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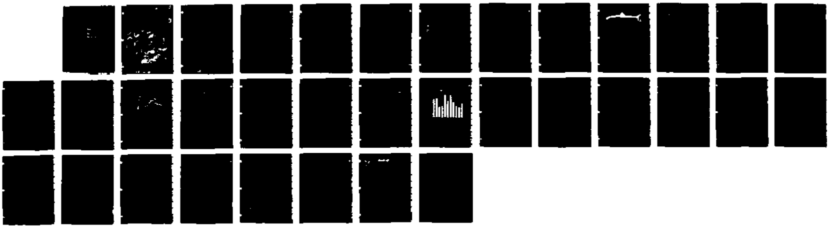

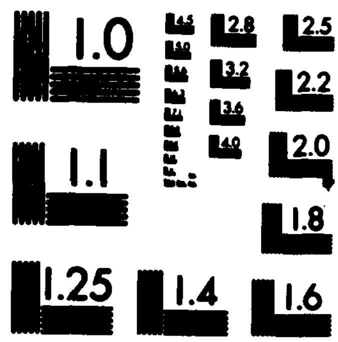

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Biological Report 82(11.62)
August 1986

WES TR EL-82-4.62

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)

STEELHEAD TROUT

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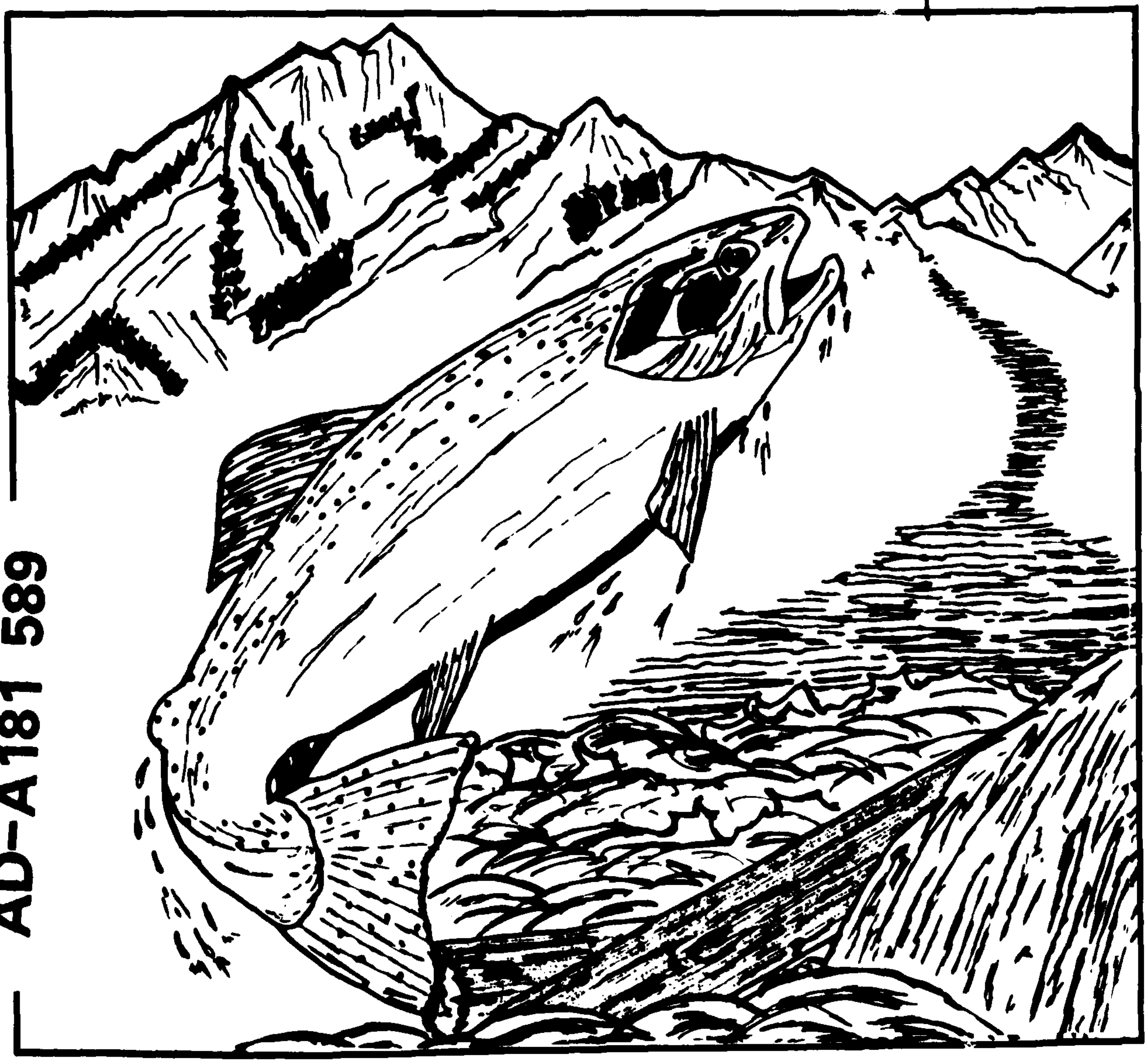

Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

8

Biological Report 82 (11.62)
TR EL-82-4
August 1986

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)

STEELHEAD TROUT

by

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Pauley, G.B., B.M. Bortz, and M.F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) -- steelhead trout. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.62). U.S. Army Corps of Engineers, TR EL-82-4. 24 pp.

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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Post Office Box 631
Vicksburg, MS 39180

Keywords: → cont'd pg 1 →

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F - 32)	Celsius degrees

CONTENTS

FIGURES

ACKNOWLEDGMENTS

We are grateful to Peter Hahn and Robert Gibbons of the Washington State Department of Game for their review of the manuscript and valuable unpublished information. We also thank Vali Frank for her assistance and preparation of figures.

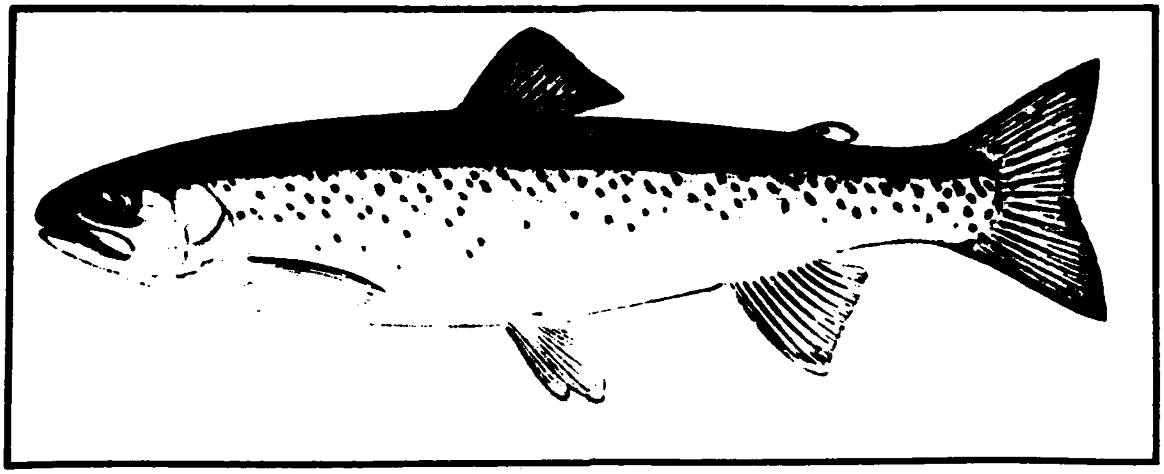

Figure 1. Steelhead trout.

cont'd

STEELHEAD TROUT

NOMENCLATURE/TAXONOMY/RANGE

Scientific name.....Salmo gairdneri Richardson

Preferred common name..Steelhead trout (Figure 1)

Other common names.....Coastal rainbow trout; silver trout; salmon trout; ironhead; steelie; steelhead

Class.....................Osteichthyes

Order....................Salmoniformes

Family....................Salmonidae

Geographic range: The steelhead trout is found from central California to the Bering Sea and Bristol Bay coastal streams of Alaska. Most streams in the Puget Sound region and many tributaries of the Columbia and Snake Rivers have steelhead populations. Major winter steelhead runs are found in many Pacific Northwest rivers (Figure 2). Figure 3 shows the major summer-run steelhead rivers in Washington, while Figure 4 shows the major summer-run steelhead rivers in Oregon.

MORPHOLOGY/IDENTIFICATION AIDS

Body moderately compressed; length to 114 cm with average length between 51 and 76 cm. Weight up to 19.5 kg. Head length about 20% of total body length (TL). Gill rakers 16-22 (usually 6-9 on the upper limb, 11-13 on the lower limb). Branchiostegal rays 9-13. One dorsal fin with 10 to 12 fin rays; adipose fin fleshy with small base; caudal fin not forked; pectoral fins with about 15 fin rays; pelvic fins with about 10 fin rays; anal fin with 8-12 fin rays. Scales cycloid, rather small, and variable with different stocks. Pyloric caeca number between 27 and 80 (Carl et al. 1973; Hart 1973; Scott and Crossman 1973).

