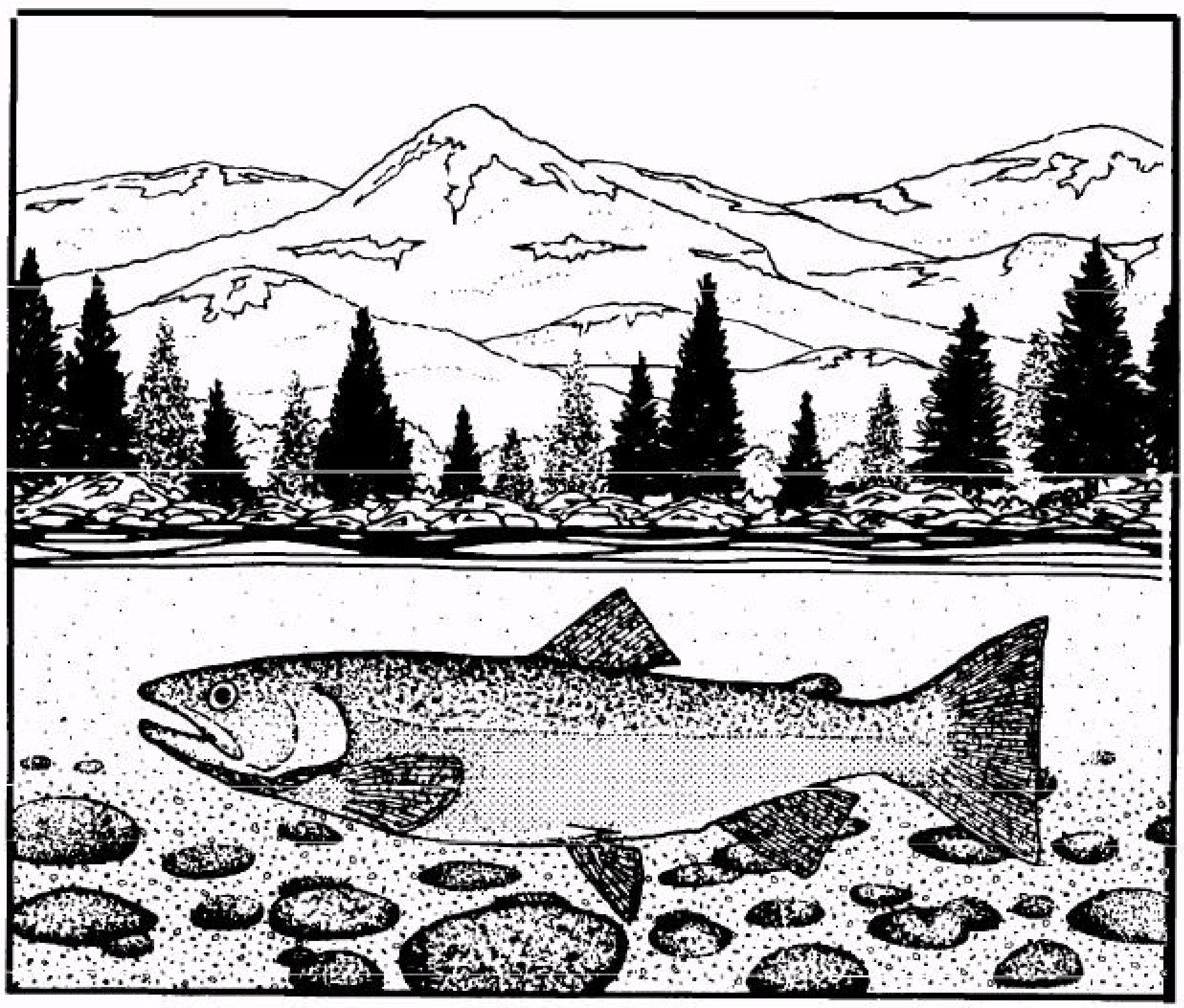
Biological Report 82(11.48)
April 1986

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

COHO SALMON



Coastal Ecology Group
Fish and Wildlife Service — Waterways Experiment Station
U.S. Department of the Interior — **U.S. Army Corps of Engineers**

Biological Report 82(11.48)
TR EL-82-4
April 1986

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

COHO SALMON

by

Jeffrey C. Laufle, Gilbert B. Pauley, and Michael F. Shepard
Washington Cooperative Fishery Research Unit
College of Ocean and Fishery Sciences
University of Washington
Seattle, WA 98195

Project Officer
John Parsons
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

Performed for
Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers
Vicksburg, MS 39180

and

National Coastal Ecosystems Team
Division of Biological Services
Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This series should be referenced as follows:

U.S. Fish and Wildlife Service. 1983-19 Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish Wildl. Serv. Biol. Rep. 82(11). U.S. Army Corps of Engineers, TR EL-82-4.

Laufle, J.C., G.B. Pauley, and M.F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--coho salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.48). U.S. Army Corps of Engineers, TR EL-82-4. 18 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 taxonany, 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.

Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slide11 Computer Complex
1010 Gause Boulevard
Slidell, LA 70458

or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
Post Office Box 631
Vicksburg, MS 39180

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

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (mi)	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

ACKNOWLEDGMENTS

We gratefully acknowledge the reviews by Sam Wright, Washington Department of Game, Olymoia, and Gary Thomas, School of Fisheries, University of Washington, Seattle.

