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Status Review for Oregon's Illinois River Winter Steelhead

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CONTENTS

SUMMARY

This report summarizes biological information gathered in conjunction with an Endangered Species Act (ESA) status review for winter steelhead (*Oncorhynchus mykiss*) from the Illinois River, a tributary of the Rogue River in southern Oregon. The National Marine Fisheries Service (NMFS) received a petition in May 1992 asking that this population be listed as a threatened or endangered species under the ESA. In evaluating the petition, two key questions had to be addressed: Do Illinois River winter steelhead represent a species as defined by the ESA? and, if so, is the species threatened or endangered? With respect to the first question, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. NMFS policy 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.

The petitioners argued that geographic isolation of the Illinois River spawning grounds, the partial barrier of Illinois River Falls, life history differences between steelhead from the Illinois and Rogue Rivers, and evidence for genetic differences between steelhead from southern and northern Oregon demonstrate reproductive isolation of Illinois River winter steelhead. Distinctive life history and habitat characteristics were the primary factors identified by the petitioners as evidence that Illinois River winter steelhead contribute

substantially to the species' ecological/genetic diversity. A tenfold decline in angler catch of Illinois River winter steelhead since 1971 was cited as evidence that the population qualifies for listing under the ESA.

In evaluating the status of Illinois River winter steelhead, NMFS focused on information for coastal steelhead populations from southern Oregon and northern California. The National Marine Fisheries Service concluded that available information does not make a strong case for reproductive isolation of Illinois River winter steelhead. Genetic data, including new data gathered for this status review, fail to show that Illinois River winter steelhead as a group are distinct from other coastal steelhead populations. Although this does not prove that Illinois River winter steelhead are not reproductively isolated, it does mean that evidence to support reproductive isolation must be found elsewhere. Other lines of information are largely inconclusive in this regard. Straying data for naturally spawning steelhead in the region are largely nonexistent. Geographic features such as the Illinois River Falls are potential isolating mechanisms, but evidence that they operate in this way is lacking. Although other explanations are possible, life history characteristics suggest some degree of reproductive isolation from Rogue River steelhead. However, these same characteristics fail to show differences between Illinois River winter steelhead and most other coastal steelhead populations.

With respect to the second criterion for defining an ESU, several phenotypic and life history characteristics show modest differences between Illinois River winter steelhead and steelhead from the Rogue River. These differences suggest that either a) there are some genetic differences between steelhead from the two rivers, b) the natural environments of the two rivers differ in at least some respects, or c) artificial propagation has affected life history characteristics of Rogue River steelhead, thus causing them to differ from Illinois River winter steelhead. In any case, in the larger context of coastal steelhead from southern Oregon and northern California, it is the Rogue River fish, rather than the Illinois River winter steelhead, that appear to be somewhat anomalous. That is, steelhead from the Illinois River appear to be somewhat distinctive in comparison to Rogue River steelhead, but not in comparison to other coastal steelhead populations.

We therefore conclude that although Illinois River winter steelhead may be locally distinctive within the Rogue River basin, they do not by themselves represent an evolutionarily significant unit of the biological species *Oncorhynchus mykiss*.

Because Illinois River winter steelhead are therefore not a "species" as defined by the ESA, the question of whether they should be listed as threatened or endangered under the Act need not be addressed. Nevertheless, steelhead from the Illinois River are undoubtedly part of a larger ESU whose boundaries remain to be determined. Whether the larger ESU that contains Illinois River winter steelhead would merit protection under the ESA cannot be determined until the nature and extent of the ESU are identified and additional information about patterns of abundance in coastal steelhead is compiled. This status review, therefore, should be viewed as the first step in a process to define the larger ESU and determine whether it qualifies for protection under the ESA.

ACKNOWLEDGMENTS

The status review for the Illinois River winter steelhead was conducted by a team of scientists from the Northwest Fisheries Science Center (NWFSC). The biological review team relied on an extensive ESA public record developed pursuant to this review and comprised of public comments and research reports submitted by dedicated citizens and by state and federal agencies. Special acknowledgment should be extended to the Oregon Department of Fish and Wildlife (ODFW) and the U.S. Forest Service, who bore the burden of supplying the review team with a large number of publications required for this review.

The review team would also like to acknowledge the assistance of personnel from ODFW's Rogue River and Gold Beach District Offices, California Department of Fish and Game (CDFG) Region 1, Redwood National Park, and Six Rivers and Rogue River National Forests in the collections of steelhead for genetic analysis. Norman Buroker generously shared with us his unpublished data on steelhead mitochondrial DNA. We also would like to acknowledge personnel from the Genetics Project at the NWFSC for assistance with field collection and electrophoresis of collected samples: Paul Aebersold, Mary Ann Brainard, Jeffrey Hard, Kathleen Neely, Cynthia Shiflett, Frederick "Bud" Welch, and Stephanie Woods. Garth Griffin of the NMFS Northwest Region in Portland provided invaluable assistance in facilitating information exchange. Paul Moran and Linda Park assisted with reviewing DNA data.

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INTRODUCTION

The name steelhead refers to the anadromous form of *Oncorhynchus mykiss*. Endemic distribution of steelhead extends from the Kamchatka Peninsula in Asia, east to Alaska, and south along the Pacific coast of North America to northern Baja California (Barnhart 1986, Burgner et al. 1992).

Steelhead are commonly described as either summer-run (summer steelhead) or winter-run (winter steelhead), based on 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, a tributary to the Rogue River (Fig. 1), is generally considered to have only winter-run steelhead.

Illinois River winter steelhead were identified as being "at moderate risk of extinction" in a report on Pacific salmon stocks at risk (Nehlsen et al. 1991). Declining catch of winter steelhead from the Illinois River and public comment resulted in the imposition of no-take fishing regulations for Illinois River steelhead by the Oregon Department of Fish and Wildlife (ODFW) in 1992 (M. Jennings[1]). In response to indications that the population is declining, Oregon Natural Resources Council, Siskiyou Regional Education Project, Federation of Fly Fishers, Kalmiopsis Audubon Society, Siskiyou Audubon Society, Klamath/Siskiyou

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[1] 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.

Figure 1.--Location map of Illinois River, Oregon. See Figure 2 for detail.

Coalition, Headwaters, The Wilderness Society, North Coast Environmental Center, Oregon Chapter of The Sierra Club, and The National Wildlife Federation petitioned the National Marine Fisheries Service (NMFS) to list the Illinois River winter steelhead as a threatened or endangered "species" (ONRC et al. 1992) under the U.S. Endangered Species Act (ESA or Act) of 1973 as amended (U.S.C. 1531 et seq.). This report summarizes a review of the status of Illinois River winter steelhead conducted by the NMFS Northwest Region biological review team.

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 Act provides no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity has led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the Act to anadromous salmonid species, including steelhead (NMFS 1991). A more detailed description of this topic appears 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 Act if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that (a) is reproductively isolated from conspecific populations and (b) represents an important component in the evolutionary legacy of the species. Types of information that can be useful in determining the degree of reproductive isolation include incidence of straying, rates of recolonization, degree of genetic differentiation, and the existence of barriers to migration. Insight into evolutionary significance can be provided by data on phenotypic and protein or DNA characters; life-history characteristics; habitat differences; and the effects of stock transfers or supplementation efforts.

Thresholds for Threatened or Endangered Status

Neither NMFS nor the U.S. Fish and Wildlife Service (USFWS), which share authority for administering the ESA, has an official policy regarding thresholds for considering ESA "species" as threatened or endangered. The National Marine Fisheries Service has published a nonpolicy document on this topic (Thompson 1991). There is considerable interest in incorporating the concepts of Population Viability Analysis (PVA) into ESA threshold considerations for Pacific salmon. However, most of the PVA models require substantial life-history information that often will not be available for Pacific salmon populations.

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 current carrying capacity of the habitat; 3) trends in abundance, based on indices such as dam or redd counts or on estimates of spawner-recruit ratios; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., from strays or outplants from hatchery programs); and 6) recent events (e.g., a drought or improvements in mainstem passage) that have predictable short-term consequences for abundance of the ESU.

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 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 Act 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 an ESU.

Once the natural component of a population has been identified, the next step is to determine whether this population component is "distinct" for purposes of the ESA. In making this determination, we used guidelines in the NMFS "Definition of Species" paper (Waples 1991). We considered factors outlined in the section entitled "Effects of artificial propagation and other human activities" to determine the extent to which artificial propagation may have affected the natural fish, through either direct supplementation or straying of hatchery fish. Thus, fish meeting the definition of "natural" adopted here could be excluded from ESA considerations.

Threshold determinations also will focus on natural fish, on the premise that an ESU is not healthy unless a viable population exists in the natural habitat.

PETITION TO LIST ILLINOIS RIVER WINTER STEELHEAD

This section summarizes claims made by the petitioners (ONRC et al. 1992) to support the designation of the Illinois River winter steelhead as an ESU. Organization of this section, and references to the criteria of Reproductive Isolation and Evolutionary Significance, follows that of the petition. After discussing information relevant to each of these issues in the next section of this status review, we evaluate the merits of the petitioners' arguments in the Discussion and Conclusions section.

Reproductive Isolation

Geographic Isolation

North-south genetic differences--The petition cited Hatch (1990), who conducted electrophoretic analyses on steelhead from several Oregon streams and found evidence for a genetic difference between steelhead populations from northern vs. southern Oregon coastal drainages. The petitioners argued that these genetic differences presumably reflect reproductive isolation. Hatch identified Cape Blanco as a genetic break point and suggested that "there is a less than average amount of straying between the populations north and south of this feature" (Hatch 1990, p. 33-34). The petitioners pointed out that the mouth of the Rogue River is 43 km south of Cape Blanco.

Distance to Illinois River spawning grounds--The petitioners stated that steelhead migrate up to 121 km up the Illinois River to spawn, which isolates them from other Rogue River basin steelhead stocks.

Illinois River Falls--The petitioners proposed that navigating the natural falls at River Kilometer (RKm) 64 may have been a selective factor in the evolution of the Illinois River winter steelhead. They stated that prior to modification and ladder construction, stray steelhead "would not arrive at the proper time nor have the persistence to get over the barrier" (ONRC et al. 1992, p. 4).

Distinctive Life History and Body Size Characteristics

Absence of half-pounders[2]--The petitioners described half-pounders as "a common life history type found in winter and summer steelhead that spawn in tributaries to the middle and upper Rogue River" (ONRC et al. 1992, p. 4). They contended that the absence of half-pounders in the Illinois River supports the theory of genetic isolation of Illinois River winter steelhead.

Timing of peak spawning--The petitioners referenced Rivers (1964), who indicated that peak spawning for Illinois River winter steelhead occurs 1 April, which he said was 2 weeks earlier than the peak for the middle Rogue River and 2 weeks later than the peak for the Applegate River. The petitioners cited timing of spawning as a heritable trait (Ricker

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

1972) and the importance of "run timing, emergence, and rearing patterns to streams that go dry or become uninhabitable by mid-summer" (ONRC et al. 1992, p. 4).

Smolt age--Rivers (1964) was cited for describing the Illinois River winter steelhead as having the longest freshwater phase of Rogue River basin steelhead stocks.

Age and body size at first spawning--The petitioners cited Rivers (1964), who concluded that "at the time of first spawning, winter steelhead in the Illinois River were older and were heavier at a given length than counterparts captured in the middle Rogue and in the Applegate River" (ODFW 1990, p. 34). The petition stated that "the larger body size of Illinois River adult steelhead may help them jump the Illinois River Falls" (ONRC et al. 1992, p. 5).

Effects of Hatchery Fish

The petitioners referred to ODFW records to document a low incidence of straying of hatchery steelhead into the Illinois River. The petition (ONRC et al. 1992, p. 5) stated that

> Scale samples from 52 Illinois River steelhead caught during 1984-85 were all interpreted as wild fish by ODFW....The Illinois River winter steelhead is the only winter steelhead population known to be in compliance with the Wild Fish Policy because of low straying rates of hatchery fish into the Illinois River.

Evolutionary Significance

Geographic Location

The petitioners described the Illinois River as "an interior valley in the southern fourth of the steelhead species' range" (ONRC et al. 1992, p. 5). They reiterated Hatch's (1990) findings of "phenotypic differences supporting a separation of steelhead south of Cape Blanco, Oregon" (ONRC et al. 1992, p. 5).