Lateral line is complete, slightly curved anteriorly, with 100-150 pored lateral line scales. Color varies with habitat, size, and sexual condition. Marine adult steelhead are generally metallic blue on the dorsal surface and silvery on the sides. There are black spots on

life cycles; reproduction; habitats; marine biology

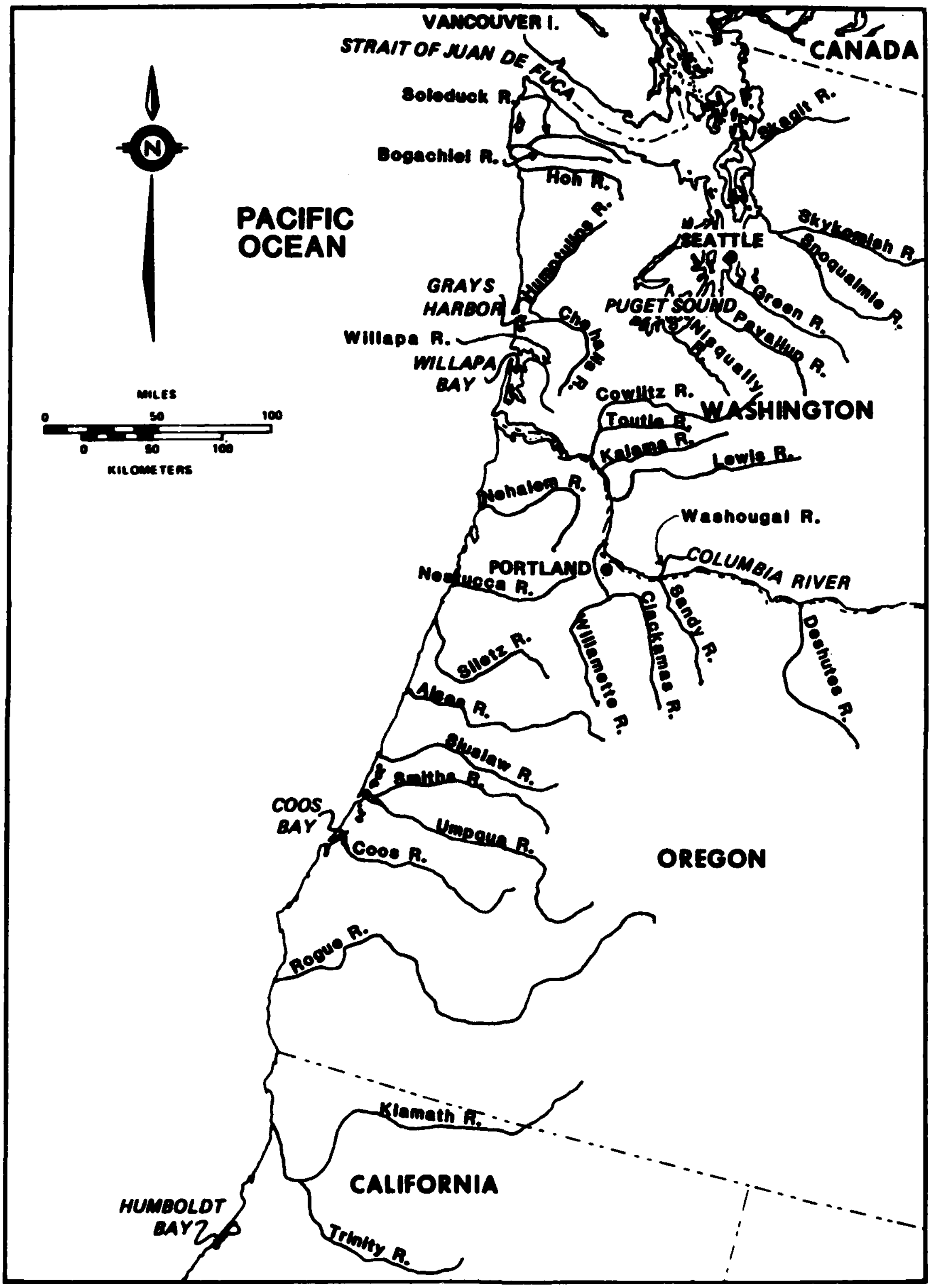

Figure 2. Primary distribution of winter-run steelhead in Pacific Northwest rivers.

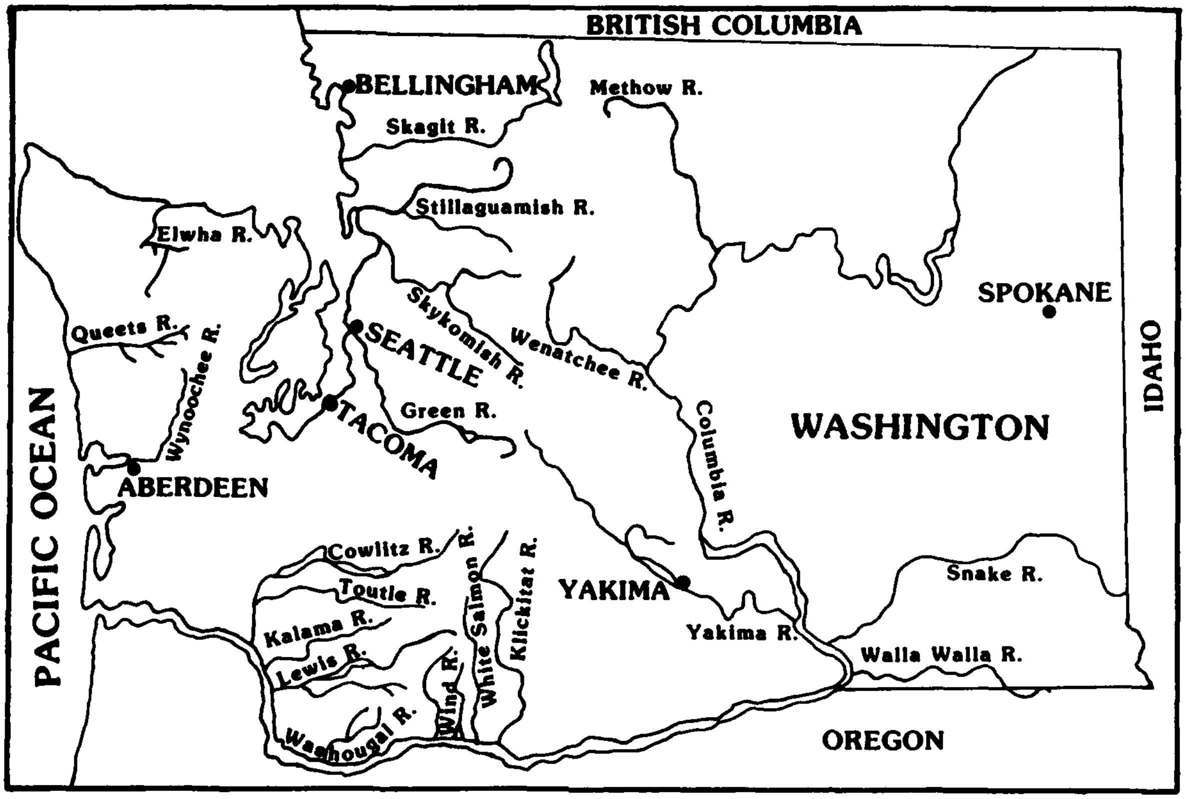

Figure 3. Major Washington State rivers that have summer-run steelhead.

the back, and on the dorsal and caudal fins. Spawning colors are considerably darker with males having a pink or red band on the sides. There is no red dash under lower jaw, which distinguishes steelhead from coastal cutthroat trout, Salmo clarki clarki.

REASON FOR INCLUSION IN SERIES

Historically, steelhead have been a valuable resource in the Pacific Northwest and are the major trophy game fish in some areas such as western Washington (Pautzke and Meigs 1940). In the Columbia River Basin, the abundant and apparently inexhaustible salmon and steelhead populations generated an intensive fishery. However, mainstream dams and reservoirs, which cause loss of natural habitat and increased mortality of smolts (fish migrating to the sea), contributed to the reduction of the Columbia River salmon and steelhead natural runs to seriously low levels (Chaney 1978; Raymond 1979). Poor logging, road building, and irrigation practices along with overgrazing by livestock have also contributed to the decline of salmon and steelhead (Yee and Roelofs 1980; Platts 1981; Chamberlin 1982). Natural steelhead runs are heavily supplemented by hatchery stocking in Washington, Oregon, and California. Presently, 17 hatcheries plant steelhead smolts into the Columbia River system (Ayerst 1977). Steelhead were, and still are, an integral part of the economic, social, and religious life of Indian Tribes throughout much of Washington, Oregon, and Idaho. Steelhead are one of the most highly prized

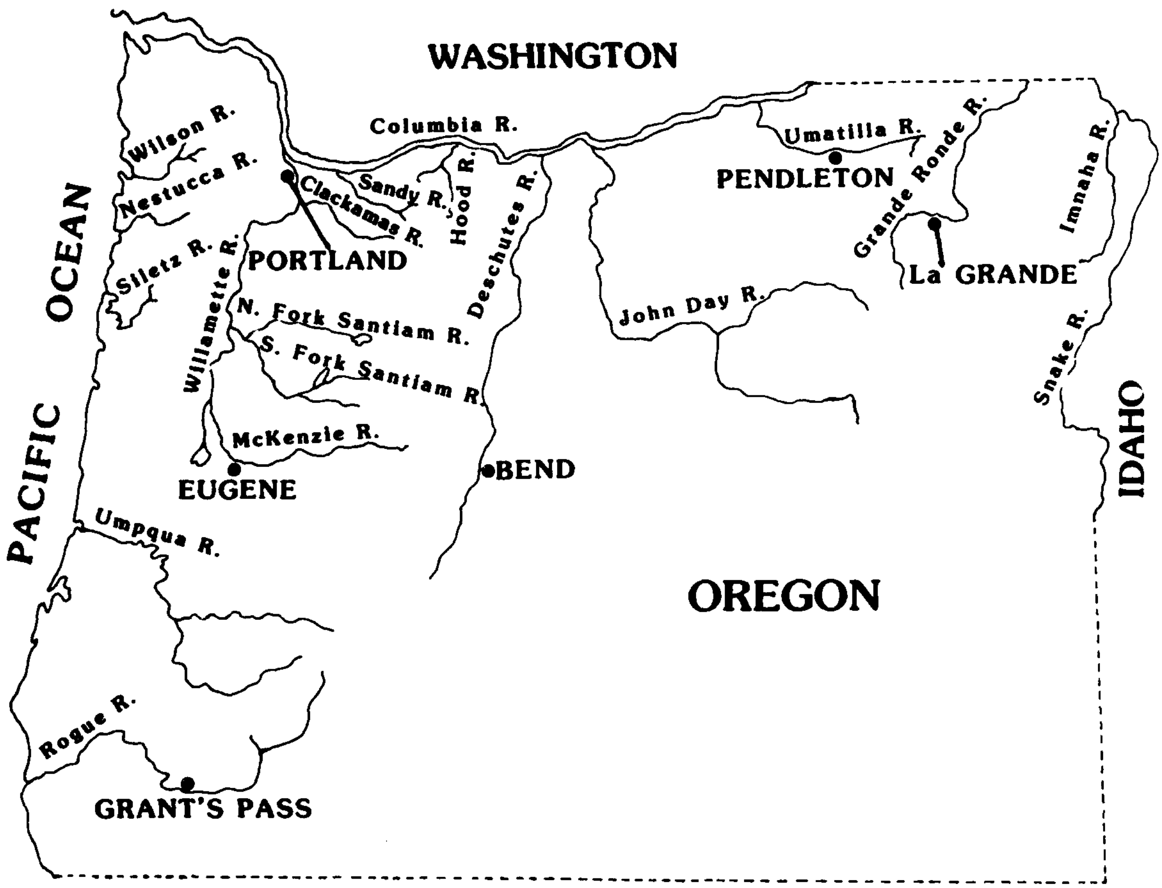

Figure 4. Major Oregon State rivers that have summer-run steelhead.

game fish in the Pacific Northwest. Approximately 110,000-130,000 anglers participate in this fishery each year in Washington State (Peter Hahn and Robert Gibbons, Washington State Department of Game [WDG]; pers. comm.).

LIFE HISTORY

Run and Stock Types

Steelhead are sea-run (anadromous) rainbow trout (Salmo gairdneri Richardson) that primarily use coastal streams from Alaska to California and tributaries of the Columbia River basin. Two races, or runs, of steelhead exist (Smith 1960, 1968; Chilcote et al. 1980). Winter-run steelhead migrate to their native stream in the late fall and winter, and summer-run steelhead migrate upstream during the spring and summer. Winter-run steelhead enter their home stream in various stages of maturation and spawn within the next few months after entering the river, usually by May. Summer-run steelhead enter their home stream as green (immature) fish and do not mature and spawn until the following spring. Native or wild winter-run fish may spawn between late

March and early May, while hatchery fish spawn earlier from December through February (Smith 1960; Sheppard 1972; Robert Gibbons, WDG, pers. comm.) There is potential for summer- and winter-run steelhead spawners to interbreed, as well as for hatchery and wild group interbreeding (Chilcote et al. 1983). Shapovalov and Taft (1954) noted that in some large rivers such as the Sacramento, Klamath, and Columbia, steelhead may enter from the ocean during most of the year. Entry of steelhead into streams is positively correlated with the occurrence of freshet conditions (Withler 1966). When adult steelhead enter freshwater, they rarely eat any food and grow little if at all at this time (Maher and Larkin 1954).

Sheppard (1972) reviewed various stocks from different States and found that (1) California stocks apparently consist of only winter-run fish because of unsuitable summer stream conditions; (2) Washington, Oregon, and southern British Columbia stocks are a mixture of both summer and winter-run fish; (3) Idaho stocks are primarily summer-run fish that migrate up the Columbia and Snake Rivers; and (4) Alaska and northern British Columbia stocks are primarily summer-run steelhead.

Spawning, Fecundity, and Sex Ratios

Steelhead spawn in cool, clear, well-oxygenated streams with suitable gravel and current velocities (Reiser and Bjornn 1979). After choosing the redd (spawning nest) site, the female begins digging a depression by repeatedly turning on her side and dislodging gravel with rapid lateral movements of the tail. Redd depth may vary from about 7 cm to more than 30 cm, and the redd will occupy about 5.5 m^2 of stream bottom. Suitable spawning area consists of 1.3 cm to 11.4 cm diameter gravel and well-aerated water having a flow of approximately 76.2 cm/sec. Unlike salmon, which die after spawning, some steelhead return from the ocean to their native streams several times in successive years to spawn. Most repeat spawners are female fish (Peter Hahn and Robert Gibbons, WDG; pers. comm.). Fecundity appears to vary with size and geographic origin of the steelhead (Bulkley 1967). According to Bulkley (1967), fecundity of steelhead from the Alsea River, Oregon, increases with size: 3,500 eggs for 508-mm fish; 5,000 eggs for 610-mm fish; 8,000 eggs for 711-mm fish; and 10,000 to 12,000 eggs for 813-mm fish. Alsea River steelhead produced approximately 32% fewer eggs than females from Trinity River, California, and 51% less eggs than fish from Scott Creek, California, when similar-sized fish were compared (Bulkley 1967).

Sheppard (1972) suggested that the sex ratio of steelhead returning to streams along the entire Pacific Coast from California to Alaska is 1:1. This ratio is apparently the mean or average situation, with substantial variation occurring in individual runs in various rivers from year to year (Peter Hahn and Robert Gibbons, WDG; pers. comm.). Although females appear to survive as repeat spawners considerably more often than males, the number of steelhead that return as second and third time repeat spawners declines progressively, and only a few fourth time spawners have been reported (Washington 1970). The incidence of repeat spawners decreases from south to north along the Pacific Coast (Withler 1966). The number of repeat spawners also varies from stream to stream (Withler 1966; Salo 1974). Repeat spawners do not show any significant size gain (Salo 1974).

Hatching and Juveniles

The eggs usually hatch in 4 to 7 weeks, and the newly hatched young (alevins) absorb the yolk and become free swimming in 3 to 7 days. Time of hatching varies with region, habitat, water temperature, and spawning season.

As the young fish grow, move to deeper parts of the stream, and establish territories, food items change from microscopic aquatic organisms to larger organisms such as isopods, amphipods, and both aquatic and terrestrial insects (Shapovalov and Taft 1954). They primarily eat food items associated with the stream bottom (Wydoski and Whitney 1979).

Streamside vegetation and submerged cover in the form of rocks, logs, and aquatic vegetation are extremely important to steelhead during rearing, perhaps more so than at any other time (Narver 1976; Reiser and Bjornn 1979). Cover plays an important role in the selection of habitat by young steelhead. In as much as this cover provides food, temperature stability, and protection from predators, the densities of young steelhead are highest in areas containing instream cover (Johnson 1985). The maintenance or reestablishment of streamside vegetation is a major part of successful stream management for steelhead and other anadromous salmonids (Narver 1976; Reeves and Roelefs 1984; Johnson 1985).

Smolts

Parr are young fish found in freshwater streams before migration to saltwater and are characterized by heavy dark blotches on their sides called parr marks. Juvenile steelhead remain in freshwater from 1 to 4 years before transformation to smolts. Smolting is a process of morphological, behavioral, and biochemical changes in which bottom-dwelling parr transform into pelagic smolt that are fully capable and prepared to migrate to saltwater. Smolts are characterized by a silvery color and the absence of parr marks.

Wild juvenile steelhead commonly spend 2 or 3 years in freshwater, but hatchery fish only 1 year. Recent reviews suggest that development of the smolt stage and seaward migration are initiated by various environmental factors including photoperiod, water temperature, and water chemistry (Folmar and Dickhoff 1980; Wedemeyer et al. 1980). Marine survival of smolts is a function of size and not age, with 14 to 16 cm being the critical minimum size at which steelhead can become smolts and subsequently survive in saltwater (Conte and Wagner 1965; Fessler and Wagner 1969).

Marine Distribution and Growth

A rapid growth phase occurs after the smolts reach the ocean. Steelhead usually remain in the ocean for 2 to 3 years, and occasionally 4 years (Shapovalov and Taft 1954). Many of the summer-run stocks in the Columbia River system spend only one year at sea (Peter Hahn, WDG, pers. comm.). Sheppard (1972) found that steelhead of British Columbia origin do not travel as far as other steelhead stocks, but, like steelhead originating in Washington, Oregon, California, and Idaho, they spend at least part of their ocean residency in the Alaskan gyre (Figures 5 and 6). Sheppard (1972) indicated that steelhead tagged in both the Gulf of Alaska and near Adak Island, Alaska, returned to North American coastal streams and that fish tagged at Skamania Hatchery in Washington were recovered 3 years later, 45 mi south of Adak, Alaska. The knowledge of steelhead migratory patterns on the high seas is incomplete because the fish are difficult to sample since they do not form schools and do not use areas where intensive commercial salmon fishing occurs. Sutherland (1973) indicated that the relative abundance of steelhead trout captured at sea was far less than that of any of the Pacific salmon (*Oncorhynchus* spp.), and that steelhead distribution at sea appears to be influenced by surface water temperatures. The

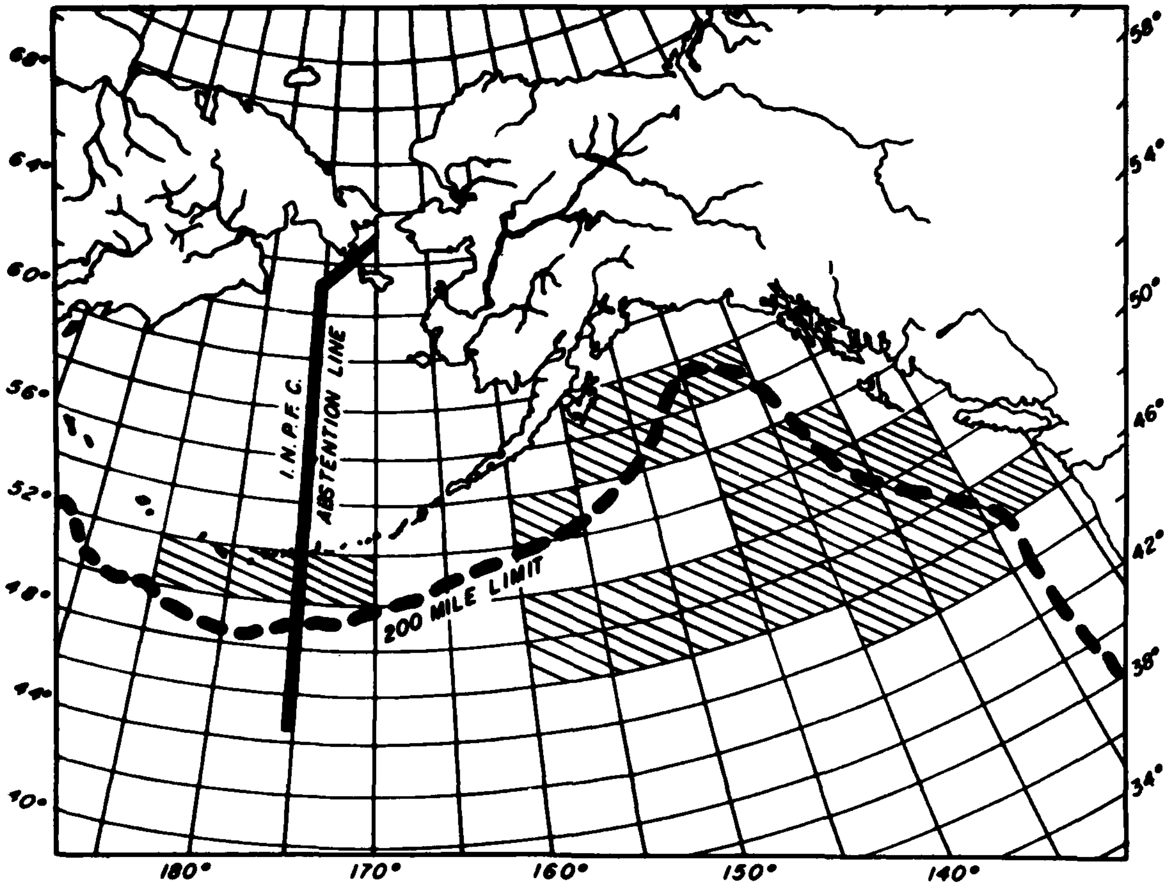

Figure 5. Hatched areas indicate oceanic distribution for steelhead trout of Washington, Oregon, and California origin based on tagging-recapture studies from 1956 to 1969 (after Sheppard 1972). Note that the International North Pacific Fish Commission abstention line, which restricts Japanese gill-net fishing, has been moved recently.

distribution conforms closely to the 5 °C isotherm on the north and the 15 °C isotherm on the south.

Steelhead age groups are designated to indicate the amount of time spent in freshwater and in the ocean; thus 2/3 refers to fish that spent 2 years in freshwater and 3 summers or winters in the ocean (Maher and Larkin 1954). Most mature, returning wild adult steelhead usually fall into one of four major categories for age: 2/2, 2/3, 3/2, and 3/3. Returning hatchery adult steelhead usually are 1/1, 1/2, or 1/3. No correlation exists between the number of years spent in freshwater and in saltwater. However, the length of residence in both freshwater and saltwater increases in steelhead populations from south to north along the Pacific coast (Withler 1966). The maximum life span of steelhead appears to be between 8 and 9 years (Sumner 1945; Washington 1970).

Length at first maturity is a function of the number of years spent

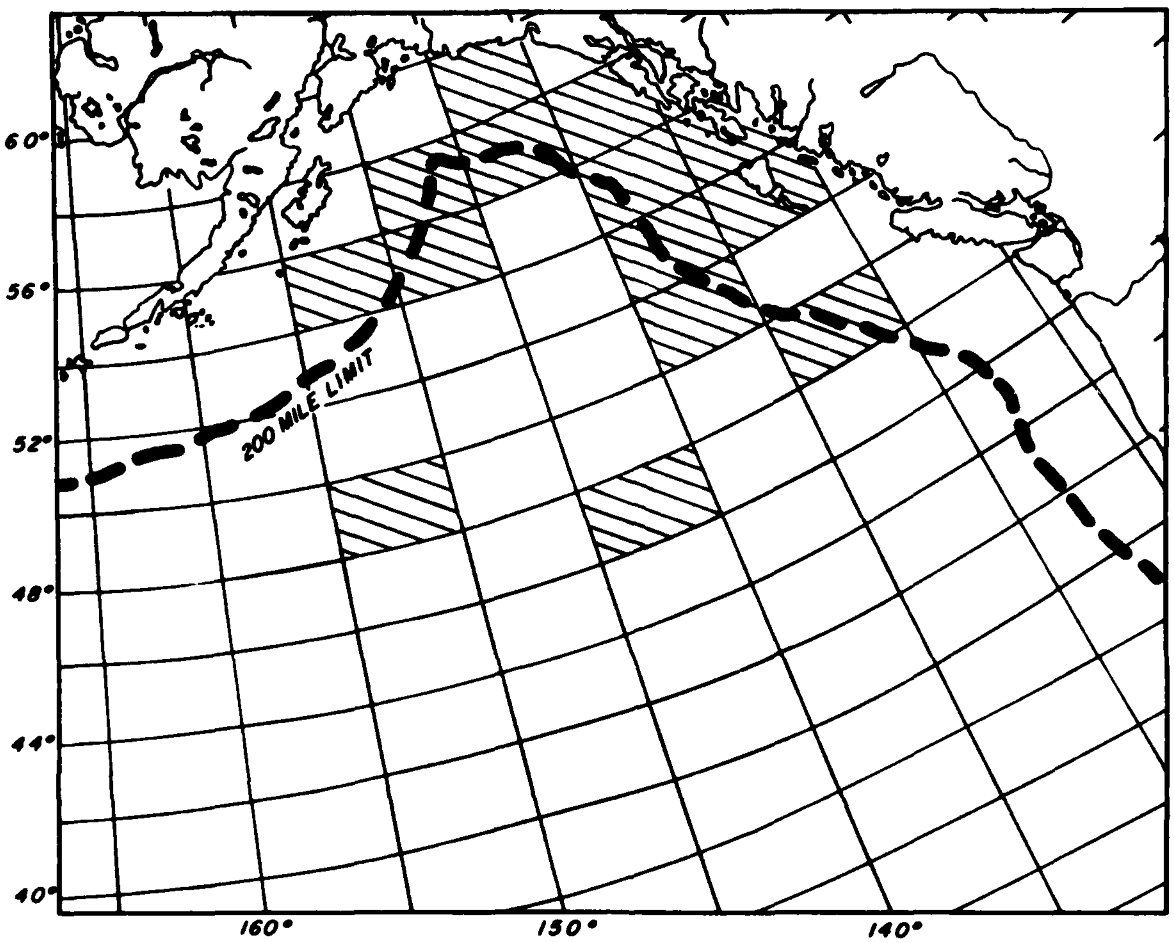

Figure 6. Hatched areas indicate oceanic distribution for steelhead trout of British Columbia origin based on tagging-recapture studies from 1956 to 1969 (after Sheppard 1972).

in saltwater, according to Maher and Larkin (1954), with representative mean lengths of adult steelhead in British Columbia increasing with time spent in saltwater residence: 47.2 cm for 1 year, 70.1 cm for 2 years, 81.3 cm for 3 years, and 87.9 cm for 4 years. The more northern populations of steelhead along the Pacific coast attain the greatest adult length (Withler 1966). Representative mean lengths of adult steelhead after 2 years in saltwater are 58.2 cm for California, 66.8 cm for central Oregon, and 71.9 cm for southern British Columbia (Withler 1966). A fish that has spent 4 years in saltwater is almost twice as long as one that has spent only 1 year in saltwater, regardless of the number of years spent in freshwater. Since weight varies approximately as the cube of the length, increments in lengths of longer fish are associated with larger gains in weight (Maher and Larkin 1954). A rough estimate of a steelhead's weight can be made by assuming it weighs 2.3 kg at 58 cm and will increase by about 0.4 kg for each additional 2.5 cm.

Homing Instinct

The sensitivity of the homing instinct in steelhead has never been explained, but a learning process called imprinting is probably involved initially (Slatick et al. 1981). The homing instinct is particularly important in steelhead because the fishery is limited almost entirely to the watersheds where they return as adults and reproduce (Royal 1972). Even though a significant amount of other anadromous salmonid species stray between neighboring streams of adult steelhead planted as smolts in a particular river are usually available for harvest in the stream of origin or closely neighboring river systems (Royal 1972).

COMMERCIAL FISHERY

Commercial fishing for steelhead in the Pacific Northwest started in the mid-1880's. The recording of commercial catch statistics for Washington, Oregon, and California began in 1892, when 5.3 million pounds of steelhead were caught (Sheppard 1972). The steelhead commercial catch peaked in 1945 at 8.7 million pounds, with the commercial catch declining in subsequent years (Sheppard 1972). Commercial fishing for steelhead in California ended in 1924, and is now restricted in Washington and Oregon to specific Indian tribes as guaranteed by particular treaty rights (Withler 1972; Clark 1985). In British Columbia, steelhead are incidental catches in commercial salmon gill nets and totaled 20,726 fish for all the years between 1960-71 (Withler 1972). According to Sheppard (1972), the commercial catch of steelhead in Alaska is small: between 1942 and 1967, the annual catch averaged 14,671 lb in Alaska's southeast region and 5,230 lb in the central region.

SPORT FISHERY

The Fishery and Its Management

Steelhead in Washington and Oregon are currently managed exclusively for recreational fisheries and tribal Indian fisheries. The majority of fish caught upstream in rivers are landed by recreational anglers, and most of those caught near the river mouth estuaries are taken by Indians. Steelhead catch allocations are currently divided between treaty Indian and nontreaty fishermen approximately 50:50 for numbers caught in Washington State waters in accordance with the recent Federal Court ruling commonly known as the Boldt Decision (Clark 1985). Before this court ruling, Sumner (1945) noted that Indian nets were capable of selecting, on the average, larger and probably older fish than sport anglers catch by hook and line. In addition to interacting with various Indian fisheries, the sport fishery must also interact with other types of recreation and timber management as reviewed by Clark et al. (1985).

Since the early 1900's, particularly after World War II, sportfishing for steelhead has become increasingly popular because of advanced hatchery technology and widespread stocking. Runs of adult steelhead have been built up substantially by planting hatchery fish (Larson and Ward 1954). Pauley (1982) reviewed the effects of recreational fishing on anadromous salmonids, including the benefits and drawbacks of using hatchery salmonids to supplement the sport fishery. Since the native stock is the result of natural selection over centuries, hatchery stocks changed through selective breeding should not be expected to be as genetically robust as the native stocks.

Fishing is conducted with both natural bait and artificial lures (Fagerstrom 1976) even though the fish do not actively feed in freshwater.

Natural baits include fish eggs, night crawlers, and shrimp. Popular artificial lures are spoons, spinners, diving plugs, flies, and brightly colored drift bobbers. Bait casting, spinning, and fly-fishing gear are all used by steelhead anglers. The main types of fishing are drift fishing and plunking from the river banks, and drift fishing and plug pulling from professionally guided or privately owned drift and jet boats (Fagerstrom 1976; Luch 1976). Most of the steelhead caught by anglers are taken in rivers, although there are a few saltwater areas where steelhead are consistently taken (Figure 7) using modified drift gear (Rudnick 1981).

Oregon and Washington have a compulsory punchcard system for anglers to record their steelhead catch. The information is used in conjunction with creel survey data taken along various streams to estimate the steelhead sport catch for each river and lake. In comparing recreational catch data from Washington, Oregon, California, British Columbia, and Alaska, Sheppard (1972) found that Washington had the largest annual sport catch of steelhead between the years 1962 and 1970, while Oregon was second. The average annual catch in Washington between 1961 and 1981 was 38,040 summer-run fish and 103,940 winter-run fish (Peter Hahn, WDG; pers. comm.). Sheppard (1972) also found that one out of every five anglers in Washington for the period from 1949 to 1970 succeeded in catching a steelhead, based on punchcard returns. These punchcard returns are biased toward successful anglers, who return their cards at a considerably higher rate than do unsuccessful steelhead anglers (Peter Hahn, WDG; pers. comm.).

During 1983-84, Washington State anglers harvested 37,134 summer-run (May-October) steelhead and 68,647 winter-run (November-April) steelhead for a total of 105,781 fish (Washington Department of Game 1985a). Figure 8 depicts the number of steelhead caught annually in Washington State by steelhead anglers from 1973 to 1984, the period that the Boldt Decision had been in effect. The Washington State Treaty Indian steelhead catch in 1983-84 was 20,395 summer-run fish and 59,826 winter-run fish for a total of 80,221 steelhead (Washington Department of Game 1985b).

The increased popularity of sportfishing and the declining quality and quantity of natural habitat have caused all the Pacific States and British Columbia to closely manage their steelhead stocks. Withler (1966) indicated that more females than males may be caught and then kept by anglers. Two factors are involved in this bias toward females in the sex ratio of fish kept by anglers. First, the frequency of repeat spawners is greater among female steelhead than among males due to increased post-spawning survival. Consequently, the slightly greater number of females in the population results in larger female catches by anglers. Second, males deteriorate in appearance to a greater extent than females as spawning approaches. Therefore, more males than females are released alive by anglers after being captured during the spawning season. Recent data from Washington State indicate that females are not more vulnerable than males to angling, and that the sport catch sex ratio is an unbiased estimate of the true sex ratio (Peter Hahn, WDG; pers. comm.).

