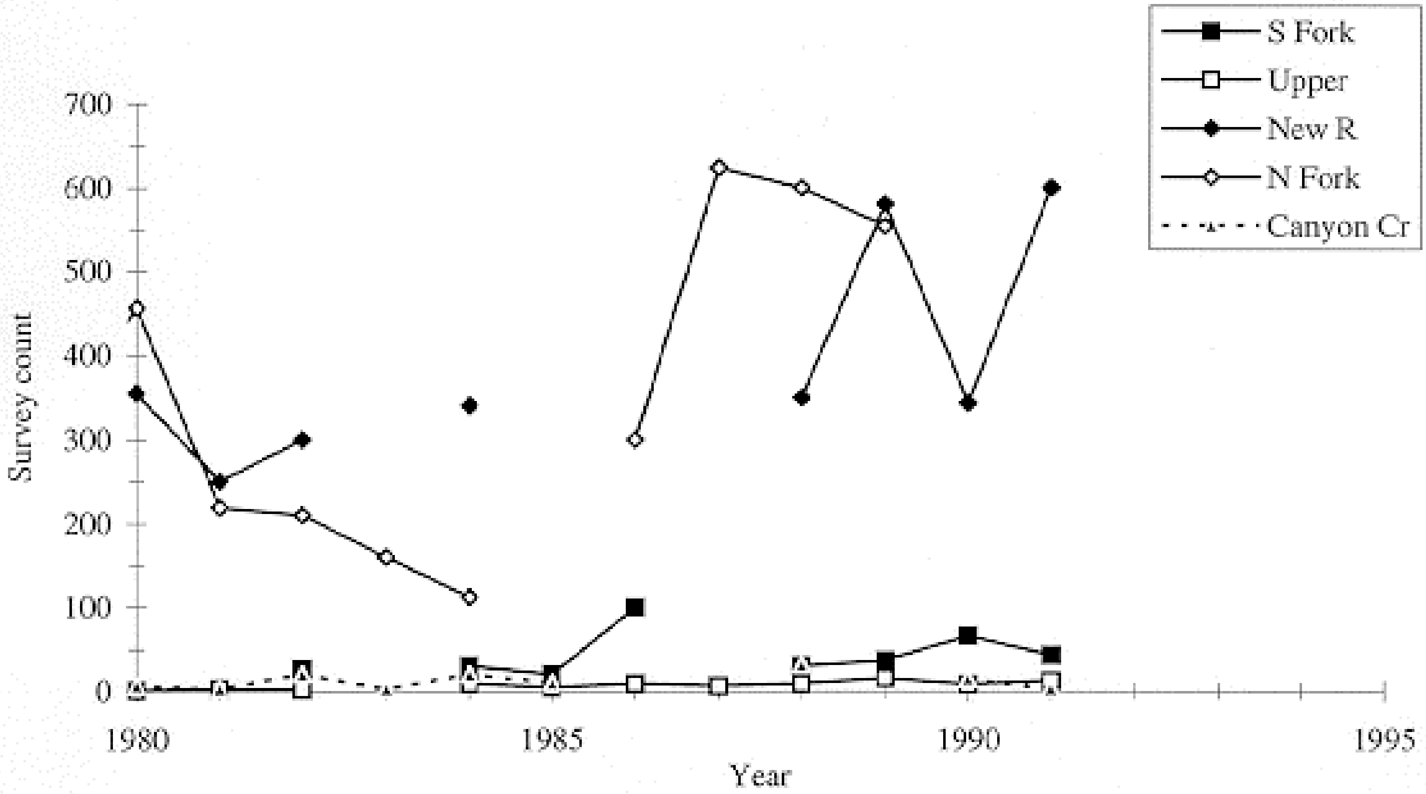


Figure B-18. Summer steelhead survey counts for five tributaries of the Trinity River. Based on data from Roelofs (1983), McEwan (1992), and Pisano (1992).

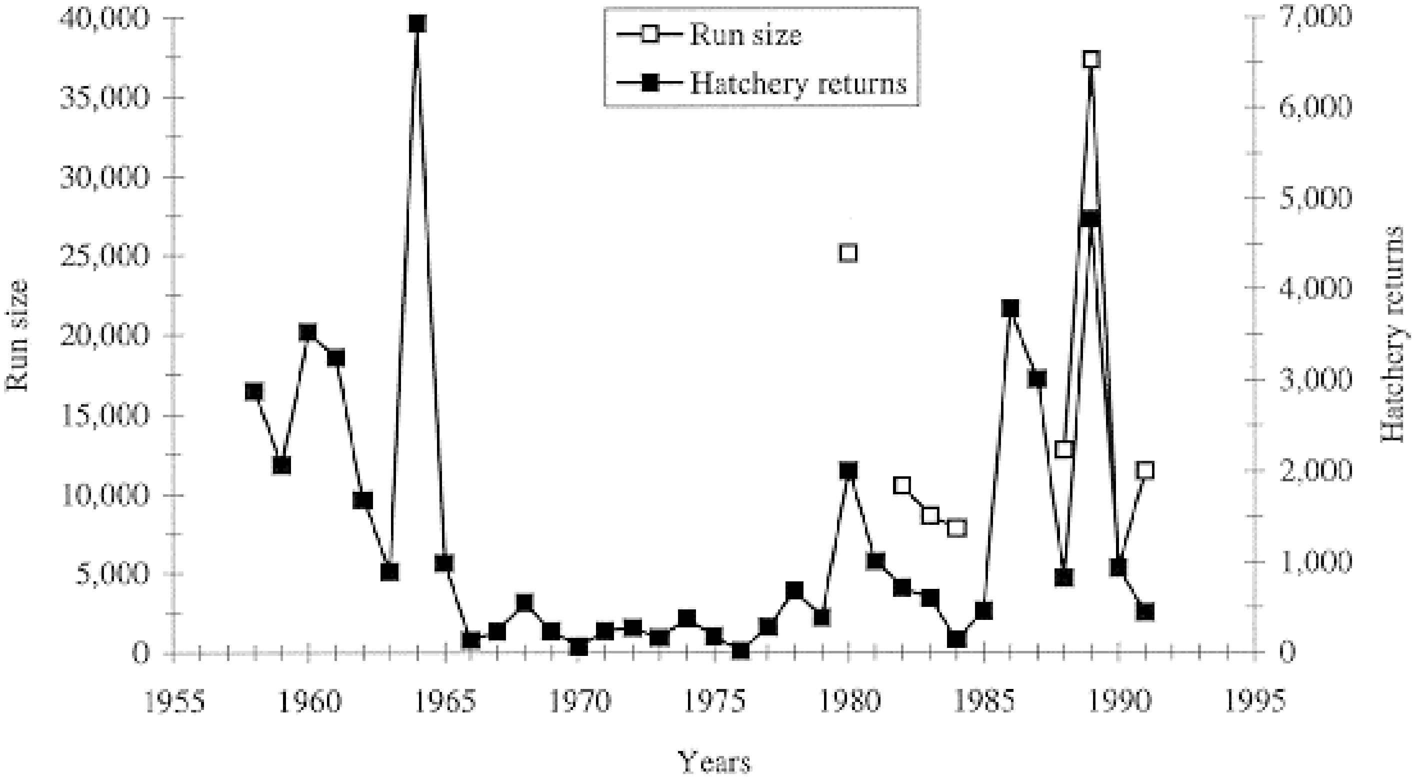


Figure B-19. Fall steelhead run size estimates above Willow Creek on the Trinity River and returns of adult steelhead to Trinity River Hatchery. Based on data from Heubach (1992) and Pisano (1992).

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