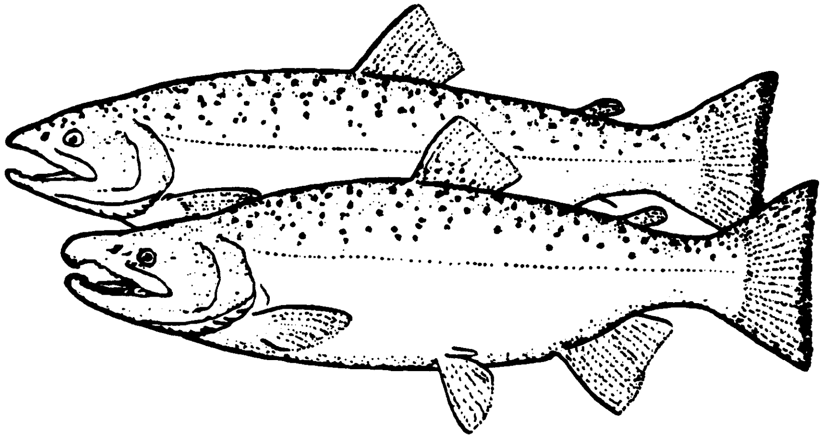


Figure 1. Coho salmon adults, with spawning phase of male at bottom (from Scott and Crossman 1973).

COHO SALMON

NOMENCLATURE/TAXONOMY/RANGE

Scientific name ..... *Oncorhynchus kisutch* (Walbaum)
Preferred common name Coho salmon (Figure 1)
Other common names Silver salmon, silver trout (in freshwater), coho, sea trout, blueback, hooknose (Haw and Buckley 1973; Scott and Crossman 1973)
Class .... Osteichthyes
Order .... Salmoniformes
Family .... Salmonidae

Geographic range: Anadromous in north Pacific Ocean, and coastal area from Monterey, California, north to Point Hope, Alaska, through the Aleutians, and from the Anadyr River, U.S.S.R., south to Korea and Hokkaido, Japan. Most abundant between southern Oregon and southeast Alaska. Coho have been planted successfully in lakes and reservoirs in Alaska, Washington, Oregon, California and in some cases in Montana for many years. The first successful stocking in the Great Lakes was in 1966, with a continued sport fishery since then. Other plantings include Atlantic States from Maine to Maryland (moderate success) plus Argentina and Chile (some success in Chile) and Alberta, Canada (apparently successful: Scott and Crossman 1973). Major spawning rivers and areas of concentration for the Pacific Northwest United States are shown in Figure 2, and

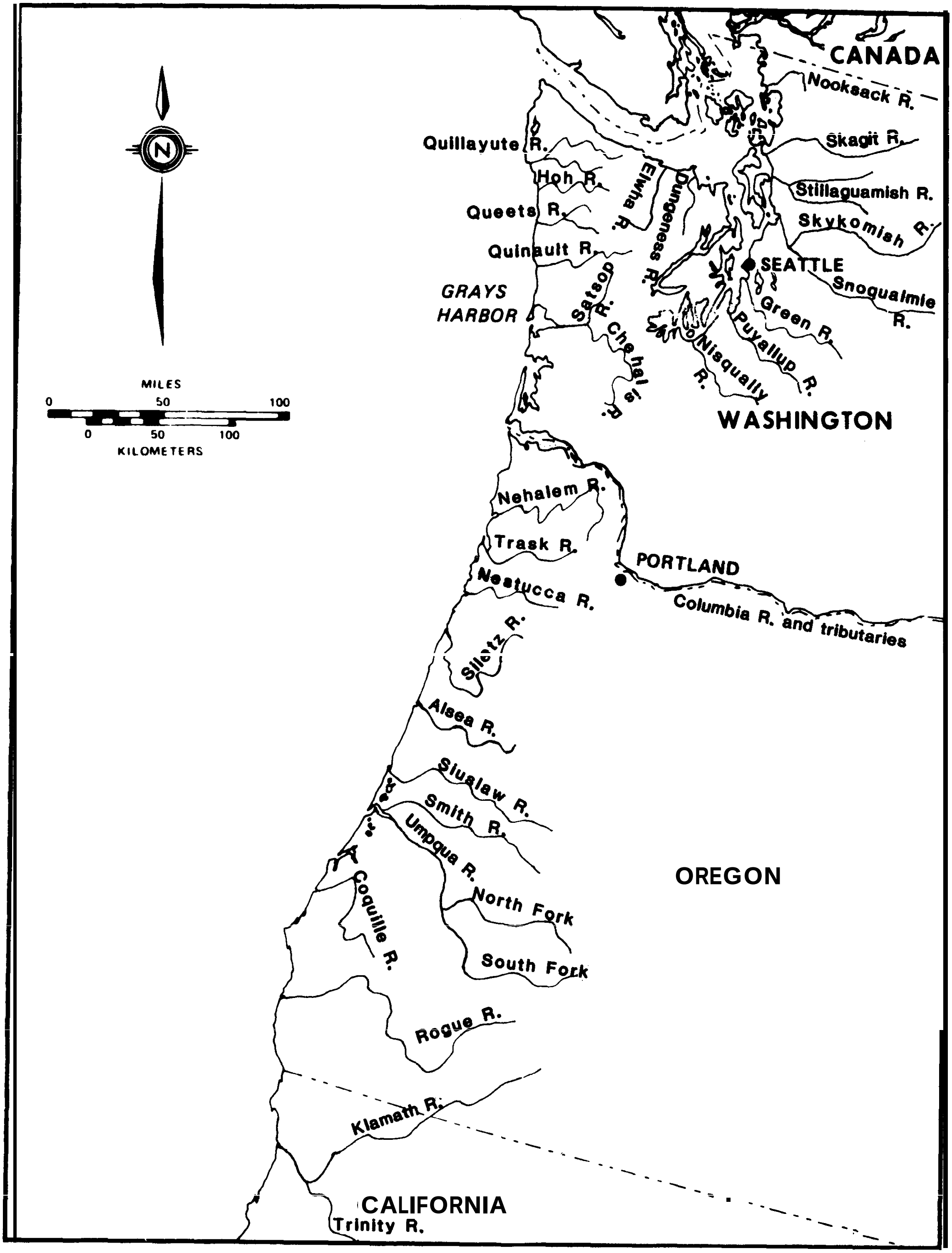


Figure 2. Major Pacific Northwest spawning rivers of coho salmon. Coho are found in all marine waters of the area (Scott and Crossman 1973).

saltwater migration patterns of adult coho salmon as determined from tagged and marked hatchery smolts are shown in Figure 3. Juveniles can migrate to southeast Alaska and farther in the first few months at sea.