Hatchery Program

Washington, Oregon, Idaho, and California all have hatchery programs to supplement their natural fish runs. Hatcheries can be utilized to rebuild, improve, or even establish new runs of steelhead, but they should not be used to attempt to replace wild stocks of fish (Ayerst 1977). Washington State's steelhead management program is a two-phase project:

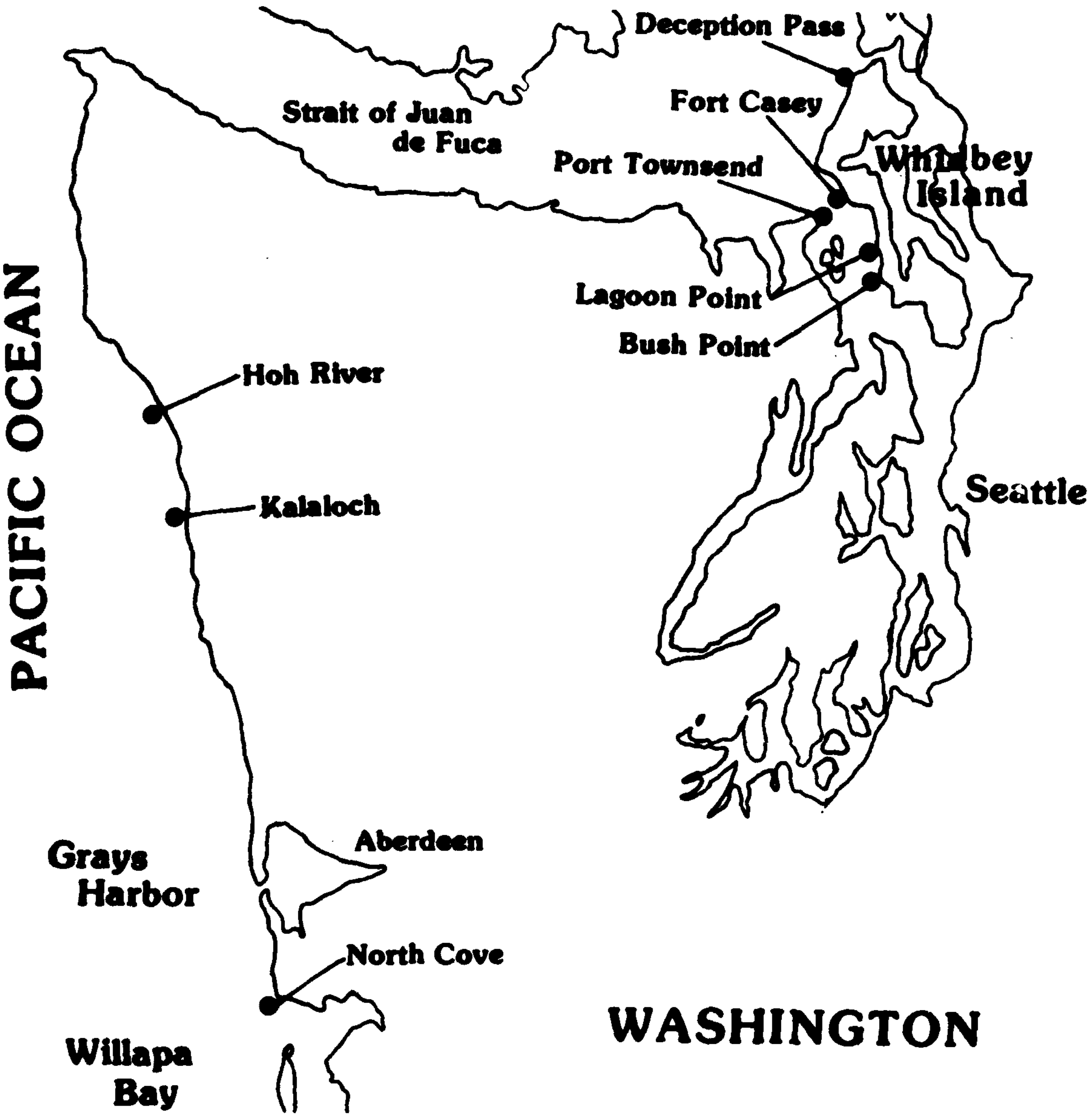

Figure 7. Saltwater locations on the outer Washington coast and the area around Whidbey Island where sport anglers have taken steelhead using modified freshwater drift gear.

(1) supplementing depleted runs and heavily fished runs with hatchery fish, and (2) attempting to protect the natural runs of steelhead already present in various streams (Larson and Ward 1954). The second phase is currently the major priority in Washington (Peter Hahn, WDG, pers. comm.). In 1971, Washington State had 14 hatcheries and 10 seminatural rearing ponds producing over 3 million winter steelhead smolts; Oregon had 11 hatcheries and few rearing ponds producing 1.5 million winter steelhead

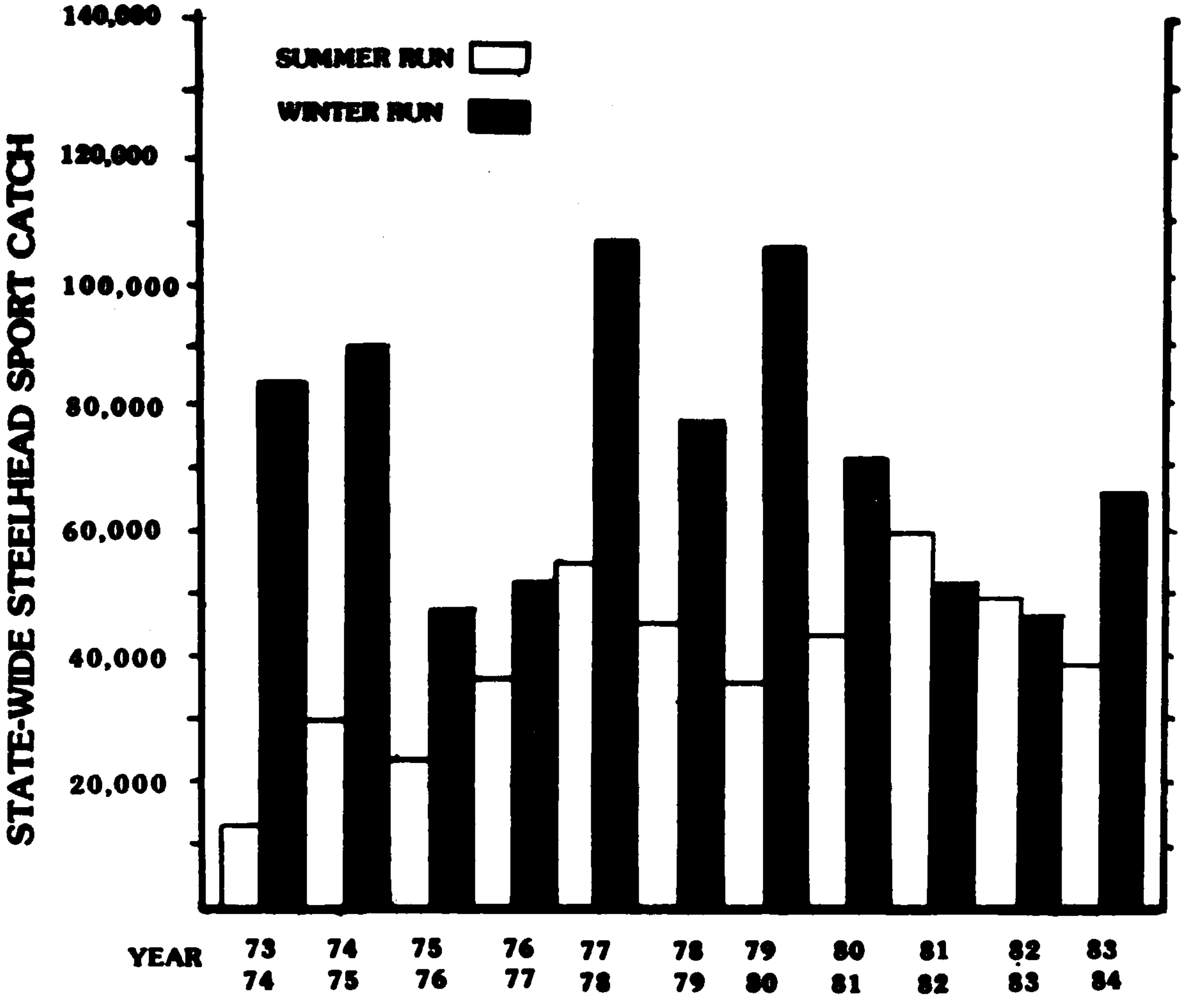

Figure 8. State-wide numbers of individual steelhead caught by sportfishermen in Washington State for 1973-84 showing both summer-run and winter-run totals.

smolts in 1968; California had four hatcheries releasing 1.88 million winter-run steelhead smolts in 1968; and Idaho released 350,000 smolts in 1971 (Sheppard 1972).

Hatchery steelhead smolts are generally 1 year old when released, whereas natural wild smolts are 2 years old before they become smolts and migrate to the sea (Royal 1972). Available data indicate that the optimum release date for hatchery-reared steelhead smolts coincides with the peak downstream movement of wild steelhead smolts (Wagner et al. 1963), which occurs in late April (Wagner 1968).

Hatchery propagation has affected the length of time spent at sea and has altered the return migration pattern of adult steelhead (Salo 1974). Hatchery fish tend to return to the streams sooner than natural wild fish (Royal 1972). Evidence also indicates that increased plant- ings of hatchery fish can cause a corresponding decline in the number of wild steelhead that return as adults (Wagner et al. 1963; Salo 1974), even though hatchery smolts do not always seem to survive as well as wild smolts (Bjornn 1977; Reisenbichler and McIntrye 1977). This reduction in wild fish numbers is brought about by genetic alteration with the possible elimination of wild genotypes in steelhead. A decline in the numbers of returning wild steelhead is also caused by overfishing of wild steelhead because of increased fishing pressure following the stocking of abundant hatchery fish (Narver 1976). Recent data from Washington rivers indicate that genetic alteration is a minor problem, while overfishing is a major problem (Peter Hahn and Robert Gibbons, WDG; pers. comm.). In an attempt to solve this problem, Washington State currently requires that all native or wild fish must be released by anglers in most rivers. Returning hatchery steelhead and wild steelhead can be distinguished with near 100% accuracy by scale-pattern characteristics (Chapman 1958) or with a high degree of accuracy by examination of the dorsal fin (Pauley 1982). The latter method is used by sport fishermen to justify keeping or releasing their fish. Wild fish have dorsal fin rays that are not bent or crooked in any way and are generally more than 2.0 inches high when fully extended. Hatchery fish, on the other hand, have dorsal fin rays that are bent or crooked and that are usually less than 2.0 inches high when fully extended. Hatchery fish in most rivers in Washington State also have clipped adipose fins.

ECOLOGICAL ROLE

A variety of predators eat juvenile steelhead: large resident rainbow trout (*Salmo gairdneri*), searun cutthroat trout (*Salmo clarki*), sculpins (*Cottus* spp.), great blue herons (*Ardea herodias*), mergansers (*Mergus merganser*), and various mammals (Sheppard 1972). Johnson (1981) found that steelhead eggs in streams were subject to predation by both brook trout (*Salvelinus fontinalis*) and juvenile steelhead, where eggs composed 20.1% to 59.2% of the total dry weight of the diet of the predators examined.

In Idaho, Bjornn (1978) found that steelhead fry were at least as viable as resident rainbow trout fry and possibly more viable. The steelhead fry tended to displace resident rainbow trout, but did not appear to affect resident brook trout populations. Stocking hatchery rainbow trout (*Salmo gairdneri*) into streams caused localized temporary displacement of juvenile steelhead (Pollard 1978). Hatchery rainbow trout usually chose greater stream velocities and deeper water than steelhead. Because of these differences, interaction between rainbow trout and juvenile steelhead apparently is not great (Pollard 1978). Hartman and Gill (1968) reviewed the distribution of juvenile steelhead and cutthroat trout in southeastern British Columbia. They reported that steelhead were found predominantly in large streams with drainage areas over 130 km^2 and streams with steep gradients, while cutthroat trout were found predominantly in small streams with drainage areas under 13 km^2 with slightly sloping gradients.

Stream-dwelling steelhead trout, which have evolved in sympatry with various other species of anadromous salmonids, have developed mechanisms that partition the available habitat and probably promote coexistence (Allee 1981). Everest and Chapman (1972) found that chinook salmon (*Oncorhynchus tschawytscha*) and steelhead segregated during the summer in two Idaho streams. The steelhead occupied similar niches whether they were present alone or together with chinook salmon. Most juvenile steelhead preferred rubble substrates with water velocities less than 15 cm/s and a depth of 0.15 m. When steelhead grew larger, they moved to deeper, faster water. Hartman (1965) found that interaction between juvenile coho salmon (Oncorhynchus kisutch) and juvenile steelhead depended upon three factors: population densities in the stream, levels of aggressiveness, and size differences of the fish. Young steelhead demonstrated more aggressive behavior and territorial defense in the riffle environment, and coho salmon were more strongly motivated to defend space in pools rather than in riffles. By winter, the steelhead attained a size range approximating that of the coho salmon and moved into the pools. However, steelhead did not establish stable social groups in the pools as coho salmon did. This resulted in steelhead and coho utilizing the pool space differently. Coho salmon formed groups in open water above the bottom and occupied space beside or downstream from stones. Steelhead scattered across the bottom as individuals and occupied space under stones.

Juvenile steelhead tended to be more closely associated with the bottom of streams than either coho or chinook salmon (Hartman 1965; Edmunson et al. 1968; Bustard and Narver 1975). In the winter, young steelhead become inactive and hide in any available cover (Bustard and Narver 1975).

Survival of young fish as they migrate seaward depends somewhat upon size: the probability of survival is 2.5% for 1-year-old fish, 6.0% for 2-year-olds; 18% for 3-year-olds (Shapovalov 1967). While at sea, steelhead feed heavily upon juvenile greenling (Hexagrammos spp.), squids, and amphipods (LeBrasseur 1966; Manzer 1968) and travel great distances, primarily in the upper 12.2 m of the water column (Sheppard 1972). Marine mammals and fish are predators of steelhead and salmon although their impact is difficult to assess.

ENVIRONMENTAL REQUIREMENTS

Water Temperature

Water temperature requirements of steelhead vary with life stage. Although no specific optimum migration temperatures are given for steelhead, Reiser and Bjornn (1979) stated that unusual stream temperatures during adult upstream migration can alter the time of migration, accelerate or retard maturation, and lead to outbreaks of disease. They suggested that most stocks of anadromous salmonids have evolved with specific temperature patterns and that significant abrupt deviations can adversely affect their survival. Shepard (1972) found that in small- to moderate-sized streams timing of the upstream winter migration of steelhead was related to stream flows and corresponding low temperatures. In larger streams, the relationships were less defined, but suggested that stocks may have evolved migration timing that corresponds to generally suitable stream flow and temperature levels.

Bell (1973) suggested that the spawning temperatures of steelhead were between 3.9 and 9.4 °C. Reiser and Bjornn (1979) indicated that salmonid spawning may cease with a sudden drop in stream temperature, resulting in decreased nest building and reduced production. Although recommended incubation temperatures were not specifically given for steelhead, Reiser and Bjornn (1979) listed the incubation temperatures for all salmonid embryos as 4.0 to 14 °C. Embryos can develop normally at lower temperatures if they are sufficiently acclimated.

According to Reiser and Bjornn (1979), water temperature during rearing can influence growth rate, population density, swimming ability, ability to capture and use food, and ability to withstand disease outbreaks. Bell (1973) listed the preferred rearing temperatures of steelhead as 7.2 to 14.5 °C, with an optimum of about 10.0 °C and an upper lethal limit of 23.9 °C.

Dissolved Oxygen

During upstream migration, reduced dissolved oxygen concentrations can adversely affect swimming performance of migrating salmonids and cause avoidance reactions or cause migration to cease (Reiser and Bjornn 1979). Experiments have shown that at temperatures of 10.0 to 20 °C, the maximum sustained swimming abilities of juvenile and adult coho salmon were adversely affected when dissolved oxygen was reduced from air-saturation levels and decreases in performance were observed at all temperatures when dissolved oxygen concentrations measured 6.5 to 7.0 mg/l (Davis et al. 1963).

Dissolved oxygen levels are critical to steelhead and other salmonids during incubation. From experiments conducted by various authors (Alderdice et al. 1958; Silver et al. 1963; Shumway et al. 1964) on coho, chum, and chinook salmon, and steelhead, Reiser and Bjornn (1979) summarized the effects of dissolved oxygen on salmonid egg development. They indicated that (1) sac fry embryos incubated in low and intermediate dissolved oxygen concentrations were smaller and weaker than those reared at higher concentrations and may not survive as well; (2) reduced oxygen concentrations led to longer incubation periods and smaller newly hatched fry; and (3) low dissolved oxygen concentrations may delay hatching and increase the incidence of anomalies in the early stages of development and can stimulate premature hatching during the later stages. There is a positive correlation between the survival of steelhead embryos and intragravel dissolved oxygen concentrations (Coble 1961; Phillips and Campbell 1961). Reiser and Bjornn (1979) recommended that dissolved oxygen concentrations during incubation of anadromous salmonids be at or near saturation with temporary reductions to no lower than 5.0 mg/l.

Dissolved oxygen concentrations are also important during the rearing phase. Reiser and Bjornn (1979) summarized dissolved oxygen criteria developed by Davis (1975) for salmonids, which indicated that freshwater salmonid populations function without impairment at dissolved oxygen concentrations of 7.8 mg/l; exhibit initial distress symptoms at 6.0 mg/l; and are adversely affected at 4.3 mg/l. Reiser and Bjornn (1979) indicated that freshwater salmonid populations can function without impairment when dissolved oxygen is at the following saturation levels (dependent on temperature): 76% at 0 to 15 °C; 85% at 20 °C; and 93% at 25 °C. Initial distress symptoms appear with saturation levels of 57% at 0 to 10 °C; 59% at 15 °C; 65% at 20 °C; and 72% at 25 °C. Fish populations are adversely affected with saturation levels of 38% at 0 to 10 °C; 42% at 15 °C; 46% at 20 °C; and 51% at 25 °C. Low dissolved oxygen levels can affect the rate of metabolism, swimming speed, growth rate, food consumption rate, efficiency of food utilization, behavior, and ultimately the survival of anadromous salmonids.

Supersaturation of atmospheric gases has caused problems to various salmonids as discussed by Ebel and Raymond (1976) and Weitkamp and Katz (1980). Serious histopathological problems associated with gas-bubble disease have been noted in fingerling salmonids under conditions of supersaturation (Pauley and Nakatani 1967).

Substrate

The composition of the stream substrate is particularly important to steelhead as well as to other salmonids during spawning, incubation, and rearing. The preferred size of gravel substrate varies with the different sizes and species of salmonids (Reiser and Bjornn 1979). The acceptable gravel substrate has a wide range of sizes for steelhead as indicated by several authors. The gravel composition on steelhead spawning areas ranges from 1.0 to 10.0 cm according to Hunter (1973). Bell (1973) states that since stream bed composition is a result of slope and quantity of flow, the substrate composition of the spawning bed for salmon and trout may vary from 2.0 to 10.0 cm. Reiser and Bjornn (1979) indicated suitable substrate for spawning was 1.3 to 11.7 cm in diameter.

Reiser and Bjornn (1979) indicated that spawning bed materials can influence the development and emergence of salmonid fry. In general, high substrate permeability is essential for good salmonid production. Excessive sand and silt in the gravel hinders successful fry emergence. Bjornn (1969) and McCuddin (1977) demonstrated that when sediments less than 6.4 mm in diameter constituted at least 20% to 25% of the substrate, both survival and emergence of chinook salmon and steelhead embryos were reduced. Gravel mixtures containing high percentages of fine sediments caused decreased embryo survival, smaller steelhead fry, and emergence before yolk-sac absorption was complete (Tappel and Bjornn 1983).

During the rearing phase, the substrate composition probably affects salmonid production mostly by regulating the production of invertebrates, a valuable food source. Reiser and Bjornn (1979) indicated that the highest production of invertebrates is in habitats with gravel- and rubble-sized materials and that invertebrate production decreases proportionately as the size of the substrate particles decreases. In all cases, the composition of the stream substrate was a function of water velocity, with the size of the material increasing with water velocity. Reiser and Bjornn (1979) developed overall criteria for optimum salmonid food production in streams: water velocity, 0.5 to 1.1 m/s; depth, 0.5 to 0.9 m; substrate composition, largely coarse gravel from 3.2 to 7.6 cm in diameter, and rubble from 7.6 to 30.4 cm in diameter.

Water Depth

Insufficient water depth can be a barrier to the upstream migration of steelhead and other anadromous salmonids. The minimum depth required for the successful upstream migration of adult steelhead is 18 cm (Thompson 1972). Waterfalls, however, can be obstacles even when the water depth below the falls exceeds 18 cm. Reiser and Bjornn (1979) indicated that spawning steelhead preferred water depths of 24 cm or more.

As with substrate size, the depth of water required by rearing salmonids may be most closely associated with food production. Literature reviewed by Reiser and Bjornn (1979) suggested that the most productive areas in terms of aquatic insect production are shallow areas typical of riffles. Hooper (1973) found that when substrates and velocities were suitable, the highest invertebrate production was associated with stream depths between 15 and 91 cm.

Water Movement

Suitable stream velocities (stream flows) are important during migration upstream, spawning, incubation, and rearing of steelhead. The maximum water velocity that allows successful upstream migration of steelhead is 2.4 m/s (Thompson 1972). Any section of a stream can become an obstacle, regardless of depth, when stream velocities exceed the swimming speeds of steelhead. Minimum and maximum acceptable stream flows for migration of adult steelhead can be calculated for specific stream sections using methods outlined in Thompson (1972).

The preferred water velocity for spawning steelhead ranges between 40 and 91 cm/s (Smith 1973). Total streamflow, a function of velocity and depth, regulates the amount of spawning area available (Reiser and Bjornn 1979). Reiser and Bjornn (1979) cited several authors (Sams and Pearson 1963; Thompson 1972; Collings 1972, 1974; Waters 1976; Stalnaker and Arnett 1976) who provided detailed descriptions of spawning flow methodology.

During the incubation stage, the velocity of water moving through the interstitial spaces in the gravel may be the single most important factor in the embryos' intragravel environment, since it determines the amount of dissolved oxygen supplied and the rate at which metabolic waste products are removed (Reiser and Bjornn 1979). Phillips and Campbell (1961) found that the survival of steelhead and coho salmon eggs was high when apparent intragravel velocities were greater than 20 cm/h. Coble (1961) also demonstrated higher survival of salmon embryos with higher apparent velocities, between 5 cm/h and 100 cm/h.

Reiser and Bjornn (1979) stated that most recommended stream flows for salmonid rearing habitat have been based on food production, cover, and microhabitat needs of the fish, rather than the direct relationships between fish production and stream flow. They listed the following recommendations for stream flow and stream characteristics developed by Thompson (1972) for salmonid rearing habitat: depth of 0.46 to 0.91 m over riffles for optimum food production; riffle/pool ratio near 1:1; approximately 60% of riffle area covered by water; riffle water velocities of 31 to 46 cm/s; pool water velocities of 9 to 24 cm/s; and some type of stream cover available as shelter for fish.

Suspended and Deposited Sediment

During adult upstream migration, salmonids may cease movement when silt load exceeds 4,000 mg/l (Bell 1973). A thermal barrier may develop as a result of the increased absorption of radiation in turbid waters (Reiser and Bjornn 1979). Excessive amounts of sand and silt in the gravel may also inhibit salmonid fry emergence from the gravel (Reiser and Bjornn 1979). Fish subjected to continuous clay turbidities of approximately 50 nephelometric turbidity units (NTV) grew less well than those living in clear water, and more of them emigrated from the test channels containing turbid water (Sigler et al. 1984).

During rearing, suspended and deposited fine sediment can directly affect salmonids by abrading and clogging gills, and indirectly by causing reduced feeding, avoidance reactions, destruction of food supplies, reduced survival of eggs or alevins, and changed rearing habitat (Reiser and Bjornn 1979). Bell (1973) indicated that silt loads averaging less than 25 mg/l permit good freshwater fisheries.

Other Environmental Factors

Partial or complete barriers such as waterfalls, debris jams, excessive velocities (Reiser and Bjornn 1979), high temperatures, high turbidity (Bell 1973), and dams can impede or prevent the upstream migration of adult steelhead and, in some cases, the outmigration of juvenile fish (Northwest Power Planning Council 1985).

The amount, type, and location of cover is important during the adult freshwater phase and the rearing phase of steelhead. Reiser and Bjornn

(1979) stated that cover is essential to adult steelhead due to the protracted periods they spend in freshwater before they spawn. They suggested that the proximity of cover may be important in the selection of spawning sites. They listed cover types as overhanging vegetation, undercut banks, submerged vegetation, submerged objects such as logs and rocks, and floating debris. Cover may be most important during the rearing phase; it provides shaded areas, reduces predation, and generally allows increased salmonid production (Reiser and Bjornn 1979). Riparian vegetation, in addition to providing cover, provides habitat for terrestrial insects that fall into the stream and become food for juvenile salmonids, and provides plant materials that become food of aquatic invertebrates (Reiser and Bjornn 1979). Some limited success has been accomplished in enhancing stream habitat for anadromous salmonids (Reeves and Roelofs 1982).

The Northwest Power Planning Council (1985) has recently reviewed the impact of hydroelectric facilities on anadromous salmon and steelhead. The outmigration time of juveniles is delayed as is the upstream migration of adults. The reservoirs created behind the facilities have inundated important spawning areas. The greater surface area of these impounded waters causes abnormal increases in river water temperatures. Other operational impacts on salmon and steelhead include turbine mortalities of juveniles, gas supersaturation of the water that can result in gas-bubble disease, stunning of outmigrants making them more susceptible to predators, and regulated stream flow fluctuations that cause stranding and mortality of fish.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the range, life history, and environmental requirements of coastal aquatic species. They are designed to assist in environmental impact assessment. The steelhead is an anadromous form of the rainbow trout Salmo gairdneri found from central California to Alaska. The commercial fishery in the Pacific Northwest is restricted to specific Indian tribes. Washington and Oregon support an important recreational fishery. In Washington and Oregon, two runs of steelhead exist. Winter-run steelhead enter their native streams in late fall and winter, and usually spawn by the following May. Summer-run steelhead return to their home streams in spring and summer, and usually spawn in the following spring. California stocks apparently consist only of winter-run fish. Female steelhead bury their eggs in gravel in streams after spawning. Proper temperature and dissolved oxygen levels are necessary for incubation of eggs and rearing in streams. Adequate particle size of stream gravel and adequate stream velocity are essential for incubation.

17. Document Analysis a. Descriptors

Competition	Trout	Depth	Life cycles
Growth	Fisheries	Sediments	Animal migrations
Oxygen	Salinity	Feeding habits	
Streams	Temperature	Suspended sediments	

b. Identifiers/Open-Ended Terms

Steelhead trout	Salmo gairdneri
Spawning	Predators

c. COSATI Field/Group

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