Thermal Adaptation

The petitioners calculated population size for Illinois River winter steelhead from 1966 to 1990 using ODFW catch data. They contended that the population "historically demonstrated a high level of productivity in an environment that appears extremely hostile to a cold water fish" (ONRC et al. 1992, p. 5). They cited ODFW (1990, p. 34) who reported that "adaptations to survive warm water in the Illinois River basin may be quite different than adaptations to survive in small tributaries of the Rogue River close to the coast."

Spawning Distribution

"Widely distributed spawning populations located throughout the Illinois Basin ensure genetic continuity and continued high productivity during natural environmental catastrophes" (ONRC et al. 1992, p. 5).

Anadromous Life History

"The anadromous life history is crucial to the steelhead's high degree of life history diversity. Anadromy allows Illinois River winter steelhead to colonize streams where local extinctions have occurred and also confers a competitive advantage through large body size and increased fecundity" (ONRC et al. 1992, p. 5-6).

Population Trends

The petitioners cited a tenfold decline in angler catch of Illinois River winter steelhead since 1971. They recognized that trends in catch may be affected by trends in angler effort but believed that such a dramatic decline in effort was unlikely. They also estimated that Illinois River winter steelhead survival has been below replacement level in 13 of 16 years (1971-86), with no prospect for improvement in the near future. The petitioners interpreted this consistent inability of the population to replace itself as evidence it is endangered according to the framework of a draft policy statement by NMFS and USFWS (1980).

SUMMARY OF BIOLOGICAL AND ENVIRONMENTAL INFORMATION

In this section, we summarize biological and environmental information that is relevant to the petition. Although we make particular efforts to address issues raised by the petitioners, we do not confine the evaluation to those issues alone. Information presented in this section forms the basis for conclusions regarding the species and threshold questions, which are addressed in the following section.

Steelhead may have the most variable life history of any anadromous Pacific salmonid species (Shapovalov and Taft 1954, Barnhart 1986). The complexity of steelhead life histories "reflect[s] extreme adaptability to a wide variety of environmental conditions" (Burgner et al. 1992, p. 9). The present northern and southern limits of spawning by steelhead are the Copper River basin, Alaska (63°N) and Malibu Creek, California (34°N), respectively (Burgner et al. 1992). Rivers utilized by steelhead exhibit considerable diversity with respect to geology, hydrology, stream flow, temperature regime, stream gradient, and biotic community structure.

Environmental Features

Across their distribution, steelhead utilize river basins of all sizes. The Illinois River drains a watershed of approximately 2,565 square kilometers. Average discharge is 128 cubic meters per second, based on 1960-74 data (Forest Service 1977). The Illinois River enters the Rogue River at RKm 44 near the town of Agness, Oregon. Arising in northern California, the Illinois River flows northwest through the Siskiyou Mountains of the Klamath Mountain Geological Province.

Klamath Mountain Geological Province

The Klamath Province includes a complex of mountain ranges in southwest Oregon and northwest California (approximately 40-43°N). 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 (T. Atzet[3]). 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 (Forest Service 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).

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[3]T. Atzet, Zone Hydrologist, USDA Forest Service, Region Six, Siskiyou and Umpqua National Forests. Supervisor's Office, Siskiyou National Forest, 200 NE Greenfield Road, P.O. Box 440, Grants Pass, OR 97526-0242. Pers. commun., November 1992.

Although it is true that the Illinois River is nearly in the southern fourth of the steelhead species' range (ONRC et al. 1992, p. 5), there are many steelhead-bearing streams south of the Illinois River, including the Klamath and Sacramento River basins. The Illinois River is located in a geologically and botanically unusual area; however, this area (the Klamath Mountain region) includes a number of rivers besides the Illinois River.

Water temperature

Across their distribution, steelhead are exposed to a wide range of water temperatures. In experiments, steelhead demonstrate an upper preferred temperature limit of 13°C, but they can survive water temperatures up to 24°C (Bell 1986). Temperature data collected in the Illinois River basin between 1989 and 1992 (Forest Service 1992b) indicate mid-day summer stream temperatures ranging between 11.1°C and 22.8°C in several Illinois River tributaries which are thought to have steelhead (Table 1)--generally above the preferred limit, but most well within the lethal limit. Dambacher (1991) recorded summer stream temperatures in the Steamboat Creek basin of the North Umpqua River, approximately 140 km northeast of the Illinois River. In 1987 and 1988, he found tributary temperatures from 10°C to over 20°C, and temperatures exceeded 25°C in the mainstem. Further, Everest (1973) reported that, prior to the construction of Lost Creek Dam in the 1970s, Rogue River summer steelhead often sought temporary thermal refuge in the relatively cooler water of the lower Illinois River. Therefore, present temperature readings for the Illinois River may not be indicative of long-term patterns.

There are, without doubt, locations within the Illinois River basin where summer water temperatures exceed the preferred range for steelhead. However, it is evident that relatively cooler areas also exist, with temperatures similar to those in other steelhead-bearing river

Table 1.--Summer stream temperatures from Illinois River tributaries which are thought to be utilized by steelhead (Forest Service 1992b).

Location	Comments	Date	Time	Temperature (°C)
Baker Creek	At confluence	July 1992	1530	16.8
Briggs Creek	At confluence	July 1992	1200	21.1
	Lower reach, average	July-Sept 1989-90	--	17.2
	Middle reach, average	July-Sept 1989-90	--	14.4
	Upper reach, average	July-Sept 1989-90	--	14.4
Clear Creek (tributary to Deer Creek)	Reach 2, average	June-July 1990	--	13.3
Daily Creek	At confluence	July 1992	0900	15.6
Deer Creek	At confluence	Aug 1992	1030	22.8
Fall Creek	At confluence	July 1992	1030	18.1
Indigo Creek	Reach 3	Aug 1990	--	17.8
Little Silver Creek	Reach 4, average	Aug-Sept 1991	--	11.7
	Reach 5, average	Aug-Sept 1991	--	11.1
Panther Creek	At confluence	July 1992	1200	20.0
Salmon Creek	At confluence	July 1992	1100	19.4
Sixmile Creek	At confluence	July 1992	1030	19.4

basins located farther north, and that these areas have historically attracted steelhead from the Rogue River. It is possible that rather than (or in addition to) adapting to warm water, Illinois River steelhead seek out habitat that is within their temperature preference range.

Illinois River Falls

A notable feature of the Illinois River is a waterfall at RKm 64. Accounts differ as to whether steelhead succeeded in navigating the falls prior to any anthropogenic modification. However, a newspaper clipping[4] dated December 1895 stated that "salmon" were going over the falls "in great numbers in search of spawning grounds in the headwaters of the stream." It is possible that these "salmon" were actually steelhead.

Hydrology of the Rogue River basin, including the Illinois River, shows a strong increase in discharge in December-January, which could make the falls naturally passable by steelhead. The ability of steelhead to navigate a waterfall is greatly affected by streamflow levels. A waterfall that is a complete barrier at one flow level may be easily passable at a higher or lower flow. Therefore, migration timing and basin hydrology are important factors for determining whether a waterfall is a migration barrier to a population of steelhead. Withler (1966) described a waterfall on the Coquihalla River in British Columbia that is a barrier to winter steelhead but not summer steelhead, and many steelhead bearing streams besides the Illinois River have waterfalls that may be seasonal barriers to anadromous fish passage.

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[4]Copy of a newspaper clipping of unknown origin, dated 21 December 1895, from a file labeled "Fish" at the Josephine County Historical Society, 508 SW-5th Street, Grants Pass, OR 97526 (503-479-7827), and submitted to the ESA Administrative Record for Illinois River Winter Steelhead on 14 September 1992.

The history of modification of the Illinois River Falls for fish passage is unclear. The earliest account is of miners' attempts to blast 3 feet of material from the top of the falls in 1910 (Palmisano 1992). A resident of the area stated that the falls were first modified by the State of Oregon in 1912 (Forest Service 1992a). Three to 4 feet of material were reportedly blasted from the top of the falls. The next account is of a fishway blasted on the south side of the falls in 1930 (Palmisano 1992). Rivers (1963) stated that a Forest Service biologist recommended and oversaw the blasting of 50 tons of rock from the falls in October 1935. Finally, a fish ladder was constructed in 1956-57 (Palmisano 1992).

Because of this uncertainty about the history of fish passage and alterations to the Illinois River Falls, we were unable to determine what effect, if any, the falls have had on reproductive isolation of Illinois River winter steelhead.

Life History

Steelhead exhibit variations in life history characteristics both across their distribution and within populations. Variable characteristics include age at smoltification, length of ocean residency, timing and duration of spawning migration, incidence of repeat spawning, and degree of residualization. Some of these variations have geographic trends. Fishery biologists group steelhead populations on the basis of life history, distribution, and genetic characteristics.

Steelhead may be grouped as coastal or inland populations (Behnke 1970). Allendorf (1975) reported genetic distinctions between steelhead populations of the Fraser and Columbia River basins (inland) and steelhead populations of basins west of the Cascade mountain range (coastal). Illinois River steelhead are included in the coastal group.

Steelhead utilize two main spawning migration strategies. Summer-run steelhead enter fresh water between May and October. Upon stream entry, their gonads are immature and secondary sex characteristics are lacking; summer steelhead spend up to 10 months in fresh water prior to spawning (Smith 1969). Winter-run steelhead migrate from November to April. They have well developed gonads at stream entry and spawn within 4 months of entering fresh water (Smith 1969). The Illinois River is generally considered to have only winter-run steelhead (but see below under **Summer- and winter-run steelhead**).

Freshwater Life History and Smoltification

Juvenile steelhead commonly spend 1 to 3 years in fresh water prior to smoltification and outmigration (Neave 1944, Behnke 1979), but up to 6 or more years in some cases (Peven 1990). Age at smoltification tends to increase among steelhead populations from south to north (Withler 1966, Burgner et al. 1992) (Table 2). Bali (1959) studied scales from 14 coastal Oregon winter steelhead populations. In each of these populations, over 70% of the steelhead smolted at age 2 or older. Scale data (ODFW 1992a) from 125 adult steelhead caught in the Illinois River from January 1982 to February 1990 indicate that 99% smolted at age 2 or older. This is not unusual in comparison with other coastal steelhead populations (Table 2); however, it is a somewhat higher age at smolting compared to Rogue River steelhead (ODFW 1990). We were unable to determine whether the relatively young age at smolting for Rogue River steelhead predated the effects of artificial propagation, which tends to accelerate smoltification.

Several studies have described the relationship of steelhead smolt size to ocean survival (e.g., Seelbach 1987, Ward and Slaney 1988). Burgner et al. (1992) stated that the average fork length for wild steelhead at smolting is about 160 mm for most populations.

Table 2.--Comparison of smolt age frequency for selected populations of winter steelhead. Populations are arranged from north to south.

Population	Sample size	Freshwater age 1	2	3	4	Reference
Chilliwack River, BC	771	0.02	0.62	0.35	0.01	Maher and Larkin 1955
Kalama River, WA	3,114	--	0.88	0.11	<0.01	Leider et al. 1986
Sand Creek, OR	170	--	0.74	0.26	--	Bali 1959
Alsea River, OR	978	0.01	0.80	0.18	<0.01	Chapman 1958
Coquille River, OR	81	--	0.54	0.45	0.01	Bali 1959
Rogue River, OR*	714	0.12	0.66	0.21	0.01	ODFW 1990
Illinois River, OR	125	0.01	0.59	0.38	0.02	ODFW 1992a
Chetco River, OR	90	0.01	0.39	0.55	0.05	Bali 1959

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

Bali (1959) backcalculated length at age for 620 winter steelhead from 14 coastal Oregon drainages; the smallest average smolt length was 162 mm for populations in the Wilson River and Sand Creek. No steelhead from the Rogue River basin were included in Bali's work. The only report of smolt size for Illinois River winter steelhead is from Rivers (1957), who stated that the average smolt was 147 mm. However, Rivers provided no data to support this statement, and it has been questioned by some ODFW biologists (T. Satterthwaite[5]), whose data indicate that average smolt size for Rogue Basin winter steelhead ranges from 199 to 275 mm, depending on life history pattern (ODFW 1990). However, there is evidence in the literature of other steelhead populations with average smolt size below 160 mm, similar to that reported by Rivers for Illinois River winter steelhead (Maher and Larkin 1955, Chapman 1958; see Table 3).

Thus, although data are incomplete, it appears that steelhead from the Illinois River may on average smolt at a size near the low end of the range found in other coastal steelhead populations. Average age at smolting of Illinois River winter steelhead appears to be higher than for Rogue River steelhead but comparable to other coastal steelhead populations.

Half-Pounders

The steelhead life history pattern called the "half-pounder" (Snyder 1925) is limited in North America to the Rogue, Klamath, Mad, and Eel River drainages of southern Oregon and northern California (Barnhart 1986). Half-pounders return from the ocean 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

[5]T. Satterthwaite, Supervising Fish and Wildlife Biologist, Oregon Department of Fish and Wildlife, 5375 Monument Drive, Grants Pass, OR 97526. Pers. commun., January 1993.

Table 3.--Comparison of mean smolt size for selected populations of winter steelhead. Populations are arranged from north to south.

Population	Mean smolt size (mm)	Reference
Keogh River, BC	173	Ward and Slaney 1988
Chilliwack River, BC	152-215	Maher and Larkin 1955
Necanicum River, OR	175	Bali 1959
Nehalem River, OR	165	Bali 1959
Wilson River, OR	162	Bali 1959
Trask River, OR	173	Bali 1959
Sand River, OR	162	Bali 1959
Nestucca River, OR	165	Bali 1959
Salmon River, OR	168	Bali 1959
Siletz River, OR	180	Bali 1959
Alsea River, OR	147-168	Chapman 1958
South Fork Coos River, OR	175	Bali 1959
Coquille River, OR	183	Bali 1959
Sixes River, OR	170	Bali 1959
Elk River, OR	200	Bali 1959
Illinois River, OR	147	Rivers 1957
Chetco River, OR	218	Bali 1959
Winchuck River, OR	200	Bali 1959

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. Most half-pounders found by Everest (1973) on Rogue River spawning grounds were 355-406 mm.

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 Klamath and Rogue half-pounder runs.

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 brood stock indicated a half-pounder frequency of approximately 30% (M. Evenson[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

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[6]M. Evenson, Hatchery Biologist, Oregon Department of Fish and Wildlife, Cole Rivers Hatchery, 200 Cole Rivers Drive, Trail, OR 97541. Pers. commun., January 1993.

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 brood stock at Cole Rivers Hatchery (on the Rogue River), scale patterns were used to select fish that lacked the half-pounder life history (M. Evenson[7]). 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 strongly influenced by environmental conditions.

Illinois River steelhead scale data from ODFW (1992a) 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.

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

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[7]M. Evenson, Hatchery Biologist, Oregon Department of Fish and Wildlife, Cole Rivers Hatchery, 200 Cole Rivers Drive, Trail, OR 97541. Pers. commun., January 1993.

the Rogue River that have half-pounders (i.e., the Klamath, Mad and Eel Rivers) have tributaries like the Illinois River that lack the trait.

Saltwater Life History

Steelhead generally remain in salt water for 1 to 4 years before their first spawning migration. Withler (1966) in North America and Maksimov (1976) in Russia reported that, in general, residency period in the ocean increases across the species distribution from south to north. We found that 86% of Rogue River winter steelhead and 83% of Illinois River winter steelhead spent 2 years in the ocean prior to their first spawning migration. Data for other coastal Oregon steelhead populations showed considerable variation in saltwater age at first spawning (Table 4). However, these data were obtained in four different studies covering a wide range of years, so at least some of the interpopulational differences shown in this table may be attributable to these factors.

Information on the behavior of steelhead during their saltwater phase is limited. Pearcy et al. (1990) published observations based on 134 juvenile steelhead collected at sea from 1981 to 1985. They found that steelhead originating south of Cape Blanco, Oregon, rarely migrated north of that point. Burgner et al. (1992) interpreted data collected from 1955 to 1990 by research vessels of the United States, Canada, and Japan. Outmigrating smolts occurred in nearshore sampling in May, but by July they had moved offshore. The only nearshore area where steelhead in their first ocean year (age .0) remained by July was off northern California. These fish were interpreted to be half-pounders preparing to move into fresh water. Burgner et al. (1992, p 33) also noted that

> a small concentration of age .1 juveniles appears in the spring off the coast of southern Oregon and northern California.... These fish are separated from the main mass of age .1 steelhead and are likely half-pounders returning to sea.

Table 4.--Saltwater age frequency for selected winter steelhead populations. Populations are arranged from north to south.

Population	Sample size	Saltwater age at first spawning				Reference
		1	2	3	4	
Sand Creek, OR	170	0.25	0.73	0.02	--	Bali 1959
Alsea River, OR	978	0.05	0.66	0.26	0.03	Chapman 1958
Coquille River, OR	81	0.51	0.44	0.05	--	Bali 1959
Rogue River, OR*	547	0.14	0.86	--	--	ODFW 1990
Illinois River, OR	122	0.07	0.83	0.10	--	ODFW 1992a
Chetco River, OR	90	0.89	0.11	--	--	Bali 1959

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

Burgner et al. (1992, p. 43) found that throughout the ocean phase,

> steelhead from coastal Oregon and California may have more restricted westward migrations than do the more northern stocks.... Although these results may be an artifact of the lack of coded-wire tagged smolt releases from coastal Oregon and the relatively low number of releases from California, there may well be a true difference in ocean distribution of these stocks.

Although data are limited, authors studying ocean distribution of Pacific salmonids have described differences in ocean migration patterns among steelhead originating south of Cape Blanco, Oregon; this area includes the Illinois River. We are not aware of any ocean distribution data specifically for Illinois River steelhead.

Spawning

Migration, or "run," timing varies both among and within steelhead populations. Several authors describe a heritable component to run timing which has facilitated selection for early maturing steelhead in some hatchery programs (Cramer et al. 1985). The heritability of run timing may allow steelhead populations to exploit or avoid environmental factors which are fairly consistent from year to year. An example is the phenomenon of lagoon formation in coastal streams of southern Oregon and northern California, such as occurs in the Pistol and Mattole Rivers. Sand berms close the mouths of these streams during summer low flow, making them inaccessible from approximately June to September each year. Migration timing must coincide with months when the berm is breached by streamflow and wave action.

Authors reporting the migration timing of steelhead generally use one or more of the following methods of data collection: reports from anglers, collection of fish entering fresh water (by seining or electrofishing), or observations of fish at a dam or fishway. Relatively few authors report the actual spawning time. This is due in part to the difficulty of observing steelhead under the high streamflow conditions in which they generally spawn. Spawning surveys were attempted in the Rogue River basin, including the Illinois River, in the 1950s, but high water flow and difficult field conditions hampered the efforts (Fish and Wildlife Service 1956). We were not able to find any comprehensive spawning survey information for steelhead in the Illinois River.

Summer- and winter-run steelhead--Migration timing does not necessarily provide a good indicator of when steelhead spawn. Summer steelhead enter fresh water in a reproductively immature state, as early as May, and do not spawn for many months. "Winter steelhead" migrate when they are closer to reproductive maturity. Both summer and winter steelhead spawn in the winter to early spring. In drainages with sympatric populations of summer and winter steelhead, there may or may not be temporal or spatial separation of spawning. Everest (1973) described spawning for Rogue River summer steelhead as December-March and for winter steelhead as March-June. Large rivers such as the Klamath and Rogue may have migrating steelhead throughout the year (Kesner and Barnhart 1972). Often, there are peaks in migration which are used to describe different runs. The most commonly described are the summer and winter runs, with the names referring to the season in which the steelhead enter fresh water. Spring- and fall-run steelhead enter fresh water reproductively immature and, therefore, are grouped with summer-run steelhead in this document. Rivers (1957) described three runs of steelhead in the Rogue River basin: spring (early summer), fall (late summer), and winter. Within these runs, he described 11 geographic "races" (Table 5). These included the Illinois River winter steelhead and a very weak run of Illinois River fall (summer) steelhead. These summer steelhead may actually have been Rogue River summer steelhead that historically sought thermal refuge in the

Table 5.--Runs and races of Rogue River steelhead described by Rivers (1957).

Run	Race
Spring	Upper Rogue Big Butte
Fall	Illinois[a] Applegate[b] Middle Rogue Upper Rogue
Winter	Lower Rogue Illinois Middle Rogue Applegate Upper Rogue

[a]Identified as very weak (Rivers 1957).
[b]Identified as almost extinct (Rivers 1957).

Illinois River (Everest 1973). The most current information on run timing for Rogue River basin steelhead comes from ODFW. "ODFW now views the Rogue River basin as having two runs of steelhead: a summer run that generally enters the Rogue River from April through October; and a winter run that generally enters from November through March" (Fustish et al. 1989, p. 4; see also Table 6).

At present, only winter steelhead are believed to utilize the Illinois River (M. Jennings[8]). However, a 46-cm steelhead in Indigo Creek, 2 miles above the confluence with the Illinois River, was documented in August 1990 (Forest Service 1992b). The date would seem to indicate that this was a summer steelhead.

Spawn timing may be heritable at least in part, but it is also subject to modification by streamflow, water temperature, and other variables. Rivers (1963) stated that in years of average streamflow and water temperature, Rogue Basin winter steelhead demonstrated the following pattern in peak spawning activity: Rogue River, 15 March; Illinois River, 1 April; and Applegate River, mid- to late April. Notably, Everest (1973) found a 2-week shift in peak spawning between years for Rogue River summer steelhead.

Age and body size at first spawning--Although Shapovalov and Taft (1954) found some steelhead which spawned prior to outmigrating to the ocean, steelhead generally spawn after a period of saltwater residency. Age at first spawning is thus a function of both the age at smoltification and the duration of saltwater residency. Data indicate that age at first spawning for Illinois River steelhead is similar to that of other coastal winter steelhead populations in Oregon (Table 7). Based on interpretation of 232 scale samples provided by

[8]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.

Table 6.--Rogue River basin steelhead run timing, based on time of river entry, as described by the Oregon Department of Fish and Wildlife historically (Rivers 1963) and at present (Fustish et al. 1989). This document follows the description of Fustish et al. 1989.

Run name	Rivers (1963)	Fustish et al. (1989)
Spring	March-June	---
Summer	---	April-October
Fall	August-October	---
Winter	November-February	November-March

Table 7.--Frequency of total age at first spawning for selected winter steelhead populations. Populations are arranged from north to south. See Table 2 for sample sizes.

Population	Total age 2	3	4	5	6	Reference
Kalama River, WA	--	0.04	0.58	0.36	0.02	Leider et al. 1986
Sand Creek, OR	--	0.14	0.69	0.17	--	Bali 1959
Alsea River, OR	--	0.04	0.55	0.36	0.05	Chapman 1958
Coquille River, OR	--	0.22	0.56	0.21	0.01	Bali 1959
Rogue River, OR*	<0.01	0.15	0.66	0.18	<0.01	ODFW 1990
Illinois River, OR	--	0.03	0.53	0.39	0.05	ODFW 1992a
Chetco River, OR	0.01	0.36	0.51	0.12	--	Bali 1959

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

anglers, Rivers (1957) reported average lengths at first spawning migration for Rogue Basin winter steelhead: Illinois River, 60 cm; Rogue River, 44 cm; and Applegate River, 39 cm. For comparison, Shapovalov and Taft (1954) found the average length at first spawning for Waddell Creek (California) steelhead ranged from 39 to 78 cm, depending on life history pattern. Therefore, it is evident that there is considerable variability in the size a winter steelhead attains prior to its first spawning migration even within a given stream. Rivers (1957) stated that the largest steelhead caught by anglers in the Rogue River basin were Illinois River winter steelhead, which averaged 64 cm overall. Rivers (1957) stated that the average angler-caught Illinois River winter steelhead weighed 2.9 kg; he gave no weight for winter steelhead from the Rogue and Applegate Rivers.

Repeat spawning--Incidence of repeat spawning tends to decrease from south to north (Withler 1966), with much variation among populations. Up to five spawning migrations have been recorded for an individual (Bali 1959); however, more than two is unusual. The majority of repeat spawners are female, presumably due to the extended time and energy males spend on the spawning ground competing for and guarding females (Shapovalov and Taft 1954, Withler 1966, Barnhart 1986). Columbia River steelhead are essentially semelparous (Long and Griffin 1937), typically surviving only one spawning migration. The Oregon Department of Fish and Wildlife found a repeat spawning frequency for Rogue River winter steelhead of 14.5% (ODFW 1990). From ODFW data (ODFW 1992a), we calculated a 20% repeat spawning frequency for Illinois River winter steelhead.

Distribution of spawning in Illinois River--Distribution of juvenile fish, especially young of the year, may provide an indication of spawning distribution in streams for which spawning surveys are unavailable. Recent stream surveys (Forest Service 1992b) provide a partial record of distribution of juvenile steelhead in the Illinois River basin. Juvenile steelhead have been found in tributaries to the lower Illinois River as well as above the falls. This suggests that spawning by steelhead is distributed throughout the basin. Biologists have evaluated Illinois River tributaries for habitat quality and salmonid production capability (Forest Service 1992b). They concluded that the Indigo and Silver Creek basins of the lower river are "the most important tributaries of the Illinois River drainage in terms of fish production, natural flow and cooler summer water temperature" (Forest Service 1992b). However, these surveys were primarily limited to tributaries below Illinois River Falls.

Resident Fish

Rainbow trout are the resident, or nonanadromous, form of steelhead (alternatively, steelhead can be viewed as the anadromous form of rainbow trout). Both forms are part of the biological species *Oncorhynchus mykiss*, and the taxonomy of this species, as well as the relationship between rainbow trout and steelhead, has been studied for several decades (e.g., Kendall 1920, Snyder 1925, Behnke 1992). No set of morphological or genetic characteristics have been found that consistently distinguish the two forms. It seems likely that resident rainbow trout have arisen independently many times following colonization of new areas by the anadromous steelhead. Foote et al. (1989) reached a similar conclusion for the species *O. nerka*--that is, that the resident form (kokanee) has arisen from the anadromous form (sockeye salmon) several times.

Because the focus in ESA evaluations of Pacific salmon and steelhead is on identifying and conserving genetic resources that are important to the evolutionary legacy of the biological species (Waples 1991), it is important to consider the genetic relationship between resident and anadromous forms. With respect to this status review, if resident rainbow trout share a common gene pool with steelhead, the two forms should be considered together as a unit.

Unfortunately, little is known about the genetic relationship between steelhead and rainbow trout in any systems in which they co-occur. Native rainbow trout exist in the Rogue River basin (Behnke 1992), but we could find no published or unpublished information about the relationship between resident and anadromous forms in this system. Because of this lack of information about rainbow trout, this status review will focus exclusively on steelhead. The relationship between the two forms should be reevaluated if substantial information becomes available about rainbow trout in southern Oregon coastal streams.

History of Hatchery Stocks and Outplantings

Steelhead Hatcheries

Annual hatchery production of steelhead on the west coast of North America has increased since 1960 from about 3 million juvenile steelhead 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 8), and this figure is dominated by steelhead from hatcheries concentrated in the Columbia River basin (Light 1989).

Releases in the Illinois River

There are no steelhead hatcheries in the Illinois River basin; however, ODFW does have records of steelhead from elsewhere being released there (Table 9). The primary source for steelhead released into the Illinois River has been the Cole Rivers Hatchery on the Rogue River.

Scales collected from adult steelhead angled from the Illinois River have been analyzed by ODFW to determine frequency of hatchery and naturally produced steelhead.

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

Location (number)	Average annual smolt production, 1978-87	Percent of 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

Table 9.--Hatchery steelhead introductions in the Illinois River basin (ODFW 1992d).

Year	Quantity	Life history stage	Run type	Source
1934-76	27,438	fingerlings	winter	unknown
1976	5,391	fingerlings	summer	unknown
1978-80	3,000	adults	winter	Cole Rivers Hatchery
1985-89	340,525	egg-box fry	winter	Cole Rivers Hatchery
1989	4,096	fingerlings	winter	Cole Rivers Hatchery
1990	15,000	fingerlings	summer	Cole Rivers Hatchery

Scale data from ODFW (1992a) indicate that 4% of 162 steelhead caught in the Illinois River from January 1982 to February 1990 were of hatchery origin. It is possible that these hatchery steelhead were strays from the Rogue River. Rogue River steelhead are known to stray temporarily into the lower Illinois River in large numbers (Everest 1973). The Illinois River is listed as complying with ODFW wild fish policy (Chilcote et al. 1992), which states that escapement of at least 300 breeding fish per spawning season must be maintained and that up to 50% of those fish can be of hatchery origin if genetically similar to the native stock, or 10% if they are genetically dissimilar. The Illinois and Chetco Rivers contain the only Oregon populations of winter steelhead considered by ODFW to be in compliance with this policy (Chilcote et al. 1992).

Genetics

Previous Studies

Protein electrophoresis--Numerous protein electrophoretic studies of population structure in coastal anadromous and resident *O. mykiss* have been published since the early 1970s. Allendorf (1975) first distinguished two major genetic groups of *O. mykiss*, inland and coastal, separated geographically by the Cascade crest. These two groups have large and consistent differences in allele frequency that apply to both anadromous and resident forms of *O. mykiss*; 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. 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).

Genetic differentiation based on timing of upstream migration in steelhead has also been investigated by allozyme analysis. Allendorf (1975) and Utter and Allendorf (1977) found that, like resident and anadromous forms, 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 studies on steelhead from the Rogue River (Reisenbichler et al. 1992). However, in each of these more recent studies, the summer-run stocks have had some extent of hatchery introgression and may not represent the indigenous population. Furthermore, in at least some cases, interpretation of the results is complicated by difficulties in determining run timing of the sampled fish.

There is also evidence to suggest that the overall population structure of steelhead in the Pacific Northwest has been affected by artificial propagation. 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.

Allozyme studies of Oregon steelhead, including some populations from the Rogue River basin, were reported by McIntyre and Schreck (1976), 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, including Lawson Creek, a tributary of the lower Illinois River. He also sampled two tributaries of the lower Rogue River (Lobster and Saunders Creeks). Hatch found evidence for a "north-south cline" in allelic frequencies in 5 of the 13 enzyme systems analyzed, but only in river systems larger than 350 km^2. Hatch (1990; p. 17) also reported that "the area south of the Coos River was marked by sharp transition in four different enzymes..." and (p. 33) "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."

Data reported by Reisenbichler et al. (1992) are based on steelhead collected from 24 natural sites and 13 hatcheries in the Pacific Northwest in 1971-78 and analyzed for 10 gene loci. Twenty-four of the collections were from the Oregon coast, including eight localities in the mainstem Rogue River and its tributaries, but none were from the Illinois River. Collections were also made in northern California from the Mad River Hatchery (winter run) and the Trinity River (summer run).

Results from Reisenbichler et al. (1992) do not suggest a geographic cline of allele frequencies; instead, evidence was found for some genetic differentiation between clusters of populations. In their analysis, steelhead from north of the Umpqua River formed a separate cluster from steelhead in southern Oregon and northern California. Genetic differences between fish 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). Significant differences were detected between hatchery fish and naturally spawning populations, including Cole Rivers Hatchery and a number of natural stocks from the Rogue River.

Reisenbichler et al. (1992) found that samples from the Rogue River basin tended to group together (Cole Rivers Hatchery with the lower and upper Rogue River mainstem collections, and Galice Creek with Shasta Costa Creek and Big Windy Creek). There were two exceptions to this pattern: steelhead from Saunders Creek and Slate Creek were genetically more similar to samples from northern Oregon than they were to other Rogue River samples. The only natural sample from northern California (Trinity River) also grouped with the Rogue River fish. Steelhead from Mad River Hatchery grouped by themselves, separate from other natural and hatchery populations in California and Oregon.

Genetic differentiation between clusters of populations from the north and south Oregon coasts was also reported in a previous allozyme study (McIntyre and Schreck 1976). Collection sites were from 15 natural locations, including 1 at the mouth of the Illinois River, and 2 hatcheries. The authors examined seven polymorphic loci.

Chromosomal studies--Chromosome karyotypes in steelhead and rainbow trout have been extensively studied (see review in Thorgaard 1983). Chromosome numbers from 56 to 68 have been reported in *O. mykiss*, but Thorgaard (1983) found that a 58-chromosome karyotype was the most commonly observed karyotype in a survey of steelhead from Alaska to central California.

In contrast to results for studies of morphological and allozyme characters, Thorgaard's (1983) analysis did not reveal chromosomal differences between interior and coastal *O. mykiss* populations. All interior trout populations had predominately 58 chromosomes (Wilmot 1974; Miller 1972; Gold 1977; Thorgaard 1976, 1977, 1983) and most (but not all) coastal rainbow trout and steelhead populations also typically had 58-chromosome karyotypes (Wilmot 1974, Thorgaard 1983, Busack et al. 1980).

Thorgaard (1983) did detect a geographic pattern in chromosomal variability between some northern and southern sample sites. Although the 58-chromosome karyotype was predominant throughout the sampled range, there were two geographic regions 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 not the same. Northern fish with 59 or 60 chromosomes had a different number of subtelocentric and acrocentric chromosomes than did southern fish with 59 or 60 chromosomes (Thorgaard 1976). The groups may differ by a pericentric inversion or by the addition or deletion of heterochromatin. Even farther south, winter steelhead in the Mad and Gualala Rivers and resident trout in the San Luis Rey River commonly had 64 chromosomes.

Thorgaard (1983) also analyzed chromosomal variability in winter- and summer-run steelhead from the Quinault River (Washington) and the Rogue River. Chromosome number from these two river systems was different, but the chromosome number in summer and winter steelhead within each river system was similar. This is consistent with the previously discussed allozyme (e.g., Utter and Allendorf 1977) and morphological studies (Behnke 1992).

DNA analysis--Restriction endonuclease analysis of mitochondrial DNA (mtDNA) has been used to examine the structure of natural populations for over a decade (Avise et al. 1979, Brown et al. 1979). Although the mitochondrial genome in salmonids has also been studied (Wilson et al. 1985, Ferris and Berg 1987, Gyllensten and Wilson 1987), we have found no published information on DNA in steelhead from southern Oregon. The only such study we are aware of remains unpublished (N. Buroker[9]). Buroker's study included 120 individuals from 23 major river systems in Alaska, British Columbia, Idaho, Washington, Oregon, and California. Steelhead from southern Oregon were found to be highly diverse in mtDNA clonal types. In the 120 fish analyzed, 18 mtDNA clones 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 haplotypes observed throughout the study. In contrast, the Columbia River had relatively low levels of mtDNA haplotype diversity.

New Data

The above studies reported data for far fewer genetic markers (loci) than can be resolved using current techniques. Furthermore, in recent studies, only Hatch (1990) examined steelhead from the Illinois River, and then only from one location. To remedy these shortcomings in the dataset, NMFS biologists analyzed new samples of coastal steelhead from 13 natural and 2 hatchery populations, focusing on the Illinois and Rogue River drainages (Table 10; Fig. 2). The four Illinois River samples included two from the lower river (Lawson Creek and Indigo Creek), one from the middle river below Illinois River Falls (Briggs Creek), and one from the upper river (Grayback Creek).

Samples from natural populations were collected by electrofishing in September and October 1992 and consisted of juvenile fish 49 mm to 209 mm fork length. In general, it is difficult to determine the adult run timing of juvenile steelhead. Most of the samples are considered to represent winter-run fish because they came from streams that are believed to have only winter-run steelhead. In some cases, however, both summer and winter steelhead

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

Table 10.--Sample sizes and indices of genetic variability for steelhead populations examined in the genetic analysis. For run timing, W = winter, S = summer, and W/S = uncertain or a mixture of both forms.

Drainage Population	Run timing	Sample size	Polymorphic loci (%)	Heterozygosity
Illinois River				
Briggs Creek	W	40	43.6	0.091
Grayback Creek	W	40	53.8	0.094
Indigo Creek	W/S	40	51.3	0.083
Lawson Creek	W/S	30	53.8	0.080
Rogue River				
Lobster Creek	W/S	40	46.2	0.071
Little Butte Creek	W/S	40	61.5	0.080
Cole Rivers Hatchery	W	40	53.8	0.072
Coastal Oregon				
Nehalem River	W	40	46.2	0.097
Yaquina River	W	40	38.5	0.074
Elk River	W	40	59.0	0.086
Bandon Hatchery (Coquille R. stock)	W	40	30.8	0.074
Pistol River	W	40	48.7	0.091
Winchuck River	W	40	61.5	0.098
Coastal California				
Smith River	W	40	51.3	0.084
Klamath River	W/S	40	53.8	0.080
Snake River				
Camp Creek (1990)	S	99	53.8	0.090
Camp Creek (1992)	S	10	35.9	0.103

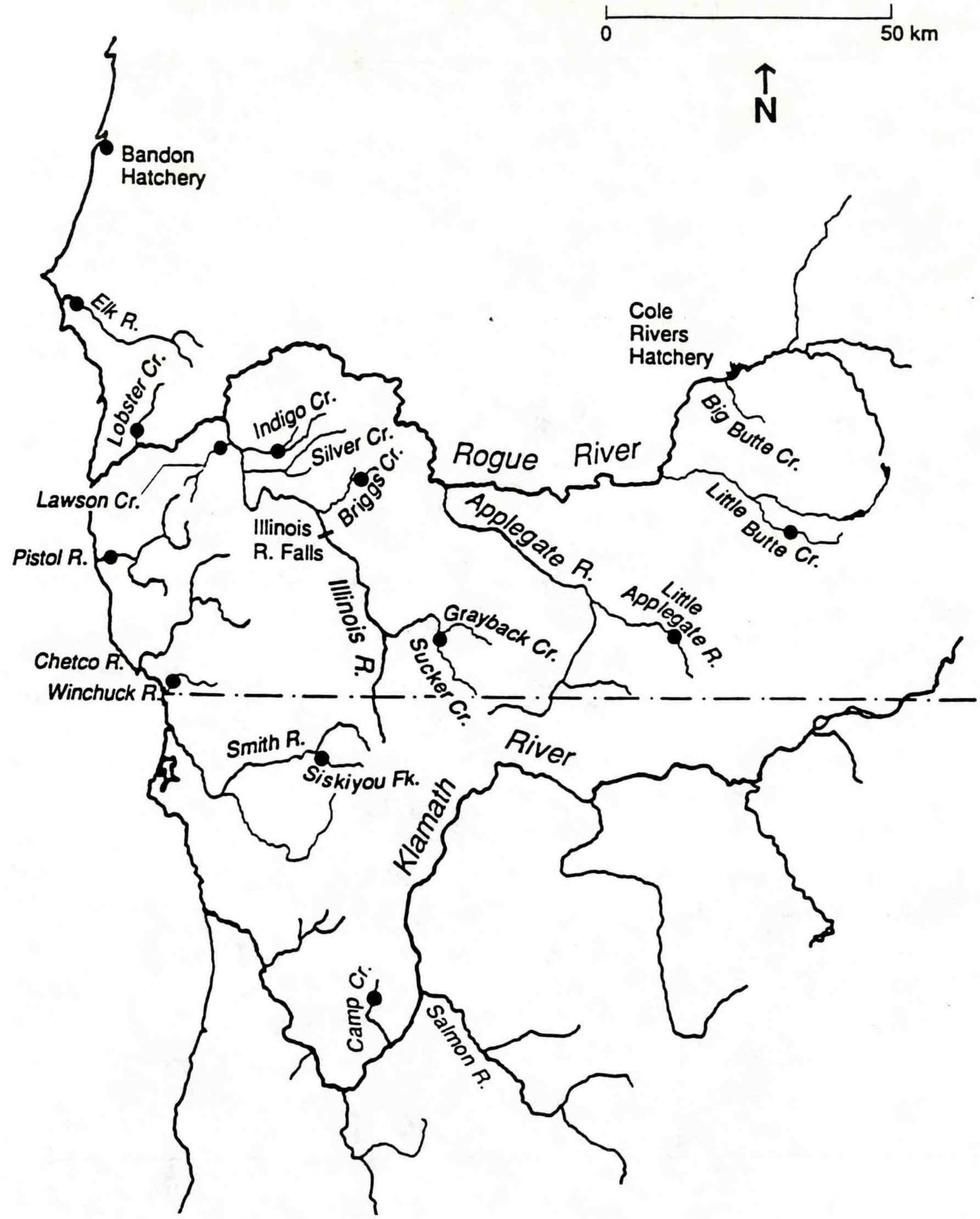

Figure 2.--Collecting sites in the Rogue River basin and surrounding area for samples used in the genetic analysis. Collections were also made in the Smith and Klamath Rivers in northern California, and Yaquina and Nehalem Rivers in northern Oregon (Table 10).

occur (e.g., in the Rogue and Klamath River drainages), and samples from these areas are considered to be of unknown run timing (Table 10). The Illinois River is often cited as having only winter-run steelhead, but there is some indication that summer-run fish may exist in the lower part of the river (Forest Service 1992b). Therefore, the two samples from the lower Illinois River (Lawson Creek and Indigo Creek) are also considered to be of uncertain run timing.

Protein electrophoresis followed procedures described by Aebersold et al. (1987), modified somewhat to take advantage of recent improvements developed by NMFS for the study of Snake River steelhead and by Washington Department of Fisheries for the study of Yakima Basin steelhead (Busack et al. 1991). Although 50 or more fish were collected from most populations, time and resources limited the genetic analysis to a maximum of 40 fish per sample. In addition to the 15 samples of coastal steelhead, a sample of 10 Snake River steelhead (from Camp Creek, a tributary of the Imnaha River in northeastern Oregon) was included as a control to help ensure that the locus and allele designations were consistent with those used in existing datasets.

Screening of 46 enzyme systems resulted in the collection of data for 69 presumptive gene loci that could be scored in all samples. Table 10 summarizes levels of genetic variability for 39 loci that were polymorphic (more than one allele present) in at least one sample. The percentage of loci that were polymorphic in a population ranged from 30.8% in Bandon Hatchery to 61.5% in Little Butte Creek and Winchuck River. Average heterozygosity over the 39 polymorphic loci ranged from 0.071 in Lobster Creek to 0.098 in Winchuck River (with a value of 0.103 found for the 1992 Snake River sample). These values are consistent with the relatively high levels of genetic variability reported for steelhead in previous studies.

To examine population genetic structure, we computed genetic distance values between each pair of populations based on the 39 polymorphic loci. The unweighted pair-group method with arithmetic averaging was used to cluster populations based on the matrix of genetic distance values. Genetic distances were computed using Nei's (1978) unbiased method, which includes a correction for sampling error in small samples. In addition to the 15 coastal populations and the 1992 sample of 10 Snake River steelhead, we included previously compiled data for a larger sample (99 fish) from the Snake River taken in 1990.

The dendrogram resulting from clustering the genetic distance values is shown in Figure 3. The large genetic difference between coastal and inland *O. mykiss* that has been reported by many previous authors is readily apparent: the distance between the two Snake River samples and the coastal populations (0.025) is an order of magnitude larger than the distances between most pairs of coastal populations. Within the coastal group, the three populations from north of Cape Blanco (Bandon Hatchery, Nehalem River, and Yaquina River) form a small cluster that differs from the more southerly populations at a genetic distance level of approximately 0.004. This is consistent with results reported by McIntyre and Schreck (1976), Hatch (1990), and Reisenbichler et al. (1992), who found evidence for some genetic differentiation between populations in northern and southern Oregon.

Another measure of genetic differentiation is Wright's (1978) F_{ST}, which represents the proportion of total genetic variance attributable to differences between populations. Considering only the coastal populations, F_{ST} was 0.038, similar to the value (0.034) found for Snake River spring/summer chinook salmon from the Grande Ronde, Imnaha, and Salmon

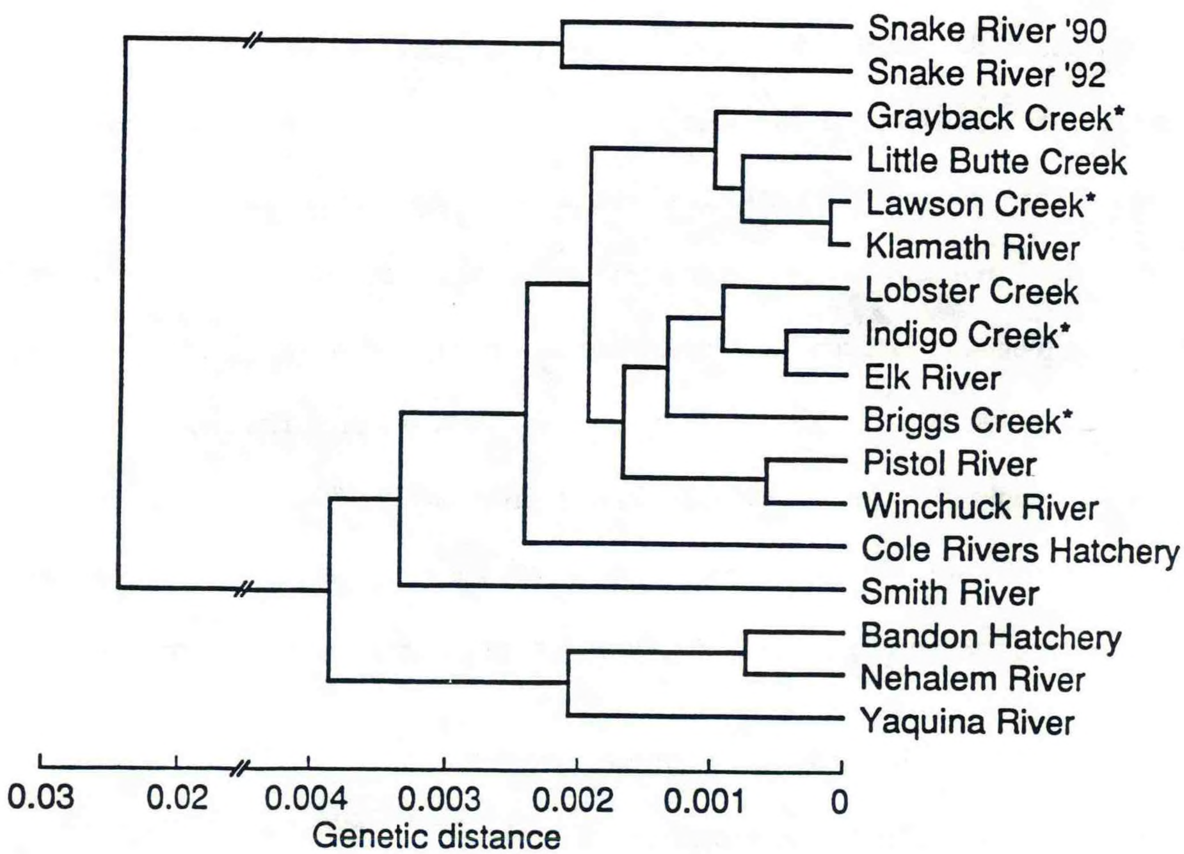

Figure 3.--Dendrogram depicting genetic relationships between coastal steelhead populations analyzed for this study. The figure was constructed by clustering of Nei's (1978) unbiased genetic distance values between pairs of samples. The four Illinois River samples are denoted by asterisks (*). Note the change of scale involving genetic distances to samples from the Snake River, which were included to provide a comparison with inland steelhead populations.

River drainages (Waples et al., in press). Genetic distance values between the coastal steelhead populations were also similar in magnitude to those found between spring/summer chinook salmon populations in the Snake River (Waples et al. 1991 and Waples et al. in press). Snake River spring/summer chinook salmon are considered a single species under the ESA and are listed as threatened (NMFS 1992).

Apart from the north/south differences noted above, there is only weak evidence for further structuring of the coastal steelhead populations. Although statistically significant differences were found between each pair of samples when data for all gene loci were considered, the differences were not large in an absolute sense, and little geographic pattern is evident. The four samples from the Illinois River do not form a coherent genetic group. In fact, three of the four samples are genetically more similar to a sample from outside the Rogue River drainage than they are to other Illinois River samples (Table 11). The exception is Briggs Creek, for which Indigo Creek was the most similar population; however, the Indigo Creek sample was genetically closer to the Elk River sample than it was to Briggs Creek.

Population Trends

Regional Overview of Steelhead Abundance

Three substantial reviews of North American steelhead abundance have been undertaken, by 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 from an average of 2,700,000 kg in the 1890s to an average of 370,000 kg in the 1960s--a sevenfold decline. 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

Table 11.--Genetic affinities of Illinois River winter steelhead populations. Populations with the smallest genetic distance (Nei 1978) to each of the four sampled Illinois River populations are indicated.

Illinois River population	Most similar population	Genetic distance
Briggs Creek	Indigo Creek	0.00085
Grayback Creek	Klamath River	0.00089
Indigo Creek	Elk River	0.00046
Lawson Creek	Klamath River	0.00017

Indian gill-net fishery with relatively stable effort, so statistics for that fishery do 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 (1948) and then Oregon (1952) instituted punchcard systems. California began using questionnaires to estimate steelhead catch in 1953 but discontinued regular reporting after 1956. In both Washington and Oregon, 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. 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 12). The coastwide total of 1.6 million is 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

Table 12.--Estimates of average annual steelhead runs in the mid-1980s (Light 1987).

Region	Thousands of adults			Percent
	Hatchery	Wild	Total	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
Total	799	772	1,571	49

estimate. They noted a recent (1985 to 1991) decline in steelhead returns (both hatchery and wild) in British Columbia, Washington, and Oregon, and they suggested common factors that might be responsible for that decline, 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 (primarily in unauthorized fisheries).

Historical Abundance in Southern Oregon

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.

Specifically regarding the Illinois River, he reported (p. 55)

> interest in sport fishing for steelhead in the Applegate and Illinois sections of the drainage was limited. A few people fished the Applegate, but up to 1941, there were less than 25 people known to fish the Illinois River for steelhead. The anglers were attracted by the concentration of fish at the Illinois Falls ladder.

Rivers (1957) estimated that the steelhead catch for 1950-56 in the Illinois River averaged zero for spring run (early summer-run), 10-40 for fall run (late summer-run), and 1,400-1,800 for winter run.

Abundance of Illinois River Winter Steelhead

Two sources of data on abundance of Illinois River steelhead are available: angler catch estimates generated by ODFW from returns of salmon/steelhead punchcards covering the period 1952-91 (Tables 13 and 14), and records of juvenile steelhead caught in irrigation diversion traps, primarily for the period 1975-91. The diversion trap records (ODFW 1992c) have not been consistently kept, the traps are operated differently in different seasons and years, and the trap catches are affected by changes in river flow and irrigation practices; thus, the records do not provide a reliable indication of population trends and will not be discussed.

Interpreting population abundance from the 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. All three of these problems have been discussed for the Illinois River basin by Cramer (1992), who argued that catch estimates are

Table 13.--Estimated angler catch of Illinois River Steelhead. Total steelhead catch by calendar year for 1953 to 1972 from Koski (1963) and Phelps (1973).

Calendar year	Total catch
1953	3,441
1954	2,695
1955	N/A*
1956	2,439
1957	2,140
1958	2,201
1959	4,079
1950	2,384
1961	1,006
1962	1,251
1963	1,188
1964	936
1965	1,088
1966	1,472
1967	966
1968	1,935
1969	2,519
1970	2,669
1971	2,985
1972	2,595

*Data for 1955 are unavailable.

Table 14.--Estimated angler catch of Illinois River Steelhead. Steelhead catch by run for 1969-70 to 1990-91 from ODFW (1980, 1992b).

Run Year	Run		Total
	Winter	Summer	
1969-70	2,395	38	2,433
1970-71	3,444	189	3,633
1971-72	2,699	69	2,768
1972-73	1,893	41	1,934
1973-74	2,491	62	2,553
1974-75	2,815	150	2,965
1975-76	1,772	120	1,892
1976-77	641	97	738
1977-78	1,597	149	1,746
1978-79	638	25	663
1979-80	534	0	534
1980-81	1,261	0	1,261
1981-82	797	0	797
1982-83	384	22	406
1983-84	526	0	526
1984-85	1,150	0	1,150
1985-86	606	0	606
1986-87	995	0	995
1987-88	403	0	403
1988-89	550	0	550
1989-90	233	0	233
1990-91	171	0	171

not a good index of steelhead abundance in that system. We discuss each problem briefly below.

Variation in fishing effort and effectiveness--One letter received by NMFS from a local angler (Williams 1992) suggested that fishing pressure in the Illinois River has declined substantially and that this decline could account for the decline in catch. To our knowledge, no accurate records of fishing effort on the river are available to evaluate this claim. For comparison, statewide salmon and steelhead fishing effort (as indexed by number of punchcards issued) has been relatively constant since the late 1970s (Fig. 4), 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. 5).

Nonreporting bias--Catch data can be used to develop population abundance estimates and population trend estimates. While it is probable that reporting rates in the Illinois River basin differ from the statewide average, this would only result in a general bias in estimates of total catch, making estimates of total population abundance questionable. We have no indication of whether there is any local trend in reporting rate that would result in a bias in population trend estimates.

Local variation in fishing effort--A substantial problem with catch data in the Illinois River basin is that fishing effort is concentrated in the upper river near Cave Junction, and there is very little fishing in the lower river. We have no good information regarding historical or present distribution of steelhead spawning throughout the basin. From catch data, we cannot conclude whether spawning in the lower river tributaries represents a substantial portion of the total population. Cramer (1992) argued that the lower river

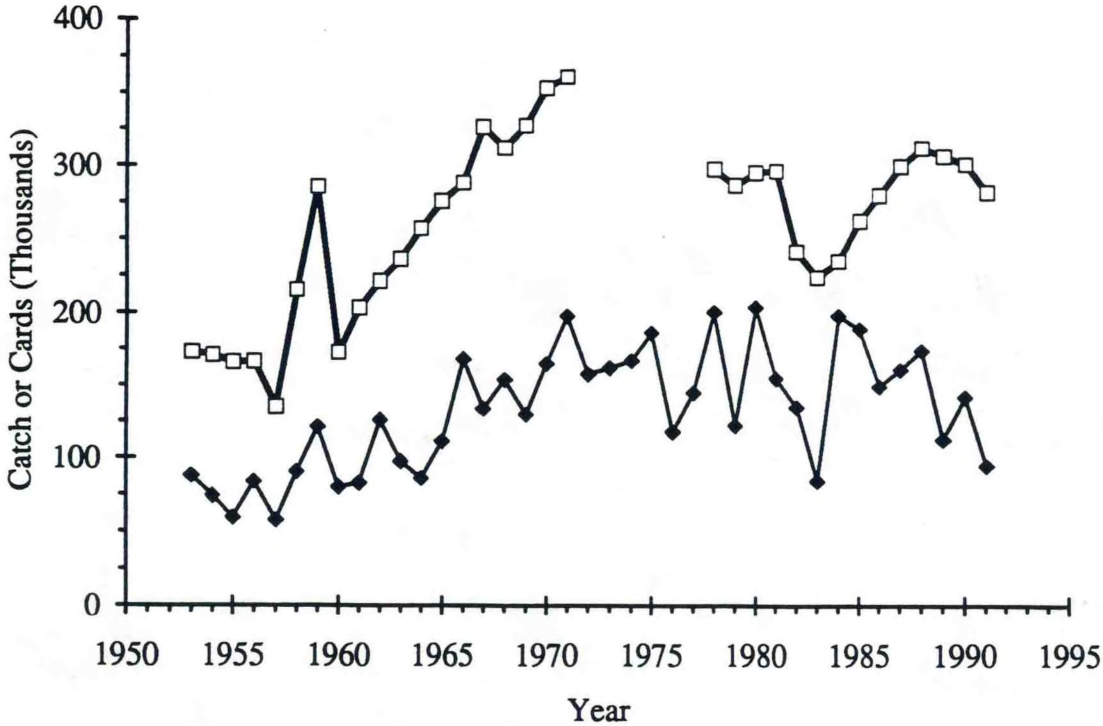

Figure 4.--Oregon statewide total angler fishing effort and steelhead catch. Effort is indexed by annual salmon-steelhead punchcards issued (heavy line, squares). Catch (thin line, diamonds) is statewide total, all runs. Effort for 1972 to 1977 omitted because reported totals include daily punchcards in addition to annual punchcards. Based on data from Koski (1963), Phelps (1973), Berry (1983), and ODFW (1992b).

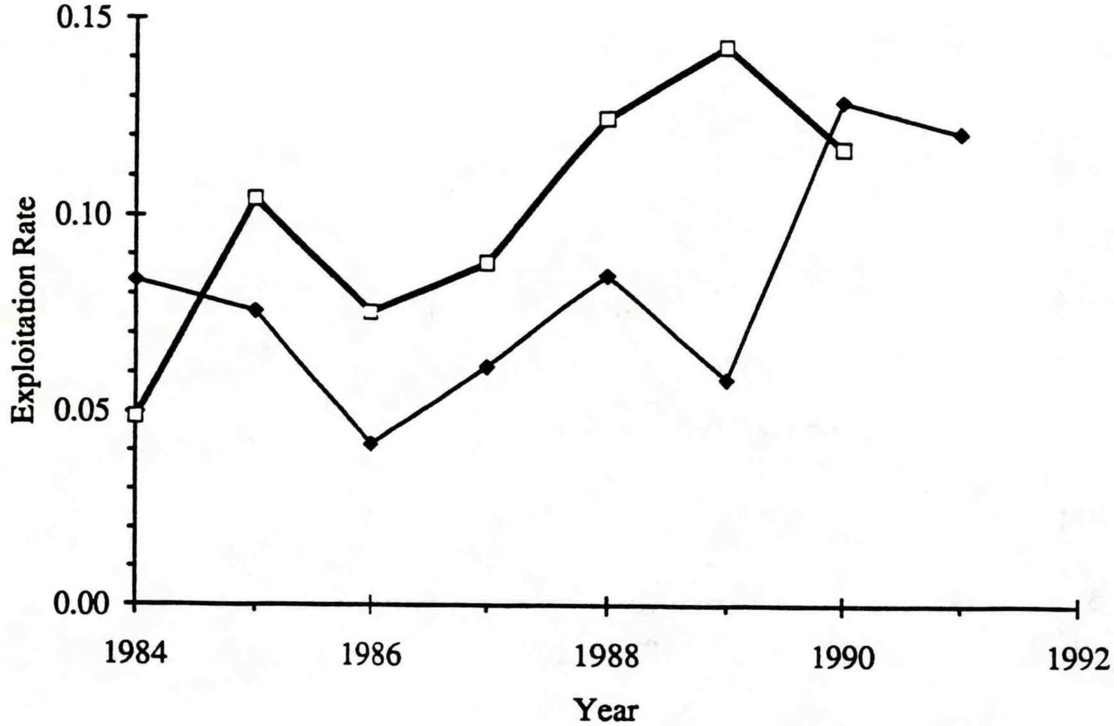

Figure 5.--Winter steelhead exploitation rates for the upper North Umpqua River (heavy line, squares) and upper Rogue River (thin line, diamonds). Rates are calculated as the ratio of angler catch to total run size estimated from adult dam passage counts, as in Kenaston (1989). Catch data are from ODFW (1992b); 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) and ODFW (unpubl. data. 2501 SW First Avenue, P.O. Box 59, Portland, OR 97207).

represents better spawning habitat than the upper river, and that "steelhead populations in these streams could be near carrying capacity even when catch for the basin as a whole is at record low levels." While this is possible, we have no evidence to suggest that lower river stocks operate independently of upper river stocks. Without definite knowledge of factors influencing the populations, we must either assume that upper river trends reflect abundance in the total basin, or conclude that it is impossible to determine population trends from available data.

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 does not adequately represent the complete river basin, but believe that changes in catch still provide an indication of trends in population abundance.

The trend in catch of Illinois River winter steelhead over the historical record has been downward, when expressed as either absolute catch or relative to total Rogue River or statewide steelhead catches (Fig. 6). This implies that there are specific local factors causing a decline beyond the recent regional declines in steelhead abundance. Analysis of returns-per-spawner indicates that production has been below replacement in most years (Fig. 7), and fitting an exponential trend to the catch time series (Fig. 6A) indicates an average decline of about 5.5% per year over the entire record (1956-90).

Because there are no direct estimates of catch rate for the Illinois River, only rough estimates of total run size can be calculated, and those only for the upper river where the fishery is concentrated. Kenaston (1989) classified the Illinois River steelhead fishery as "low intensity" and applied an average exploitation rate of 0.08 which was estimated for other low intensity winter steelhead fisheries (upper North Umpqua River and upper Rogue River) to

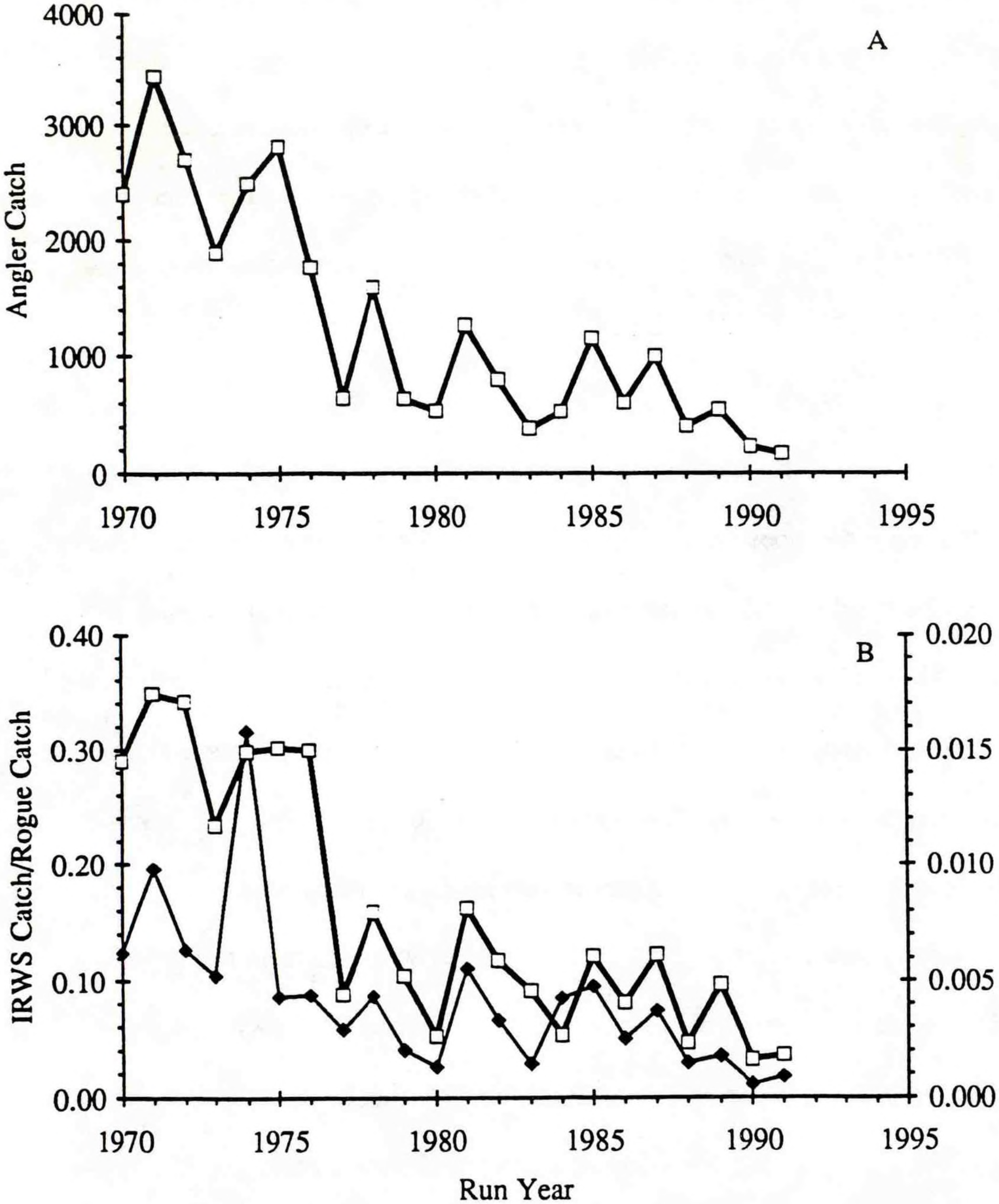

Figure 6.--Trends in Illinois River winter steelhead (IRWS) catch. A) Estimated IRWS angler catch. B) Ratio of IRWS catch to total Rogue Basin steelhead catch (diamonds, left axis) and to total statewide steelhead catch (squares, right axis) (ODFW 1980, 1992b).

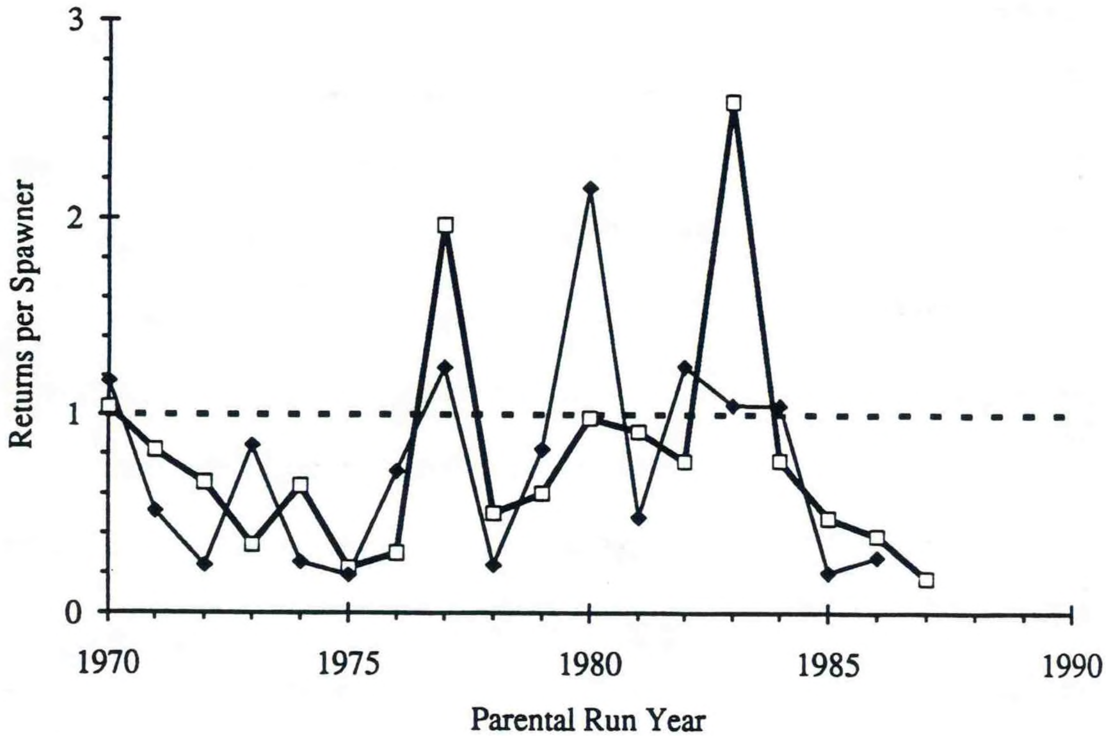

Figure 7.--Indices of adult returns per spawner for Illinois River winter steelhead. Returns per spawner were calculated as the ratio of angler catch in year t+4 (squares) or t+5 (diamonds) to angler catch in year t (parental run year). The horizontal dashed line is the replacement line (ODFW 1980, 1992b).

estimate total run size for the Illinois River for 1981-85. In recent years, estimated exploitation rate for these fisheries has ranged from 0.04 to 0.14, with a mean of 0.09 (Fig. 5). If the steelhead exploitation rate in the total upper Illinois River is comparable to these fisheries, then the upper Illinois River steelhead run size would be in the range of 7 to 25 times the annual catch.

Abundance of Steelhead in Southern Oregon

To provide some perspective on Illinois River steelhead abundance, we briefly reviewed other steelhead stocks in southern Oregon (south of Cape Blanco). There are seven main steelhead rivers in this area: Elk, Pistol, Rogue, Applegate, Illinois, Chetco, and Winchuck. Of these, four (Elk, Pistol, Illinois, and Winchuck) are managed for "wild" production and should have little or no direct hatchery influence (Nickelson et al. 1992), although there may be some effect of straying and unaccounted hatchery plants. We considered the hatchery-influenced rivers (Rogue, Applegate, and Chetco) separately from the "wild" coastal rivers.

Rogue, Applegate, and Chetco Rivers--The presence of Cole Rivers Hatchery, which releases smolts of both summer and winter steelhead into both the Rogue and Applegate Rivers, makes evaluation of trends in naturally spawned stocks difficult. We have no direct estimates of "natural" spawning runs for the Applegate River, but overall catch (hatchery and natural fish combined) for both summer and winter runs have been steady over the last 20 years (Fig. 8). Overall catch of both runs in the Rogue River has been steady or increasing (Fig. 8), and available "wild" fish counts at Gold Ray Dam (up to 1987) indicate that this is true of both hatchery and naturally-spawned fish. The Chetco River supports a considerable winter steelhead fishery and is stocked with steelhead from Elk River Hatchery.

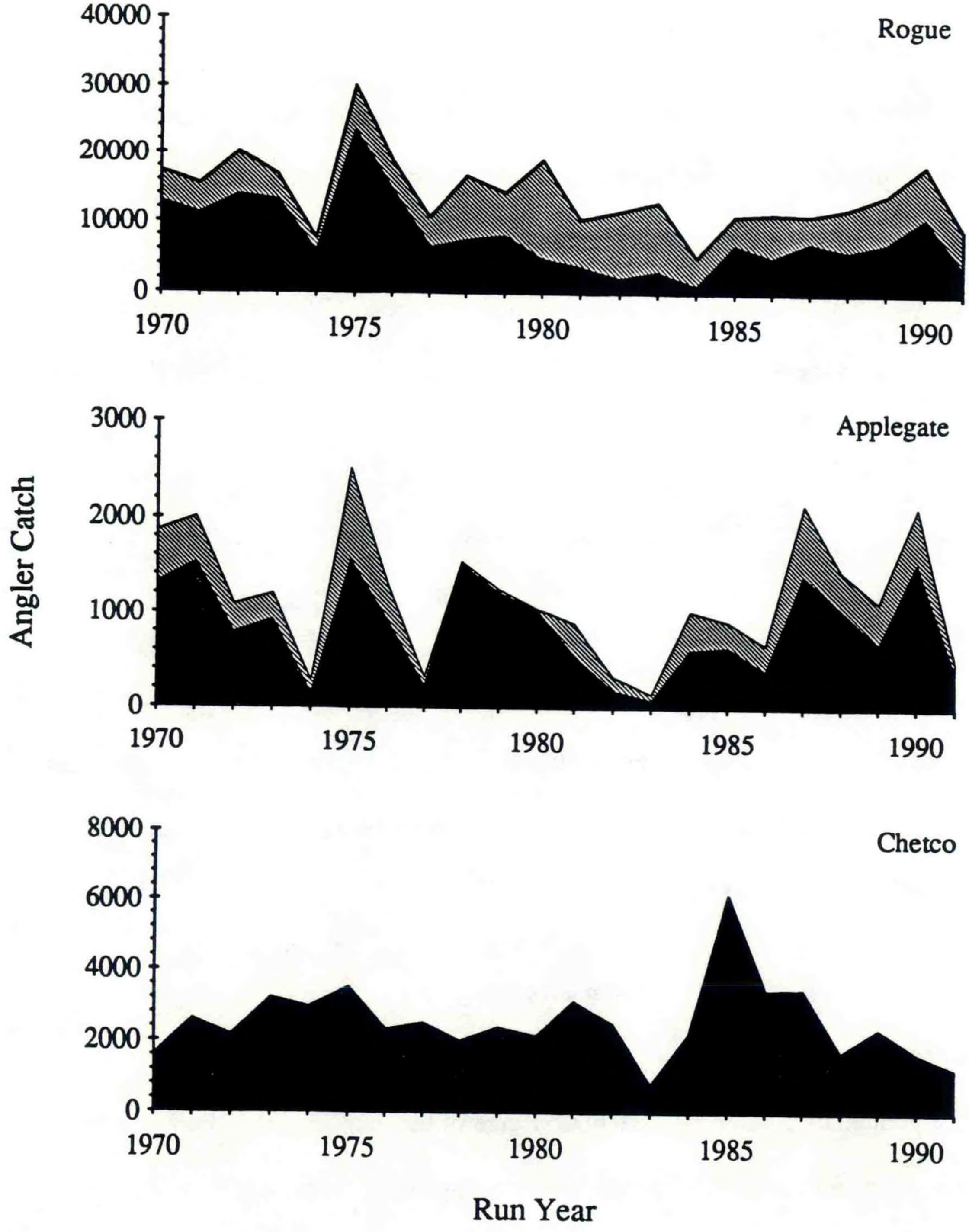

Figure 8.--Estimated steelhead angler catch for Rogue, Applegate, and Chetco Rivers. Both winter run (black) and summer run (shaded area) catch are illustrated (ODFW 1980, 1992b).

We have no data to separate hatchery from naturally-spawned fish, but the overall trend in catch has been level (Fig. 8).

Elk, Pistol, and Winchuck Rivers--These rivers, along with the Illinois River, represent the majority of southern Oregon steelhead production outside of the hatchery-influenced rivers. All have predominantly winter-run steelhead. Elk River steelhead catches (Fig. 9) have experienced a decline similar to that for the Illinois River stock (Fig. 6). The Pistol and Winchuck Rivers have maintained low, fluctuating steelhead catches, with no apparent trend (Fig. 9).

DISCUSSION AND CONCLUSIONS

In this section, we address the two key questions raised at the start of this status review: Do Illinois River winter steelhead represent a species as defined by the ESA? and, if so, is the species threatened or endangered? We begin by summarizing evidence developed in the status review that is relevant to the two criteria that must be met for a population to be considered an ESU, and hence a species under the ESA.

Reproductive Isolation

Straying Rates

As the petitioners pointed out, the high degree of homing fidelity of Pacific salmon and steelhead allows for the possibility that individual spawning populations can experience substantial reproductive isolation. This general argument, however, provides no specific evidence that this has occurred with Illinois River winter steelhead. We are not aware of current or historical data on straying rates of natural steelhead either into or out of the Illinois River.

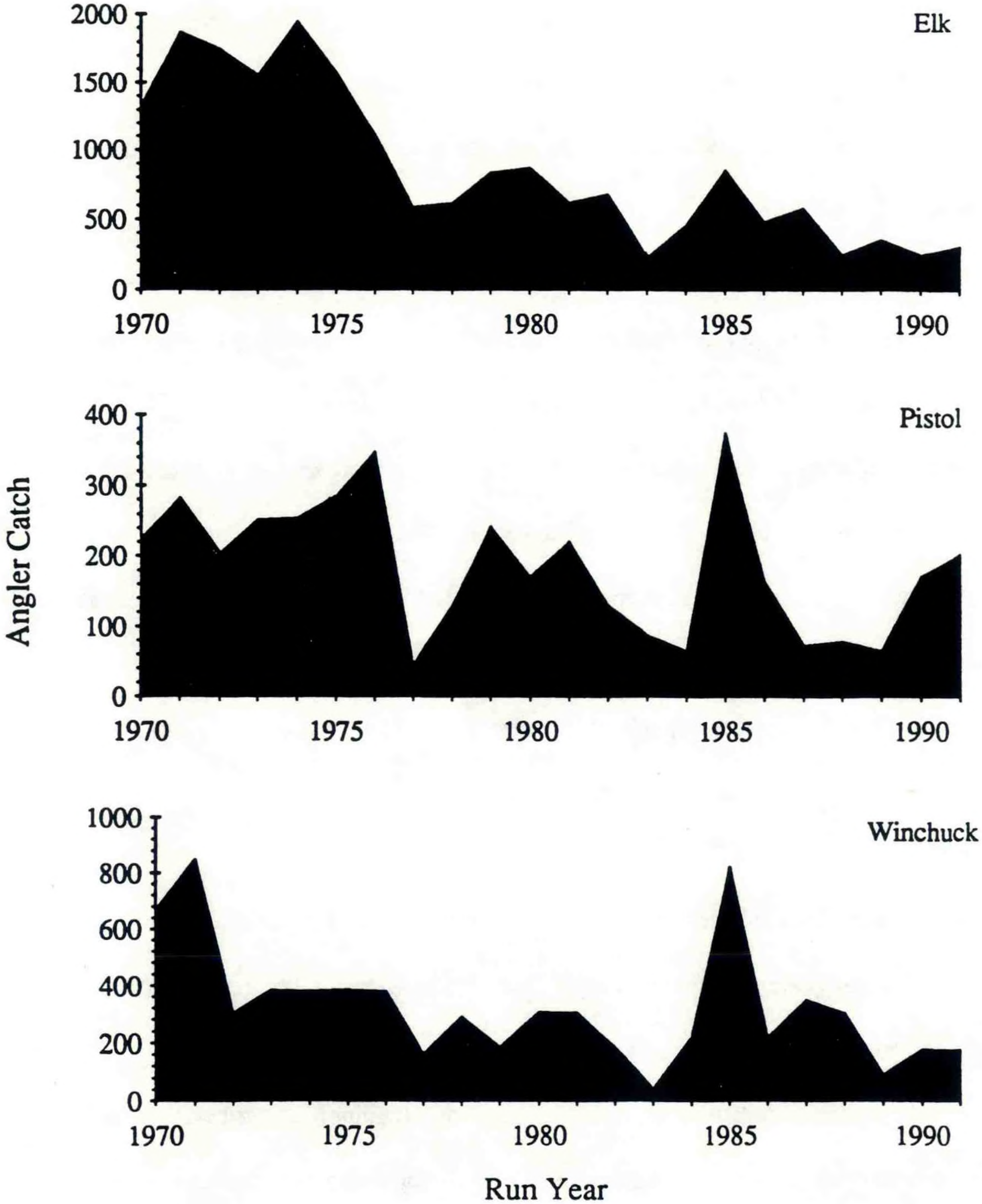

Figure 9.--Estimated winter steelhead angler catch for the Elk, Pistol, and Winchuck Rivers (ODFW 1980, 1992b).

Barriers to Migration

The Illinois River Falls (RKm 64) is a convenient landmark for separating the Illinois River into upper and lower sections. Important spawning grounds for steelhead are found in the upper section, but it is not clear whether this was the case prior to modification of the falls to improve fish passage earlier in this century. It is possible, as the petitioners speculated, that the falls historically acted as an isolating mechanism by selecting against strays that might not arrive at the proper time and might not have the ability to surmount the barrier. Again, however, we found no direct evidence that this was the case.

Steelhead that spawn in the upper parts of the river are separated by as much as 120 km from the confluence of the Illinois and the Rogue Rivers, and this may contribute to reproductive isolation of steelhead spawning above Illinois River Falls. However, there is evidence that streams in the lower Illinois River may be an important source of steelhead smolt production. These areas are considerably closer to (and hence potentially less isolated from) steelhead spawning areas in other river systems.

Genetic Data

Data from several studies provide evidence for some level of genetic differentiation between steelhead from north and south of Cape Blanco. However, a protein electrophoretic survey conducted as part of this status review failed to find evidence for genetic distinctiveness of steelhead from four locations throughout the Illinois River basin. This finding is consistent with results reported by Hatch (1990) for steelhead from Lawson Creek, a lower Illinois River tributary.

Life History Traits

The 2-week shift in time of peak spawning for steelhead from the Illinois River relative to some other populations in the Rogue River basin may reflect reproductive isolation. However, this shift is relatively small; in fact, it is no larger than year-to-year differences in spawn timing observed in Rogue River summer steelhead. A longer time series of data is necessary to determine whether spawn timing of Illinois River winter steelhead differs consistently from steelhead in nearby drainages.

In other life history characteristics (e.g., smolt age, age and size at first spawning, and absence of half-pounders), Illinois River winter steelhead appear to differ somewhat from Rogue River steelhead. Again, this may reflect reproductive isolation between steelhead from the two rivers. Alternatively, these differences may simply reflect habitat differences between the Illinois and Rogue Rivers, since it is known that these and other life history traits can be strongly influenced by environmental conditions. A large hatchery program for Rogue River steelhead has been in operation for several decades, and it is also possible that artificial propagation has affected life history parameters in Rogue River steelhead, thus contributing to observed differences from Illinois River winter steelhead.

Finally, with respect to these life history characteristics, Illinois River winter steelhead are similar to most other coastal steelhead populations from outside the Rogue River basin. Thus, the degree to which Illinois River winter steelhead are isolated from these other populations is unclear.

Summary

Available information does not make a strong case for reproductive isolation of Illinois River winter steelhead. Genetic data fail to show that Illinois River winter steelhead as a group are distinct from other coastal steelhead populations. Although this does not prove that Illinois River winter steelhead are not reproductively isolated, it does mean that evidence to support reproductive isolation must be found elsewhere. Other lines of information are largely inconclusive in this regard. Straying data for naturally spawning steelhead in the region are largely nonexistent. Geographic features such as the Illinois River Falls are potential isolating mechanisms, but evidence that they operate in this way is lacking. Although other explanations are possible, life history characteristics suggest some degree of reproductive isolation from Rogue River steelhead is likely. However, these same characteristics fail to show differences between Illinois River winter steelhead and other coastal steelhead populations.

Evolutionary Significance

Habitat Characteristics

Adaptations to environmental conditions such as elevated water temperature may contribute substantially to ecological/genetic diversity of species such as Pacific salmon and steelhead, which have a limited tolerance for water above about 18°C. Water temperatures in at least some sections of the Illinois River appear to be higher than are found in some nearby coastal streams. However, other coastal rivers (e.g., the Umpqua River) have temperature profiles similar to those in the Illinois River. Furthermore, in light of reports that steelhead from the Rogue River historically entered the lower Illinois River in temporary search of cooler water, present water temperatures in the Illinois River may not be a good indication of historical temperature patterns.

Phenotypic and Life History Traits

Many of the life history traits cited by the petitioners as evidence for reproductive isolation are also important to consider with respect to the contribution of Illinois River winter steelhead to ecological/genetic diversity of the species *O. mykiss*. For example, the half-pounder life history has a limited distribution and is considered unusual. Although it is not well understood why this life history is common in some steelhead populations, it appears to represent an evolutionary adaptation that may contribute substantially to ecological/genetic diversity of the biological species. In contrast to other Rogue River basin steelhead populations that have been studied, Illinois River winter steelhead lack this trait. It could be argued that this indicates ecological/genetic differentiation between steelhead from the Illinois and Rogue Rivers. However, in other drainages where half-pounders occur (e.g., the Klamath and Eel River drainages), it is not clear that all tributaries have half-pounder runs, so the Illinois River may not be unique in this respect. Furthermore, as half-pounders occur only in certain rivers in southern Oregon and northern California, Illinois River winter steelhead are similar to most other coastal steelhead populations in lacking this trait. Other life history traits identified by the petitioners show a similar pattern: Illinois River winter steelhead are somewhat different from Rogue River steelhead, but not distinctive in comparison with other coastal steelhead populations.

Genetic Data

It is generally presumed that genetic characters detected by protein electrophoresis are largely neutral with respect to natural selection and therefore do not provide direct evidence about important adaptations. Nevertheless, the occurrence of substantial genetic differences at neutral markers would suggest that there has been ample opportunity for selection to foster adaptive differences at other parts of the genome. Genetic data for Illinois River winter steelhead provide no evidence to suggest such adaptive differences.

Effects of Artificial Propagation

Although Illinois River winter steelhead are generally considered to be the best remaining example in Oregon of an indigenous, "wild" steelhead run, we found records of introductions of hatchery fish from outside the basin. Nevertheless, the hatchery releases were few and did not involve large numbers of fish. Furthermore, many of the releases involved early life history stages of steelhead whose survival rate was likely very low. Absent any information to the contrary, it is reasonable to assume that the permanent effects of these hatchery releases on population structure of Illinois River winter steelhead have been small.

The very limited scale data for Illinois River winter steelhead also are consistent with the theory that straying of hatchery fish into the Illinois River occurs at a low rate.

Summary

Several phenotypic and life history characteristics show modest differences between Illinois River winter steelhead and steelhead from the Rogue River. These differences suggest that either a) there are some genetic differences between steelhead from the two rivers, b) the natural environments of the two rivers differ in at least some respects, or c) artificial propagation has affected life history parameters of Rogue River steelhead, thus causing them to differ from Illinois River winter steelhead. In any case, in the larger context of coastal steelhead from southern Oregon and northern California, it is the Rogue River fish, rather than the Illinois River winter steelhead, that appear to be somewhat anomalous. That is, steelhead from the Illinois River appear to be somewhat distinctive in comparison to Rogue River steelhead, but not in comparison to other coastal steelhead populations.

Conclusions

At best there is weak evidence that Illinois River winter steelhead experience substantial reproductive isolation from other coastal steelhead populations. In several respects, Illinois River winter steelhead differ somewhat from Rogue River steelhead, but in these same characteristics, steelhead from the Illinois River are similar to most other coastal steelhead populations. We therefore conclude that although Illinois River winter steelhead may be locally distinctive within the Rogue River basin, they do not by themselves represent an evolutionarily significant unit of the biological species *Oncorhynchus mykiss*.

Because Illinois River winter steelhead are therefore not a "species" as defined by the ESA, the question of whether they should be listed as threatened or endangered under the Act need not be addressed. Nevertheless, steelhead from the Illinois River are undoubtedly part of a larger ESU whose boundaries remain to be determined. Whether the larger ESU that contains Illinois River winter steelhead would merit protection under the ESA cannot be determined until the nature and extent of the ESU are identified and additional information about patterns of abundance in coastal steelhead is compiled. This status review, therefore, should be viewed as the first step in a process to define the larger ESU and determine whether it qualifies for protection under the ESA.

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APPENDIX

Glossary

GLOSSARY

Ageing

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

Artificial Propagation

See hatchery.

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.

ESA

The U.S. Endangered Species Act.

ESU

Evolutionary Significant Unit; a "distinct" population, and hence a species, under the Endangered Species Act.

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).

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 brood stock 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.

Phenotype

The phenotype is the appearance of an organism resulting from the interaction of the genotype and the environment.

Punchcard

A card (alternatively called a tag or stamp) used by steelhead and salmon anglers to record catch information.

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*.

RECENT TECHNICAL MEMORANDUMS

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