MORPHOLOGY/IDENTIFICATION AIDS

Dorsal fin 9-12 rays; adipose present; anal fin 12-17 rays; pectoral fin 13-16 rays; ventral fin 9-11 rays with axillary process; lateral line scales 121-148; pyloric caeca 45-83; vertebrae 61-69; gill rakers 18-26 on first gill arch; branchiostegal rays 11-15. Measurements as percent: body depth 24 (in standard length); head length 22 (in total lenqth); head longer in spawning males (Hart 1973).

Body fusiform, somewhat compressed laterally; fork length usually 46 to 61 cm, maximum 98 cm; and 3.6 to 4.5 kg, with a maximum of 14 kg in marine populations (Scott and Crossman 1973).

Pigmentation: Juveniles colored blue-green dorsally, with silvery sides, and 8 to 12 widely spaced, narrow parr marks; lateral line through center of marks; dark adipose fin; oranqe caudal fin; and large orange anal fin with three lonq white anterior rays and black posteriorly. Ocean-dwelling adults steel-blue to greenish dorsally; silvery sides, and white ventral surface; small black spots on back, upper sides, dorsal fin base, and upper lobe of caudal fin. Before spawning, males acquire darker, dusky blue-green back, with bright red stripe on dull sides, grey to black ventral surface.

Pale gums in marine adult coho distinguish it from chinook salmon (Oncorhynchus tshawytscha), which have black qums. Spotting confined to upper lobe of caudal fin (spotting on both lobes in chinook), and number of pyloric caeca less than 83 in coho and greater than 140 in chinook, according to Dahlberg and Phinney (1967). Juvenile coho have piqmentation over entire adipose fin, while juvenile chinook have an unpigmented adipose (Dahlberg and Phinney 1967).

REASON FOR INCLUSION IN SERIES

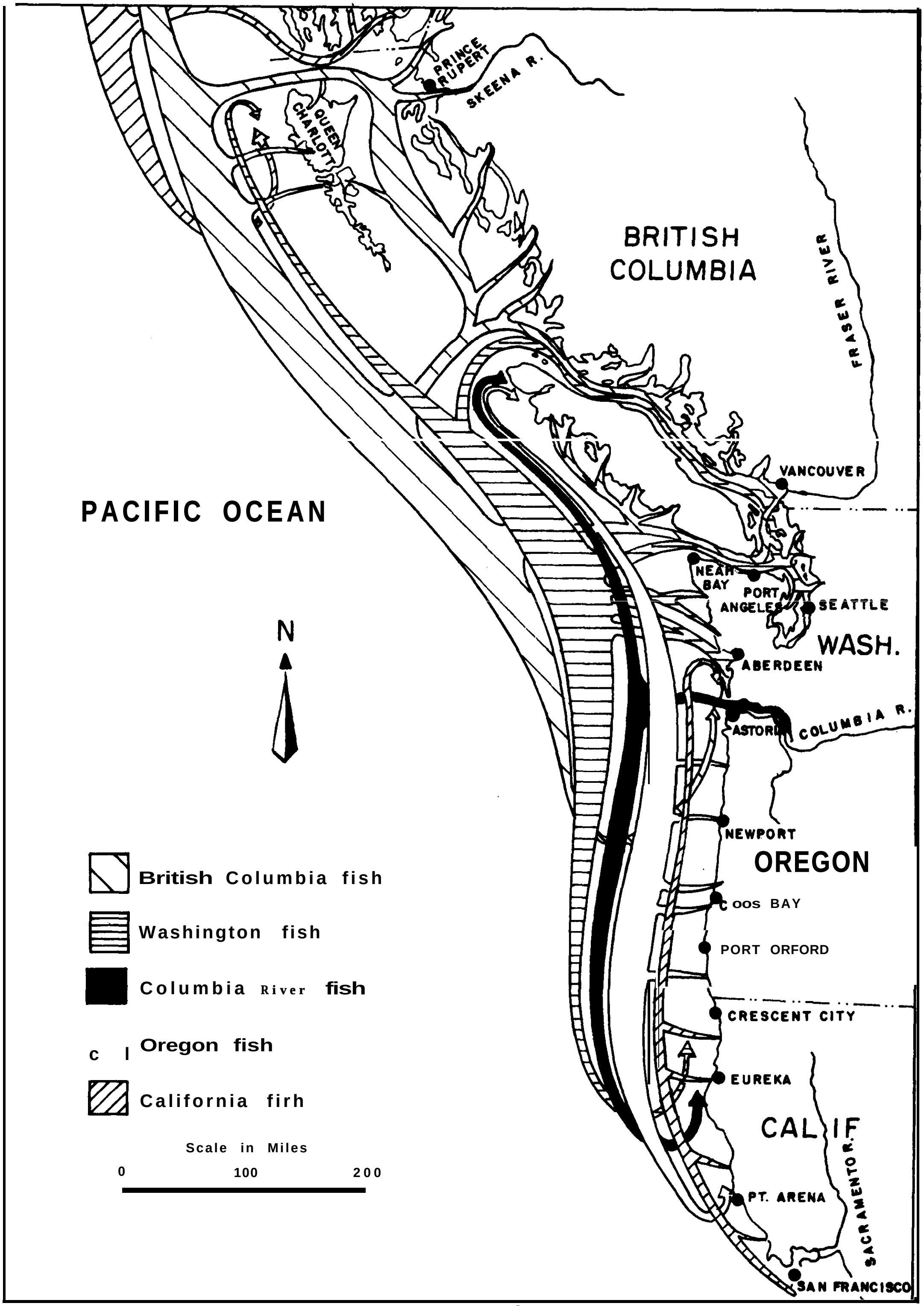
Coho salmon constitute a valuable part of the commercial and sport fisheries of the west coast freshwater and marine environments. They are the object of extensive hatchery rearing and release programs. They are tertiary carnivores, and are themselves preyed upon.

LIFE HISTORY

Spawning and Eggs

Coho are anadromous, entering freshwater to spawn (Godfrey 1965). Beginning in July, but later than August in some areas such as Grays Harbor, they return from the open ocean to coastal areas near the outlets of their natal streams. They enter rivers on all but peak floods, moving upstream primarily in daylight. Runs take place from August to February. Eames and Hino (1981) reported a November peak in a Washington stream.

Coho salmon spend 30 to 60 days in freshwater, and in North America, peak spawning occurs from late September to January, and continues as late as March. The fish usually spawn in small streams, but also use large main streams, thouph seldom more than 240 km above the mouth. They spawn in relatively fast water (0.3 to 0.5 m/sec vs. 0.1 m/sec for sockeye), normally in riffles or where ground seepage occurs. Although numbers of males and females in a spawninq run are similar males may predominate early in the run and females later. More males are present overall due to jacks (sexually precocious males that return early), while females predominate



'igure 3. Oceanic migration patterns of adult coho salmon on the west coast of British Columbia, Washington, Oregon and northern California, as determined from tagged and marked hatchery smolts (Wright 1968).

slightly in the older adults. More than one male often competes for a spawning female. Spawning takes place at temperatures of 0.8° to 7.7° C in Kamchatka, U.S.S.R. (Gribanov 1948) and at 4.4° to 9.4° c on the west coast of the United States (Reiser and Bjornn 1979).

Fecundity of coho salmon is variable depending on the size of the female, geographic area, and year. Scott and Crossman (1973) cited a range of about 1,440 to 5,700 eggs for females 44 to 72 cm long in Washington, and an average of 2,100 to 2,789 eggs per female (no lengths given) in British Columbia. Estimates in Kamchatka put coho salmon second to chinook salmon in fecundity, but no lengths were given. Shapovalov and Taft (1954) developed the following fecundity formula:

$$\text{number of eggs} = 0.0115 \times \text{fork length}^{9403}.$$

The female may deposit eggs in three or four redds (nests), which she digs by lying on her side and beating out the gravel with her tail. A dominant male moves in and joins the female; the spawning act consists of vibration by both fish, with gapimg mouths, and the release of eggs and milt. The eggs are covered with gravel displaced from the uostream side of the nest. Eggs are demersal, large (about 4.5 to 6.0 mm), and red. The female guards the nest for a short time, but both parents die soon after spawning (Scott and Crossman 1973). Incubation time apparently varies inversely with temperature, as shown by the following observations:

38 days at 11" C averaqe
48 days at 9" C averaqe
86-101 days at 4.5° C.

Larvae, Fry, and Smolts.

Newly hatched larvae possess a large yolk sac, which they absorb while remaining in the gravel for 2 to 3 weeks following hatching. They are at first photonegative, but become photopositive, and face upcurrent as well. Newly emerged fry have been observed from March to July. The fry live in shallow qravel areas, at first schooling; after a short time disperse up- and downstream. Optimum rearing habitat for coho consists of a mixture of pools and riffles, abundant instream and bank cover, water temperatures that average between 10° and 15° C in the summer, dissolved oxygen near saturation, and low amounts of fine sediments (Reiser and Bjornn 1979).

Small numbers of coho salmon may miqrate to sea, but at least a year's residence in freshwater is normal. However, there is a gradation from 1 year in freshwater in Washinqton up to 2 years in freshwater in central British Columbia, with more northerly fish usually spending 2 years in freshwater. For example, fish in the Yukon River drainage spend 2 years in freshwater (Scott and Crossman 1973). As they grow, the fry move to deeper water, feeding on progressively larger foods. In winter they feed and grow little. The juveniles usually migrate downstream from April to August of the year followinq their hatching, with peak migrations in May in nearly all areas. Nighttime migration appears to be the rule (McDonald 1960).

Size and age of the fish, as well as stream conditions, trigger outmigration. The radical physiological and behavioral changes that occur during smoltification make salmon in this stage particularly sensitive to environmental stress factors. For examole, elevated water temperatures can accelerate the onset of smoltification and shorten the smolting period, sometimes resulting in seaward migration of smolts at a time when conditions are unfavorable (Wedemeyer et al. 1980). Larger juveniles are believed to be the first to go downstream, but aggression by larger fry may induce early downstream movement by smaller ones soon after emergence (Chapman 1962; Mason and Chapman 1965).

Ocean Life

Early studies indicated that coho salmon did not migrate far offshore, but more recent hiqh-seas research has shown differently. They have been captured as far as 1,930 km away from their point of origin on the North American west coast. Movement of these fish is not random, since marked adult fish from the Columbia River are rare in Alaska salmon catches. The North American west coast oceanic migration patterns of adult coho salmon, as determined from taqqed and marked hatchery fish, are depicted in Figure 3. Offshore miqrations by juveniles commence in July and August, as evidenced by sharp declines in inshore catches of juveniles at that time. There are two migration types of coho salmon in Washington and British Columbia: "ocean," or high-seas dwellers, migrate great distances, while "inshore" fish such as those living as residents in the Strait of Georgia or Puget Sound migrate very little and stay near their river of origin. Four types of life histories occur in the Puget Sound-Georgia Strait area: (1) ocean migrants that go to sea in the spring of the second year; (2) resident fish that go to the ocean in the fall of the second year after spendinq the summer in inside marine waters; (3) resident fish that go to the ocean in the spring of their third year after 1 year in inside marine waters; and (4) true residents that spend their entire lives in the inside marine waters. Each of these groups is proqressively smaller in average size, due to less time in the open ocean. High-seas fish of North American origin probably winter south of 45° N. lat., and move north in mid- to late summer, later than do other salmon.

Coho salmon apparently concentrate in the Gulf of Alaska in the summer, dispersing coastward from there. Milne (1950) indicated that migrations are mostly direct rather than alongshore. Fish reportedly move slowly, wandering as they migrate, although they have averaged up to 30 mi per day over long distances. The delays are attributed to intensive feeding until late in their journey.

Most coho salmon, including juveniles and adults, are found within 10 m of the sea surface except when covered by a shallow layer of warmer "tuna" water. This zone is where the sport fishery concentrates its efforts (Haw and Buckley 1973).

As a rule, adult coho salmon spend two growing seasons at sea, appearing offshore near the outlets of their rivers of oriqin in the second summer after they enter saltwater. In southeast Alaska and northern British Columbia, they arrive in large numbers in July, and in southern British Columbia, Washington, and Oregon their arrival is later, with a general timing gradation that is progressively later the more southerly the run. They home almost entirely to the streams of their origins, and the small percentages that do stray migrate primarily to nearby streams.

Survival

Various studies (Salo and Bayliff 1958; Tagart 1976) were used by the Washington Department of Fisheries (in press) to derive a composite life sequence to predict average smolt production per female coho salmon. From this, an average production of 75 smolts/female was estimated. This is applicable only to the 3-year-old fish that spend 2 years at sea in the southern part of their range, south of central British Columbia.

GROWTH CHARACTERISTICS

Most coho salmon reside in the ocean for two growing seasons, returning at the end of the second summer. These are designated aqe 3_2 or 4_3 upon return for spawning (integer is total age and the subscript is year of life at outmigration). Those that spend 1 year in freshwater would be 3_2, while those that spend 2 years in freshwater before outmigrating would be age 4,. The precocious males ("jacks") or females ("jills" or "jennies") that return to spawn after only one summer are designated as 2,.

California coho salmon averaged 16 cm at outmigration, and grew an average of about 52 cm while at sea (Shapovalov and Taft 1954). Kamchatkan coho salmon were similar, with ocean growth much faster than freshwater growth for both 3, and 4_3 fish (Gribanov 1948). The Kamchatkan returnees averaged 60 cm FL (range 40-87 cm), and 3.5 kg (range 1.5 - 6.5 kg). Males were larger than females. The California returnees' sex, age, and average fork length were as follows: 2_2 males, 46 cm FL; 3_2 males, 64.7 cm; 3, females, 63.9 cm. Males were typically larger than females.

THE FISHERY

Coho salmon are a highly valued species, the object of large commercial (Table 1) and sport (Table 2) fisheries. Additional data demonstrate the value of coho salmon in U.S. commercial fisheries: in 1980, 39.3 million pounds, worth $43.1 million, were landed; in 1981, 35.2 million pounds were landed, at $33.3 million (U.S. Department of Commerce 1982). Most commercial landings are close to shore (29.7 million pounds from 0 to 4.8 km out, versus 5.5 million pounds from 4.8 to 322.0 km out, in 1981). Coho ranked consistently fourth behind sockeye salmon (Oncorhynchus nerka), oink salmon (O. gorbuscha), and chum salmon (O. keta), in the Pacific coast commercial fishery from 1968 to 1978, and made up 8% to 11% of the total catch (International North Pacific Fisheries Commission 1971-81). The Lake Michigan coho salmon sport fishery is outproducing the entire U.S. Pacific Coast coho salmon sport fishery (Tanner 1974).

Coho salmon are fished commercially with gill nets, set nets (treaty Indians only, in Washington), purse seines, and trolling gear (Washington Department of Fisheries et al. 1973). Sport fishing is by hook and line in saltwater and in streams. Saltwater angling is both off-coast and inshore, with Puget Sound, for example, supporting a substantial fishery in late summer for ocean and resident fish. Haw and Buckley (1973) discussed sport fishing techniques in detail. Salo (1974) estimates that anglers spent between $100 and $125 in 1966 to catch a coho salmon.

Many coho salmon are reared and released from State, Federal, and other hatcheries; about 40% to 50% of the net-caught salmon in Puget Sound are estimated to be of hatchery origin. Coho salmon and chinook salmon are the most successfully reared salmonid species. Hatcheries have become important because of such developments as pellet-sized food, better disease treatment, and the rearing of fish to the yearling stage (Fulton 1970). Columbia River runs have been enhanced by hatcheries since 1959.

Current management objectives of the Washington Department of Fisheries are toward maximum sustained harvest, with the treaty Indian Tribes under the Boldt Decision (United States vs. State of Washington) having a legal right to 50% of the catchable allocation. Preseason run sizes for each individual river are estimated and escapement goals for each river are predicted (Zillges 1977; an escapement goal is the number of spawners necessary to maintain the run of a given size, and a goal may vary from year to year. In-season run reassessments are also made (Zillges 1977). From these predictions and projections each year, the catchable

Table 1. Annual canmercial landings of coho salmon by State or Province in metric tons (MT) and number of fish (in thousands) for the years 1968-78. Data from International North Pacific Fisheries Commission (1971-81).

	British Columbia		Alaska		Washington		Oregon	
Year	MT	Fish	MT	Fish	MT	Fish	MT	Fish
1968	15,100	5,257	9,530	2,751	3,950	1,275	2,620	929
1969	7,990	2,414	3,660	1,133	3,220	920	2,240	802
1970	13,649	3,946	5,407	1,527	7,885	1,870	5,935	1,401
1971	14,089	4,788	5,208	1,447	6,100	2,002	5,341	1,695
1972	10,536	3,359	6,415	1,831	4,471	1,253	2,941	925
1973	11,227	3,531	4,948	1,457	5,854	1,672	3,314	937
1974	10,379	3,724	6,394	1,862	6,923	2,117	4,562	1,328
1975	7,736	2,332	3,233	1,014	6,389	1,837	2,641	772
1976	9,325	3,698	5,063	1,432	5,530	2,162	5,096	1,936
1977	9,856	3,341	6,987	1,815	5,536	1,745	1,493	478
1978	19,152	3,350	9,062	2,821	4,222	1,480	1,870	730

Table 2. Estimated numbers of coho salmon caught in the recreational fisheries of four States during 1970-78. Asterisk (*) indicates marine catches only. Data from International North Pacific Fisheries Commission (1971-81).

Year	Alaska	Washington	Oregon	California
1970	32,075	540,231*	279,602	14,615*
1971	50, 500	845,735*	335,003	67,421*
1972	37,510	615,895*	135,078	43,770*
1973	42,575	552,255	254,610	31,641*
1974	50,550	788,981	339,126	78,162*
1975	70,300	701,721	273,892	20,860*
1976	59,100	1,195,579	127,490	57,642*
1977	104,090	683,108	212,371	26,788*
1978	131,945	713,219	268,980	44,282*

allocation of coho salmon in each individual river is made with non-Indians receiving 50% and treaty Indians receiving 50%. The non-Indian share is then divided between commercial fishermen and sport anglers.

Management methods for coho and other salmon must include freshwater habitat assessment, stock assessment including run size, habitat protection and improvement, and artificial propaqation. The Washington Department of Fisheries has been usinq Smoker's (1953) preseason method in Puget Sound to predict coho salmon catches from stream discharge data, as well as the previous year's jack run size. Such factors, however, as environmental extremes, saltwater environmental variations, and fishing intensity also play a role (Zillqes 1977). Other methods are being developed and used in other areas by cooperative effort between State biologists and tribal biologists.

Wright (1951) described the complexities of salmon management, stating that good run forecasts with accurate and timely reassessments are important. Also, runs dependent upon hatcheries could be harvested at a higher rate than wild runs because of high survival of juveniles in hatcheries. Where two stocks coexist geographically, maximum sustainable yield should be defined for the weaker stock, with the surplus fish taken where the stronger stock is easier to tarqet. He argued against depending on user groups, i.e., fishermen, for sound management; the vitality of the resource should be the primary criterion used in designing management procedures.

ECOLOGICAL ROLE

Coho salmon fill different niches in freshwater and in saltwater. The alevins living in gravel do not feed, but depend on the yolk sac for nourishment. Even though part of the yolk sac may remain after emergence, the fry begin to feed immediately after emergence (Godfrey 1965). Johnson (1970) stated that juvenile salmon in Washington, depending on the season and stream, ate various life stages of aquatic insects (mostly at the surface), such as dipterans, ephemeropterans, plecopterans and other insects, as well as crustaceans and fishes. If their normal food is scarce, juvenile coho will eat insect exuviae, though this provides no nutrition (Mundie 1969). Alaskan coho fingerlings prey on sockeye salmon fry (Oncorhynchus nerka); 30% of coho captured between May and July had sockeye remains in their stomachs (Roos 1960). They ate the sockeye even though sticklebacks were more abundant.

Fresh et al. (1981) categorized the food of coho salmon by zones in Puget Sound and other Washington marine waters. Juvenile fish from sublittoral habitats had stomach contents consisting mainly of decapod crustacean larvae,. plus fishes (mostly herring), amphipods, and polychaetes. In the nearshore pelagic zone, some juveniles examined had brachyuran crab larvae as their primary food item. Young coho from the offshore pelagic zone ate euphausids, fishes (mainly herring), gammarids, and decapod larvae. Fishes formed the hiahest biomass, but occurred in only 30% of the coho salmon stomachs. Offshore in the Pacific, near the Columbia River, young adult coho examined were larger than those in Puget Sound and ate mostly fishes, including anchovy, surf smelt, whitebait smelt, herring, juvenile chinook, and juvenile rockfish. They also fed on euphausids and crab larvae off Oregon and Washington (Silliman 1941; Heg and Van Hynning 1951). In the Great Lakes, coho and other salmon have confirmed hopes that they would consume the smelt and alewives present there in abundance (Scott and Crossman 1973).

Coho salmon themselves are the prey of a variety of animals. Coho juveniles are taken by other fishes, including other coho salmon, trout, squawfish, and sculpins (Scott and Crossman 1973). Birds that prey upon coho include merqansers, kingfishers, and loons. Spawning adults are eaten by animals such as bears and eagles. Seals and killer whales prey on ocean-dwelling salmon, while man and parasitic lampreys prey on coho in marine and freshwater environments.

The predation by adult coho on juvenile sockeye salmon, chinook salmon and coho salmon is indicative of their aggressiveness. Scott and Crossman (1973) stated that coho salmon also eat chum and pink salmon fry. Mason and Chapman (1965) indicated that coho fry are agqressive and territorial soon after emergence, and establish intraspecific dominance hierarchies. Where coho and chinook fry occurred toqether in streams. the coho were socially dominant, defending territory accessible to incoming food (Stein et al. 1972). Coho were the faster growing of the two, and were heavier than chinook fry of the same length.

Production of juvenile coho salmon in three Oregon streams averaged 9 $g/m^2/yr$ over 4 years (Chapman 1965). Measurements were made over 14 months of stream residence time. Monthly averaqes were 1.9 to 2.8 g/m2 following emergence, dropping to 0.2-0.3 g/m^2 by winter. Pearson et al. (1970) found that coho production per unit area was higher in pools with large riffles upstream than in pools downstream of small riffles, because of a greater available food supply.

Dill (1969) stated that fry expand their territories at 1.5 to 2 months. The reduction in density may be a result of predation, which Godfrey (1965) postulated may be a major factor in an observed decline in numbers following the peak of emergence.

ENVIRONMENTAL REQUIREMENTS

Reiser and Bjornn (1979) reviewed the habitat needs of coho in streams which are summarized in Table 3. McMahon (1883) has constructed a Habitat Suitability Index pertaining to riverine habitat for various life stages of coho salmon.

Temperature

Preferred temperatures for coho salmon in streams range between 11.8° and 14.6°C (Bell 1973), and 25.8°C is the upper lethal limit. As stated earlier, incubation time varies with temperature. The shortest time given by Godfrey (1965) was 38 days at 11°C, and the longest was 86 to 101 days with a temperature of 4.5°C. Godfrey (1965) listed 4.0° to 15.2°C as the oceanic temperature range where coho salmon have been taken, with the best catches occurring between 8° and 12°C. Streamside vegetation plays an important role in regulating the stream temperatures.

Water Depth

Adult coho salmon can spawn in shallow water (0.18 m), but young fish apparently prefer deeper water (0.3-1.2 m), where most of the available riffle area is submerged (Table 3).

Water Velocity

Adults can swim in water velocities as high as 2.44 m/sec, with even faster bursts of speed, while adult spawning and juvenile rearing must take place in water velocity of well under 1 m/sec (Table 3). Water velocities preferred by invertebrate food items are in the range of 0.15 to 1.22 m/sec.

Oxygen

Coho salmon, especially embryos and juveniles, prefer highly oxygenat-

Table 3. Summary of preferred habitat requirements for coho salmon in streams (from Reiser and Bjornn 1979).

Habitat requirements	Value
Temperature	
Adult migration upstream	7.2° - 15.6°C
Spawning	4.4° - 9.4°C
Incubation	4.4° - 13.3°C
Upper lethal	25.8°C
Preferred range	11.8' - 14.6°C
Water depth	
Adult migration upstream (minimum)	0.18 m
Spawning (minimum)	0.18 m
Age 0 fish (preferred) (60% of riffle should be submerged)	0.30 - 1.22 m
Water velocity	
Adult migration upstream (maxmium)	2.44 m/sec
Spawning	0.31 m/sec
Aqe 0 fish (preferred)	0.09 -<0.30 m/sec
Riffle velocity for rearing	0.31 - 0.46 m/sec
Pool velocity for rearing	0.09 - 0.24 m/sec
Adult swimming speeds: cruising	0 - 1.04 m/sec
sustained	1.04 - 3.23 m/sec
darting	3.23 - 6.55 m/sec
Invertebrate food organisms	0.15 - 1.22 m/sec
O_2	
Weiqht gain in fry stage	4 - 9 mg/l for 70% - 100% gain over 19 - 28 days
Food conversion (9 mg/l maximum tested)	4 - 9 mg/l
Juvenile swimming speed (maximum)	100% saturation
Incubation	Near saturation (>5 mg/l)
Space (area)	
Average size of redd	2.8 m^2
Recommended area per spawninq pair	11.7 m^2
Year 1+ fish	2.4 - 5.5 m^2 fish
Substrate	
Spawning	20% fine sediment <6.4 mm in riffle substrate
Silt loads	<25 mg/l preferable
Other	Good overhead and submerged cover Riffle/pool ratio of 1:1

ed water. Growth and food conversion decline at levels below about 4 mg/l. Swimming ability of juveniles also can drop in unsaturated water. Reduced oxygen levels inhibited growth and lengthened incubation time for coho embryos (Shumway et al. 1964). Low oxygen concentrations reduced survival of coho embryos (Phillips and Campbell 1961).

Space

Spatial requirements for spawning and rearing are known (Reiser and Bjornn 1979). Space requirements for juveniles increase as they grow and are probably food related (Chapman 1966), though Chapman (1962) stated that food was not involved in the intraspecific agqressiveness he found in coho fry. Pearson et al. (1970) did find greater production in pools, a situation that would seem to mitigate density-dependent factors involved in aggression.

Other Factors

A substrate (gravel) size range of 1.3 to 10.2 cm necessary for spawning was cited by Reiser and Bjornn (1979). Dill (1969) found that coho salmon survival at emergence was greater in large gravel than in small, but their condition was poorer; he attributed the survival to greater ease of water penetration and the poorer condition to less support for the alevins.

Low siltation is important for survival of eggs and juveniles. Reiser and Bjornn (1979) listed silt loads of less than 25 mg/l as best. High water velocities reduce deposition of fine sediment, which should make up less than 40% of the riffle substrate. Large amounts of deposited silt restrict oxygen flow to eggs and fry, and trap fry attemptinq to leave the gravel (Lantz 1976). Sigler et al. (1984) reported that chronic turbidity affected the emergence and rearing of young coho salmon; a lower growth rate was observed in fish subjected to continuous clay turbidities compared to fish grown in clear water. Stober et al. (1981) studied the reactions of coho and chinook salmon to Mt. St. Helens, Washington, volcanic ash and mudflow sediment in two rivers. In field livebox experiments they obtained 96-h LC_{50}'s at 1,217 and 509 mg/l of suspended mud and ash for coho presmolts and smolts, respectively. A comparative static bioassay with ash produced 96-h LC_{50}'s at 18,672 and 28,184 mg/l for presmolts and smolts, respectively. A static 96-h bioassay using mudflow sediments produced mortality in smolts at 29,580 mg/l Complete presmolt mortality occurred in the Cowlitz River in the summer following the 18 May 1980 eruption (Stober et al. 1981). As pointed out by Reiser and Bjornn (1979), high levels of suspended sediments can clog and abrade gills, curtail feeding, and cause avoidance of areas by fish. Sediment also may destroy food supplies (Cordone and Kelley 1961).

Salmon abundance has been linked to available cover in a stream (Reiser and Bjornn 1979). Overhead cover provides shade and protection from terrestrial predators, while submerged cover provides shelter from current and predators.

A list of examples of habitat alterations and how they adversely affect Salmonid populations was reported by the Washington Department of Fisheries et al. (1973). Logging, for instance, causes sedimentation, elevated water temperatures from lack of adequate cover, stream damming, decomposition of orqanics and high biological oxygen demand (BOO), and possible severe erosion and rapid runoff (especially in clearcuts). Hall and Lantz (1969) cited daily stream temperature fluctuations caused by logging operations as serious threats to coho salmon. The Washington Department of

Fisheries et al. (1973) additionally listed irriqation (removinq water, adding pollutants, entraininq juveniles), damminq (migration delay or prevention, spawning habitat destruction from reservoir coverage, turbine- and spillway-related mortalities, possible increased predation in reservoirs), industrial projects (water consumption, pollution), channelization (pool and riffle elimination, siltation), and residential development (floodinq and erosion), as detrimental to Salmonid habitat. Detailed summaries on several human-made structures and activities that negatively impact Salmonid habitat have been published: paper mills (Schmiege 1980), forest roads (Yee and Roelofs 1980). mining (Martin and Platts 1981), livestock grazing (Platts 1981), logging (Chamberlin 1982), and silviculture (Everest and Harr 1982).

LITERATURE CITED

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Useful factors in life history of most common species. U.S. Army Corps of Engineers, Fish.-Eng. Res. Program, Portland, Oreg. (unpublished; cited in Reiser and Bjornn 1979).

Chamberlin, T.W. 1982. Timber harvest. Pages 1-30 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-136. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emiqration. J. Fish. Res. Board Can. 19(6): 1047-1080.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Trans. Am. Fish. Soc. 94(1): 40-52.

Chapman, D.W. 1966 Food and space as requlators of Salmonid populations in streams. Am. Nat. 100: 345-357.

Cordone, A.J., and D.W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish Game 47(2): 189-228.

Dahlberg, M.L., and D.E. Phinney. 1967. The use of adipose fin pigmentation for distinguishing between juvenile chinook and coho salmon in Alaska. J. Fish. Res. Board Can. 24(1): 209-211.

Dill, L.M. 1969. The subgravel behavior of Pacific salmon larvae. Pages 88-99 in T.G. Northcote, ed. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver, Canada.

Eames, M., and M. Hino. 1981. A mark-recapture study of an enumerated coho spawning escapement. Wash. Dep. Fish. Prog. Rep. 148. 22 pp.

Everest, F.H., and R.D. Harr. 1982. Silvicultural treatments. Pages 1-19 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-134. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Fresh, K.L., R.D. Cardwell, and R.R. Koons. 1981. Food habits of Pacific salmon, baitfish, and their potential competitors and predators in the marine waters of Washington, August 1978 to September 1979. Wash. Dep. Fish. Prog. Rep. 145. 58 pp.

Fulton, L.A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River basin--past and present. U.S. Natl. Mar. Fish. Serv. Spec. Sci. Rep. Fish. 618. 37 pp.

Godfrey, H. 1965. Coho salmon. Int. North Pac. Fish. Comm. Bull. 16: 1-39.

Gribanov, V.I. 1948. Coho (Oncorhynchus kisutch Walb.) (General Biology) Izvetstiia TINRO, Vol. 28. (Transl. from Russian by W.E. Ricker) Fish. Res. Board Can. Transl. Ser. No. 370.

Hall, J.D., and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 in T.G. Northcote, ed. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver, Canada.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can. Bull. 180. 740 pp.

Haw, F., and R.M. Buckley. 1973. Saltwater fishing in Washington. Stan Jones Publishing, Inc., Seattle, Wash. 198 pp.

Heg, R., and J. Van Hynning. 1951. Silver salmon taken off the Oregon Coast. Oreg. Fish. Comm. Res. Briefs 3(2):32-40.

International North Pacific Fisheries Commission. 1971-81. Statistical yearbooks 1968-79. Vancouver, Canada.

Johnson, J.M. 1970. Food and feeding habits of juvenile coho salmon and steelhead trout in Worthy Creek, Washington. M.S. Thesis. University of Washington, Seattle. 77 pp.

Lantz, R.L. 1976. Protection of salmon and trout streams in logging operations. Pages 14-20 in A.R. Grove, ed. Stream management of salmonids. Trout 17(1): winter supplement.

Martin, S.B., and W.S. Platts. 1981. Effects of mining. Pages 1-15 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-119. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Mason, J.C., and D.W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. J. Fish. