

Orlay Johnson

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Status Review for Oregon's Umpqua River Sea-Run Cutthroat Trout

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CONTENTS

Summary	v
Acknowledgments	x
Introduction	1
Terminology	8
Key Questions in ESA Evaluations	9
The "Species" Question	9
Hatchery Fish and Natural Fish	10
Thresholds for Threatened or Endangered Status	11
Summary of Arguments Presented by the Petitioners	12
Reproductive Isolation	12
Philopatry	12
State Agency Designation	13
Geographic Isolation	13
Genetic Isolation	13
Ecological and Genetic Diversity	14
Population Trends	15
North Umpqua River	15
South Umpqua River	16
Summary of Environmental Information on the Umpqua River Basin	16
General Description of Basin	16
Climate and Precipitation	18
Hydrology and River Flows	18
River Water Temperature	20
Water Temperature Data from Steamboat Creek	20
Water Temperature Data from Winchester Dam	24
Barriers to Fish Passage	28
Summary of Environmental Factors	29
Summary of Biological Information on Coastal Cutthroat Trout	30
Life-History Forms of Coastal Cutthroat Trout	33
Sea-Run or Anadromous <i>O. c. clarki</i>	33
Nonmigratory or Resident <i>O. c. clarki</i>	34
Resident fish in the Umpqua River Basin	34
River-Migrating or Potamodromous <i>O. c. clarki</i>	36
Potamodromous fish in the Umpqua River Basin	40
Life History of Coastal Cutthroat Trout	42
Early Life History	42
Parr Movements	43
Smoltification	43
Timing of smolt migrations in the Umpqua River	44
Estuary and Ocean Migration	45
Ocean migrations by Umpqua River cutthroat trout	46

Adult Freshwater Migrations	47
Run-Timing in the Umpqua River Basin	48
Straying	49
Spawning	50
Spawning sites in the Umpqua River Basin	51
Interactions of Cutthroat Trout with Other Salmonids	52
Temperature Tolerance in Cutthroat Trout	56
Genetics	58
Future Genetic Studies	62
Genetic Relationship of Life-History Forms	62
Genetic Studies on Life-History Forms in Other Species	63
Arctic char	64
Brown trout	65
Brook trout	66
Atlantic salmon	67
Sockeye salmon	67
Steelhead/rainbow trout	69
Sex Ratios of Different Salmonid Life-History Forms	69
Hatchery Releases in Umpqua River Basin	70
Hatchery Releases in the North Umpqua River	71
Return-timing of hatchery and natural adults	74
Hatchery Releases in the Lower Umpqua River	75
Hybridization Between Cutthroat and Rainbow Trout	77
Releases of Hatchery Rainbow Trout in the Umpqua River	80
Population Trends	82
Sea-Run Cutthroat Trout	82
Resident and Potamodromous Cutthroat Trout	84
Discussion	85
Reproductive Isolation	85
Relationship Between Different Life-History Forms	85
Reproductive Isolation of Umpqua River <i>O. clarki</i>	88
Ecological and Genetic Diversity	89
Physical and Environmental Features of the	
Umpqua River Basin	89
Distance of Freshwater Migration	90
Run Times and Water Temperatures	91
Effects of Artificial Propagation	93
The Threshold Question	95
Conclusions	97
Prospects for Additional Information	100
Citations	101
Glossary	118

SUMMARY

A petition to list sea-run cutthroat trout (*Oncorhynchus clarki clarki*) from the North and South Umpqua Rivers in Oregon as a threatened or endangered species under the Endangered Species Act (ESA) was received in April 1993 by the National Marine Fisheries Service (NMFS). This report summarizes biological information gathered in conjunction with the status review of these cutthroat trout. The review focused on two key questions: Do Umpqua River sea-run cutthroat trout 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 is that a population will be considered a species 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 first issue addressed was the relationship between anadromous (sea-run) and nonanadromous resident and potamodromous (river-migrating) life-history forms in the Umpqua River. Based on studies of life-history traits in

cutthroat trout and other salmonid species, we concluded that, at least until better information is developed, anadromous cutthroat trout should be considered in the same ESU as resident and potamodromous *O. c. clarki*.

We then addressed the issue of whether all life-history forms of Umpqua River *O. clarki* were reproductively isolated from *O. clarki* stocks in other coastal drainages. Because sea-run cutthroat trout in the Umpqua River have not been the focus of rigorous scientific inquiries, no genetic or tagging data were identified that are directly relevant to this issue. However, the preponderance of secondary information suggested that *O. clarki* as a group in the Umpqua River probably satisfy the ESU criterion of substantial reproductive isolation from other conspecific populations. Information evaluated in this context included genetic studies on anadromous cutthroat trout from Puget Sound and the Oregon coast, locations of possible anadromous *O. clarki* spawning sites in the Umpqua River Basin, and the possibility that the lower part of the mainstem Umpqua River is too warm for cutthroat trout during much of the summer and may be an isolating mechanism.

Factors considered for the second ESU criterion regarding ecological/genetic diversity include distinctive physical and environmental features of the Umpqua River drainage, lengthy freshwater migration for the anadromous form, distinctive run times of sea-run fish, and possible adaptations for dealing with high water-temperatures. The Umpqua River Basin has a variety of distinctive features, including one of the largest coastal basins in Oregon and headwaters that begin

farther inland and at a higher elevation than most other Oregon coastal rivers. Further, anadromous cutthroat trout that spawn in the upper tributaries of the North and South Umpqua Rivers would migrate farther inland (240 to 280 km) than do cutthroat trout from most other rivers in North America.

However, other factors relating to ecological/genetic diversity were more difficult to evaluate because of the lack of information on *O. clarki* in the Umpqua River Basin. Historically, Umpqua River sea-run cutthroat trout apparently had a bimodal run-timing, with both peaks occurring slightly earlier than in other streams that have been studied. However, from 1961 to 1976, large numbers of sea-run cutthroat trout from the Alsea River hatchery were released below Winchester Dam on the North Umpqua River. During this time, there was a dramatic increase in numbers of adult cutthroat trout passing Winchester Dam. Alsea River fish have a slightly later run-timing than the Umpqua River fish, and a statistically significant shift toward later run-timing could be detected in fish that returned to Winchester Dam during this period of supplementation. After supplementation was stopped, there was a significant shift back toward the original run-timing, although the later (October) peak of the run virtually disappeared.

Although the pattern of abundance and tag/recovery data during the period of supplementation indicated that Alsea River hatchery fish returned as adults to Winchester Dam in some numbers, it is apparent that 15 years of hatchery releases did not result in a viable, self-sustaining population of naturally

spawning fish. The unresolved issue is, What do the few remaining anadromous *O. clarki* represent: remnants of the original Umpqua River gene pool, descendants of the Alsea River hatchery fish, or a mixed lineage? The run-timing shift suggested that an indigenous component may remain.

The precarious status of the remaining sea-run fish in the Umpqua River is well documented in this review, but evidence is inconclusive as to the evolutionary heritage of these fish. Furthermore, we have concluded that resident and potamodromous fish should also be considered part of the ESU, but data on river-migrating fish within the Umpqua River are very limited, and the total information we were able to develop on abundance of resident *O. clarki* in the Umpqua River drainage amounted to a list of lakes and tributaries believed to contain cutthroat trout. However, even if the nonanadromous forms were determined to be healthy, risk of loss of the anadromous form still would be an ESA concern if the trait has a genetic basis and it contributes substantially to ecological/genetic diversity. Thus, after considering all available information, we concluded that there were two general approaches to the listing decision, given the available scientific information:

- 1) Since nonanadromous *O. c. clarki* are included in the ESU, the petition could be denied because the petitioned entities (North and South Umpqua River sea-run cutthroat trout) are not by themselves ESA "species." This, however, would not be a resolution of the issue.

2) A proposal to list could be based on the precarious status of sea-run cutthroat trout in the North Umpqua River. This would require taking a conservative approach, similar to the one used with Redfish Lake sockeye salmon, to each of the three major unresolved issues: the geographic boundaries of the ESU, the heritage of the remaining sea-run cutthroat trout, and the abundance and population trends of the resident and potamodromous fish. A framework for doing this would presumably involve the following assumptions:

- 1) All life-history forms of *O. clarki* in the Umpqua River Basin are a single ESU distinct from other coastal populations.
- 2) This ESU represents the evolutionary legacy of the historical *O. clarki* population prior to the releases of Alsea River hatchery fish.
- 3) All life-history forms of *O. clarki* in the Umpqua River Basin have experienced extensive declines in abundance such that they are presently threatened or in danger of extinction; or alternatively, although there is little information regarding the abundance of nonanadromous *O. clarki* in the basin, the depressed sea-run component of the population is a substantial and important component of the ESU and its loss would compromise the distinctness and viability of the inclusive ESU.

ACKNOWLEDGMENTS

The status review for the Umpqua River sea-run cutthroat trout was conducted by a team from the Northwest Fisheries Science Center. The biological review team relied on an ESA record developed pursuant to this review and comprised of comments and research reports submitted by the public and by state and federal agencies. Special acknowledgment is extended to the Oregon Department of Fish and Wildlife (ODFW) and the U.S. Forest Service, who supplied the review team with a large number of required publications.

The review team also acknowledges the assistance of personnel from ODFW's Roseburg District Office, from the U.S. Forest Service's Umpqua National Forest Office, from the Bureau of Land Management's Roseburg Office, and from the Washington Department of Fisheries and Wildlife's Olympia, Bellingham, and Port Townsend offices in securing documents and scientific information. Garth Griffin of the NMFS Northwest Region in Portland provided invaluable assistance in facilitating information exchange. Special appreciation is due to Patrick Trotter for assistance in data collection and to Jeffrey Hard for analysis of run-timing data.

Members of the biological review team were Peggy Busby, David Damkaer, Robert Emmett, Stephen Grabowski, Orlay Johnson, Conrad Mahnken, Gene Matthews, Michael Schiewe, Thomas Wainwright, William Waknitz, Robin Waples, Laurie Weitkamp, John Williams, and Gary Winans.

INTRODUCTION

Sea-run cutthroat trout is the common name for the anadromous life-history form of coastal cutthroat trout (*Oncorhynchus clarki clarki*). The subspecies is found in the coastal temperate rainforests of western North America from southeast Alaska to northern California (Trotter 1989) (Fig. 1). Coastal cutthroat trout belong to the same genus as Pacific salmon and steelhead, but they are generally a smaller fish, rarely overwinter in the sea, and do not usually make long ocean migrations. Like steelhead, but unlike other Pacific salmon, cutthroat trout are iteroparous rather than semelparous, and adult cutthroat trout have been known to spawn each year for over 6 years.

The life history of coastal cutthroat trout may be the most diverse and flexible of any *Oncorhynchus* species. They have adapted to a wide variety of climatological conditions, a diversity of marine and freshwater habitats, and competition with other salmonids for food and space. Populations often show differences in size and age at migration, timing of migrations, age at maturity, and frequency of repeat spawning. Although all coastal cutthroat trout populations with access to the sea are believed to have an anadromous component, not all members of the subspecies migrate to the sea (Trotter 1989, P. Trotter¹). Some cutthroat trout simply remain in headwater tributaries, while others migrate only within rivers or lakes.

¹ P. Trotter, Fishery Science Consultant, 4926 26th Ave. S., Seattle, WA 98108. Pers. commun., July 1993.

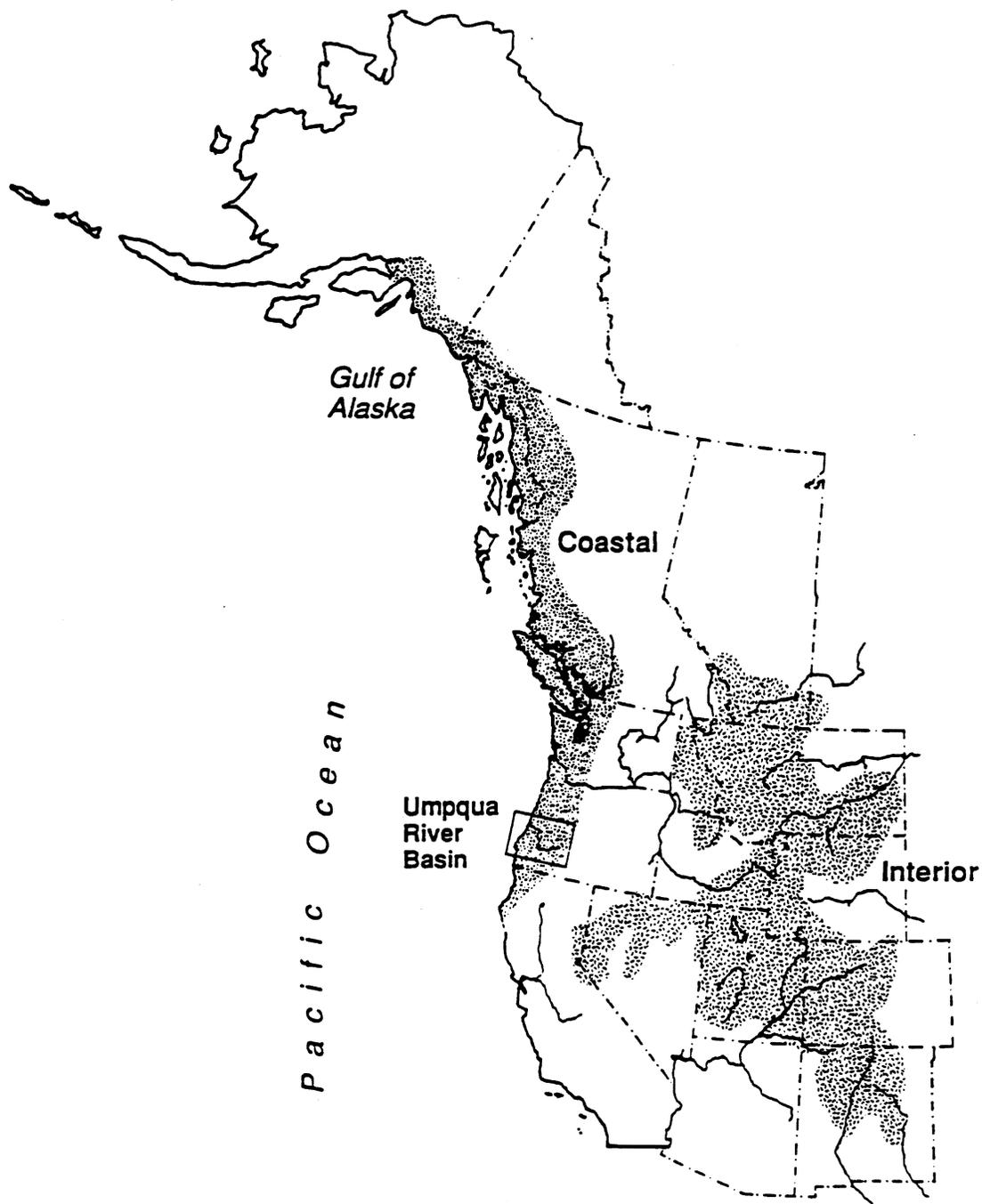


Figure 1. Range of coastal cutthroat trout (*Oncorhynchus clarki clarki*) (shading on coast) and of 13 interior subspecies (*O. c. subsp.*) (shading inland) identified in Table 2. Framed area represents Umpqua River Basin depicted in Figure 2.

Because coastal cutthroat trout have not been as intensely studied as Pacific salmon and steelhead, and because anadromous cutthroat trout in the Umpqua River are depauperate, very little biological information is available on Umpqua River cutthroat trout life history. A description of cutthroat trout in the Umpqua River by the Oregon State Fish Commission in 1946 (FCO and OSGC 1946, p. 25) is still apt:

Very little is yet known about these fish and they have been rightly called the "problem children" of the State Game Commission.... Since insufficient information has been accumulated to justify making recommendations, no changes are suggested....

This response was reflected by many state and federal resource agencies across the range of cutthroat trout. The attitude toward cutthroat trout ranged from benign neglect to outright exterminations (Behnke 1981). Perhaps most destructive was the widespread release of hatchery rainbow trout (*O. mykiss*) throughout the native range of interior cutthroat trout. The two species hybridize, to the extreme detriment of *O. clarki*, and it has been estimated that "just within the last century perhaps 99 percent of the unique cutthroat strains of interior drainages have been lost forever" (Willers 1991, p. 10). "In less than 100 years after the first [United States] settlements in the West, the cutthroat trout vanished from most of its vast range..." (Behnke 1988, p. 1). Today, of 16 recognized subspecies of cutthroat trout, 2 are extinct and 12 are given protected status by individual states; 8 of the latter are listed under the U.S. Endangered Species Act (ESA) (Behnke 1979, Johnson 1987, Allendorf and Leary 1988).

Coastal cutthroat trout are considered the healthiest of the subspecies of cutthroat trout and, across their range, have experienced the least habitat destruction, hybridization with introduced species, or overfishing pressures (reviewed in Pauley et al. 1989, Trotter 1989, Trotter et al. 1993). Still, the Endangered Species Committee of the American Fisheries Society (AFS) identified all populations of anadromous cutthroat trout as being at some risk of extinction, and coastal cutthroat trout from all Oregon streams as being at moderate risk of extinction (Nehlsen et al. 1991, Trotter et al. 1993). Sea-run cutthroat trout populations from Hood River in Oregon and from the Wind and Klickitat Rivers in Washington were identified as extinct.

A serious impediment to the conservation and management of coastal cutthroat trout is that little information is available on population sizes or trends. Across the range of *O. c. clarki* there is only one location where long-term counts of migrating adult sea-run cutthroat trout have been made--at Winchester Dam on the North Umpqua River near Roseburg, Oregon (Table 1, Fig. 2). Counts of anadromous salmonids have been made since 1946, and they revealed a dramatic decline in cutthroat trout in the late 1950s (Fig. 3). In fact, more sea-run cutthroat trout (1,138) were counted passing Winchester Dam in 1946 than have passed the dam in the last 15 years (less than 825; Loomis et al. 1993). In the winter of 1992-93, no sea-run cutthroat trout were counted passing the dam, and only 29 were counted in the winter of 1993-94.

Table 1. Numbers of returning adult anadromous cutthroat trout passing Winchester Dam on the North Umpqua River from 1946 to 1993, and releases of Alsea River hatchery cutthroat trout immediately below Winchester Dam from 1961 to 1976, in Smith River from 1975 to 1993, and in Scholfield Creek from 1982 to 1993 (Loomis et al. 1993). For locations, see Figure 2.

Year	Number of smolts released below Winchester Dam	Number of smolts released in Smith River	Number of smolts released in Scholfield Creek	Number of returning adults
1946	-	-	-	1,138
1947	-	-	-	974
1948	-	-	-	437
1949	-	-	-	439
1950	-	-	-	664
1951	-	-	-	1,508
1952	-	-	-	761
1953	-	-	-	1,838
1954	-	-	-	706
1955	-	-	-	960
1956	-	-	-	982
1957	-	-	-	87
1958	-	-	-	108
1959	-	-	-	48
1960	-	-	-	106
1961	5,000	-	-	306
1962	10,000	-	-	308
1963	10,000	-	-	142
1964	10,000	-	-	420
1965	20,000	-	-	796
1966	20,000	-	-	2,364
1967	20,000	-	-	2,200
1968	20,000	-	-	1,031
1969	20,000	-	-	942
1970	19,000	-	-	1,880
1971	20,000	-	-	289
1972	19,000	-	-	1,094
1973	20,000	-	-	1,712
1974	20,000	-	-	622
1975	17,000	9,900	-	427
1976	9,000	7,500	-	544
1977	-	10,000	-	123
1978	-	15,100	-	104
1979	-	11,100	-	25
1980	-	12,700	-	74
1981	-	20,100	-	86
1982	-	19,100	2,600	156
1983	-	9,100	2,700	43
1984	-	15,800	4,500	104
1985	-	15,800	4,500	88
1986	-	1,200	4,000	53
1987	-	8,100	8,000	35
1988	-	11,900	4,000	47
1989	-	12,000	4,000	38
1990	-	12,000	4,000	34
1991	-	12,000	4,000	10
1992	-	12,000	4,000	0
1993	-	12,000	4,000	29

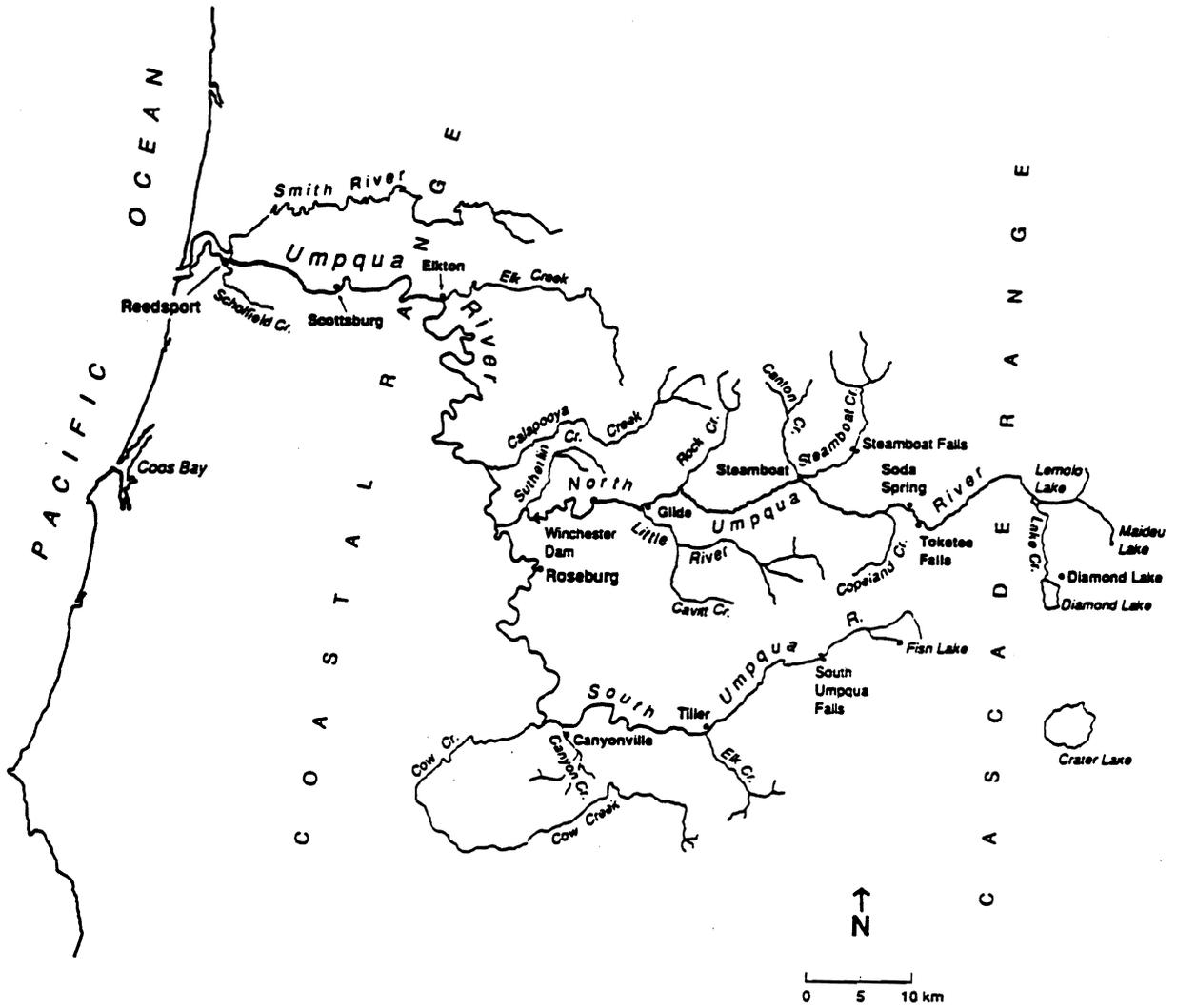


Figure 2. Location map of the Umpqua River Basin on the Oregon coast (see also Figure 1).

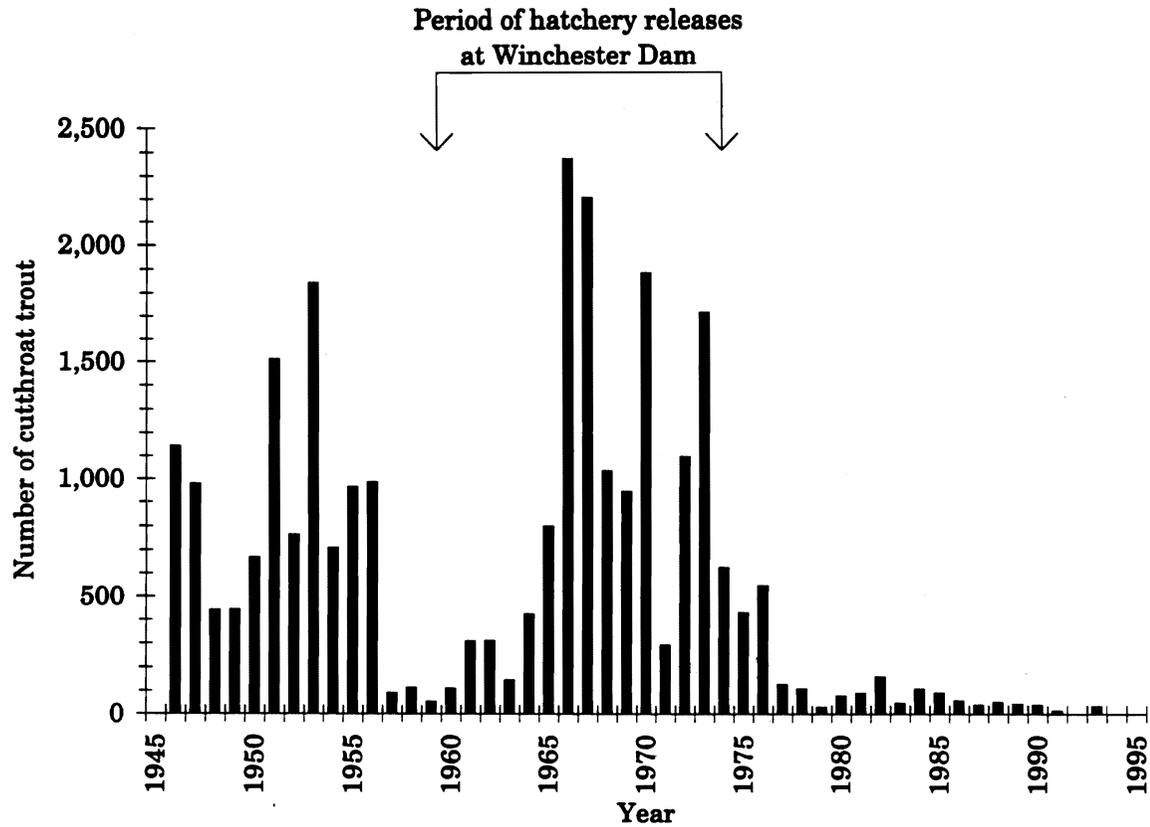


Figure 3. Yearly counts of cutthroat trout passing Winchester Dam on the North Umpqua River from 1946 to 1993 (Loomis et al. 1993). Also River hatchery cutthroat trout were released into the North Umpqua River Basin immediately below Winchester Dam from 1961 to 1976.

In response to this information and indications from a report of the AFS Endangered Species Committee (Nehlsen et al. 1991) that coastal cutthroat trout populations throughout their range may also be experiencing a severe decline, the Oregon Natural Resources Council, the Wilderness Society, and the Umpqua Valley Audubon Society (ONRC et al. 1993) petitioned the National Marine Fisheries Service (NMFS) to list the North and South Umpqua River sea-run cutthroat trout as a threatened or endangered species under the ESA. This report summarizes a review of the status of these fish conducted by the biological review team of NMFS Northwest Fisheries Science Center.

Terminology

A difficulty in conducting a status review on a species that has received little scientific attention is that historical surveys, reports, or other scientific documents often do not differentiate sea-run cutthroat trout from other species of salmonids (especially steelhead, the sea-run form of *O. mykiss*), or else refer to them with a variety of confusing local names. In the literature, sea-run cutthroat trout have been most often referred to as sea-run trout, but they have also been called harvest trout, blueback, salmon trout (Roth 1937), steelhead cutthroat (Shultz 1936), and sea trout (Clemens and Wilby 1946). The freshwater or resident form of the subspecies has often been simply identified as trout, but also as native, mountain, speckled, or brook trout (Behnke 1972b, 1992).

In this document, we will refer to the entire subspecies (all life-history forms) as coastal cutthroat trout or cutthroat trout, but when discussing only the anadromous form, we will use the term "sea-run" or "anadromous" cutthroat trout.

KEY QUESTIONS IN ESA EVALUATIONS

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

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

The "Species" Question

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. However, the ESA provided no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity led to the use of a variety of criteria in listing decisions over the past decade. To clarify the issue for Pacific salmon, NMFS published a policy describing how the agency will apply the definition of "species" in the ESA to anadromous salmonid species, including sea-run cutthroat trout and steelhead (NMFS 1991b). A more detailed description of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991). The NMFS policy stipulates that a salmon population (or group of populations) will be considered "distinct" for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species. An ESU is defined as a population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component in the evolutionary legacy of the species. Information that can be useful in determining the degree of reproductive isolation 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 genetic and life-history characteristics, habitat differences, and the effects of stock transfers or supplementation efforts.

Hatchery Fish and Natural Fish

Because artificial propagation of Pacific salmonids has been widespread for many years, the influence of hatchery fish needs to be considered in most ESA status reviews. NMFS policy stipulates that in determining whether a population is distinct for purposes of the ESA, attention should focus on "natural" fish, which are defined as the progeny of naturally spawning fish (Waples 1991). This approach directs attention to fish that spend their entire life cycle in natural habitat and is consistent with the mandate of the ESA to conserve threatened and endangered species in their native ecosystems. Implicit in this approach is the recognition that fish hatcheries are not a substitute for natural ecosystems.

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

Thresholds for Threatened or Endangered Status

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. An information document on this topic (Thompson 1991) has been published by NMFS. There is considerable interest in incorporating the concepts of population viability analysis (PVA) into ESA threshold considerations for Pacific salmon. However, available PVA models generally require substantial life-history information that is not available for most Pacific salmon populations.

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

SUMMARY OF ARGUMENTS PRESENTED BY THE PETITIONERS

This section summarizes arguments made by the petitioners (ONRC et al. 1993) to support a designation of the Umpqua River sea-run cutthroat trout as a threatened or endangered species under the ESA. Organization of this section, and references to the criteria of Reproductive Isolation, Ecological and Genetic Diversity, and Population Trends, follows that of the petition. The information relevant to these criteria is discussed in the following sections of this status review. Finally, in the Discussion and Conclusions sections, we will evaluate this information as it pertains to the identification and population trends of one or more ESUs for cutthroat trout in the Umpqua River Basin.

Reproductive Isolation

Philopatry

The petitioners (ONRC et al. 1993, p. 2) argue that "homing ensures that sea-run cutthroat, which reproduce in the North and South Umpqua River, maintain their genetic integrity distinct from sea-run cutthroat that home to other rivers (e.g., Smith River, Siltcoos River, etc.)." In support of the above argument, the petitioners cite a report by Percy et al. (1990) and a personal communication from W. Percy to R. Nawa which states: "A sea-run cutthroat tagged at sea was later captured near Elkton...in the Umpqua River, 290 km south of the tagging location" (ONRC et al. 1993, p. 2, footnote 9).

State Agency Designation

The petitioners also argue (ONRC et al. 1993, p. 2) that because "Nehlsen et al. [1991] state that individual fish stocks defined by Ricker (1972) could qualify for protection under the ESA" and that the petitioned stocks are recognized and managed as distinct population segments by Oregon Department of Fish and Wildlife (ODFW) (Chilcote et al. 1992), "therefore North Umpqua and South Umpqua sea-run cutthroat must qualify as a "species" under the Endangered Species Act."

Geographic Isolation

The petitioners (ONRC et al. 1993) argue that upper Umpqua River Basin sea-run *O. clarki* are isolated because in both the North and South Umpqua Rivers, they spawn over 265 km from their nearest sea-run cutthroat trout neighbor (in the Smith River) and 240 km from the ocean. The petitioners document these locations (Steamboat Creek and Canton Creek drainages) where sea-run cutthroat trout spawn in the North Umpqua River from historic accounts and local sources. In the South Umpqua River, the presence of cutthroat trout spawning locations is based "on observations by Forest Service biologist Jeff Dose, [that] some sea-run cutthroat in the South Umpqua River probably spawn in tributaries above South Umpqua Falls" (ONRC et al. 1993, p. 3).

Genetic Isolation

The petitioners argue that electrophoretic studies on sea-run cutthroat trout from Puget Sound suggest that the subspecies may be divided into small

geographically clustered populations, "of which the upper Umpqua stocks could comprise at least one" (ONRC et al. 1993, p. 4).

Ecological and Genetic Diversity

The petitioners argue that sea-run *O. c. clarki* in the upper Umpqua River Basin represent substantial ecological and genetic importance to the species (*O. clarki*) as a whole because 1) upper Umpqua River Basin cutthroat trout migrate farther inland (240 to 280 km) than any other cutthroat trout; 2) they display a unique timing of adult migration due to high summer temperatures which block upstream passage at certain times of the year; 3) they have unique physiological adaptations to withstand the high summer temperatures in the river; 4) they are anadromous and can "re-colonize streams where local extinctions may have occurred," 5) they "have a competitive advantage through large body size and increased fecundity"; 6) they inhabit "a unique geographic location" in relation to the biological species distribution; and 7) they are part of a subspecies which is declining across its range (Gerstung 1981, Trotter 1989).

In relation to the last two points, the petitioners argue that ecological and genetic diversity has a "contextual aspect." They contend that although an imperiled fish stock from an otherwise healthy population may not represent a substantial portion of that species' ecological and genetic diversity, the same stock in a population that is broadly declining across its range may be representative. Since sea-run *O. clarki* are considered to be at some risk of extinction across their range, the petitioners argue that sea-run cutthroat trout in the Umpqua River Basin meet this last criterion to be considered a species under the ESA.

Population Trends

North Umpqua River

The petitioners contend that sea-run cutthroat trout in the Umpqua River suffered a severe decline in numbers in the 1950s and that the population has been unable to recover due to habitat degradation (ONRC et al. 1993). The petitioners cite counts of cutthroat trout passing Winchester Dam near Roseburg, Oregon as evidence for the decline in numbers of fish. The data, collected from 1946 to 1992, show that hundreds of cutthroat trout passed the dam each year from 1946 to 1956, but the numbers dropped to only 87 fish in 1957 and remained low until hatchery supplementation began in 1961. Following the end of hatchery supplementation, the number of cutthroat trout in the river dropped to presupplementation levels and has continued at this level ever since. In 1991-92, only 10 cutthroat trout were counted at the dam and none were counted in 1992-93 (ONRC et al. 1993).

The petitioners argue that although approximately 20,000 hatchery smolts of Alsea River origin were stocked into the North Umpqua River each year from 1961 to 1976, these fish were not adapted to the Umpqua River and did not contribute to the "wild population" (ONRC et al. 1993, p. 5). The petitioners believe "the prompt decline in the run when stocking ceased is evidence that Alsea hatchery stock failed to interbreed successfully, and the low but persistent return since then represents the original adapted native stock" (ONRC et al. 1993, p. 6).

South Umpqua River

The petitioners state that there are no counts of sea-run cutthroat trout in the South Umpqua River, but believe "one can reasonably infer that South Umpqua sea-run cutthroat have experienced declines similar to those recorded in the North Umpqua River and are presently at a very low level" (ONRC et al. 1993, p. 6). In support of this statement, they quote a U.S. Forest Service (USFS) report that "a very small, wild, sea-run cutthroat trout population probably exists in the South Umpqua system" and that this run was once "widespread" and "dramatically larger than at present" (USDA 1992, p. 25). The petitioners also footnote a personal communication stating that "Jeff Dose (Umpqua National Forest fish biologist) has observed sea-run cutthroat trout in the South Umpqua River above South Umpqua Falls" (ONRC et al. 1993, p. 6 footnote 34).

SUMMARY OF ENVIRONMENTAL INFORMATION ON THE UMPQUA RIVER BASIN

General Description of Basin

The greater Umpqua River Basin is located in Douglas County in southwestern Oregon and stretches from the Cascade Mountain crest to the Pacific Ocean at Reedsport, Oregon (Fig. 2). The spawning sites of the petitioned cutthroat trout populations are in the North and South Umpqua Rivers and their tributaries, which combine to form the mainstem Umpqua River about 11 km northwest of Roseburg, Oregon. The drainages of the North and South Umpqua Rivers together make up about two-thirds of the greater basin drainage, and each river is about 170 km long. The mainstem Umpqua River flows in a northwesterly

direction another 180 km to the ocean. Together, the three rivers form one of the longest coastal basins in Oregon, approximately 340 km in length, with a drainage area of over 12,200 km². Major tributaries of the mainstem Umpqua River include Calapooya (River Kilometer [RKm] 164), Elk (RKm 78), and Scholfield Creeks (RKm 18) and the Smith River (RKm 18). The estuary of the Umpqua River is one of largest on the Oregon coast and has a large seawater wedge that extends as far inland as Scottsburg, Oregon at RKm 45.

The North Umpqua River has long been known for its rugged terrain, world class trout fishing, and poetic inclinations:

The Umpqua is a quality of spirit. Its shining length is scarred with lava ledges and outcroppings, its folded bedrock and igneous serrations polished by centuries of snowmelt and spates. Its gorge is still cloaked in forest, their vaulted choirs of spruce and sugar pine and fir softly carpeted with moss and fiddlebacks and pine needles. The forests are mirrored in the emerald pools, all stillness and shadows, with the hush of Mont Saint-Michel or Chartes (Schwiebert 1979).

What makes these "emerald pools" possible is that the North Umpqua River, almost alone among the coastal rivers of Oregon, begins and remains for a portion of its length high enough in the Cascade Mountains that its snowpack usually lasts until summer. This snowpack melts into porous soils and sustains a strong summer water flow. The headwaters of the North Umpqua River are located at an elevation of over 1,830 m on the slopes of the High Cascade Mountain Range near Maidu Lake. The river is separated from the headwaters of the Willamette River by the Calapooya Mountains. The South Umpqua River also begins at an elevation of around 1,830 m on the slopes of the Rogue River

Mountain Range, but quickly descends (Hayes and Herring 1960; USDA 1990, USDA and BLM 1992). Only 3% of the South Umpqua River watershed lies above 1,700 m, but over 20% of the North Umpqua River watershed exceeds this elevation (Hayes and Herring 1960).

Climate and Precipitation

The Umpqua River Basin is characterized by a temperate, maritime climate with wet, mild winters and moderately dry, warm summers (28°C July mean temperature) (Hayes and Herring 1960, Lauman et al. 1972). Because the river begins at high elevations in the Cascade Mountains, it receives more precipitation and a heavier snowpack than lower headwater elevation coastal rivers. Most precipitation falls in the winter (90% of the precipitation that falls at the Steamboat Creek weather station falls outside the June through September dry period) and varies from around 76 cm to over 100 cm per year in the different regions of the basin (Hayes and Herring 1960; Lauman et al. 1972; USDA 1990, USDA and BLM 1992).

Hydrology and River Flows

Both the North and South Umpqua Rivers have a rugged topography with steep canyons and rapid elevation changes, and both have been heavily influenced by volcanic activity. In the upper North Umpqua River, above Soda Spring Dam (RKm 109) and along nearby Copeland Creek, deep pumice soils absorb snowmelt and rain. Shallower and more rocky soils, which characterize the North Umpqua River below Soda Spring, and the South Umpqua River, release runoff quickly.

Consequently, winter runoff in the upper North Umpqua River is low (maximum flow at Copeland Creek is primarily caused by snowmelt and does not occur until May), but it is at a maximum downstream and in the South Umpqua River. High winter runoff results in scouring and flash winter floods, like those in 1955 and 1964, which occurred when warm rains and condensation melted a deep snowpack (Hayes and Herring 1960; Lauman et al. 1972; USDA 1990, USDA and BLM 1992).

There is little rain June to October in southern-central Oregon, and most regional streams barely flow during those months; because of the snowmelt stored in deep pumice and other volcanic soils, water flow in the upper North Umpqua River remains relatively constant, with deep, swift, and cold water. Downstream in the North Umpqua River, and even more so in the South Umpqua River, the flow is erratic, with shallower, slower moving, and warmer water. The importance of the snowmelt stored in deep pumice and other volcanic soils of the North Umpqua River can be seen in that the drainage area feeding the North Umpqua River at the stream gauge above Copeland Creek is the same size as the South Umpqua River drainage above Tiller (1,230 km²), but summer flow on the North Umpqua River is *20 times* that of the South Umpqua River (Hayes and Herring 1960).

In recent years, another factor has slowed the reduction of flow during summer in the North Umpqua River. Presently, the entire summer flow of the upper North Umpqua River goes through Pacific Power and Light's (PP&L) Soda Springs powerhouse below Soda Spring Dam; PP&L policy limits river fluctuation

to approximately 50 cfs change per hour when the river is flowing above 1,000 cfs in summer (USDA and BLM 1992).

River Water Temperature

The North Umpqua River in the late 1940s and 1950s was described by Hayes and Herring (1960, p. 10) as a "cold, typically clear stream." By the late 1960s, the Oregon State Game Commission (Lauman et al. 1972) found that water temperatures over 21°C commonly accompanied low summer flows; miscellaneous maximum water temperatures from the Umpqua River Basin were reported as 27.8°C on the Umpqua River near Elkton, 34.4°C on the South Umpqua River near Winston, 26.1°C at Rkm 2.9 on the North Umpqua River, and 25.7°C on Steamboat Creek near its confluence with the North Umpqua River.

Long-term water temperature data are available from the upper North Umpqua River in Steamboat Creek Basin (from 1969) and from the lower river at Winchester Dam (from 1946). The data from Steamboat Creek have been extensively analyzed and modeled by Hostetler (1991) and Holaday (1992), primarily to evaluate the effects of forestry management practices on stream temperatures. Dambacher (1991) evaluated the effect habitat changes in the Steamboat Creek Basin had on steelhead abundance and distribution.

Water Temperature Data from Steamboat Creek

The impetus for the analysis by Hostetler (1991) and Holaday (1992) of the Steamboat Creek Basin data was to evaluate the effects of extensive clear-cut logging on stream temperature and water quality. Major timber harvests in the

North Umpqua River watershed began in 1955 (USFS statistics as referenced in Hostetler 1991), and by 1990, 34% of the North Umpqua River Basin had been harvested (over 14,000 ha in Steamboat Creek Basin) (Hostetler 1991, Holaday 1992). During much of this time, clear-cut logging was standard forest management policy, stream channels had often served as skid roads for log transport (Clare and Marston 1968 as cited in Dambacher 1991), and all riparian vegetation and woody debris was removed from stream channels and adjacent areas. Attempts to repair or prevent riparian degradation, such as leaving uncut forest buffer strips adjacent to streams, and supplementation of large woody debris in streams, have been instituted since the mid-1970s.

Although data are lacking on stream temperatures prior to extensive logging in the basin, post-logging increases in water temperature in the North Umpqua River Basin were identified in 1969 by Brown et al. (1971). They found substantial increases in stream temperatures (over 8°C in a 1,280 m distance of Cedar Creek) by measuring areas above and below clearcuts. A variety of studies (reviewed in Meehan 1991) have reported that stream temperatures increase in a forest after clear-cut logging. Maximum temperatures are observed several years after the logging has occurred, followed by gradual recovery and decreasing stream temperatures as forest canopies and riparian vegetation regrow.

In 1969, after most clear-cut logging in riparian areas of the basin had ended (Hostetler 1991), the USFS placed temperature recording devices at several locations in Steamboat Creek Basin. These devices provide a 20-year record of stream temperatures during recovery from riparian logging in the basin.

Hostetler used a time-series to model components of this stream temperature decline over the period from 1969 to 1989. He found a significantly decreasing temperature trend in all streams and reaches affected by logging. Streams unaffected by logging did not have a significant temperature trend. He also found that since the mid-1980s, some stream temperatures had increased in the upper and lower reaches of Steamboat Creek, although air temperature had not. Overall, Hostetler concluded that streams affected by pre-1969 logging were still recovering from elevated stream temperatures caused by loss of riparian vegetation and shading canopies. Hostetler cautioned that although he found stream temperatures had generally decreased, most streams were still near the upper limit of tolerance for juvenile steelhead.

Holaday (1992) also evaluated stream temperatures from 1969 to 1990 and found that maximum daily stream temperatures in lower Steamboat Creek did not change significantly during the time period. He further compared these results with stream temperature readings taken in 1960 from an area not previously clear-cut. The results from this analysis suggested to Holaday that historical maximum stream temperatures in lower Steamboat Creek may have been high.

In 1987 and 1988, the direct effects of stream habitat changes on distribution, abundance, and movement of juvenile steelhead in Steamboat Creek Basin were evaluated by Dambacher (1991). He found 5-day mean maximum summer temperatures in tributaries ranged from 10° to over 20°C, while Steamboat Creek mainstem temperatures ranged from 13° to over 27°C. All

mainstem temperatures exceeded the preferred temperatures (13°C) for steelhead and even exceeded the lethal limit (24°C) for days at a time.

Dambacher (1991) suggested that steelhead and cutthroat trout were able to survive in these warm waters by moving to lower-temperature refugia. He found that when tributaries containing cooler water (such as Big Bend Creek or Canton Creek) entered the river mainstem, water temperatures in the mainstem were reduced by as much as 3°C. He also found distinct diurnal water temperature regimes in the basin, where daily minimum temperatures were as much as 5°C lower than maximum temperatures. Fish would remain at the confluence of cooler temperature tributaries during the day and move upstream at night during minimum river temperatures.

Dambacher (1991) also analyzed the water temperature data collected from 1969 to 1989 at USFS temperature monitoring sites in Steamboat Creek. He found that although there was a decreasing trend in the mean 10-day maximum summer water temperatures in Steamboat Creek Basin, the water temperature still consistently exceeded 14°C in the tributaries and almost 20°C in the mainstem. Although data were not available for every year from every monitoring site, Dambacher found that in 12 of the 19 years reported, mainstem temperatures above Canton Creek exceeded the lethal limit for steelhead. Dambacher concluded that the decreasing trend he observed represented a cumulative response from recovery of multiple clear-cut sites upstream from the temperature monitoring stations. Further, he believed that the "single most important factor limiting juvenile steelhead production in the Steamboat Creek Basin is high summer water

temperature" (Dambacher 1991, p. 98). River-migrating or sea-run cutthroat trout would have to pass through the Steamboat Creek drainage or other basins with similar forestry management regimes (Dambacher 1991, Holaday 1992) to reach spawning areas in upper tributaries of the North Umpqua River. Further, cutthroat trout apparently are less tolerant of high water-temperatures and experience a lower lethal limit than steelhead (Golden 1975, Bell 1986).

Water Temperature Data from Winchester Dam

Long-term (1946-93) bimonthly water temperature data are available from Winchester Dam (Loomis and Anglin 1992, Loomis et al. 1993, ODFW 1993a, D. Loomis²). The petitioners (ONRC et al. 1993) and others (ODFW 1993a) have suggested that warm water in the North Umpqua River may have resulted in local adaptation of cutthroat to high water-temperatures, and may also be a factor in determining when the adult migrating cutthroat trout pass the dam, since they assert that the river is too warm for passage during certain months of the year.

Comprehensive analysis or modeling of these data has not been published, but simple regression analysis of the average yearly and maximum yearly temperatures from 1946 to 1993 reveals a positive trend for both parameters ($R^2 = 0.19$, $P = 0.002$ for average temperature and $R^2 = 0.21$, $P = 0.001$ for maximum temperatures) (Fig. 4). When the data are divided at 1969 (the year when Hostetler and Holaday began their analyses), neither the average temperatures for

² D. Loomis, District Biologist, Oregon Department of Fish and Wildlife, Roseburg District Office, 4192 North Umpqua Highway, Roseburg, OR 97470. Pers. commun., September 1993.

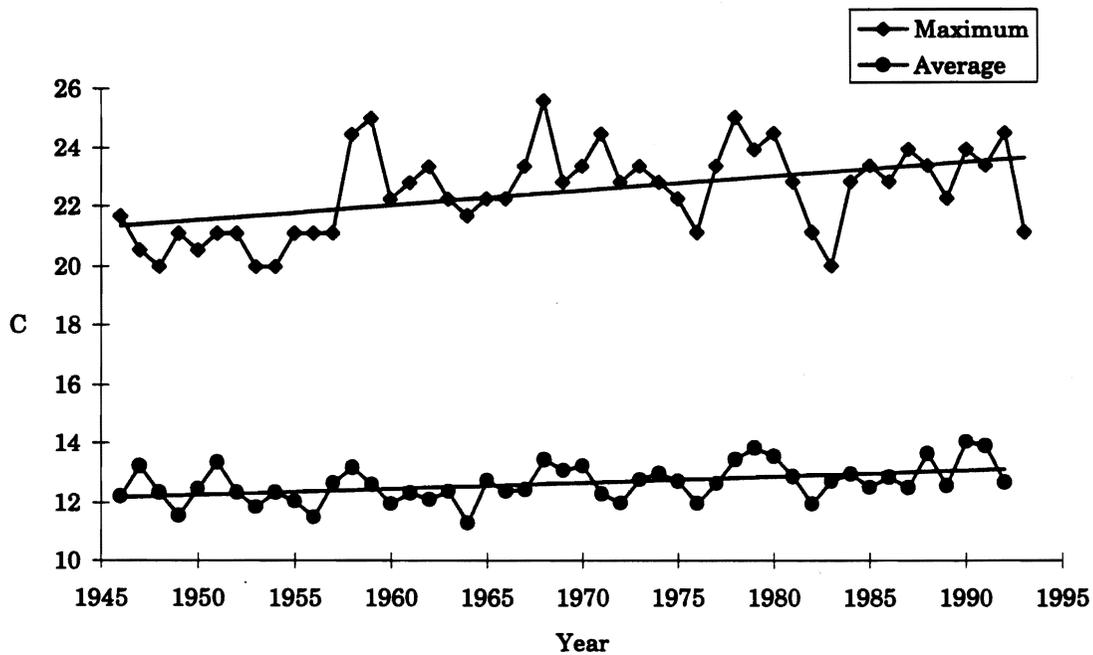


Figure 4. Average yearly water temperature for 1946 to 1992, and maximum yearly water temperature for 1946 to 1993 taken at Winchester Dam (Umpqua Rkm 116) on the North Umpqua River (ODFW 1993a). The regression analysis suggests that overall average and maximum water temperatures have significantly increased since 1946 ($R^2 = 0.19$, $P = 0.002$ for average temperature, and $R^2 = 0.21$, $P = 0.001$ for maximum temperatures).

the years 1946 to 1968 nor for the years 1969 to 1993 show a trend ($R^2 = 0.002$, $P = 0.83$ and $R^2 = 0.07$, $P = 0.2$, respectively). However, analysis of maximum temperatures reveal a warming trend from 1946 to 1968 ($R^2 = 0.44$, $P = <0.001$), but not from 1969 to 1993 ($R^2 = 0.004$, $P = 0.76$) (Fig. 4).

Observations of maximum monthly water temperatures during July and August when the summer-run of anadromous cutthroat trout are passing Winchester Dam show a distinct warming trend from 1946 to 1968 ($R^2 = 0.36$, $P = 0.0008$ for July and $R^2 = 0.56$, $P = 0.00004$ for August), but none from 1969 to 1993 ($R^2 = 0.02$, $P = 0.001$ for July and $R^2 = 0.005$, $P = 0.73$ for August) (Fig. 5).

Observations of maximum monthly temperatures during September, October, and November from 1946 to 1993 do not show any distinct trend in water temperatures ($R^2 = 0.054$, 0.01 , and 0.04 , respectively, and $P = 0.11$, 0.43 , and 0.16 , respectively), nor is a trend evident when the years are divided by pre- and post-1969 (Fig. 5).

Correlation of these trends with fish passage is difficult to interpret (Fig. 4.; see also subsection Temperature Tolerance in Cutthroat Trout and the Discussion and Conclusion sections), but sustained increases in river temperatures occurred at the same time as the collapse of cutthroat trout numbers crossing the dam. Prior to 1954, the highest maximum July temperature was 21.7°C ; by July 1958, the maximum temperature was 25°C .

Regardless of the trend, water temperature readings during many years since the mid-1950s reveal that maximum water temperatures approached experimental lethal limits for cutthroat trout (Golden 1975, Bell 1986; see also

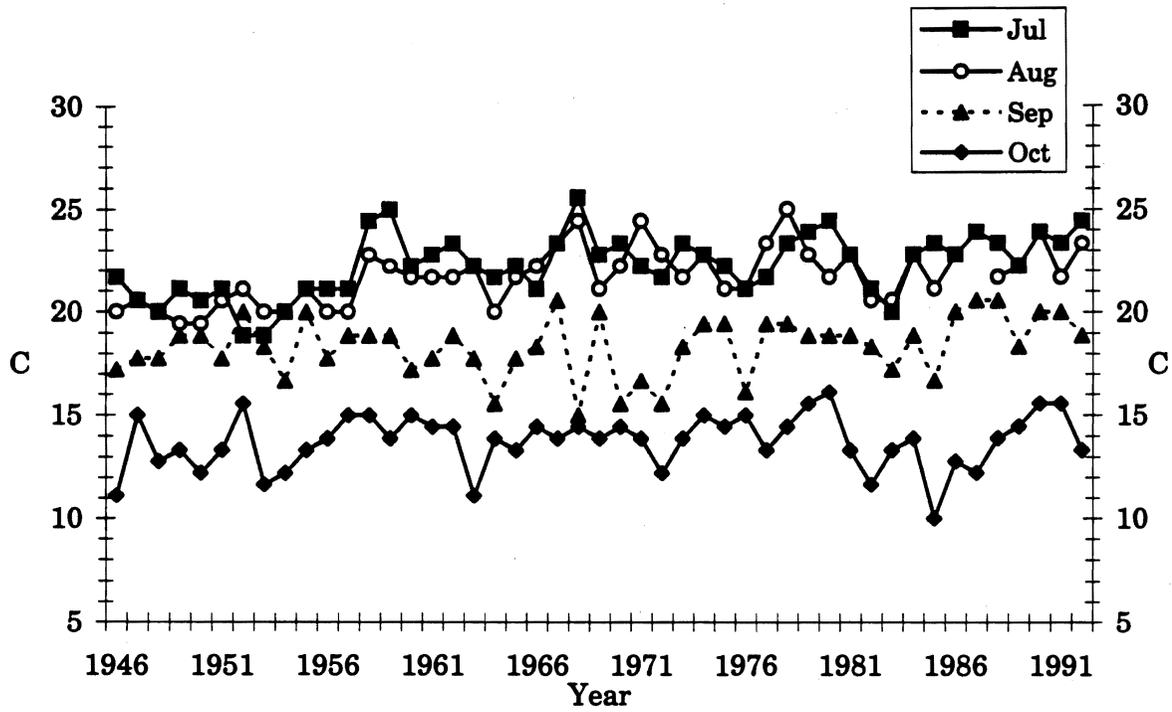


Figure 5. Monthly maximum water temperatures for July, August, September, and October. Temperatures were taken at Winchester Dam on the North Umpqua River from 1946 to 1993.

subsection Temperature Tolerance in Cutthroat Trout) at Winchester Dam during the times when sea-run trout were passing. This would suggest that during certain times of the year, a major portion of the North, South, and mainstem Umpqua River exceeded the preferred temperature range of cutthroat trout. However, temperature increases during September at Winchester Dam do not seem a reasonable explanation for the break between summer and fall peaks in cutthroat trout migration across Winchester Dam. Water temperatures in September at Winchester Dam are consistently lower than July and August (when fish pass the dam; see Fig. 4) and no trend of increasing water temperature was found at the dam in September from 1946 to 1993.

Barriers to Fish Passage

As cutthroat trout often home to natal spawning headwaters that are at high elevations, *O. clarki* can be more severely impacted by human barriers to fish passage than mainstem or lower tributary spawning salmonids might be. Historic barriers to full or partial fish passage in the Umpqua River were numerous (FCO and OSGC 1946, Lauman et al. 1972). Splash dams blocked fish passage on mainstem tributaries at Camp and Weatherly Creeks. On the South Umpqua River, a grist mill dam near Roseburg "was a major obstacle to migrant fish at lower water stages, as were other dams at Canyon and Deadman Creeks" (FCO and OSGC 1946, p. 6).

On the North Umpqua River, anadromous fish passage extends to around Rkm 113, where historically impassable natural barriers (and presently the 35-m high Soda Spring Dam) terminate salmon migrations (Lauman et al. 1972).

The dam at Winchester (RKm 11) on the North Umpqua River was built in 1890 and considered a "definite barrier" to fish passage at low water; however, fish could apparently surmount the dam through a modified spillway at the north end (FCO and OSGC 1946). Although the fish ladder at the dam was modified in the early 1980s to improve fish passage, issues regarding the use and future of the dam are still highly controversial (Blumm and Kloos 1986). Present fish passage facilities are reported to be satisfactory at all flow levels (D. Loomis, see footnote 2).

Large natural barriers to fish passage in the Umpqua River watershed, such as Smith River Falls, South Umpqua Falls, and Steamboat Falls, have been laddered to facilitate fish passage (Lauman et al. 1972; D. Loomis, see footnote 2).

Summary of Environmental Factors

Because the North Umpqua River begins farther inland and flows for a substantial distance at a higher elevation than most other Oregon coastal rivers, it historically had cooler water and larger summer water flows than the other rivers. Because of these factors the North Umpqua River contained a large and diverse salmonid population. The South Umpqua River also begins at a high elevation but rapidly drops in elevation; it has always had higher water temperatures and a lower summer flow than the North Umpqua River. Beginning in the mid-1950s, summer water temperatures and the frequency of winter flooding increased in the Umpqua River watershed due to clear-cut logging. Summer water temperatures were often above the preferred limit for cutthroat trout in portions of the river. In recent years, the riparian forest canopy has begun to recover in the North

Umpqua River watershed, but maximum water temperatures are still higher than those preferred by cutthroat trout and other salmonids.

SUMMARY OF BIOLOGICAL INFORMATION ON COASTAL CUTTHROAT TROUT

Cutthroat and rainbow trout are native to western North America.

Historically, cutthroat trout were the more broadly distributed species (Behnke 1979, 1992), but in recent years they have been replaced by rainbow trout or other introduced species in many parts of their range. There are 14 extant subspecies of cutthroat trout recognized in the current literature, but all except *O. c. clarki* are found east of the temperate rainforest region of the Pacific Northwest (Fig. 1, Table 2) (Behnke 1979). Because of hybridization with rainbow trout, habitat degradation, and other reasons, many of these inland subspecies have declined in numbers to an extent that they are now protected by state and federal endangered species legislation (Table 2) (Johnson 1987).

O. c. clarki has a karyotype ($2n = 68-70$, Simon 1963, Gold et al. 1977) that is unique among cutthroat trout subspecies (Gold et al. 1977, Thorgaard 1983, Loudenslager and Thorgaard 1979, Behnke 1992) as well as several unique alleles detected by protein electrophoresis (Leary et al. 1987, Allendorf and Leary 1988). Phenotypically, coastal cutthroat trout differ from all other trout by their profusion of small to medium-size spots of irregular shape (Behnke 1992). In addition, they do not develop the brilliant colors associated with inland cutthroat trout. In sea-run coastal cutthroat trout, spots and colors are further obscured by the silvery skin deposit common to anadromous salmonids. Resident,

Table 2. Subspecies of cutthroat trout and their federal and state protection status (Modified from Allendorf and Leary 1988). The eight major subspecies are endemic to large geographical areas (Behnke 1979). Underlined abbreviations represent legal protection and nonunderlined abbreviations represent fishes of Special Concern according to Johnson (1987): CA = California, CO = Colorado, ID = Idaho, MT = Montana, NM = New Mexico, NV = Nevada, US = United States, UT = Utah, and WY = Wyoming.

Common name	Subspecies	Legal protection
Major subspecies		
Bonneville	<i>Oncorhynchus clarki utah</i>	US, ID, NV, <u>UT</u> , WY
Coastal	<i>O. c. clarki</i>	--
Colorado	<i>O. c. pleuriticus</i>	US, CO, <u>UT</u> , WY
Greenback	<i>O. c. stomias</i>	<u>US</u> , <u>CO</u>
Lahontan	<i>O. c. henshawi</i>	<u>US</u> , CA, <u>UT</u>
Rio Grande	<i>O. c. virginialis</i>	CO, NM
Westslope	<i>O. c. lewisi</i>	ID, MT
Yellowstone	<i>O. c. bouvieri</i>	ID, MT
Minor subspecies		
Alvord	<i>O. c. alvordensis</i>	extinct
Bear Lake	<i>O. c. subsp.</i>	ID
Humboldt	<i>O. c. subsp.</i>	--
Mountain	<i>O. c. alpestris</i>	--
Paiute	<i>O. c. seleniris</i>	<u>US</u> , CA
Snake River	<i>O. c. subsp.</i>	ID
Willow/Whitehorse	<i>O. c. subsp.</i>	US
Yellowfin	<i>O. c. macdonaldi</i>	extinct

nonanadromous fish tend to be darker, with a "coppery or brassy" sheen (Behnke 1992).

The distribution of coastal cutthroat trout is greater than for any other cutthroat trout subspecies. It extends along the Pacific coast of North America from the Eel River in northern California (DeWitt 1954) to the Prince William Sound area of southeast Alaska, bounded by Gore Point on the Kenai Peninsula (Sumner 1948, 1972; DeWitt 1954; Scott and Crossman 1973; Behnke 1992). The eastern range of the subspecies rarely extends farther inland than 160 km and is usually less than 100 km. The eastern range appears to be bounded by the Cascade Mountain Range in California, Oregon, and Washington and by the Coast Range in British Columbia and southeast Alaska (Fig. 1). As pointed out by Trotter (1989) and Trotter et al. (1993), this range coincides closely with the coastal temperate rain forest belt defined by Waring and Franklin (1979), and even when the fish have access beyond the coastal rainforest, such as in the Columbia River, they penetrate only a limited distance (Sumner 1972; Trotter 1987, 1989).

Life-History Forms of Coastal Cutthroat Trout

The life history of coastal cutthroat trout is probably the most complex and flexible of any Pacific salmonid (Johnston and Mercer 1976; Johnston 1981; Trotter 1987, 1989). Partly because of their subordinate behavior to other salmonids, cutthroat trout have evolved to exploit habitats least preferred by these other species (Johnston 1981). Unlike other anadromous salmonids, sea-run cutthroat trout do not overwinter in the ocean and only rarely make long extended migrations across large bodies of water. They migrate in the nearshore marine habitat and usually remain within 10 km of land (Giger 1972, Sumner 1972, Jones 1976, Johnston 1981). While most anadromous cutthroat trout enter seawater as 2- or 3-year-olds, some may remain in fresh water for up to 5 years before entering the sea (Giger 1972, Sumner 1972). Other cutthroat trout may never outmigrate at all, but remain as residents of small headwater tributaries. Still other cutthroat trout may migrate only into rivers or lakes (Nicholas 1978b, Tomasson 1978, Moring et al. 1986, Trotter 1989), even when they have seawater access (Tomasson 1978). In the Umpqua River Basin, anadromous, resident, and potamodromous (river-migrating) life-history forms have been reported (Trotter 1989, Loomis and Anglin 1992, Loomis et al. 1993).

Sea-Run or Anadromous *O. c. clarki*

This is the best known life-history form of the subspecies, and most of the biological information presented in the following sections was derived from studies on sea-run individuals. Sea-run trout are the fish petitioned by ONRC et al. (1993) for protection under the ESA.

Nonmigratory or Resident *O. c. clarki*

Some cutthroat trout do not migrate long distances; instead, they remain in upper tributaries near spawning and rearing areas and maintain small home territories (Trotter 1989). Wyatt (1959) surveyed resident cutthroat trout in the Willamette River (Lookout Creek) and found that in a year less than 3% of the fish moved more than 200 m from their home areas. Resident cutthroat trout appear to be slower growing than potamodromous or anadromous trout (Tomasson 1978, Trotter 1989); they seldom grow larger than 150-200 mm in length and rarely live longer than 2 to 3 years (Wyatt 1959, Nicholas 1978a, June 1981).

Resident fish in the Umpqua River Basin--Resident cutthroat trout have been observed in the upper Umpqua River drainage (Roth 1937, FCO and OSGC 1946 , ODFW 1993a), but, until recently, little specific information has been available on them. In 1992, Waters (1993) radio-tagged what he believed were 25 "resident" cutthroat trout, 154-234 mm in length (Table 3), in three tributaries of Rock Creek in the North Umpqua River drainage (Fig. 2) for a study on river flow and winter habitat utilization of cutthroat trout in the North Umpqua River Basin. He found that some of these radio-tagged fish moved over much larger distances than others (Table 3). Fish smaller than 180 mm maintained home ranges that averaged less than 14 m of stream length and moved an average of only about 27 m during the study. Fish larger than 180 mm had home ranges that averaged 76 m and moved an average total distance of about 166 m. One of these larger fish (length 191 mm) was particularly active, had a home range of over 433 m, and moved over 1,305 m during the study.

Table 3. Date tagged, stream location of tagging, and characteristics of radio-tagged cutthroat trout from a study on the North Umpqua River (Waters 1993).

Date of tagging	Total length (mm)	Weight (g)	Number of observations over 51 days	Number of unique locations	Home range (m)	Total distance moved (m)
McConnas Creek						
12/22/92	166	35	3	2	9	9
12/22/92	210	70	22	4	59	188
12/23/92	169	39	22	1	5	0
12/24/92	206	72	22	3	66	98
12/26/92	215	83	22	5	52	120
12/26/92	170	40	22	1	5	0
12/26/92	205	75	22	2	23	46
12/26/92	154	32	22	4	12	69
12/26/92	173	39	22	2	5	33
12/27/92	220	84	22	3	33	66
1/5/93	234	89	10	5	42	55
Kelly Creek						
1/18/93	164	38	2	1	5	0
1/19/93	191	53	22	2	8	8
1/26/93	194	52	5	2	68	68
1/26/93	186	46	17	5	152	181
Harrington Creek						
2/3/93	165	32	14	4	20	51
2/3/93	191	52	26	14	433	1,305
2/3/93	200	80	25	3	33	41
2/5/93	159	30	2	2	45	45
2/9/93	205	72	23	1	4	0
2/9/93	170	38	14	5	27	63
2/10/93	186	52	4	2	12	12
3/9/93	206	54	12	2	21	21
3/9/93	162	32	12	1	6	0
3/11/93	184	50	11	6	130	288

River-Migrating or Potamodromous *O. c. clarki*

Some cutthroat trout may move within large river basins but not migrate to the sea. These potamodromous migrations are best documented in rivers with physical barriers to anadromous fish, such as above Willamette Falls in the Willamette River. Historically, the falls apparently barred access of anadromous fish to the upper river, and above this barrier, schools of cutthroat trout were found to migrate from natal spawning areas to mainstem feeding areas and back (Dimick and Merryfield 1945; Nicholas 1978a,b; Moring et al. 1986).

Potamodromous cutthroat trout have also been reported as schooling in "large streams above migration barriers in southwest Oregon, e.g., Bald Mountain Creek (Elk Basin), upper Chetco River, upper Silver Creek (Illinois Basin)" (ODFW 1993b).

Only rarely have potamodromous cutthroat trout been reported below barriers or in locations with access to anadromous fish. In the Rogue River, Tomasson (1978) documented the presence of potamodromous fish that do not enter seawater, but had physical access to the sea and were sympatric with anadromous and resident trout. Tomasson differentiated between the anadromous and nonanadromous fish by chemical analysis of scale tissue. Previously, Bagenal et al. (1973) had developed a technique for the measurement of strontium (Sr) concentrations in fish tissue and had reported large differences between Sr concentrations in the scales of anadromous and nonanadromous brown trout (*Salmo trutta*). Tomasson modified these techniques to measure the ratio of Sr to calcium (Ca) in the scales of cutthroat trout. Tomasson reported that there was

almost a seven-fold difference between the ratio of these two elements in fresh water and seawater, and he believed that using the ratio of Sr to Ca, rather than simply measuring Sr concentrations, would be more accurate and require less tissue. In preliminary studies, Tomasson (1978) found large and reproducible differences between Sr:Ca ratios from unidentified freshwater and marine fishes. Tomasson also used traditional scale and otolith analysis, length frequency distributions, gonadal dissections, and back calculation of length from scale data to describe the abundance, distribution, and migration patterns of cutthroat trout in the Rogue River.

In Tomasson's study, cutthroat trout were collected from the Rogue River estuary and mainstem between 1974 and 1977 and from small upper tributaries in 1977 and 1978. Tomasson classified cutthroat trout collected in the Rogue River estuary as sea-run or anadromous fish. No fish were collected at sea. Because of the amount of scale material required for Sr:Ca analysis, most scale samples from the estuary and all scale samples for each tributary had to be pooled. Based upon analysis of the scales, only those from first-time migrants to the estuary, collected at the same time and location, were pooled.

Tomasson reported that there were differences between Sr:Ca ratios in known resident fish (mean was approximately 1.5×10^{-3}) and in first-time migrants captured in the estuary (mean was approximately 2.8×10^{-3}). He found that there was a significant increase in the Sr:Ca ratio with time fish spent in the estuary (from approximately 2×10^{-3} to 3.2×10^{-3}). Tomasson concluded that this increase indicated these fish oversummered in seawater.

In the Sr:Ca analysis of eight samples collected from the lower Rogue River (RKm 5.6 to 44.2), Tomasson found that six of these showed low Sr:Ca ratios (1.10×10^{-3} to 1.58×10^{-3}). He considered these fish potamodromous. The other two fish showed high Sr:Ca ratios (2.52×10^{-3} and 2.97×10^{-3}), and Tomasson concluded that these were anadromous fish. Although all the lower-river fish were collected after spawning should have been completed, only the two (presumably sea-run) fish with high Sr:Ca ratios had definite spawning checks on their scales. Although Tomasson concluded that these fish represent two different populations (anadromous and potamodromous), a second interpretation might be that the immature fish were parr that would migrate to seawater in future years.

Twenty samples from the upper Rogue River (RKm 104 to 252) had low Sr:Ca ratios (0.94×10^{-3} to 1.70×10^{-3}), indicating to Tomasson they were freshwater residents and did not have seawater exposure. He "concluded that only rarely, if at all, do anadromous trout migrate above km 104" (Tomasson 1978, p. 34). Tomasson found high Sr:Ca ratios (2.52×10^{-3}) in scale samples from fish collected from Edison Creek, a stream that empties just above the estuary. He concluded that the fish from this creek had spent some time in the estuary. A short period of rapid growth was also identified from scale analysis.

Length-frequency distributions differed between fish captured in the lower Rogue River or estuary and fish captured in the upper river (Tomasson 1978). He found that fish captured in the estuary and lower river had growth peaks at three different times which corresponded to lengths at first entrance to the estuary (140-150 mm), length at end of first growing season in the estuary (270-310 mm),

and length at end of second growing season in the estuary (350-430 mm). Cutthroat trout captured in the upper river had a more uniform, but slower, growth. Tomasson concluded that because trout collected in the main stem appeared to have grown equally well in the main stem and the estuary, the three peaks indicated that anadromous and potamodromous were intermixed or "superimposed" in the lower river (Tomasson 1978, p. 35). He also concluded that the upper-river length distributions were "indicative of a homogeneous population." However, Tomasson did caution that the lower-river peaks may reflect a sampling problem as more fish were caught outside the growing season in the lower river than in the upper river.

Although Tomasson was able to identify three different life-history forms in the Rogue River (sea-run, potamodromous, and resident) he emphasized that his study had several shortcomings. The number of scales required for the analysis of Sr:Ca ratios required pooling, and inconsistent results often occurred when the larger samples of scales were analyzed. Tomasson determined that the cause of this inconsistency was precipitation of Sr at certain Ca concentrations. Consequently, Tomasson developed a standard curve of Sr and Ca ratios from large quantities of scales collected from landlocked Willamette River fish. From the standard curve, Tomasson was able to accurately determine Sr:Ca ratios only within a portion of the curve where Sr precipitation was minimal. Because of this, he was limited in his evaluations to only 77 samples (11 from known resident fish, 20 from upper-river fish, 8 from lower-river fish, and 38 from the estuary).

In summary, Tomasson was the first to identify migratory cutthroat trout with access to seawater that did not enter the marine habitat, but moved only within a river system (potamodromous). He also was the first to identify potamodromous fish sympatric with sea-run fish and sea-run fish in the Rogue River that migrated only to the estuary and did not enter the open ocean. However, Tomasson emphasized that the behaviors he had identified in Rogue River cutthroat trout may be unique to cutthroat trout from that river system. He believed the Rogue River had several unique characteristics that might result in different or unusual salmonid behaviors (such as half pounder steelhead). He also emphasized that the purpose of his work was to document the status of cutthroat trout in the river prior to the opening of Lost Creek Dam. The operation of the dam was anticipated to dramatically change some of the physical factors in the riverine environment (such as water temperature and flows) that may have led to some of the unusual behavior of the trout he studied.

Potamodromous fish in the Umpqua River Basin--Potamodromous fish have only recently been identified in the Umpqua River Basin. No sea-run cutthroat trout had been counted over Winchester Dam in the fall of 1992, when biologists from ODFW conducted a series of radio-tagging studies on large (length 300-400 mm) cutthroat trout in the Steamboat and Canton Creek drainages in the North Umpqua River Basin (Fig. 2). Personnel from ODFW radio-tagged five cutthroat trout from Steamboat Creek and three cutthroat trout from Canton Creek in October 1992 and tracked their movements until February 1993 (Loomis et al. 1993). The fish remained in the tagging area until the fall rains began, at which

time they moved upstream 6.5 to 16 km (4 to 10 miles) to overwintering sites where they remained for the rest of the study (D. Loomis, see footnote 2; T. Loynes³). It is unclear whether these fish were sea-run trout that had remained in fresh water after spawning the previous winter or potamodromous fish that spend their entire life cycle in fresh water. It was also possible the radio-tagged fish would migrate to the sea in the future.

In Waters's (1993) radio-tagging study of resident cutthroat trout (length 154-234 mm) previously discussed in the Nonmigratory or Resident *O. c. clarki* subsection, it was found that fish greater than 180 mm tended to move greater distances than smaller fish, but that some fish, regardless of size, were particularly active (Table 3). Waters (E. Waters⁴) believed that the fish that made more active and longer distance movements may represent either potamodromous fish or future sea-run fish.

ODFW conducted further and continuing radio-tagging studies beginning in the summer of 1993 on resident fish and in October 1993 on a presumed sea-run cutthroat trout that was trapped while passing Winchester Dam (D. Loomis, see footnote 2; T. Loynes, see footnote 3).

³ T. Loynes, Fishery Biologist, Oregon Department of Fish and Wildlife, Roseburg District Office, 4192 North Umpqua Highway, Roseburg, OR 97470. Pers. commun., September 1993.

⁴ E. Waters, Bureau of Land Management, Roseburg District Office, 777 N.W. Garden Valley Blvd., Roseburg, OR 97470. Pers. commun., February 1994.

Large cutthroat trout have also been observed in the upper Umpqua River by biologists from several agencies (J. Dose⁵; D. Loomis, see footnote 2; T. Loynes, see footnote 3; E. Waters, see footnote 4) at times when sea-run trout are not thought to be present or are in numbers greater than those of sea-run trout that have been counted across Winchester Dam in that year. But until these reports are published and chemical analyses of scales or other tissues have been conducted to confirm freshwater life histories, it is impossible to determine whether these were potamodromous, resident, or overwintering anadromous fish.

Life History of Coastal Cutthroat Trout

Early Life History

Cutthroat trout spawning occurs between December and May and eggs begin to hatch within 6-7 weeks of spawning, depending on temperature. Alevins remain in the redds for a further few weeks and emerge as fry between March and June, with peak emergence in mid-April (Giger 1972, Scott and Crossman 1973). At emergence, fry quickly migrate to channel margins and backwaters with low stream gradients, where they remain throughout the summer (Edie 1975, Glova and Mason 1976).

In the absence of other species, cutthroat trout prefer to rear in pools (Giger 1972), but when coho salmon (*O. kisutch*) are present, the cutthroat juveniles move to less preferred, low gradient riffle areas, where they remain until displaced

⁵ J. Dose, Forest Fishery Biologist, USDA Forest Service, Umpqua National Forest, P.O. Box 1008, Roseburg, OR 97470. Pers. commun., August 1993.

by winter flows (Glova and Mason 1977, Glova 1987). In winter, the cutthroat trout go to pools near log jams or overhanging banks (Bustard and Narver 1975).

Parr Movements

After emergence from redds, cutthroat trout juveniles generally remain in upper tributaries until they are 1 year of age, when they may begin extensive movement up and down streams. Directed downstream movement by parr usually begins with the first spring rains (Giger 1972) but has been documented in every month of the year (Sumner 1953, 1962, 1972; Giger 1972; Moring and Lantz 1975; Johnston and Mercer 1976; Johnston 1981). As an example, from 1960 to 1963 (Lowry 1965) and from 1966 to 1970 (Giger 1972) in the Alsea River drainage, large downstream migrations of juvenile fish began in mid-April with peak movement in mid-May. Some juveniles (parr) even entered the estuary and remained there over the summer, although they did not smolt nor migrate to the open ocean (Giger 1972). In Oregon, upstream movement of juveniles from estuaries and main stem to tributaries begins with the onset of winter freshets during November, December, and January (Giger 1972, Moring and Lantz 1975). At this time, these 1-year and older juvenile fish averaged less than 200 mm in length.

Smoltification

Time of initial seawater entry of smolts bound for the ocean varies by locality and may be related to marine conditions or food sources (Lowry 1965, 1966; Giger 1972; Johnston and Mercer 1976; Trotter 1989). In Washington and

Oregon, entry begins as early as March, peaks in mid-May, and is essentially over by mid-June (Sumner 1953, 1972; Lowry 1965; Giger 1972; Moring and Lantz 1975; Johnston 1981). In Alaska, the migration begins in April and peaks in late May or early June (Baade 1957, Armstrong 1971, Jones 1976), although two other additional surges may occur: one in mid-June and one in mid-July. Jones (1976) reported that the mid-June rush was composed of outmigrating cutthroat trout over 250 mm and indicated that "these were not believed to be initial migrant smolts." Jones also found that the average size of outmigrants in a mid-July peak at Petersburg Creek in southeast Alaska was less than 200 mm. This run occurred at night on moderate stream flows and stopped during extreme high or low stream flows in all years studied.

Seaward migration of smolts to protected areas appears to occur at an earlier age and a smaller size than to more exposed areas. Johnston (1981) reported that in Puget Sound and the Columbia River, smolts make their first migration at age 2 or 3, with a mean size of about 160 mm. On the less protected Oregon coast, cutthroat trout tend to migrate at an older age (age 3 and 4) and at a size of 200 to 255 mm (Lowry 1965, 1966; Giger 1972). The oldest recorded initial age of seawater entry was a 6-year-old fish that was 280 mm in length from the Alsea River on the Oregon Coast (Giger 1972).

Timing of smolt migrations in the Umpqua River--In the Umpqua River, some information has been gathered on movement of juvenile salmonids from smolt traps operated by ODFW at various locations in the North Umpqua River (Loomis et al. 1993). Trap data from seven locations in the North Umpqua River

in 1958 and from three locations in Steamboat Creek between 1958 and 1973 indicate that juvenile movement is similar to that reported by Lowry (1965) and Giger (1972) in other Oregon coastal rivers. Movement peaked in May and June, with a sharp decline in July, although some juveniles continued to be trapped through September and October. It is unknown whether Umpqua River cutthroat trout juveniles migrate from the upper basin areas to the estuary, but it seems unlikely considering the distance (well over 185 km) and the river conditions (average August river temperature at Winchester Dam since 1957 is 23.3°C) (ODFW 1993a).

Estuary and Ocean Migration

Migratory patterns of sea-run cutthroat trout differ from other Pacific salmon in two major ways: few, if any, cutthroat overwinter in the ocean, and the fish do not usually make long open-ocean migrations, although they may travel considerable distances along the shoreline (Johnston 1981, Trotter 1989, Pauley et al. 1989). Studies by Giger (1972) and Jones (1973, 1974, 1975) indicated that cutthroat trout, whether initial or seasoned migrants, remained at sea an average of only 91 days, with a range of 5 to 158 days. In these studies, the majority of cutthroat trout seemed to migrate in similar patterns from year to year, rarely crossed bodies of water over 8 km in width, and closely followed shorelines, sometimes for up to 71 km. Only in the Columbia River plume have cutthroat trout been documented to move considerable distances offshore, where Dawley et al. (1978, 1979, 1980) and Percy et al. (1990) reported cutthroat trout over 27 km

offshore. Pearcy et al. (1990) also reported cutthroat trout moved as far as 250 km along the Oregon shoreline.

Not all sea-run trout populations migrate into the ocean. As previously discussed, Tomasson (1978) concluded from catch data that Rogue River sea-run cutthroat trout did not enter the open sea, but remained in the estuary throughout the summer. All other studies of cutthroat trout (reviewed in Trotter 1989) have found some ocean-migrating component in an anadromous population. Tomasson (1978) speculated that sea-run Rogue River cutthroat trout may remain in the estuary to avoid half-pounder steelhead that reside during the summer in the nearshore ocean margin, where sea-run cutthroat trout usually occur.

Ocean migrations by Umpqua River cutthroat trout--We found no published scientific reports on ocean migrations of Umpqua River cutthroat trout. However, information from the popular fishing literature suggests that Umpqua River cutthroat trout may remain in the estuary longer than has been reported (Giger 1972) for the Alsea, Siuslaw, and Nestucca Rivers: "Anglers who fish the lower [Umpqua River] estuary around Reedsport and Gardner may find fish any time of year, because these anadromous cutthroat rarely enter the open ocean, instead preferring to roam the estuaries" (Shewey 1992, p. 61). However, large numbers of Alsea River hatchery cutthroat trout have been released into Smith River and Scholfield Creek in the Umpqua River estuary for many years (see Table 1), and it would be expected that these fish would follow the migrational timing and pattern evolved in the Alsea River.

Adult Freshwater Migrations

Across the subspecies range, information on the timing of adult upriver migrations of cutthroat trout is based on fish counts across Winchester Dam (the only dam with long-term cutthroat trout counts), angler surveys, limited tagging studies, and trapping and inventory studies. Cutthroat trout may return to freshwater feeding/spawning areas from late June through March. Re-entry timing has been found to be temporally consistent from year to year within streams, but with wide variation between streams (Giger 1972). Return migrations to large rivers seem to consistently occur earlier than to shorter coastal rivers (Giger 1972, Johnston and Mercer 1976, Johnston 1981). It has been suggested that this may be due to adaptation of distinct populations to different environmental conditions, such as distance from seawater to spawning sites (Giger 1972, Johnston and Mercer 1976, Johnston 1981, reviewed in Pauley et al. 1989 and Trotter 1989).

In small streams, such as Carnation Creek in British Columbia, Sand Creek in Oregon, and Minter Creek in Washington, peak returns occur in December and January, and fish may continue to return through March (Sumner 1953, Anderson and Narver 1975, Johnston 1981). These streams usually have low flows (< 0.6 m³/second) and flow directly into seawater.

In large river systems in Washington and Oregon, such as the Stillaguamish, Columbia, Cowlitz, and Alsea Rivers, cutthroat trout return migrations usually begin earlier, in late June, and continue through October with peaks in late September and October (Lavier 1963; Bulkley 1966; Hisata 1971,

1973; Duff 1972; Giger 1972; Wright 1973; Tipping and Springer 1980; Tipping 1981, 1986). As an example, Giger (1972) found that the earliest known entrance dates of sea-run cutthroat trout in the Alsea River between 1965 and 1970 ranged from June 23 to July 21. He also noted that these first fish were the "forerunners of larger runs which peaked at later dates..." and that "...smaller numbers of fish were known to enter as late as early October" (p. 11).

Run-Timing in the Umpqua River Basin--In the Umpqua River, it is reported (ODFW 1993a) that cutthroat trout historically began upstream migrations in late June and continued to return through January (Fig. 5), with bimodal peaks in late-July and October. Giger (1972) reported a similar return pattern, but with slightly later modal peaks (mid-August and late-October to mid-November) on the Alsea River.

Giger (1972) suggested that the early run of fish in the Alsea River may consist of older fish, with first-time spawners making up the later October-November run. In contrast, at Winchester Dam on the North Umpqua River, observers believe that fish returning in October are larger than those in the August run (D. Loomis, see footnote 2; W. Metzler⁶). However, there are no published data on sizes of adult cutthroat trout passing Winchester Dam or from other locations in the North or South Umpqua Rivers.

⁶ W. Metzler, Fishery Biologist, Oregon Department of Fish and Wildlife, Roseburg District Office, 4192 North Umpqua Highway, Roseburg, OR 97470. Pers. commun., September 1993.

It is unknown where the fish that compose these two peaks are going (although on-going radio-tagging studies by ODFW should provide information on this question) or whether they represent two runs of fish from a single population, or the returns of two or more different populations.

Straying--In reviewing cutthroat trout life history, Pauley et al. (1989, p. 5) reported that "homing of native sea-run cutthroat is extremely precise (Campton 1980), although hatchery-planted fish may stray as much as 30%, which makes survival rates impossible to determine (Johnston and Mercer 1976)."

Jones reported (1975, 1976) that in tagging studies from Petersburg Creek in southeast Alaska, many wild fish wandered during their first year's return to fresh water and were captured in 13 nearby streams. As second year migrants, a much higher proportion of tagged fish were captured in their home stream. Overall, Jones (1976) found that less than 50% of initial returning migrants were sexually mature and suggested that first year fish found wandering to nonnatal rivers were on feeding runs.

In Oregon, Sumner (1953) found that over 95% of returning initial migrant wild females were sexually mature. Giger (1972) found that tagged wild fish from streams in the Alsea River did not stray and were only recaptured in their natal streams. However, over 30% of the tagged hatchery fish entered streams up to 133 km from the release stream.

Johnston (1981), like Jones, believed wandering cutthroat trout were on feeding runs, and suggested that in localities where a large proportion of first time migrants are not sexually mature, perhaps due to low food availability, they may

conduct feeding runs to randomly chosen rivers. In the following year, when a larger proportion of these fish are sexually mature, they will home to natal streams.

Spawning

As reviewed in Trotter (1989) and Pauley et al. (1989), cutthroat trout generally spawn in the tails of pools located in streams with low stream gradient and low flows, usually less than $0.3 \text{ m}^3/\text{second}$ during the summer (Johnston 1981). "You can step across a cutthroat spawning stream, but you have to jump a steelhead stream," R. Dimick, founder of Oregon State University Department of Fisheries and Wildlife, was fond of saying (C. Bond⁷). Spawn timing varies among streams but generally occurs between December and May, with a peak in February (Trotter 1989).

It is believed that the choice by cutthroat trout of spawning sites in small tributaries at the upper limit of spawning and rearing sites of coho salmon and steelhead has evolved to reduce competitive interactions and to reduce hybridization with rainbow trout and steelhead. In many drainages where rainbow trout and cutthroat trout coexist, there is believed to be a slight difference in spawn timing between the two species that would also reduce the opportunity for hybridization (Cramer 1940, DeWitt 1954, Sumner, 1972, Glova and Mason 1977, Johnston 1981). However, as discussed later, hybridization between

⁷ C. Bond, Department of Fisheries and Wildlife, Oregon State University, Nash Hall 104, Corvallis, OR 97331-3803. Pers. commun., February 1994.

cutthroat and rainbow trout has been documented in locations in Puget Sound where spawning areas and time of spawning overlap (Campton and Utter 1985).

Cutthroat trout are iteroparous and have been documented to spawn each year for at least 5 years (Giger 1972), although some cutthroat trout do not spawn every year (Giger 1972) and some do not return to seawater after spawning, but remain in fresh water for at least a year (Giger 1972, Tomasson 1978). Spawners may experience high postspawning mortality due to weight loss of as much as 38% of pre-spawning mass (Sumner 1953) and other factors (Cramer 1940, Sumner 1953, Giger 1972, Scott and Crossman 1973). Still, in one Oregon stream, over 39% of one year's spawning population returned to spawn a second year, 17% returned to spawn a third year, and 12% for the fourth year (Sumner 1953). However, in another stream with an intense sport fishery, only 14% returned to spawn in the second year (Giger 1972).

Spawning sites in the Umpqua River Basin--Little is known of spawning locations or sites for cutthroat trout in the Umpqua River Basin (D. Loomis, see footnote 2; T. Loynes, see footnote 3; J. Dose, see footnote 5), although T. Loynes observed a possible sea-run cutthroat trout redd near a steelhead redd on Cedar Creek. He also observed presumed sea-run or potamodromous cutthroat trout in Williams Creek, slightly upstream from coho salmon spawning locations and in the same area as steelhead redds. This tributary is blocked by a small falls upstream from the observation point, and cutthroat trout redds dug near the observation point would be accessible to resident, potamodromous, and sea-run cutthroat trout.

In the Umpqua River Basin there is no information available on how many sea-run cutthroat trout survive spawning and return to spawn a second or third time. Considering the intense fishery for hatchery cutthroat trout in the Umpqua River estuary (Shewey 1992, ODFW 1993a), and the distance the fish would have to travel, it is unlikely that the percentage of second- or third-time spawners would be very high.

Interactions of Cutthroat Trout with Other Salmonids

The population structure of cutthroat trout in the Umpqua River cannot be considered in isolation from other salmonids. Cutthroat trout, more than any other salmonid species, are known to change their behavior in the presence of other salmonids (Johnston 1981, Trotter 1989), and there are large populations of steelhead, coho salmon, and rainbow trout in the basin. Although there are no published studies on the interactions of cutthroat trout with other salmonids in the Umpqua River, there are extensive studies on this issue in other regions (reviewed in Griffith 1988).

Studies of the fossil record and natural distribution of Pacific salmon and trout show that cutthroat trout were the first salmonid to colonize the western United States (Johnston 1981, Behnke 1992). Many cutthroat populations became well established before other species of salmonids were abundant, and they remained isolated from these other species for thousands of years (Behnke 1979, 1992; Johnston 1981). As an example, the only other native fish historically present with the Yellowstone cutthroat trout (*O. c. bouvieri*) in Yellowstone Lake (Yellowstone National Park) was the longnose dace (*Rhinichthys cataractae*)

(Gresswell and Varley 1988). In another example, only eight other fish species historically occurred in the Lahontan Basin in Nevada-California along with the Lahontan cutthroat trout (*O. c. henshawi*) (Behnke 1992).

Because of this isolation, many interior species of cutthroat trout never competed with other salmonids, and introductions of other salmonids (primarily rainbow trout) into the inland American west resulted in a dramatic decline of many cutthroat trout populations (Behnke 1972a, 1992; Gresswell 1988). This decline has been partly caused by habitat modification and destruction (e.g., Clancy 1988), but it is primarily attributed to interspecific interactions such as introgressive hybridization (Behnke 1972a, 1992; Allendorf and Leary 1988), predation (reviewed in Marnell 1988), and competition (Griffith 1988).

It is worthwhile noting that one study (Platts 1974) found that westslope cutthroat trout (*O. c. lewisi*) density peaked at a channel gradient of about 10%, which was higher than for peak densities of bull (*Salvelinus confluentus*), rainbow, or brook trout (*Salvelinus fontinalis*). Platts suggested that the cutthroat trout in this study represented populations in gradients least preferred by other salmonids.

Coastal cutthroat trout are believed to have been less severely affected by these interspecific interactions because they evolved in close contact with other salmonids. This subspecies has developed a variety of habitat partitioning techniques, subordinate behaviors, and a flexible life history, all of which act to reduce competition with other species and help reduce opportunities for hybridization (Johnston 1981, Campton and Utter 1987, Griffith 1988).

In studies where cutthroat and rainbow trout or steelhead occupied the same watersheds, the cutthroat trout have been found primarily in the headwater tributaries, while steelhead and rainbow trout occupied the larger river reaches (Hartman and Gill 1968, Edie 1975, Hanson 1977, Jones 1978, Nicholas 1978a, Johnson et al. 1986). Nicholas (1978a) also found that in western Oregon streams, cutthroat trout grew more slowly and matured at an earlier age than did sympatric rainbow trout. They also spawned earlier in the spring and in smaller or different tributaries than did the rainbow trout. Nicholas felt this resource partitioning reduced the opportunity for hybridization and helped maintain the integrity of the cutthroat trout populations.

In lake studies, Nilsson and Northcote (1981) found that cutthroat trout showed changes in behavior, prey items, and growth in the presence of rainbow trout. In laboratory studies, the rainbow trout were consistently more aggressive and they quickly killed cutthroat trout when they were paired together. The two species successfully coexisted in the natural lake environment.

Coastal cutthroat trout are not the only cutthroat trout subspecies to have evolved sympatrically with other salmonid species; westslope cutthroat and rainbow trout/steelhead coexist in the Snake River Basin. In a study on abundance and distribution of the two species, Hanson (1977) found that in drainages where both occur, cutthroat trout occupied upper portions of streams, and *O. mykiss* were found in the lower portions. Hanson also determined that age-0 steelhead displaced previously established age-0 cutthroat trout, but cutthroat could not displace steelhead. Hanson suggested there is "interactive

segregation" where both species co-occur, despite, or because of, the fact that the species apparently have coexisted for thousands of years.

Coho salmon have also been shown to be dominant to cutthroat trout in field (Giger 1972, Glova 1984) and laboratory (Glova 1986) studies. In the absence of coho salmon, cutthroat trout prefer to rear in pools (Giger 1972). However, when coho salmon are present, they are able to dominate cutthroat trout fry because the juvenile coho salmon emerge from redds earlier and have a large body size (Giger 1972). Cutthroat trout juveniles then move to less preferred, low gradient riffle areas, where they remain until winter flows force changes because of displacement (Glova and Mason 1977; Glova 1984, 1987). In winter, the cutthroat trout go to pools near log jams or overhanging banks (Bustard and Narver 1975).

The effect of these interactions is not clearly understood and may differ depending on a variety of factors. While cutthroat trout may be competitively excluded from preferred rearing habitats by dominant coho salmon (Glova 1984, 1986, 1987) and steelhead (Hartman and Gill 1968), it has been suggested that in some cases this interaction may be positively correlated to sea-run cutthroat trout abundance. In Cumins Creek, a wilderness area on the Oregon coast, cutthroat trout seem to have slower growth and only moderate smolt outmigrations in years with poor coho salmon runs. Coho salmon may be predators on age-0 cutthroat trout, but it has been suggested that this may allow the remaining cutthroat trout

to grow faster and may result in better survival of anadromous cutthroat trout (T. Nickelson⁸).

In the Umpqua River Basin, a variety of native and introduced salmonid species are present, including coho and chinook (*O. tshawytscha*) salmon; brown, brook, and rainbow trout; and steelhead (ODFW 1993a). Considering the precipitous declines experienced by interior cutthroat trout subspecies due to interactions with other salmonid species (Behnke 1992), it might be expected that cutthroat trout in the Umpqua River also have experienced similar negative impacts. However, the mechanisms evolved by the coastal subspecies to reduce opportunities for social interactions and hybridization with other salmonids (Griffith 1988) may have helped isolate the subspecies and allow the persistence of distinct populations. In fact, considering the flexibility of life-history characteristics such as potamodromy, iteroparity, and isolation of spawning habitats, the subspecies may be at a relative survival advantage compared to other salmonid species with more rigid life histories.

Temperature Tolerance in Cutthroat Trout

The biological significance of the high temperatures and temperature trends in the Umpqua River discussed in the subsection River Water Temperature is unclear. Coastal cutthroat trout are exposed to a wide range of water temperatures across their distribution and, relative to other salmonids, little information on their habitat requirements is available (reviewed in Bjornn and

⁸ T. Nickelson, Research and Development Section, Oregon Department of Fish and Wildlife, Corvallis, OR 97331-3803. Pers. commun., November 1993.

Reiser 1991). Still, like other salmonids, coastal cutthroat trout have evolved to take advantage of temperature regimes in their home ranges. When abrupt changes occur in water temperatures or other physical factors, the fish usually compensate by finding refugia, but abrupt deviations from the normal pattern can adversely affect their survival (Bjornn and Reiser 1991).

Bell (1986), in experiments on inland cutthroat trout and other salmonids, found that preferred temperatures for spawning and incubation were 6.1° to 17.2°C for inland cutthroat trout, 2.2° to 20.0°C for rainbow trout, and 3.9° to 9.4°C for steelhead. The lethal limit for steelhead was above 24°C (Bell 1986). He also reported that the temperature range in which most Pacific salmon species were able to move upstream if depth and velocity were satisfactory was 7.2° to 15.6°C, but reached 20.0°C for one stock of summer chinook salmon.

In a variety of studies (Hunter 1973, Golden 1975, Behnke and Zarn 1976, Behnke 1992), cutthroat trout, like other salmonids, were not usually found in water temperatures higher than 22°C, although they could tolerate temperatures as high as 26°C for brief periods. Typically, the fish appeared stressed when water temperatures rose above 22°C. At 28° to 29°C the fish lost equilibrium and died, even if temperatures were gradually increased 1°-2°C per day (Behnke and Zarn 1976). Juvenile cutthroat trout preferred water temperatures around 15°C. They also lost equilibrium and died between 28°C and 30°C (Heath 1963).

Dwyer and Kramer (1975) calculated metabolic rates and scope for activity on inland cutthroat trout from Utah. They found that in their experimental fish, active metabolism and the scope for activity was greatest at 15°C and lowest at

5°C. There was also a decline at 24°C, which the authors believed is near the upper lethal temperature for cutthroat trout.

Temperature tolerance is difficult to study. Behnke (1992) described rainbow trout in Oregon that over thousands of years appear to have adapted to high water temperatures. He reported that these fish actively feed and apparently thrive in waters of 28.3°C. Other populations do not seem to successfully adapt to high temperatures. In the Firehole River, Yellowstone National Park, introduced rainbow trout have lived for 60-70 years in water temperatures that may reach 29.5°C (Kaya 1977). Adaptation to this warm water might be expected, but in a series of experiments, Kaya (1978) found that these rainbow trout survived less than 2 hours at 29.5°C and stopped feeding at 23°-24°C, even when water temperature was gradually increased. He suggested that the fish, rather than adapting to the hot water, were able to find refuge in cooler water and avoid the higher temperatures.

Genetics

Only a few studies, all involving protein electrophoresis, have been made of the genetic structure of coastal cutthroat trout populations. Campton (1981) and Campton and Utter (1987) surveyed natural and hatchery populations in Puget Sound, and Currens et al. (1992) analyzed 11 samples from southern Oregon--10 from the Coquille River and 1 from the Chetco River. Campton and Utter (1985) examined natural hybridization between steelhead and coastal cutthroat trout in northern Puget Sound streams.

Campton and Utter's (1987) study included 9 locations from Hood Canal in the western Puget Sound Basin and 12 locations in the Skagit and Stillaguamish Rivers in northern Puget Sound. This study examined 25 presumptive gene loci and found that 18 were polymorphic (more than 1 allele in at least 1 population). Campton and Utter found evidence for a substantial degree of genetic differentiation between Hood Canal populations and those in northeastern Puget Sound. Average allele frequencies differed by approximately 0.10 at five gene loci, and numerous rare alleles were restricted to just one of the two regions. Differences between populations within regions were generally smaller in magnitude but were, in many cases, statistically significant. For example, Campton and Utter found only slight differences in average allele frequency between cutthroat trout from the Skagit and Stillaguamish Rivers in northern Puget Sound, whereas populations from Hood Canal could clearly be separated into a northern and a southern group. Within drainages, significant heterogeneity of allele frequencies among streams was found for 7 of 12 loci, and the differences were larger among streams from northern Puget Sound than for Hood Canal.

Campton and Utter (1987) concluded that there is substantial restriction of gene flow between coastal cutthroat trout populations in northern Puget Sound and Hood Canal. This conclusion is consistent with the geographical separation of the two areas which are on opposite sides of the Puget Sound Basin and separated by over 250 km of shoreline. The authors also believed that the level of genetic similarity in these two regions (Nei's genetic identity > 0.97 for all pairwise comparisons of populations) suggests a common ancestry dating to recolonization

of Puget Sound after the last glacial retreat about 10,000 years ago. Campton and Utter speculated that the combination of genetic differentiation at the stream level and relatively high average heterozygosity (about 0.10) could be explained by strong homing fidelity with a low level of incidental straying among nearby streams.

With two exceptions, all of the samples analyzed by Campton (1981) and Campton and Utter (1987) were believed to represent anadromous cutthroat trout. The two exceptions, however, are informative. Campton and Utter (1987) found that the sample from Howe Creek on northern Hood Canal, which was collected above a barrier to anadromous fish, was distinct genetically from all of the other Hood Canal samples. Similarly, Campton (1981) found that a hatchery sample of resident cutthroat trout originally derived from a lake in the northeastern portion of the Puget Sound Basin (Johnston and Mercer 1976), had "diverged appreciably" (p. 79) from all of the other anadromous wild and hatchery populations he had sampled in the basin. These results suggest that in some circumstances, substantial divergence can occur between resident and anadromous cutthroat trout.

In their unpublished report on cutthroat trout in southern Oregon, Currens et al. (1992) examined 44 presumptive gene loci and found 23 that were polymorphic. Their report did not distinguish between resident and sea-run forms, but Currens⁹ indicated that some populations had access to the sea, while others

⁹ K. Currens, Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Oregon State University, Nash Hall 104, Corvallis, OR 97331-3803. Pers. commun., January 1994.

were collected above barriers to anadromous migration. All fish were less than 250 mm and one was sexually mature, indicating it was probably a resident fish, as mature sea-run fish are usually larger (K. Currens, see footnote 9). Within the Coquille River, Currens et al. (1992) found no apparent geographic structure to the pattern of genetic differentiation. Genetic differences among local populations within tributaries were statistically significant and were as large or larger than differences among populations in different tributaries. With one exception, all samples collected in the Coquille River were more similar to one another than they were to a sample from the Chetco River (over 100 km south of the mouth of the Coquille River). The exception is that fish collected from Slater Creek in the Coquille River were as genetically divergent from other Coquille River samples as they were from the Chetco River sample.

Currens et al. (1992) interpreted these patterns of genetic variation to indicate that gene flow was as restricted between local populations as it was between populations in different tributaries. He also believed that the random genetic differentiation among local populations suggested a history of genetic drift and small population sizes. Unfortunately, these conclusions must be tempered by consideration of the small samples (mean $N = 19$, range = 6 to 31). In particular, the outlier sample from Slater Creek consisted of just six individuals and the Chetco River sample was only nine fish.

Future Genetic Studies

Samples for a study of life history and genetic variation in coastal cutthroat trout from California to Alaska were collected in 1993 by the USFS (G. Reeves¹⁰). Samples were collected from various locations in Oregon, including the North and South Umpqua Rivers. The USFS planned to collect a variety of allozyme, mtDNA, meristic, and life-history data on the samples but has not yet completed sufficient analysis to release any information.

Genetic Relationship of Life-History Forms

In the context of this status review, a key issue that needs to be addressed is whether resident, potamodromous, and sea-run life-history forms are different phenotypes within a single gene pool, or whether they represent genetically differentiated gene pools, each possibly adapted to its specific environment.

There are no studies that specifically address where sea-run, resident, or potamodromous fish are located in the Umpqua River. ODFW (1993a) identified general locations where cutthroat trout larger than 300 mm have been observed and where resident fish have been observed. The fish found between these two areas may be potamodromous fish (ODFW 1993a; D. Loomis, see footnote 2). Resident fish are reported in the upper North Umpqua River, as well as in Canton and Steamboat Creeks. Anadromous cutthroat trout are reported in Sutherlin Creek, Little River, and Rock Creek. The area of the North Umpqua River between the confluence of Rock Creek and Steamboat Creek (Fig. 2) is believed by

¹⁰ G. Reeves, USDA Forest Service, Pacific Northwest Research Station, 3200 NW Research Way, Corvallis, OR 97331. Pers. commun., January 1994.

ODFW (D. Loomis, see footnote 2) to contain cutthroat trout that only migrate within the river system.

It has been suggested (Royal 1972, Edie 1975, Jones 1979) that resident cutthroat trout populations may contribute to and even maintain sea-run cutthroat trout populations. Tomasson (1978) reported that larger juvenile fish were the first to migrate out of natal spawning areas into the mainstem Rogue River. He also found that the larger fish were the first to reach the estuary--suggesting that anadromous behavior may be correlated with growth. However, in one study that addressed this possibility, that hypothesis was not corroborated (Michael 1983). Michael used mark and recapture methods to investigate whether resident populations in three creeks (Snow, Andrews, and Salmon Creeks) on the Olympic Peninsula contributed to a sea-run population. While his studies were not conclusive due to low return rates and physical problems with fish barriers, the results showed that fin-clipped seaward migrants were the progeny of anadromous fish, not residents. Based upon these results, Michael concluded that offspring of resident cutthroat trout populations make little if any significant contribution to anadromous populations.

Genetic Studies on Life-History Forms in Other Species

Although cutthroat trout have not been the focus of extensive studies on the relationship of anadromous and nonanadromous populations (Behnke 1972a, Trotter 1989), this issue has been investigated in other salmonid species, especially brown trout, arctic char (*Salvelinus alpinus*), sockeye salmon (*O. nerka*), and rainbow trout. Studies on these relationships in other species may provide

insight into similar relationships in cutthroat trout. At least three possible genetic relationships between life-history forms have been proposed (Ryman 1983):

- 1) Alternative life-history forms are genetically isolated and represent separate populations.
- 2) Alternative life-history forms are not genetically distinct.
- 3) Alternative life-history forms are genetically distinct within a local area but are more similar to one another than they are to their respective forms outside of the local area.

Arctic char--In rearing and transportation studies of arctic char, Nordeng (1983) found that offspring from Norwegian anadromous and nonanadromous ("small" and "large" morphotypes) fish may display morphological characteristics of either or both life-history forms. Nordeng concluded that these life-history forms "belong to the same gene pool" (p. 1372). However, he also found that both environmental and genetic factors contributed to the proportion of different life-history forms in the F1 generation. Similar conclusions have been drawn from life-history surveys (Skreslet 1973, Johnson 1980, Hindar and Jonsson 1982, Jonsson and Hindar 1982).

Hindar et al. (1986) electrophoretically surveyed three char morphotypes (anadromous, nonmigratory or landlocked "dwarf," and "normal" resident) from 15 sites in Norway. They found that the absolute values of Nei's genetic distance between life-history forms and populations were small (0.001). Similar studies on arctic char in Ireland (Ferguson 1981) and Scandinavia (Andersson et al. 1983)

reported similar results. All these studies concluded that differentiation among localities explains far more of the total gene diversity than differences between life-history forms.

Brown trout--Rearing studies (reviewed in Rounsefell 1958 and in Skrochowska 1969) demonstrated that resident brown trout parents can produce sea-run offspring and vice versa. However, Skrochowska concluded that the different life-history forms are not in the same gene pool because although offspring of anadromous and nonanadromous parents were reared in a common hatchery environment, they differed markedly in migration tendency and hybrids of the two life-history forms had an intermediate migrational tendency. Skrochowska also found that resident behavior was associated with slow growth as parr.

In tagging and transplantation studies, Jonsson (1982) monitored and exchanged brown trout from a land-locked lake with trout from a lake with ocean access. He showed that the trout from the land-locked lake displayed less migrational tendencies (overall movement and direction of movement) than the trout from the lake with sea access. In a later study, Jonsson (1985) found that migrational rates of the fish from the anadromous stock were associated with growth rate.

Three allozyme studies of brown trout in Europe concluded that genetic differentiation was greater among geographic areas than among anadromous and nonanadromous life-history forms (Ryman 1983, Ferguson 1989, Hindar et al. 1991). While average heterozygosities were similar in the three studies,

Hindar et al. reported slightly higher levels in mixed sea-run/resident stocks (about 3%) than in land-locked stocks (about 1%).

Two recent studies reported significant genetic differentiation between life-history forms in brown trout in the Great Lakes (Krueger and May 1987) and in Norway (Skaala and Naevdal 1989). However, as discussed by the authors, neither of these studies would exclude other causes of genetic differentiation as both studies compared life-history forms from different drainages.

In a protein electrophoretic study on the zoogeographical origin of brown trout in Russia, Osinov (1984) found greater genetic differentiation between brown trout populations separated by large distances than between anadromous and nonanadromous life history forms or between nonanadromous morphotypes within a region. According to Osinov, a number of previous studies (Berg 1948; Barach 1952; Panov 1958; Sharipov 1970, 1976) on Russian brown trout populations concluded that "as regards the anadromous, brook and lake forms, the brook and lake forms appear to be interchangeable." Osinov does not specifically mention differences between sea-run and freshwater life-history forms.

Brook trout--McGlade and MacCrimmon (1979) used analysis of morphometric, meristic, and electrophoretic characters to compare populations of brook trout from three sites, only one of which contained anadromous fish (Moisie River estuary, Quebec). Their results show a congruence between allelic frequencies and meristic counts, but not between either of these features and morphometric measurements. The meristic and electrophoretic results showed less diversity between anadromous and nonanadromous forms than between geographically

isolated populations. However, morphometric differences among populations from river, lake, and estuarine habitats were significant, suggesting that "geographically isolated populations of brook trout are, in fact, denizens of particular localities" (McGlade and MacCrimmon 1979, p. 2008).

Atlantic salmon (*Salmo salar*)--Stahl (1987) reported that the results of cluster analyses of data from protein electrophoretic surveys of European and North American Atlantic salmon support the hypothesis that nonanadromous populations were derived from anadromous stocks in postglacial times. He also found that, within broad geographic regions, anadromous and landlocked forms were genetically more similar to each other than they were to their respective forms between regions.

Sockeye salmon--In morphological studies of various *O. nerka* populations, Ricker (1940, 1959) and Nelson (1968 a,b) found that kokanee (nonanadromous sockeye salmon) more closely resembled sympatric sockeye runs than they did other geographically distinct kokanee populations. Further, Ricker (1959, 1972), Scott (1984), and Kaeriyama et al. (1992) found that after transplantations of sockeye salmon into lakes previously barren of the species, kokanee populations became established.

There is also evidence of genetic divergence between sympatric sockeye salmon and kokanee populations. In a survey of gill raker counts from rivers and lakes in northwestern North America, Nelson (1968b) found differences in gill raker counts between sympatric sockeye and kokanee populations (although

McCart (1970) did not find any electrophoretic differences in hemoglobin and muscle myogens between the two life-history forms). Nelson cautions that there was no evidence "that allopatric kokanee differ more from sockeye than those kokanee which are still sympatric and thereby perhaps having gene flow with sockeye" (p. 419). Ricker (1940) has also shown that kokanee in a lake with sockeye may spawn at different times and in different locations. Even when spawning is coincident, male sockeye salmon display a strong preference for spawning only with sockeye, although kokanee males may mate with either sockeye or kokanee females (Hanson and Smith 1967, McCart 1970, Foote and Larkin 1988).

The most extensive electrophoretic survey of *O. nerka* life-history forms is of 23 populations from various lakes in British Columbia (Foote et al. 1989). Significant and consistent genetic differences were found between sympatric kokanee and sockeye salmon in three systems where they co-occur. However, kokanee and sockeye from the same lake system always were more similar than were the same form from other lake systems. A similar result was found for sockeye salmon and kokanee from Redfish Lake in Idaho. Redfish Lake sockeye salmon were listed as an endangered species under the ESA in 1991 (NMFS 1991a). Genetic data gathered after the listing determination showed that there are large allele frequency differences at several gene loci between the few remaining sockeye salmon and the more abundant kokanee in Redfish Lake (Waples 1992). However, the genetic differences between the two forms in Redfish Lake are relatively small compared to the differences between Redfish Lake

O. nerka as a group and sockeye salmon and kokanee populations from other areas of the Pacific Northwest.

Steelhead/rainbow trout--In an electrophoretic survey of steelhead and rainbow trout from Washington, Oregon, and Idaho, Allendorf (1975) and Allendorf and Utter (1979) did not find genetic support for division of the species on the basis of life-history forms. The authors concluded that the species *O. mykiss* was genetically structured into a coastal and inland form, rather than into an anadromous and nonanadromous form. Similar results were also reported by Wilson et al. (1985) from a smaller-scale study on mtDNA variation in steelhead and rainbow trout.

Sex Ratios of Different Salmonid Life-History Forms

In a number of surveys of differences between anadromous and resident populations, it has been found that males predominated among resident spawners and females among anadromous spawners. This has been found in chinook salmon (Healy 1991), Atlantic salmon (Myers 1984), arctic char (Nordeng 1983), and sockeye salmon/kokanee (Ricker 1938). If males are less likely to outmigrate than females, this would be an indication that anadromous and resident groups could belong to the same population (Campbell 1977, Jonsson 1985).

In 1946, Sumner (1972) found a 3.1 predominance of female to male adult sea-run cutthroat trout at Sand Creek in Oregon, although in other years (1947-49) the ratio was only 1.6 to 1 in favor of the females. Although Sumner (1972, p. 24) suggests that "these figures are not 100 percent accurate" due to the

difficulty in sexing fish early in the run, he also referenced a 1954 Alsea River hatchery report that gave a ratio of 1.9 females to 1 male. Cramer (1940), however, reported a ratio of 1.1 males to 1 female obtained from a random count of spawners from the same hatchery.

We have no current data on sex ratios among wild or hatchery stocks of cutthroat trout.

Hatchery Releases in Umpqua River Basin

Since the mid-1970s, yearly hatchery production of cutthroat trout in Oregon has ranged from 200,000 to 300,000 smolts per year. Most of these plantings have been from stock derived from the Alsea River (Nickelson et al. 1992). This stock is reared at ODFW's Alsea River and Cedar Creek hatcheries. Alsea River stock are released in 6 to 10 different coastal rivers in Oregon. For example, in 1987 approximately 280,000 Alsea stock smolts were released into the Alsea River, Salmon River, Siletz River, Smith River, Scholfield Creek, and Siuslaw River. A smaller group of "Nehalem stock" cutthroat trout has also been released, mainly in northern Oregon coastal rivers. In 1993, releases of hatchery cutthroat trout in Oregon were re-evaluated and reduced in some areas (D. Loomis, see footnote 2).

In the Umpqua River Basin, Alsea River hatchery fish have been released both in the North Umpqua River below Winchester Dam and in the Smith River and Scholfield Creek at the mouth of the basin (Fig. 2).

Hatchery Releases in the North Umpqua River

There is less information available on releases of hatchery fish in the North Umpqua River than on hatchery releases in Smith River and Scholfield Creek. Between 1961 and 1976, approximately 20,000 cutthroat trout were released per year (Table 1, Fig. 6). The fish were Alsea River hatchery broodstock; smolts were released a few miles below Winchester Dam (ODFW 1993a) at Amacher County Park and Hestness Park (D. Loomis, see footnote 2). No stocking has occurred since 1976, although returns through 1979 could reflect hatchery fish, since cutthroat trout are not semelparous (Fig. 6).

The effect on native runs of the fish released into the North Umpqua River is unknown. Counts of cutthroat trout passing Winchester Dam increased dramatically during the first 3 years hatchery fish were released below the dam (1961-63), but were declining steeply before hatchery planting was stopped in 1976 (Fig. 7). For some or all of the years that hatchery fish were released below Winchester Dam, ODFW biologists adipose- or ventral-fin clipped a percentage of the fish released. Unfortunately, fin clip data collected from returning cutthroat trout at Winchester Dam are incomplete and it is unclear whether these marks were consistently recorded at the dam (D. Loomis, see footnote 2).

Although there are also no quantitative data available on straying rates during the years of hatchery releases near Winchester Dam, ODFW biologists believe that the straying rate was high, since many fin clipped cutthroat trout were found throughout the North and South Umpqua Rivers and in tributaries of the mainstem river (D. Loomis, see footnote 2).

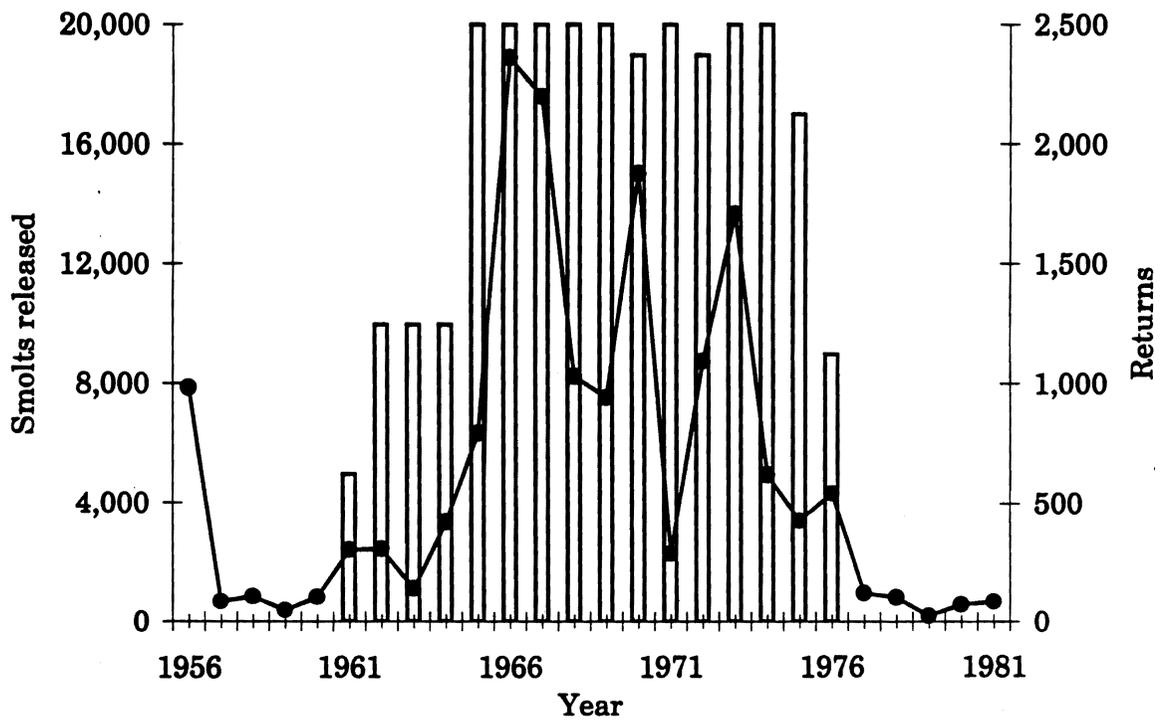


Figure 6. Yearly releases of Alsea River hatchery cutthroat trout below Winchester Dam (bars) compared to the number of adult cutthroat trout (line) passing Winchester Dam, 1956 to 1981 (ODFW 1993a).

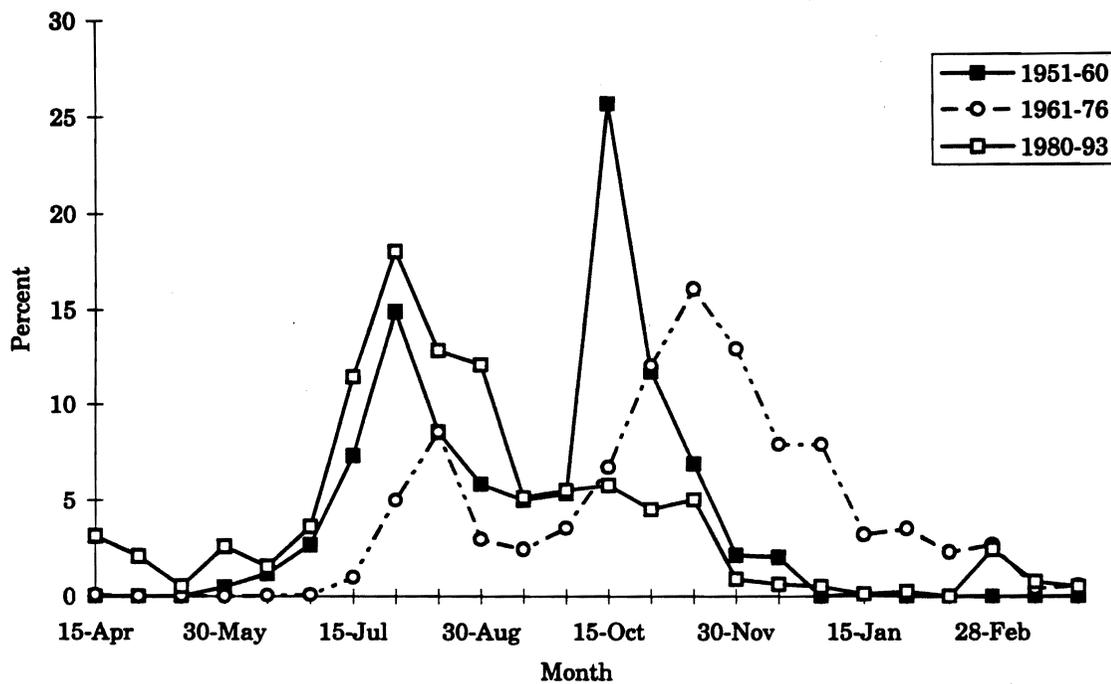


Figure 7. Bimonthly percentage of adult cutthroat trout passing Winchester Dam, 1951 to 1960 (shaded squares), 1961 to 1976 (circles, broken line), and 1980 to 1993 (unshaded squares). The time periods represent fish counts before hatchery fish were planted below Winchester Dam, during hatchery supplementation, and after hatchery plantings were stopped in 1976. Because hatchery fish may have continued to return to Winchester Dam during 1977 to 1979, these years were omitted from analysis (ODFW 1993a).

Return-timing of hatchery and natural adults--As discussed in a previous subsection, Adult Freshwater Migrations, ODFW has recorded the upstream movement of cutthroat trout passing Winchester Dam annually since 1946 and at 2-week intervals since 1951. Throughout most of this period, Umpqua River cutthroat trout passed Winchester Dam from late June through November, with a bimodal peak in mid-July and mid-October. Figure 7 depicts the seasonal timing of this movement during three periods: 1) before Alsea River hatchery cutthroat trout were planted into the Umpqua River, 1951-60; 2) during hatchery cutthroat trout plants, 1961-76; and 3) after terminating the hatchery cutthroat trout plants, 1980-93 (ODFW 1993a). Because hatchery fish may have continued to return to Winchester Dam during 1977 through 1979, these years are not included in the analysis. The plots indicate the presence of strong bimodality in cutthroat trout migration timing during the first two periods but not the latter. In addition, migration timing shifted to later dates during the period when hatchery fish were planted in the river.

Because the difference in sample size of the three time intervals analyzed was large (696 in 1951 to 1960, 918 in 1961 to 1976, and 56 in 1980 to 1993), an extension of the median test (Daniel 1978, p. 196) was used to test for differences in migration timing among the three periods. We chose this nonparametric test because of the evidence for strong departure from normality due in the data to bimodality. The extension of the median test employs a chi-square test for homogeneity to evaluate variation in the numbers of fish (across years within periods) that were counted migrating before or after the pooled median migration

date. A total of 22,428 cutthroat trout was recorded over the period 1951 to 1993 (excluding fish recorded from 1977 to 1979). Over all samples, the median migration timing occurred during the first two weeks of October. The test was performed after discarding all observations occurring during this interval to minimize the incidence of "ties" in migration timing. The resulting chi square revealed that migration timing differed significantly among the groups (chi square = 1860.4, 2 df, $P < 0.005$).

Individual median tests (Daniel 1978, p. 78), which use the normal approximation, were performed on each pair of the three samples because the extension of the median test does not provide for multiple comparisons. The individual median tests indicated that all three samples differed significantly (minimum $T = 10.31$, $P < 0.001$). The order of migration timing was 1978-93 < 1946-60 < 1961-77; thus, the timing shifted to later dates during hatchery plants but, after the plants ceased, returned to earlier dates. Interestingly, migration dates in the years since 1980 have been even earlier than they were before the hatchery plants. This may be due in part to the virtual disappearance of the late peak in returns since 1980. However, the low abundance of cutthroat trout during this period makes it difficult to determine the precise shape of the migration-timing distribution.

Hatchery Releases in the Lower Umpqua River

Hatchery releases occurred in the Smith River from 1975 to the present, and in Scholfield Creek from 1982 to the present (Table 1, Fig. 8). Approximately 12,000 hatchery fish per year have been released into the Smith River and

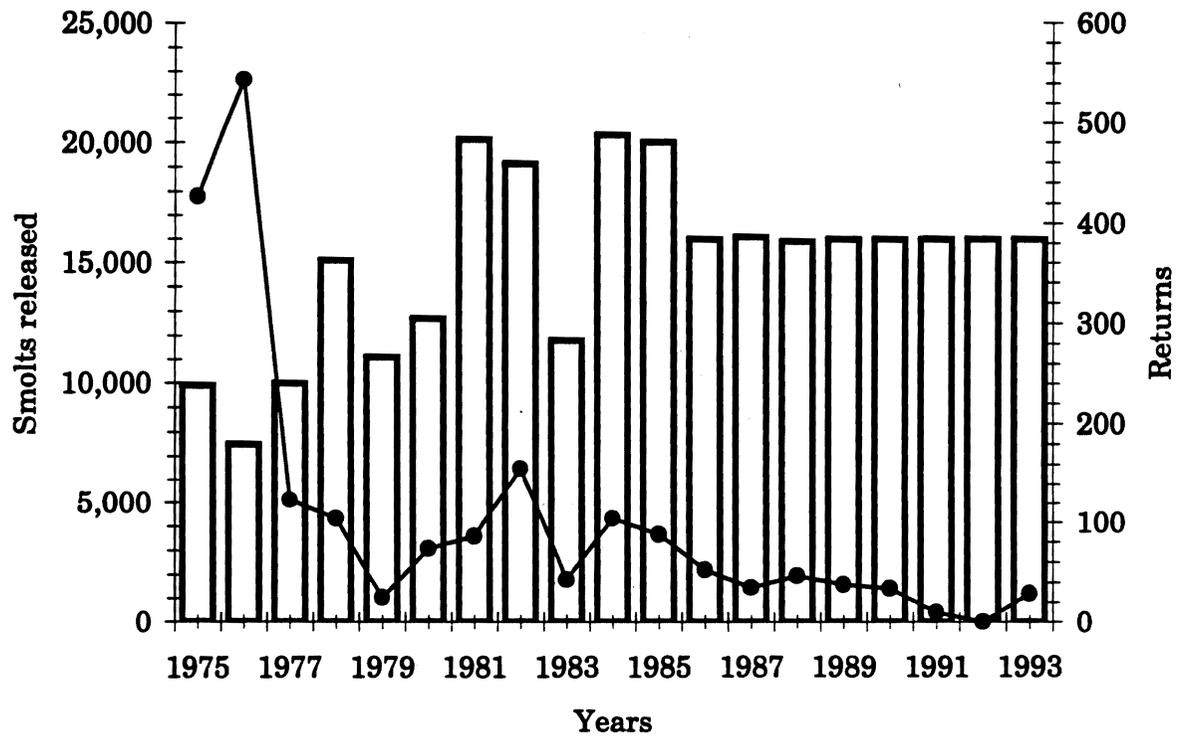


Figure 8. Yearly releases of Alsea River hatchery cutthroat trout into the Smith River and Scholfield Creek (bars) compared to the number of adult cutthroat trout (line) passing Winchester Dam, 1975 to 1993 (ODFW 1993a).

4,000 per year into Scholfield Creek. These fish are released as smolts and as legal-sized catchable trout prior to or during the trout fishing season (ODFW 1993a).

There are no reports on straying rate of cutthroat trout from the lower Umpqua River into other Umpqua River tributaries. However, beginning in 1992, all hatchery fish released in Smith River and Scholfield Creek have been fin clipped (ODFW 1993a). To date, no fin-clipped fish have been reported crossing Winchester Dam (D. Loomis, see footnote 2). Still, in 1993, ODFW reassessed their cutthroat trout hatchery program and reduced the number of hatchery cutthroat trout released into the Umpqua River (D. Loomis, see footnote 2).

There are no studies or reports on habitat utilization or competitive interactions between hatchery cutthroat trout released into Smith River or Scholfield Creek and naturally spawned fish from the North Umpqua River Basin. However, studies on cutthroat trout in other estuaries in Oregon (e.g., Alsea, Nestucca, Siuslaw, Rogue Rivers) suggest estuaries are critical areas where juvenile and adult cutthroat trout spend considerable time (Lowry 1965, Giger 1972, Tomasson 1978). It would be likely that naturally spawned fish and Alsea River hatchery fish planted into lower Umpqua River tributaries interact extensively in the Umpqua River estuary.

Hybridization Between Cutthroat and Rainbow Trout

The interbreeding or introgressive hybridization (often called introgression) of native cutthroat trout with introduced hatchery strains of rainbow trout is often cited as the major cause of the decline of cutthroat trout across the American West

(Busack and Gall 1981, Leary et al. 1984, Campton and Utter 1985, Gyllensten et al. 1985, Martin et al. 1985). It is believed this process has compromised the genetic integrity of native populations and resulted in the extinction of two cutthroat trout subspecies (Behnke and Zarn 1976; Behnke 1979, 1992; Allendorf and Phelps 1981; Busack and Gall 1981; Allendorf and Leary 1988).

The fitness and reproductive success of hybrids between cutthroat and rainbow trout has not been extensively investigated (Busack and Gall 1981, Allendorf and Leary 1988). Studies from hatchery populations have shown that hybrids between these species are often fertile and capable of interbreeding with each other and parental taxa, but they may also have lower fitness than the parental taxa (Allendorf and Leary 1988). In one study on a naturally occurring population, Busack and Gall (1981) used meristic and electrophoretic analyses to evaluate two populations of Paiute cutthroat trout (*O. c. seleniris*) from California. They found one population to be a hybrid swarm, composed of hybrids between the native trout and introduced rainbow trout.

Developmental stability as measured by meristic analysis has been used to evaluate the offspring of rainbow trout hybridized with three different subspecies of cutthroat trout. The hybrid juveniles had decreased developmental stability relative to their parental taxa (Leary et al. 1985). In another study, offspring of crosses between westslope cutthroat and rainbow trout were shown to have had slower growth rates than parental taxa under hatchery conditions (Allendorf and Leary 1988).

Natural sympatry of rainbow and cutthroat trout is rare, occurring primarily in the coastal cutthroat trout subspecies. It is believed that spatial and temporal separation of spawning have acted as isolating mechanisms to allow the two species to remain distinct in areas of sympatry (Trotter 1989). However, fish that have morphological similarities to both *O. c. clarki* and *O. mykiss* have been reported in numerous studies (DeWitt 1954, Needham and Gard 1959, Hartman and Gill 1968, Sumner 1972). Identification of natural hybrids of rainbow and coastal cutthroat trout by protein electrophoresis was first documented by Campton and Utter (1985) from fish collected in two streams from the northern basin of Puget Sound.

Sumner (1972) reported a number of possible rainbow x cutthroat trout hybrids found along the Oregon coast. He noted that, following planting of inland cutthroat trout into the Higgins Reservoir in Oregon in the late 1940s, a number of fish morphologically intermediate between rainbow and cutthroat trout were found. Sumner also reported a variety of presumed hybrids found in headwater streams at the boundary between the usual spawning areas of steelhead and cutthroat trout in the Tillamook, Miami, Wilson, and Trask Rivers. Possible rainbow x sea-run cutthroat trout were also found from the Nestucca River. These Nestucca hybrids resembled coastal cutthroat trout, but Sumner (1972, p. 85) noted that they were "above average in size" and had larger and coarser scales than cutthroat trout. According to Sumner (1972, p. 86), at one time "many years ago," cutthroat trout x steelhead hybrids were reared at the Alsea River hatchery, and "they were said to have been large for their age...."

Releases of Hatchery Rainbow Trout in the Umpqua River

The potential for introgression of cutthroat trout with rainbow trout in the Umpqua River Basin is substantial. Intense stocking of hatchery rainbow trout into the watershed began in the mid-1940s (Loomis et al. 1993) and has continued unabated for over 45 years. In 1992, about 533,000 rainbow trout were released in the basin. Although the majority of these fish (476,000) were planted into reservoirs and lakes, 57,000 legal-sized rainbow trout were planted into the North Umpqua River, South Umpqua River, Little River, Cow Creek, and Calapooya Creek.

Possible cutthroat trout and rainbow trout hybrids were collected in 1991 from Fish Creek in the North Umpqua River. Meristic analysis indicated that the fish phenotypically resembled rainbow trout (D. Markle¹¹). No cutthroat trout and rainbow trout hybrids in the Umpqua River Basin were reported in the 1992 Oregon Wild Fish Management Policy Biennial Progress Report (Chilcote et al. 1992), although both cutthroat and rainbow trout were reported from Fish Creek. While rainbow trout have been planted into the basin for over four decades, the report only listed two locations throughout western central Oregon with putative cutthroat trout and rainbow trout hybrid populations, Twomile and Crooked Creeks, neither of which are in the Umpqua River Basin.

Efforts by ODFW biologists to avoid hybridization of hatchery rainbow trout with cutthroat trout in the Umpqua District have concentrated on stocking

¹¹ D. Markle, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331-3803. Pers. commun., January 1994.

nonnative rainbow trout with different spawning times than native cutthroat trout (Kinunen and Moring 1976, Loomis et al. 1993). All rainbow trout released into the basin in 1992 were from two stocks of nonnative trout. The majority of these fish, 435,000 or 81.6%, were Oak Springs stock (ODFW stock 53) and were planted as juvenile (fingerling) trout into Diamond Lake near the headwaters of the North Umpqua River. Similar numbers of the strain have been planted into Diamond Lake and other bodies of water in the Umpqua River Basin since at least 1975 (Kinunen and Moring 1976, Chilcote et al. 1992, Loomis et al. 1993). Artificial propagation of this stock is thought to have begun in Utah in 1923. Interestingly, while this strain is fall-spawning in the hatchery, in Diamond Lake it reverts to an April-May regimen.

The other nonnative rainbow trout stock planted into the Umpqua River Basin in 1992 was from the Cape Cod strain (ODFW stock 72). These fish were stocked as legal-size trout into the North and South Umpqua Rivers as well as into tributaries of the mainstem river. The Cape Cod strain was originally from Massachusetts and was first transported to the Pacific Northwest in 1941 or 1942 (Kinunen and Moring 1976).

There are numerous populations of naturally spawning rainbow trout in the Umpqua River Basin, but how many of these are originally of hatchery or natural origin is undocumented. Chilcote et al. (1992) listed six rainbow trout populations in the basin, while Loomis et al. (1993) listed nine. These authorities have identified presumably naturally spawning rainbow trout in the mainstem North Umpqua River, upper North Umpqua River above Soda Spring Dam to Tokatee

Lake, Fish Creek, Mowich Creek, Clearwater River, and in several other tributaries (Chilcote et al. 1992, Loomis et al. 1993). In the South Umpqua River, rainbow trout populations have been identified in the mainstem above Galesville Dam, Cow Creek, and other tributaries (Chilcote et al. 1992, Loomis et al. 1993).

Several tributaries in the Umpqua River Basin contain only rainbow trout and others only cutthroat trout, but there are some tributaries, such as Cow Creek on the South Umpqua River, that contain both (Loomis et al. 1993). In tributaries that contain both cutthroat and rainbow trout, the cutthroat trout often occur in the upper headwater areas and rainbow trout in the lower areas, with a potential hybrid zone in between (J. Dose, see footnote 5). We were unable to identify any studies on possible hybridization between rainbow and cutthroat trout from these sites.

POPULATION TRENDS

Sea-Run Cutthroat Trout

The primary measure of sea-run cutthroat trout abundance in the North and South Umpqua Rivers is the time series of passage counts at Winchester Dam on the North Umpqua River from 1946 to the present (ODFW 1993a, Fig. 3). In the early part of this series (1946-56), the run averaged about 950 adults passing the dam per year. In the late 1950s, the run precipitously declined to less than one tenth of this, averaging only 90 adults in the period 1957-60. This was followed by a sharp increase, and over the period 1961-76 the run averaged 940 adults. This period of high abundance corresponded with stocking of hatchery

fish in the river below Winchester Dam. In the late 1970s, the run again precipitously declined, averaging only 62 adults per year since 1977. There is no similar data series for the South Umpqua River; in fact, there appears to be no reliable abundance information whatsoever for sea-run cutthroat trout in this river.

A table of estimates of the number of adult cutthroat trout and other anadromous salmonids spawning in the Umpqua River Basin is provided in Lauman et al. (1972), but the source of the data and date of collections are not provided. However, the report estimates 8,000 cutthroat trout were spawning in the main Umpqua River, 10,000 sea-run cutthroat trout were spawning in the South Umpqua River, but only 3,300 sea-run cutthroat trout were spawning in the North Umpqua River and its tributaries.

Assuming the data were incorporated into the report of Lauman et al. (1972) in a timely fashion, it would seem likely these figures were collected sometime in the late 1960s up to 1971. This was the same time that hatchery releases were being made into the North Umpqua River below Winchester Dam. Still, 10,000 sea-run cutthroat trout in the South Umpqua River seems high, given that the maximum number counted over Winchester Dam in any year was less than 2,000 fish.

The present condition of the South Umpqua River is suggested by a quote from the popular press (Shewey 1992, p. 62):

Hatchery-born steelhead and salmon still return to the river in limited numbers, but few, if any, wild fish inhabit the South Umpqua's damaged watershed. If not for the shad run (the first Northwest shad wandered up the Pacific from the San Francisco Bay area during the 1880s) and an unauthorized plant of small-mouth bass, the South Umpqua wouldn't be worth fishing at all.

Resident and Potamodromous Cutthroat Trout

Very little information is available regarding abundance or trends of nonanadromous cutthroat trout in the Umpqua River Basin. Biologists for ODFW and USFS have observed the general distribution and local density of cutthroat trout in some sections of the basin. ODFW reported cutthroat trout catch in angler creel censuses in the basin at three times: 13 (including 1 sea-run), 0, and 45 cutthroat trout were observed in censuses in 1977, 1990, and 1992, respectively (D. Loomis, see footnote 2). The 1992 result was expanded to an estimate of 318 cutthroat trout caught in the basin that year; no expansions are available for the other censuses. We have no measures of fishing effort or harvest rate with which to estimate total population size from these data.

DISCUSSION

In this section, we address the two key questions raised at the start of this status review: Do North and South Umpqua River sea-run cutthroat trout represent a species as defined by the ESA and NMFS policy? and, if so, Is the species threatened or endangered? We begin by summarizing evidence developed in the status review on the two criteria that must be met for a population to be considered an ESU, and hence a "species" under the ESA: reproductive isolation and contribution to ecological/genetic diversity.

Reproductive Isolation

Relationship Between Different Life-History Forms

A recurrent issue throughout this status review has been the relationship of the various life-history forms of cutthroat trout. Across their range, cutthroat trout are well known to occur in two life-history forms: anadromous and resident. A third, lesser known, form, termed river-migrating or potamodromous, has been described in the Willamette and Rogue Rivers. There is also evidence that potamodromous cutthroat trout occur in the Umpqua River system.

A key question in this status review is, Are these alternative life-history forms of *O. clarki* reproductively isolated within the Umpqua River, or are they part of the same gene pool? According to NMFS policy on this issue, anadromous and nonanadromous forms can be considered separately under the ESA if they are reproductively isolated, but they should be considered together if they are not. Figure 9 shows some possible relationships between forms of *O. clarki* in the

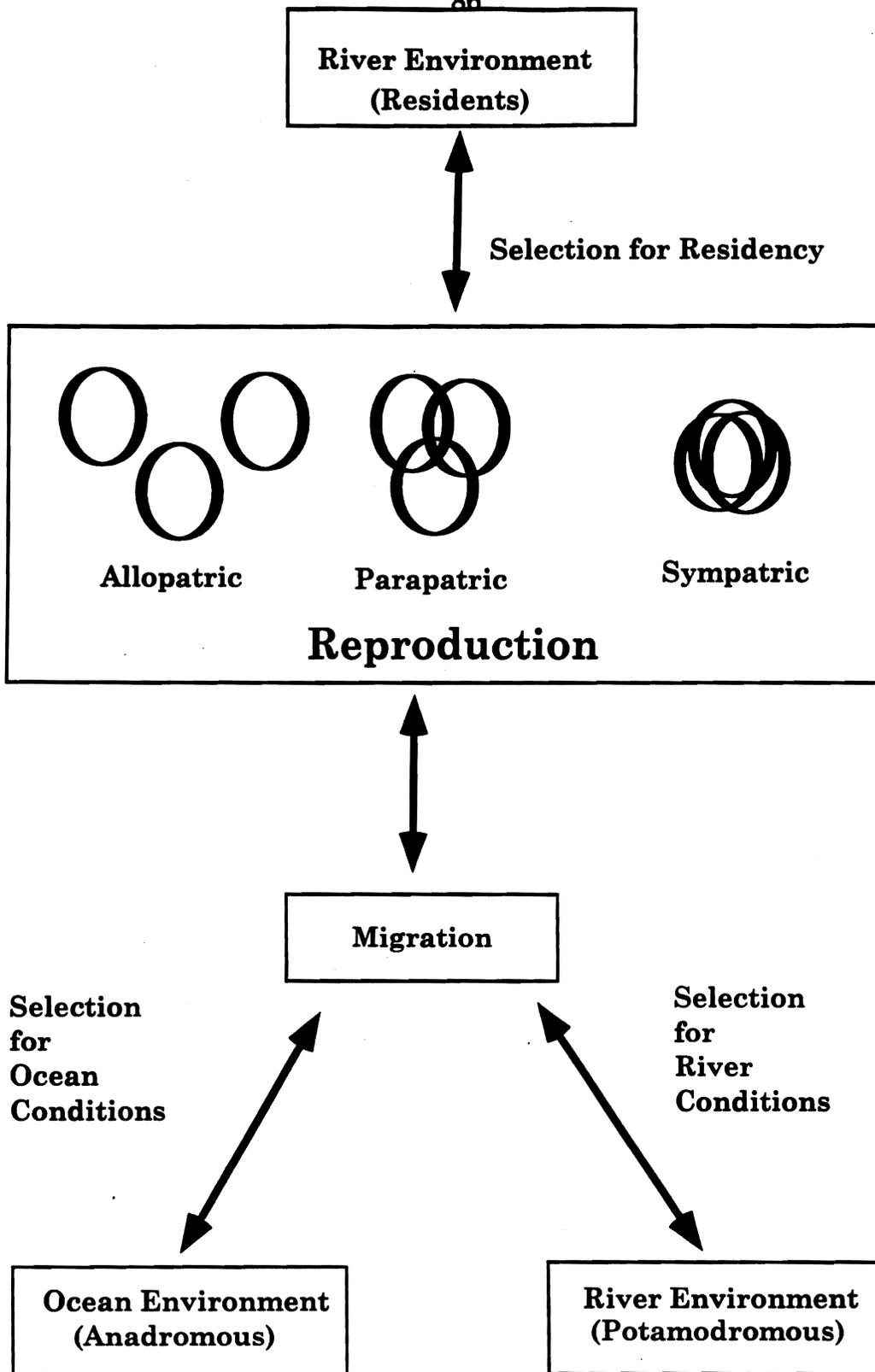


Figure 9. Some possible interactions of three cutthroat trout life-history forms.

Umpqua River that range from panmixia to complete reproductive isolation. In the latter case, the different forms represent distinct gene pools; in the former, the forms represent polymorphisms within a single gene pool. Between these extremes are a range of intermediate scenarios in which there is partial reproductive isolation (but also partial gene flow) between two or more of the forms.

Both resident and anadromous life-history forms have been identified in other species of salmonids (e.g., Arctic char, brown trout, rainbow trout, Atlantic salmon, and sockeye salmon). In these species, it has generally been found that although alternative life-history forms may be genetically distinct within a local area, they are more similar to one another than they are to their respective forms outside of the local area.

There have been no comparable studies for *O. clarki*. However, there are a number of factors related to life-history traits of cutthroat trout that suggest that the opportunities for genetic exchange between anadromous and nonanadromous forms may be greater than is generally believed to be the case for other *Oncorhynchus* species: 1) Sea-run cutthroat trout do not always die after spawning (as do Pacific salmon), and it is generally believed that the incidence of repeat spawning in anadromous cutthroat trout is higher than in steelhead. 2) Unlike species of Pacific salmon and steelhead, sea-run cutthroat trout do not overwinter at sea; rather, it is believed that they return to fresh water each year after only a few months, or even weeks, at sea. 3) It is thought that some cutthroat trout that have gone to sea and returned may spend an entire year (or

more) in fresh water before migrating to sea again. 4) A cutthroat trout may spend as much as 5 years in fresh water before migrating to the sea. 5) Evidence suggests that the different life-history forms of *O. clarki* utilize similar spawning habitat. 6) The potamodromous form may provide a link that retards divergence between anadromous and resident fish.

Returning to an evaluation of the three scenarios depicted in Figure 9, we concluded that the various life-history features discussed above suggest it is unlikely that there is complete reproductive isolation between anadromous, resident, and potamodromous forms of cutthroat trout in the Umpqua River. Based on information available from studies on anadromous/nonanadromous forms in other species (see subsection Genetic Studies on Life-History Forms in Other Species), there is also little reason to believe that matings among the three forms are completely random. Therefore, we conclude that partial gene flow between the life-history forms is the most likely scenario. The extent of the reproductive overlap is unknown but could be substantial. At least until better information is developed, the resident, potamodromous, and anadromous forms should be considered together under the ESA. The following discussion considers all forms of Umpqua River *O. clarki* as a unit.

Reproductive Isolation of Umpqua River *O. clarki*

There are no genetic or tagging data directly relevant to this issue. However, data for anadromous cutthroat trout from Puget Sound and coastal Oregon suggest some genetic structuring at the level of local populations and strong isolation of some geographic areas. Spawning sites of presumed

anadromous *O. clarki* in the North Umpqua River are a considerable distance from the ocean (240 km or more), suggesting the possibility for strong isolation. Resident forms of *O. clarki* in the Umpqua River also probably have little contact at present with conspecifics from outside the basin. Furthermore, temperature data from the Umpqua River estuary suggest that the lower part of the mainstem is too warm for cutthroat trout during much of the summer and may act as an isolating mechanism. Therefore, we concluded that available evidence supports the hypothesis that Umpqua River *O. clarki* as a group satisfy the first criterion to be an ESU: substantial reproductive isolation from other conspecific populations.

Ecological and Genetic Diversity

The second criterion to be considered for an ESU determination is that Umpqua River cutthroat trout contribute substantially to ecological/genetic diversity of the biological species. Evidence in support of this criterion includes distinctive physical and environmental features of the Umpqua River drainage, a lengthy freshwater migration for the anadromous form, and possible adaptations for dealing with high water temperatures and distinctive run times.

Physical and Environmental Features of the Umpqua River Basin

The mainstem Umpqua River and its two major tributaries, the North and South Umpqua Rivers, form one of the longest coastal basins in Oregon, approximately 340 km in length, with a drainage area of over 12,200 km². The North Umpqua River has historically had lower water temperatures and larger summer water flows than most other Oregon coastal rivers because it begins

farther inland and flows for a greater distance at a higher elevation than the other rivers. Because of these factors, the North Umpqua River contained a large and diverse salmonid population. The South Umpqua River also begins at a high elevation, but rapidly descends; it has always had higher water temperatures and a lower summer flow than the North Umpqua River.

Beginning in the mid-1950s, summer water temperatures and the frequency of winter flooding increased in the Umpqua River watershed due in part to removal of riparian cover and to other poor forestry practices in the basin . Summer water temperatures were often above the preferred limit for cutthroat trout in portions of the river. In recent years, the riparian forest canopy has begun to recover in the North Umpqua River watershed, but maximum water temperatures are still higher than those preferred by cutthroat trout and other salmonids.

Distance of Freshwater Migration

Anadromous cutthroat trout that spawn in the upper tributaries of the North and South Umpqua Rivers migrate farther inland (240 to 280 km) than do cutthroat trout from most other rivers in North America. In most medium-sized coastal streams such as the Nestucca, Siletz, or Naselle Rivers, sea-run cutthroat trout spawn within 90 km of the coast; even in the Rogue River, Tomasson (1978) concluded that only rarely, if at all, do anadromous trout migrate above Rkm 104. Only in the Columbia, Fraser, and perhaps the Skeena Rivers are cutthroat trout reported to migrate distances comparable to that in the Umpqua River (P. Trotter, see footnote 1).

Run Times and Water Temperatures

A bimodal peak of run times is not unique to sea-run cutthroat trout from the Umpqua River, but historically the timing of each of the peaks at Winchester Dam occurred earlier than in other streams. Early returning cutthroat trout (July through November) are characteristic of large river systems, but the combination of the late-July and mid-October peaks passing Winchester Dam in the 1940s and early 1950s appeared to be earlier than in other river systems.

The cause of the earlier run-timing of Umpqua River sea-run cutthroat trout is not known, but it has been suggested that high summer water temperatures may be a factor. The petitioners argue that 1) Umpqua River cutthroat trout have unique physiological adaptations to withstand the high summer temperatures in the river, and 2) their unique timing of adult migration can be attributed to high water temperatures that block upstream passage at certain times of the year. Thus, the petitioners argue both that cutthroat trout in the Umpqua River are adapted to the elevated water temperatures now common in the river, and have evolved behavioral mechanisms to avoid lethally high river temperatures found at certain times of the year.

Due to cool water and consistently high summer flows originating in the upper North Umpqua River watershed, the Umpqua River did not historically experience as high water temperatures as did other coastal streams in Oregon. Since the extensive clear-cut logging that occurred in the basin during the mid-1950s, maximum summer water temperatures in certain sections of the Umpqua River Basin have exceeded the preferred, and even lethal, temperatures

for cutthroat trout. By the mid-1970s, the stream canopy had begun to recover, and water temperatures, although still high, were no longer increasing.

Thus, it is unclear whether elevated water temperatures have played an important role in promoting adaptations of cutthroat trout within the Umpqua River Basin. The occurrence of unusually high water temperatures in the upper basin appears to be a relatively recent phenomenon that is unlikely to have substantially affected the evolutionary history of the population. Water temperature data for the upper basin also do not support the hypothesis that the bimodal peak in run times of Umpqua River sea-run cutthroat trout is caused by inhospitably warm water in the period between the runs. Maximum water temperatures at Winchester Dam during September (the time between peak runs) was consistently lower than in July or August over the period 1946-92 (Fig. 5). Finally, Alsea River hatchery fish released below Winchester Dam in the 1960s and early 1970s apparently were able to return to the dam as adults in spite of some of the highest maximum water temperatures recorded in the basin.

Water temperature may, however, be a significant factor affecting cutthroat trout in other parts of the Umpqua River Basin. In contrast to its northern counterpart, the South Umpqua River historically experienced high summer water temperatures (Roth 1937, FCO and OSGC 1946, Lauman et al. 1972), which are believed to be caused by lower overall elevation, little or no spring/summer snow pack, less-porous soils, and less heavily forested riverine habitat. Unfortunately, virtually no biological information is available on cutthroat trout in the South

Umpqua River, so we have no way of directly evaluating the importance of possible adaptations to elevated water temperatures.

As noted above, elevated water temperatures in the lower river may act as an isolating mechanism for Umpqua River cutthroat trout. It is also possible that the bimodal peak of run times at Winchester Dam may be caused in part by a thermal block in the lower river during part of the summer. However, insufficient data are available to determine whether this is the case.

Effects of Artificial Propagation

Counts of adult (presumably sea-run) cutthroat trout passing Winchester Dam show that the number of fish declined to nearly zero in the mid-1950s, increased dramatically from about 1961 to 1975, and rapidly declined again after about 1976. The period of increase coincided almost exactly with releases of sea-run cutthroat trout from the Alsea River hatchery into the Umpqua River below Winchester Dam. Although other explanations are possible, the simplest is that the increases during 1961-75 represented predominantly Alsea River hatchery fish straying to areas above Winchester Dam. Alsea River fish have a slightly later run-timing than the Umpqua River fish, and a shift toward later run-timing can be detected in fish returning to Winchester Dam after 1960 (Fig. 6). There is also evidence of a shift back toward the original run-timing after cessation of the hatchery program.

Although the pattern of abundance and tag-recovery data during the period of supplementation indicates that Alsea River hatchery fish returned as adults to Winchester Dam in some numbers, it is apparent that 15 years of hatchery

releases did not result in a viable, self-sustaining population of naturally spawning fish. One explanation for this result is that Alsea River hatchery fish are poorly adapted to conditions in the North Umpqua River. If true, this would support the concept of an ESU in the Umpqua River. Alternative explanations are that 1) the effects of hatchery rearing, rather than poor adaptation, are responsible for the lack of long-term survival of Alsea River fish, or 2) the declines following the end of the hatchery program merely reflect deteriorating conditions for sea-run cutthroat trout in the North Umpqua River.

A key unresolved issue is, What do the few remaining anadromous fish in the North Umpqua River represent: remnants of the original Umpqua River gene pool, descendants of the Alsea River hatchery fish, or a mixed lineage? The run-timing shift suggests that an indigenous component may remain in spite of the extensive stocking history, but the evidence is far from conclusive.

Extensive releases of Alsea River hatchery fish also occurred near the Umpqua River estuary in the Smith River from 1975 to the present, and in Scholfield Creek from 1983 to the present (Table 1, Fig. 7). Approximately 12,000 hatchery fish per year have been released into the Smith River and 4,000 into Scholfield Creek. These fish are released as smolts and as legal-sized catchable trout prior to or during the trout fishing season (ODFW 1993a). It is believed by ODFW (D. Loomis, see footnote 2) that the majority of these fish are caught by anglers, but no data are available to confirm this hypothesis. There is also no information on the possible impact of these fish (or the fishery for them) on natural sea-run cutthroat trout from the North or South Umpqua Rivers.

However, considering the life history of sea-run cutthroat trout, their susceptibility to angling (Pauley et al. 1989), and their extensive utilization of estuaries, the impact of these releases could be substantial.

In summary, scientific information regarding the geographic extent of the ESU that contains Umpqua River cutthroat trout is inconclusive. The relationship of the existing population to the original population and the introduced hatchery fish is uncertain. Several features of the Umpqua River Basin suggest the possibility for evolutionarily important adaptations in *O. clarki*, but there is little direct evidence on this issue. The biological review team was equally divided on the question whether there is sufficient scientific information for the presumption of a distinct ESU of cutthroat trout limited to the Umpqua River Basin.

The Threshold Question

The precarious status of the remaining sea-run fish in the Umpqua River is not in question. However, we were unable to determine if the ESU is limited to the Umpqua River. Furthermore, as discussed above, we believe that it is important to consider resident and potamodromous fish along with sea-run fish in the listing determination. Data on river-migrating fish within the Umpqua River are very limited, and the total information we were able to develop on abundance of resident *O. clarki* in the Umpqua River drainage amounted to a list of lakes and tributaries believed to contain cutthroat trout. It is reasonable to presume that widespread habitat degradation in the Umpqua River Basin has reduced the abundance of resident and river-migrating fish below historical levels (perhaps substantially below), but we have no direct information on this issue. For these

reasons, a formal threshold determination for an ESU containing anadromous, resident, and river-migrating cutthroat trout is problematical at this time.

A complicating factor in the threshold determination is the evaluation of the evolutionary significance of the anadromous life-history form to *O. clarki* as a whole. On the issue of anadromy/nonanadromy, the NMFS "species definition" paper (Waples 1991, p. 16) has this to say:

If substantial gene flow occurs or has recently occurred between the two forms, they represent polymorphisms within a single population and should be considered as a unit for purposes of the Act. In determining whether such a population unit is an ESU, the anadromous and nonanadromous traits should be considered in the same manner as other population characteristics.... The important questions are whether the traits have a genetic basis and whether they help to make the population unit "distinct" from other populations. For example, an anadromous/nonanadromous unit might be considered an ESU if other ecologically comparable populations of the species harbored only the nonanadromous form. In this case, if the population unit is considered to be an ESU solely or primarily on the basis of the anadromous trait, then the potential loss of anadromy should be a legitimate ESA concern. A key question would be whether the nonanadromous form was likely to give rise to the anadromous form after the latter had gone locally extinct. Therefore, an anadromous/nonanadromous population unit could be listed based on a threat to one of the life-history traits, if the trait were genetically based and loss of the trait would compromise the "distinctness" of the population.

Thus, even if the resident form were determined to be healthy, risk of loss of the anadromous form still would be an ESA concern if the trait has a genetic basis and it contributes substantially to ecological/genetic diversity.

Unfortunately, there is no direct information about the genetic basis for anadromy in cutthroat trout, either in the Umpqua River or anywhere else.

CONCLUSIONS

We concluded that, at least until further information becomes available, resident and potamodromous life-history forms of *O. c. clarki* should be considered part of the ESU that includes Umpqua River sea-run cutthroat trout. Therefore, the entity petitioned for listing (Umpqua River sea-run cutthroat trout) is not, by itself, an ESA species, and a determination of "not warranted" for the petition could be based on this conclusion. However, a "not warranted" determination on this narrow point would not be a resolution of the issue. There remains the undisputed fact that sea-run cutthroat trout in the Umpqua River are very close to extinction, and this option would do nothing to alleviate this problem.

On the other hand, there are difficulties in developing a scientific basis to support a proposal to list some form of Umpqua River cutthroat trout under the ESA. Such a proposal would have to deal with three key issues that we were unable to resolve strictly on the basis of available scientific evidence:

- 1) The geographic extent of the ESU. A proposal to list must include a description of the boundaries of the "distinct population segment" being considered as an ESA species. Although there is evidence to support an ESU in the upper Umpqua River Basin (North and South Umpqua Rivers), it is unclear whether the ESU should include the mainstem and/or lower Umpqua River cutthroat trout or even coastal populations. The biological review team did not reach consensus on this issue.

- 2) Alsea River hatchery fish. A proposal to list would have to be based on the premise that a component of the native, sea-run cutthroat trout still exists, in

spite of the extensive releases of Alsea River hatchery fish. Although circumstantial evidence from population abundance and run-timing suggests that a component of the native run persists, there are no data that directly address the effects of the Alsea River fish on Umpqua River native cutthroat trout.

3) Thresholds. A proposal to list would have to include a determination that the "species" was threatened or endangered. Given the lack of abundance information for nonanadromous cutthroat trout in the Umpqua River, a threatened or endangered determination presumably would focus on the sea-run component. This could be justified on the premise that anadromy is a genetically-based trait and that its presence in Umpqua River *O. clarki* contributes substantially to ecological/genetic diversity of the ESU. However, the genetic basis of anadromy has not been studied in *O. clarki*, and there is no direct information about the genetic relationships between the various forms of the species in the Umpqua River.

The lack of key scientific information for this petition is similar in some respects to the situation NMFS faced in its status review for Snake River sockeye salmon (Waples et al. 1991). At the time a determination had to be made regarding that petition, the biological review team unanimously agreed that the scientific information available was not sufficient to determine with any degree of certainty whether anadromous fish returning to Redfish Lake were derived from the indigenous sockeye salmon population or merely products of seaward drift of kokanee. NMFS elected to take a conservative approach in that listing determination because the consequences of an erroneous decision not to list almost

certainly would have been extinction of that sockeye salmon population.

Information developed since the proposed listing has shown that the sockeye salmon population in Redfish Lake is genetically distinct and should be considered separately from the kokanee (Waples 1992).

Given the extremely low numbers of sea-run cutthroat trout returning to Winchester Dam, a similar conservative approach could also be used with the Umpqua River cutthroat trout. However, there was only one key issue for Redfish Lake sockeye salmon that was unresolved at the time listing was proposed; there are three unresolved issues for the current petition. A listing proposal would have to be based on a conservative approach to each of the three unresolved issues. A framework for doing this would presumably involve the following assumptions:

1) All life-history forms of *O. clarki* in the Umpqua River Basin are a single ESU distinct from other coastal populations.

2) This ESU represents the evolutionary legacy of the historical *O. clarki* population prior to the releases of Alsea River hatchery fish.

3) All life-history forms of *O. clarki* in the Umpqua River Basin have experienced extensive declines in abundance such that they are presently threatened or in danger of extinction; or alternatively, although there is little information regarding the abundance of nonanadromous *O. clarki* in the basin, the depressed sea-run component of the population is a substantial and important component of the ESU and its loss would compromise the distinctness and viability of the inclusive ESU.

Prospects for Additional Information

Prospects for additional information that may help to resolve these key issues are mixed. It is unlikely that significant new information about the genetic basis of anadromy in cutthroat trout will be developed in the near future.

However, it should be feasible to inventory resident and potamodromous populations and develop abundance estimates throughout the basin. Assuming that adequate samples can be obtained, it should also be possible to resolve the relationship of the remaining sea-run fish to the Alsea River hatchery stock.

Oregon State University and the U.S. Forest Service are involved in two studies of genetic and life-history traits in cutthroat trout from Oregon to Alaska. When completed, these studies should provide important information that may provide insights into the unresolved issues for Umpqua River cutthroat trout.

CITATIONS

- Aebbersold, P. B., G. A. Winans, D. J. Teel, G. B. Milner, and F. M. Utter. 1987. Manual for starch gel electrophoresis: A method for the detection of genetic variation. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 61, 19 p.
- Allendorf, F. W. 1975. Genetic variability in a species possessing extensive gene duplication: Genetic interpretation of duplicate loci and examination of genetic variation in populations of rainbow trout. Ph.D. Dissertation, Univ. Washington, Seattle, 98 p.
- Allendorf, F. W., and R. F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. *Conserv. Biol.* 2(2):170-184.
- Allendorf, F. W., and S. R. Phelps. 1981. Use of allelic frequencies to describe population structure. *Can. J. Fish. Aquat. Sci.* 38:1507-1514.
- Allendorf, F. W., and F. M. Utter. 1979. Population genetics. In W. S. Hoar, D. J. Randall, and J. R. Brett (editors), *Fish physiology*, Vol. 8, p. 407-454. Academic Press, New York.
- Anderson, B. G., and D. W. Narver. 1975. Fish population of Carnation Creek and other Barkley Sound streams--1974. *Fish. Res. Board Can., Manuscr. Rep.* 1351, 73 p.
- Andersson, L., N. Ryman, and G. Stahl. 1983. Protein loci in the Arctic charr, *Salvelinus alpinus* L.: Electrophoretic expression and genetic variability patterns. *J. Fish Biol.* 23:75-94.
- Armstrong, R. H. 1971. Age, food, and migration of sea-run cutthroat trout, *Salmo clarki*, at Eva Lake, southeastern Alaska. *Trans. Am. Fish. Soc.* 100:302-306.
- Baade, R. T. 1957. Environmental studies of the cutthroat trout, Southeast Alaska. *Quarterly Progress Rep., Fed. Aid Fish Rest. Proj. F-1-R-6 Alaska Game Comm.* 6(1,2,3): 62-67.
- Bagenal, T. B., F. J. H. Mackereth, and J. Heron. 1973. The distinction between brown trout and sea trout by the strontium content of their scales. *J. Fish Biol.* 5:555-557.
- Barach, G. P. 1952. The significance of the brook trout in the reproduction of Black Sea salmon (*Salmo trutta*). *Zool. Zhur.* 31(6):906-915. (As referenced in Osinov 1984).

- Behnke, R. J. 1972a. The rationale of preserving genetic diversity. Proceedings of the Annual Conference Western Association of State Game and Fish Commissioners 52:559-561.
- Behnke, R. J. 1972b. The salmonid fishes of recently glaciated lakes. J. Fish. Res. Board Can. 29:639-671.
- Behnke, R. J. 1979. Monograph of the native trouts of the genus *Salmo* of western North America. 163 p. (Available Regional Forester, 11177 West 8th Avenue, P.O. Box 25127, Lakewood, CO 80225.)
- Behnke, R. J. 1981. Systematic and zoogeographical interpretation of Great Basin trouts. In R. J. Naiman, and D. L. Soltz (editors), Fishes in the North American deserts, p. 95-124. Wiley, New York.
- Behnke, R. J. 1988. Phylogeny and classification of cutthroat trout. Am. Fish. Soc. Symp. 4:1-7.
- Behnke, R. J. 1992. Native trout of western North America. Am. Fish. Soc. Monog. 6, 275 p. American Fisheries Society, Bethesda, MD.
- Behnke, R. J., and M. Zarn. 1976. Biology and management of threatened and endangered western trout. U.S. Forest Service Gen. Tech. Rep. RM-28, 45 p.
- Bell, M. C. 1986. Fisheries handbook of engineering requirements and biological criteria, 290 p. U.S. Army Corps of Engineers, Fish Passage Development and Evaluation Program, North Pacific Division, Portland, OR.
- Berg, L. S. 1948. The origin of trout and other salmonids. In Pamyati akademika S. A. Zernova (S. A. Zernov memorial volume), p. 159-172. USSR Acad. Sci. Press, Moscow. (As referenced by Osinov 1984).
- Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. In W. R. Meehan (editor), Influences of forest and rangeland management, p. 83-138. Am. Fish. Soc. Spec. Publ. 19, Bethesda, MD.
- Blumm, M. C., and B. Kloos. 1986. Small scale hydropower and anadromous fish: Lessons and questions from the Winchester Dam controversy. In B. B. Weyhrauch (editor), Environmental Law 16(3): 583-637. Northwestern School of Law of Lewis and Clark College, Portland, OR.
- Brown, G. W., G. W. Swank, and J. Rothacher. 1971. Water temperature in the Steamboat drainage. USDA Forest Service Research paper, PNW-119, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 17 p.

- Bulkley, R. V. 1966. Catch of the 1965 tidewater cutthroat trout sport fishery and notes on the life history of the coastal cutthroat in the Siuslaw River, Oregon. Oregon Game Comm., Fishery Research Rep. No. 4, Oregon State Univ., Corvallis, OR.
- Busack, C. A., and G. A. E. Gall. 1981. Introgressive hybridization in a population of Paiute cutthroat trout (*Salmo clarki seleniris*). Can. J. Fish. Aquat. Sci. 38:939-951.
- Bustard, D. R., and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 32:667-680.
- Campbell, J. S. 1977. Spawning characteristics of brown trout and sea trout *Salmo trutta* L. in Kirk Burn, River Tweed, Scotland. J. Fish Biol. 11:217-229.
- Campton, D. E. 1980. Genetic structure of sea-run cutthroat trout populations in the Puget Sound area. In Sea-run cutthroat status report, p. 191-193. Wash. State Game Dep. Rep. 80-14, Olympia, WA.
- Campton, D. E. 1981. Genetic structure of sea-run cutthroat trout (*Salmo clarki clarki*) populations in Puget Sound area. M.S. Thesis, Univ. Washington, Seattle, 180 p.
- Campton, D. E., and F. M. Utter. 1985. Natural hybridization between steelhead trout (*Salmo gairdneri*) and coastal cutthroat trout (*Salmo clarki clarki*) in two Puget Sound streams. Can. J. Fish. Aquat. Sci. 42:110-119.
- Campton, D. E., and F. M. Utter. 1987. Genetic structure of anadromous cutthroat trout (*Salmo clarki clarki*) populations in the Puget Sound area: Evidence for restricted gene flow. Can. J. Fish. Aquat. Sci. 44:573-582.
- Chilcote, C. D., C. Dale, K. Kostow, H. Schaller, and H. Weeks. 1992. Wild fish management policy. Oregon Dep. Fish Wildlife, Biennial Progress Rep., 31 p. (Available Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97201.)
- Clancy, C. G. 1988. Effects of dewatering on spawning by Yellowstone cutthroat trout in tributaries to the Yellowstone River, Wyoming. In R. E. Grisswell (editor), Status and management of interior stocks of cutthroat trout, p. 37-41. American Fisheries Society, Bethesda, MD.
- Clare, H. C., and R. B. Marston. 1968. Forestry practices in the North Umpqua River Basin, Oregon. Report to Federal Water Pollution Control Administration, U.S. Dep. Interior, Northwest Reg. Off., Portland, OR, 25 p.

- Clemens, W. A., and G. V. Wilby. 1946. Fishes of the Pacific Coast of Canada. Fish. Res. Board Can. Bull. 68, Ottawa, 368 p.
- Cramer, F. K. 1940. Notes on the natural spawning of cutthroat trout (*Salmo clarkii clarkii*) in Oregon. Proceedings of the 6th Pacific Science Congress 3:335-339.
- Currens, K. P., S. Krueger, and T. Tufts. 1992. Genetic variation in coastal cutthroat trout (*Oncorhynchus clarki clarki*) in the Coquille and Chetco Rivers, Oregon. Oregon Dep. Fish Wildlife, Portland, OR, 19 p.
- Dambacher, J. M. 1991. Distribution, abundance, and emigration of juvenile steelhead (*Oncorhynchus mykiss*), and analysis of stream habitat in the Steamboat Creek basin, Oregon. M.S. Thesis, Oregon State Univ., Corvallis, 129 p.
- Daniel, W. W. 1978. Applied nonparametric statistics. Houghton Mifflin, Boston, MA, 503 p.
- Dawley, E. M., C. W. Sims, and R. D. Ledgerwood. 1978. A study to define the migrational characteristics of chinook and coho salmon and steelhead trout in the Columbia River Estuary. 1977, Annual Report to Pacific Northwest Regional Commission, 23 p. (Available Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)
- Dawley, E. M., C. W. Sims, R. D. Ledgerwood, D. R. Miller, and F. P. Thrower. 1979. A study to define the migrational characteristics of chinook and coho salmon and steelhead trout in the Columbia River Estuary. 1978, Annual Report to Pacific Northwest Regional Commission, 90 p. (Available Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)
- Dawley, E. M., C. W. Sims, R. D. Ledgerwood, D. R. Miller, and J. G. Williams. 1980. A study to define the migrational characteristics of chinook and coho salmon and steelhead trout in the Columbia River Estuary. 1979, Annual report to Pacific Northwest Regional Commission, 53 p. (Available Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)
- DeWitt, J. W. 1954. A survey of the coast cutthroat trout, *Salmo clarki clarki* Richardson, in California. Calif. Fish Game 40:329-335.
- Dimick, R. E., and F. Merryfield. 1945. The fishes of the Willamette River system in relation to pollution. Oregon State College, Engineering Experimental Station Bulletin, 323, 23 p.

- Duff, R. L. 1972. The 1969-1970 and 1970-1971 sea-run cutthroat tagging and evaluation study at the Cowlitz trout hatchery. Unpubl. manusc., Washington Dep. Game. (Available Washington Department of Wildlife, 600 Capital Way N., Olympia, WA 98501.)
- Dwyer, W. P., and R. H. Kramer. 1975. The influence of temperature on scope for activity in cutthroat trout, *Salmo clarki*. Trans. Am. Fish. Soc. 4:552-554.
- Eddie, B. G. 1975. A census of juvenile salmonids of the Clearwater River basin, Jefferson County, Washington in relation to logging. M.S. Thesis, Univ. Washington, Seattle, 86 p.
- Ferguson, A. 1981. Systematics of Irish charr as indicated by electrophoretic analysis of tissue proteins. Biochem. Syst. Ecol. 9:225-232.
- Ferguson, A. 1989. Genetic differences among brown trout, *Salmo trutta*, stocks and their importance for the conservation and management of the species. Freshwater Biol. 18:629-642.
- Fish Commission of Oregon (FCO) and Oregon State Game Commission (OSGC). 1946. The Umpqua River study. Joint Report, 33 p. (Available from Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97201.)
- Foote, C. J., and P. A. Larkin. 1988. The role of male choice in the assortative mating of anadromous and non-anadromous sockeye salmon (*Oncorhynchus nerka*). Behavior 106:43-62.
- Foote, C. J., C. C. Wood, and R. E. Withler. 1989. Biochemical genetic comparison of sockeye salmon and kokanee, the anadromous and nonanadromous forms of *Oncorhynchus nerka*. Can. J. Fish. Aquat. Sci. 46:149-158.
- Gerstung, E. R. 1981. Status and management of the coast cutthroat trout (*Salmo clarki clarki*) in California. California-Nevada Wildlife Transactions 1:25-32.
- Giger, R. D. 1972. Ecology and management of coastal cutthroat trout in Oregon. Oregon State Game Commission, Fishery Research Rep. 6, 61 p.
- Glova, G. J. 1984. Management implications of the distribution and diet of sympatric populations of juvenile coho salmon and coastal cutthroat trout in small streams in British Columbia, Canada. Prog. Fish Cult. 46:269-277.

- Glova, G. J. 1986. Interaction for food and space between experimental populations of juvenile coho salmon (*Oncorhynchus kisutch*) and coastal cutthroat trout (*Salmo clarki*) in a laboratory stream. *Hydrobiologia* 132:155-168.
- Glova, G. J. 1987. Comparison of allopatric cutthroat trout stocks with coho salmon and sculpins in small streams. *Environ. Biol. Fishes* 20:275-284.
- Glova, G. J., and J. C. Mason. 1976. Interactive ecology of juvenile salmon and trout in streams. *Fish. Res. Board Can., Manusc. Rep. Ser.* 1391, 24 p.
- Glova, G. J., and J. C. Mason. 1977. Interactions for food and space between sympatric populations of underyearling coho salmon and coastal cutthroat trout in a stream simulator during spring. *Fish. Res. Board Can., Manusc. Rep. Ser.* 1428, 36 p.
- Gold, J. R., J. C. Avise, and G. A. E. Gall. 1977. Chromosome cytology in the cutthroat series *Salmo clarki* (Salmonidae). *Cytologia* 42:377-382.
- Golden, J. T. 1975. Lethal temperatures for coastal cutthroat trout under fluctuating temperature regimes. Oregon Dep. Fish Wildlife Report, Unpubl. manusc., 7 p. (Available Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97201.)
- Gresswell, R. E. (editor). 1988. Status and management of interior stocks of cutthroat trout. *Am. Fish. Soc. Symposium* 4, 140 p.
- Gresswell, R. E., and J. D. Varley. 1988. Effects of a century of human influence on the cutthroat trout of Yellowstone Lake. In R. E. Gresswell (editor), *Status and management of interior stocks of cutthroat trout*, p. 45-52. American Fisheries Society, Bethesda.
- Griffith, J. S. 1988. Review of competition between cutthroat trout and other salmonids. *Am. Fish. Soc. Symp.* 4:134-140.
- Gyllensten, U., R. F. Leary, F. W. Allendorf, and A. C. Wilson. 1985. Introgression between two cutthroat trout subspecies with substantial karyotypic, nuclear, and mitochondrial genomic divergence. *Genetics* 111:905-915.
- Hanson, A. J., and H. D. Smith. 1967. Mate selection in a population of sockeye salmon (*Oncorhynchus nerka*) stocks in Cook Inlet, Alaska. *J. Fish. Res. Board Can.* 24:1955-1977.

- Hanson, D. L. 1977. Habitat selection and spatial interaction in allopatric populations of cutthroat and steelhead trout. Ph.D. Dissertation, Univ. Idaho, Moscow.
- Hard, J. J., R. P. Jones, Jr., M. R. Delarm, and R. S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-2, 56 p.
- Hartman, G. F., and C. A. Gill. 1968. Distribution of juvenile steelhead and cutthroat trout (*Salmo gairdneri* and *S. clarki clarki*) within streams in southwestern British Columbia. J. Fish. Res. Board Can. 25:33-48.
- Hayes, G. L., and H. G. Herring. 1960. Some water problems and hydrologic characteristics of the Umpqua basin. U.S. Dep. Agric., Forest Service, Pacific Northwest, Forest and Range Experiment Station, Portland, OR, 22 p.
- Healey, M. C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). In C. Groot and L. Margolis (editors), Pacific salmon life histories, p. 311-391. Univ. British Columbia, Vancouver, BC.
- Heath, W. G. 1963. Thermoperiodism in sea-run cutthroat trout *Salmo clarki clarki*. Science 142:486-488.
- Hindar, K., and B. Jonsson. 1982. Habitat and food segregation of dwarf and normal Arctic charr (*Salvelinus alpinus*) from Vangsvatnet Lake, western Norway. Can. J. Fish. Aquat. Sci. 39:1030-1045.
- Hindar, K., B. Jonsson, N. Ryman, and J. Nordland. 1991. Genetic relationships among landlocked, resident, and anadromous brown trout, *Salmo trutta* L. Heredity 66:83-91.
- Hindar, K., N. Ryman, and G. Stahl. 1986. Genetic differentiation among populations and morphotypes of Arctic charr, *Salvelinus alpinus*. Biol. J. Linn. Soc. 27:269-285.
- Hisata, J. S. 1971. Evaluation of stocking hatchery reared sea-run cutthroat trout in streams of Hood Canal. Washington State Game Department, Progress Rep., AFS-44, Olympia, WA, 33 p.
- Hisata, J. S. 1973. An evaluation of stocking semi-natural pond reared sea-run cutthroat trout, *Salmo clarki clarki*, in some tributary streams of Hood Canal, Washington State. Washington State Game Department, Job Completion Rep., AFS 44-1, 2, Olympia, WA, 38 p.

- Holaday, S. A. 1992. Summertime water temperature trends in Steamboat Creek Basin, Umpqua National Forest. M.S. Thesis, Oregon State Univ., Corvallis, OR, 109 p.
- Hostetler, S. W. 1991. Analysis and modeling of long-term stream temperatures on the Steamboat Creek Basin, Oregon: Implications for land use and fish habitat. *Water Resour. Bull.* 27:637-647.
- Hunter, J. W. 1973. A discussion of game fish in the State of Washington as related to water requirements. Washington State Dep. Ecology, Olympia, WA, 66 p.
- Johnson, J. E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, MD, 42 p.
- Johnson, L. 1980. The arctic charr, *Salvelinus alpinus*. In E. K. Balon (editor), *Charrs: Salmonid fishes of the genus Salvelinus*, p. 15-89. Dr. W. Junk Publishers, The Hague, The Netherlands.
- Johnson, S. W., J. Heifetz, and K. V. Koski. 1986. Effects of logging on the abundance and seasonal distribution of juvenile steelhead in some southeastern Alaska streams. *N. Am. J. Fish. Manage.* 6:532-537.
- Johnston, J. M. 1981. Life histories of anadromous cutthroat with emphasis on migratory behavior. In E. L. Brannon, and E. O. Salo (editors), *Proceedings of the Salmon and Trout Migratory Behavior Symposium*, p. 123-127. School of Fisheries, Univ. Washington, Seattle.
- Johnston, J. M., and S. P. Mercer. 1976. Sea-run cutthroat in seawater pens--broodstock development and extended juvenile rearing (with life history compendium). Washington Dep. Game, Fishery Research Rep., Olympia, WA, 26 p.
- Jones, D. E. 1973. Steelhead and sea-run cutthroat trout life history in S. E. Alaska. Alaska Dep. Fish Game, Sport Fish Division, Annual Performance Rep. 14(42):11-18. (Available Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, AK 99824.)
- Jones, D. E. 1974. The study of cutthroat-steelhead in Alaska. Alaska Dep. Fish Game, Sport Fish Division, Annual Performance Rep. 15(42):15-31. (Available Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, AK 99824.)

- Jones, D. E. 1975. Steelhead and sea-run cutthroat trout life history in southeast Alaska. Alaska Dep. Fish Game, Sport Fish Division, Annual Performance Rep. 16(42): 23-24. (Available Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, AK 99824.)
- Jones, D. E. 1976. Steelhead and sea-run cutthroat trout life history in southeast Alaska. Alaska Dep. Fish Game, Sport Fish Division, Annual Performance Rep. 17(42): 29-55. (Available Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, AK 99824.)
- Jones, D. E. 1978. A study of cutthroat and steelhead in Alaska. Alaska Dep. Fish Game, Sport Fish Division, Annual Performance Rep. 19(42):68-100. (Available Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, AK 99824.)
- Jones, D. E. 1979. A study of cutthroat and steelhead in Alaska. Alaska Dep. Fish Game, Sport Fish Division, Annual Performance Rep. 20(42):27-57. (Available Alaska Department of Fish and Game, Sport Fish Division, P.O. Box 240020, Douglas, AK 99824.)
- Jonsson, B. 1982. Diadromous and resident trout *Salmo trutta*: Is their difference due to genetics? *Oikos* 38:297-300.
- Jonsson, B. 1985. Life history patterns of freshwater resident and sea-run migrant brown trout in Norway. *Trans. Am. Fish. Soc.* 114:182-194.
- Jonsson, B., and K. Hindar. 1982. Reproductive strategy of dwarf and normal Arctic charr (*Salvelinus alpinus*) from Vangsvatnet Lake, western Norway. *Can. J. Fish. Aquat. Sci.* 39:1404-1413.
- June, J. 1981. Life history and habitat utilization of cutthroat trout (*Salmo clarki*) in a headwater stream on the Olympic Peninsula, Washington. M.S. Thesis, Univ. Washington, Seattle, 116 p.
- Kaeriyama, M., S. Urawa, and T. Suzuki. 1992. Anadromous sockeye salmon (*Oncorhynchus nerka*) derived from nonanadromous kokanees: Life history in Lake Toro. *Sci. Rep. Hokkaido Salmon Hatchery* 46:157-174.
- Kaya, C. M. 1977. Reproductive biology of rainbow and brown trout in a geothermally heated stream: The Firehole River of Yellowstone National Park. *Trans. Am. Fish. Soc.* 106(4):354-361.
- Kaya, C. M. 1978. Thermal resistance of rainbow trout from a permanently heated stream, and of two hatchery strains. *Prog. Fish-Cult.* 40(4):138-142.

- Kinunen, W., and J. R. Moring. 1976. Status and origin of rainbow trout brood stock in Oregon. Oregon Dep. Fish Game, Information Rep. 76-7, 12 p. Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97201.
- Krueger, C. C., and B. May. 1987. Stock identification of naturalized brown trout in Lake Superior tributaries: Differentiation based on allozyme data. Trans. Am. Fish. Soc. 116:785-794.
- Lauman, J. E., K. E. Thompson, and J. D. Fortune, Jr. 1972. Fish and Wildlife resources of the Umpqua Basin, Oregon, and their water requirements. Completion Report to the Oregon State Water Resources Board, Oregon State Game Commission, Portland. Project F-69-R-6, Job 6, 127 p.
- Lavier, D. 1963. The sea-run cutthroat. Wash. State Game Dep. Bull. 15(3):4.
- Leary, R. F., F. W. Allendorf, and K. L. Knudsen. 1985. Inheritance of meristic variation and the evolution of developmental stability in rainbow trout. Evolution 39:308-314.
- Leary, R. F., F. W. Allendorf, S. R. Phelps, and K. L. Knudsen. 1984. Introgression between westslope cutthroat and rainbow trout in the Clark Fork River Drainage, Montana. Proceedings of the Montana Academy of Sciences 45:37-45.
- Leary, R. F., F. W. Allendorf, S. R. Phelps, and K. L. Knudsen. 1987. Genetic divergence and identification of seven cutthroat trout subspecies and rainbow trout. Trans. Am. Fish. Soc. 116:580-587.
- Loomis, D., and R. Anglin. 1992. North Umpqua River management plan: Progress Rep. 1991-1992. Oregon Dep. Fish Wildlife, Portland, OR, 29 p.
- Loomis, D., R. Anglin, and D. Harris. 1993. Fish management review. Oregon Dep. Fish Wildlife, Portland, OR, 100 p.
- Loudenslager, E. J., and G. H. Thorgaard. 1979. Karyotypic and evolutionary relationships of the Yellowstone (*Salmo clarki bouveri*) and West-slope (*S. c. lewisi*) cutthroat trout. J. Fish. Res. Board Can. 36:630-635.
- Lowry, G. R. 1965. Movement of cutthroat trout, *Salmo clarki clarki* (Richardson), in three Oregon coastal streams. Trans. Am. Fish. Soc. 94(4):334-338.
- Lowry, G. R. 1966. Production and food of cutthroat in three Oregon coastal streams. J. Wildl. Manage. 30:754-767.

- Marnell, L. F. 1988. Status of the westslope cutthroat trout in Glacier National Park, Montana. *Am. Fish. Soc. Symp.* 4:61-70.
- Martin, M. A., D. K. Shiozawa, E. J. Loudenslager, and J. N. Jensen. 1985. Electrophoretic study of cutthroat trout populations in Utah. *Great Basin Nat.* 45:677-687.
- McCart, P. J. 1970. A polymorphic population of *Oncorhynchus nerka* in Babine Lake, British Columbia. Ph.D. Dissertation, Univ. British Columbia, Vancouver, BC, 135 p.
- McGlade, J., and H. MacCrimmon. 1979. Taxonomic congruence in three populations of Quebec brook trout, *Salvelinus fontinalis* (Mitchill). *Can. J. Zool.* 57:1998-2009.
- Meehan, W. R. (editor). 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. *Am. Fish. Soc. Spec. Publ.* 19, Bethesda, MD, 751 p.
- Michael, J. H., Jr. 1983. Contribution of cutthroat trout in headwater streams to the sea-run population. *Calif. Fish Game* 69:68-76.
- Moring, J. R., and R. L. Lantz. 1975. Cutthroat trout. The Alsea watershed study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part 1-Biological Studies, Oregon Dep. Fish Wildlife, Project AFS-58, Final Rep., Corvallis, OR, 7 p.
- Moring, J. R., R. L. Youker, and R. M. Hooton. 1986. Movements of potamodromous coastal cutthroat trout, *Salmo clarki clarki*, inferred from tagging and scale analysis. *Fish. Res.* 4:343-354.
- Myers, R. A. 1984. Demographic consequences of precocious maturation of Atlantic salmon (*Salmo salar*). *Can. J. Fish. Aquat. Sci.* 41(9):1349-1352.
- National Marine Fisheries Service (NMFS). 1991a. Final Rule: Endangered status for Snake River Sockeye Salmon. *Federal Register* [Docket 910379-1256, 20 November 1991] 56(224):58619-58624.
- National Marine Fisheries Service (NMFS). 1991b. Notice of policy: Policy on applying the definition of species under the Endangered Species Act to Pacific salmon. *Federal Register* [Docket 9910248-1255, 20 November 1991] 56(224):58612-58618.
- Needham, P. R., and R. Gard. 1959. Rainbow trout in Mexico and California with notes on the cutthroat series. *Univ. Calif. Publ. Zool.* 67:1-124.

- Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. *Fisheries* 16(2):4-21.
- Nelson, J. S. 1968a. Distribution and nomenclature of North American kokanee, *Oncorhynchus nerka*. *J. Fish. Res. Board Can.* 25:409-414.
- Nelson, J. S. 1968b. Variation in gillraker number in North America kokanee, *Oncorhynchus nerka*. *J. Fish. Res. Board Can.* 25:415-420.
- Nicholas, J. W. 1978a. Life history differences between sympatric populations of rainbow and cutthroat trouts in relation to fisheries management strategy. In J. R. Moring (editor), *Proceedings of the Wild Trout--Catchable Trout Symposium*, p. 181-188. Oregon Dep. Fish Wildlife, Portland, OR.
- Nicholas, J.W. 1978b. A review of literature and unpublished information on cutthroat trout (*Salmo clarki clarki*) of the Willamette watershed. Oregon Dep. Fish Wildlife, Information Report 78-1, 21 p. (Available Oregon Department of Fish and Wildlife, P.O. Box 59, Portland, OR 97201.)
- Nickelson, T. E., J. W. Nicholas, A. M. McGie, R. B. Lindsay, D. L. Bottom, R. J. Kaiser, and S. E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Unpubl. manusc., 83 p. Research and Development Section, Oregon Dep. Fish Wildlife (ODFW), Corvallis.
- Nilsson, N. A., and T. G. Northcote. 1981. Rainbow trout (*Salmo gairdneri*) and cutthroat trout (*S. clarki*) interactions in coastal British Columbia lakes. *Can. J. Fish. Aquat. Sci.* 38:1228-1246.
- Nordeng, H. 1983. Solution to the "char problem" based on Arctic char (*Salvelinus alpinus*) in Norway. *Can. J. Fish. Aquat. Sci.* 40:1372-1387.
- Oregon Department of Fish and Wildlife (ODFW). 1993a. Letter to ESA Administrative Record for North and South Umpqua River sea-run cutthroat trout, September 17, 1993, Enclosure 28, North Umpqua sea-run cutthroat 1991 progress report for compliance with wild fish management policy (workshop notes). (Available Environmental and Technical Services Division, Natl. Mar. Fish Serv., 911 N.E. 11th Ave., Room 620, Portland, OR 97232.)

- Oregon Department of Fish and Wildlife (ODFW). 1993b. Letter to ESA Administrative Record for North and South Umpqua River sea-run cutthroat trout, September 17, 1993, Enclosure 36, Notes on cutthroat trout in south coast Oregon streams: Based on field observations between 1986-1990. C. Frissell and R. Nawa, (Available Environmental and Technical Services Division, Natl. Mar. Fish. Serv., 911 N.E. 11th Ave., Room 620, Portland, OR 97232.)
- Oregon Natural Resources Council (ONRC), The Wilderness Society, and Umpqua Valley Audubon Society. 1993. Petition for a rule to list the North and South Umpqua River sea-run cutthroat trout as threatened or endangered under the Endangered Species Act and to designate critical habitat. Unpubl. manusc., 11 p. (Document submitted to the USDOC NOAA NMFS Northwest Division, Seattle, Washington, April 1993.) Oregon Natural Resources Council, 522 SW 5th Avenue, Suite 1050, Portland, OR 97204.
- Osinov, A. C. 1984. Zoogeographical origins of brown trout, *Salmo trutta* (Salmonidae): Data from biochemical genetic markers. *J. Ichthyol.* 24:10-23.
- Panov, D. A. 1958. On the homogeneity of populations of the Black Sea salmon and the brook trout. *Nauch. dokl. vyssh shkoly. Biol. nauki*, 1:46-48. (As referenced by Osinov 1984.)
- Pauley, G. B., K. Oshima, K. L. Bowers, and G. L. Thomas. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--sea-run cutthroat trout. U.S. Army Corps of Engineers TR EL-82-4, U.S. Fish and Wildlife Service Biological Rep. 82(11.86). 21 p.
- Pearcy, W. G., R. D. Brodeur, and J. P. Fisher. 1990. Distribution and biology of juvenile cutthroat trout (*Oncorhynchus clarki clarki*) and steelhead (*O. mykiss*) in coastal waters off Oregon and Washington. *Fish. Bull.*, U.S. 88(4):697-711.
- Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification, with application to ecosystem classification. U. S. Forest Service, Billings, MT.
- Ricker, W. E. 1938. "Residual" and kokanee salmon in Cultus Lake. *J. Fish. Res. Board Can.* 4:192-218.
- Ricker, W. E. 1940. On the origin of kokanee, a fresh-water type of sockeye salmon. *Trans. R. Soc. Can.* 34:121-135.

- Ricker, W. E. 1959. Additional observations concerning residual sockeye and kokanee (*Oncorhynchus nerka*). *J. Fish. Res. Board Can.* 16:897-902.
- Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. *In* R. C. Simon, and P. A. Larkin (editors), *The stock concept in Pacific salmon*, p. 19-160. H. R. MacMillan Lectures in Fisheries, Univ. British Columbia, Vancouver, BC.
- Roth, A. R. 1937. A survey of the waters of the South Umpqua Ranger District: Umpqua National Forest. U.S. Dep. Agric. Forest Service, Portland, OR, 41 p.
- Rounsefell, G. A. 1958. Anadromy in the North American Salmonidae. *U.S. Fish. Wildl. Serv. Fish. Bull.* 58:171-185.
- Royal, L. A. 1972. An examination of the anadromous trout program of the Washington State Game Department. Washington State Game Dep., Final Rep. AFS-49, Olympia, WA, 197 p.
- Ryman, N. 1983. Patterns of distribution of biochemical genetic variation in salmonids: Differences between species. *Aquaculture* 33:1-21.
- Schultz, L. P. 1936. Keys to the fishes of Washington and Oregon and closely adjoining regions. *Univ. Wash. Publ. Biol.* 2:105-228.
- Schwiebert, E. 1979. Where flows the Umpqua? *Fly Fisherman* 10:45-50.
- Scott, D. 1984. Origin of the New Zealand sockeye salmon, *Oncorhynchus nerka* (Walbaum). *J. R. Soc. N. Z.* 14:245-249.
- Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. *Bull. Fish. Res. Board Can.* 966 p.
- Sharipov, K. O. 1970. Antigenic features of the Caspian salmon and the brook trout of the Terek and Sulaka rivers. *Vopr. ikhtiol.* 10(4):761-762. (As referenced by Osinov 1984).
- Sharipov, K. O. 1976. Immunoserological features of the brook trout from Caspian rivers and the Black Sea. *In* *Salmoniformes (Morphology, systematics and ecology)*, 124 p. Zoological Institute, Academy of Sciences, Leningrad. (As referenced by Osinov 1984).
- Shewey, J. 1992. Magic. *Fly fisherman* 24(1):37-39, 60, 62.

- Simon, R. C. 1963. Chromosome morphology and species evolution in the five North American species of Pacific salmon (*Oncorhynchus*). *J. Morph.* 112:77-97.
- Skaala, O., and G. Naevdal. 1989. Genetic differentiation between freshwater resident and anadromous brown trout, *Salmo trutta*, within watercourses. *J. Fish Biol.* 34:597-605.
- Skreslet, S. 1973. Group segregation in landlocked Arctic char, *Salvelinus alpinus* (L.) of Jan Mayen Island, in relation to the char problem. *Astarte* 6:55-58.
- Skrochowska, S. 1969. Migrations of the sea-trout (*Salmo trutta* L.), brown trout (*Salmo trutta m. fario* L.) and their crosses. *Pol. Arch. Hydrobiol.* 16:125-192.
- Stahl, G. 1987. Genetic population structure in Atlantic salmon. *In* N. Ryman and F. Utter (editors), *Population genetics & fishery management*, p. 121-140. Univ. Washington Press, Seattle.
- Sumner, F. H. 1948. The coast cutthroat trout. *Oregon Game Commission Bull.* 3(12):1, 6-8.
- Sumner, F. H. 1953. Migration of salmonids in Sand Creek, Oregon. *Trans. Am. Fish Soc.* 82:139-150.
- Sumner, F. H. 1962. Migration and growth of the coastal cutthroat trout in Tillamook County, Oregon. *Trans. Am. Fish Soc.* 91(1):77-83.
- Sumner, F. H. 1972. A contribution to the life history of the cutthroat trout in Oregon. *Oregon State Game Commission, Corvallis, OR*, 142 p.
- Thompson, G. G. 1991. Determining minimum viable populations under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-198, 78 p.
- Thorgaard, G. H. 1983. Chromosomal differences among rainbow trout populations. *Copeia* 1983(3):650-662.
- Tipping, J. M. 1981. Cowlitz sea-run cutthroat study 1980-81. *Washington State Game Dep. Rep.* 81-12, Olympia, WA, 26 p.
- Tipping, J. M. 1986. Effect of release size on return rates of hatchery sea-run cutthroat trout. *Prog. Fish Cult.* 48(3):195-197.

- Tipping, J. M., and S. G. Springer. 1980. Cowlitz River sea-run cutthroat creel census and life history study. *In* Sea-run cutthroat trout census report, p. 106-126. Wash. State Game Dep. Rep. 80-14.
- Tomasson, T. 1978. Age and growth of cutthroat trout, *Salmo clarki clarki*, in the Rogue River Oregon. M.S. Thesis, Oregon State Univ., Corvallis, OR, 75 p.
- Trotter, P. C. 1987. Cutthroat: Native trout of the west. Colorado Associated University Press, Boulder, CO, 219 p.
- Trotter, P. C. 1989. Coastal cutthroat trout: A life history compendium. *Trans. Am. Fish. Soc.* 118:463-473.
- Trotter, P. C., P. A. Bisson, and B. Fransen. 1993. Status and plight of the searun cutthroat trout. *In* J. G. Cloud and G. H. Thorgaard (editors), Genetic conservation of salmonid fishes, p. 203-212. Plenum Press, New York.
- United States Department of Agriculture (USDA) Forest Service. 1990. Land and resource management plan: Umpqua National Forest. Pacific Northwest Region, Portland, OR, 1052 p. (Available USDA Forest Service, Umpqua National Forest, P.O. Box 1008, Roseburg, OR 97470.)
- United States Department of Agriculture (USDA) Forest Service. 1992. Wild and scenic river eligibility determination: South Umpqua River, Jackson Creek, Black Rock Fork, Castle Rock Fork, and Fish Lake Creek. Pacific Northwest Region, Portland, OR, 35 p. (Available USDA Forest Service, Umpqua National Forest, P.O. Box 1008, Roseburg, OR 97470.)
- United States Department of Agriculture (USDA) Forest Service and U.S. Department of Interior (BLM). 1992. North Umpqua wild and scenic river: Environmental Assessment. Pacific Northwest Region. Portland, OR, 136 p. (Available USDA Forest Service, Umpqua National Forest, P.O. Box 1008, Roseburg, OR 97470.)
- Utter, F., P. Aebersold, and G. Winans. 1987. Interpreting genetic variation detected by electrophoresis. *In* N. Ryman and F. Utter (editors), Population genetics & fishery management, p. 21-45. Univ. Washington Press, Seattle.
- Waples, R. S. 1991. Pacific salmon, *Oncorhynchus* spp., and the definition of "species" under the Endangered Species Act. *U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev.* 53(3)11-22.

- Waples, R. S. 1992. Summary of possible ways to characterize juvenile *Oncorhynchus nerka* outmigrants from Redfish Lake, Idaho. Unpublished report, 11 p. (Available Coastal Zone and Estuarine Studies Division, Natl. Mar. Fish. Serv., 2725 Montlake Blvd. E., Seattle, WA 98112.)
- Waples, R. S., O. W. Johnson, and R. P. Jones, Jr. 1991. Status review for Snake River sockeye salmon. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-195, 23 p.
- Waring, R. H., and J. F. Franklin. 1979. Evergreen coniferous forests of the Pacific Northwest. *Science* 204:1380-1386.
- Waters, E. 1993. Winter habitat utilization of radio-tagged coastal cutthroat trout. M.S. Thesis, North Carolina State Univ., Raleigh, NC, 43 p.
- Willers, W. B. 1991. Trout biology, 2nd Edition. Lyons & Burford Publishers, New York, 273 p.
- Wilson, G. M., W. K. Thomas, and A. T. Beckenbach. 1985. Intra- and inter-specific mitochondrial DNA sequence divergence in *Salmo*: Rainbow, steelhead, and cutthroat trouts. *Can. J. Zool.* 63:2088-2094.
- Wright, S. 1973. Resident and anadromous fishes of the Chehalis and Satsop Rivers in the vicinity of Washington Public Power Supply System's proposed nuclear project No. 3. Washington State Dep. Fish. Rep., Olympia, WA, 26 p.
- Wyatt, B. 1959. Observations on the movements and reproduction of the Cascade form of cutthroat trout. M.S. Thesis, Oregon State Coll., Corvallis, OR, 60 p.

GLOSSARY

Allopatric

Occurring in different geographic regions. See **parapatric** and **sympatric**, and Figure 9.

Anadromous

Exhibiting a behavior involving migrations from freshwater to seawater and back to freshwater to spawn. **Coastal cutthroat trout** (*Oncorhynchus clarki clarki*) and most other species in the genus *Oncorhynchus* (Pacific salmon and trout) are considered anadromous.

Artificial Propagation

See hatchery.

Coastal Cutthroat Trout

A cutthroat trout of the subspecies *Oncorhynchus clarki clarki*. The subspecies is primarily found in the coastal region of northwestern North America and is the only **anadromous** subspecies of *O. clarki*.

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); 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).

ESU

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

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 the Umpqua River Basin cutthroat trout fry (young juveniles) and smolts have been released from the ODFW Alsea River Hatchery.

Iteroparous

Reproducing repeatedly, or more than once in a lifetime. In the genus *Oncorhynchus*, only *O. clarki* and *O. mykiss* are iteroparous; all other species are semelparous (i.e., all individuals die after spawning).

Parapatric

Having some geographic overlapping of distributions with the potential for gene flow between populations. See **sympatric** and **allopatric**, and Figure 9.

Phenotype

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

Potamodromous

Exhibiting a behavior involving migrations into smaller river tributaries for spawning and rearing. Potamodromous behavior does not involve migrations out of fresh water. Also called fluvial-adfluvial (Trotter et al. 1993). Potamodromous behavior is common among interior cutthroat trout (*O. clarki* subsp.).

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.

Resident

Occupying headwater reaches; may disperse locally, but generally considered nonmigratory. Also called fluvial (Trotter et al. 1993).

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.

Sea-Run

Synonymous to **anadromous** but is usually used only in reference to the anadromous component of species such as *O. clarki* and *O. mykiss* that commonly have both an anadromous and nonanadromous life history form.

Semelparous

Reproducing only once in a lifetime. All species in the genus *Oncorhynchus* are semelparous except *O. clarki* and *O. mykiss*.

Smolt

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

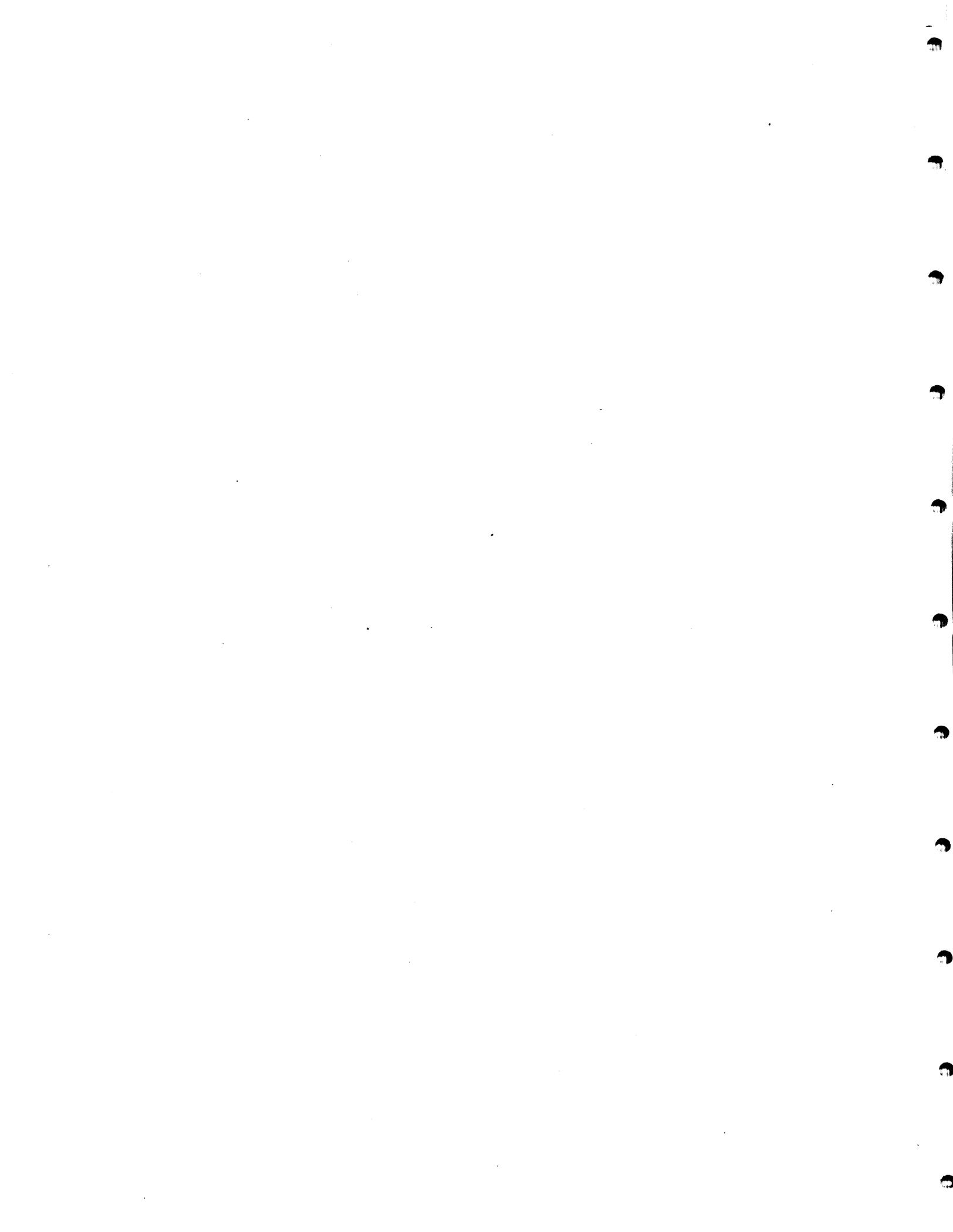
noun- A juvenile anadromous fish which has smolted.

Steelhead

The **anadromous** or **sea-run** form of *O. mykiss*.

Sympatric

Occupying the same geographic area. See **parapatric** and **allopatric**, and Figure 9.



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- 14 REICHERT, W. L., and B. FRENCH. 1994. The ³²P-Postlabeling protocols for assaying levels of hydrophobic DNA adducts in fish, 89 p. NTIS number pending.
- 13 VARANASI, U., D. W. BROWN, T. HOM, D. G. BURROWS, C. A. SLOAN, L. J. FIELD, J. E. STEIN, K. L. TILBURY, B. B. MCCAIN, and S-L. CHAN. 1993. Volume II: Supplemental information concerning a survey of Alaskan subsistence fish, marine mammal, and invertebrate samples collected 1989-91 for exposure to oil spilled from the *Exxon Valdez*, 173 p. NTIS No. PB94-134012.
- 12 VARANASI, U., D. W. BROWN, T. HOM, D. G. BURROWS, C. A. SLOAN, L. J. FIELD, J. E. STEIN, K. L. TILBURY, B. B. MCCAIN, and S-L. CHAN. 1993. Volume I: Survey of Alaskan subsistence fish, marine mammal, and invertebrate samples collected 1989-91 for exposure to oil spilled from the *Exxon Valdez*, 110 p. NTIS No. PB94-131935.
- 11 VARANASI, U., J. E. STEIN, K. L. TILBURY, J. P. MEADOR, C.A. SLOAN, D. W. BROWN, J. CALAMBOKIDIS, and S-L. CHAN. 1993. Chemical contaminants in gray whales (*Eschrichtius robustus*) stranded in Alaska, Washington, and California, U.S.A., 115 p. NTIS No. PB94-106945.
- 10 BUSBY, P. J., O. W. JOHNSON, T. C. WAINWRIGHT, F. W. WAKNITZ, and R. S. WAPLES. 1993. Status review for Oregon's Illinois River winter steelhead, 85 p. NTIS No. PB93-215853.
- 9 LEDGERWOOD, R. D., E. M. DAWLEY, P. J. BENTLEY, L. G. GILBREATH, T. P. POE, and H. L. HANSEN. 1993. Effectiveness of predator removal for protecting juvenile fall chinook salmon released from Bonneville Hatchery, 1991, 63 p. NTIS No. PB93-216315.
- 8 VARANASI, U., E. CASILLAS, M. R. ARKOOSH, T. HOM, D. A. MISITANO, D. W. BROWN, S-L. CHAN, T. K. COLLIER, B. B. MCCAIN, AND J. E. STEIN. 1993. Contaminant exposure and associated biological effects in juvenile chinook salmon (*Oncorhynchus tshawytscha*) from urban and nonurban estuaries of Puget Sound, 64 p. NTIS No. PB93-198265.
- 7 DEY, D. B. (editor). 1993. Coastal Zone and Estuarine Studies Division research activities and accomplishments: 1980-89, 205 p. NTIS No. PB93-188613.
- 6 MYERS, M. S., C. M. STEHR, O. P. OLSON, L. L. JOHNSON, B. B. MCCAIN, S-L. CHAN, and U. VARANASI. 1993. National Status and Trends Program, National Benthic Surveillance Project: Pacific Coast, Fish histopathology and relationships between toxicopathic lesions and exposure to chemical contaminants for Cycles I to V (1984-88), 160 p. NTIS No. PB93-183911.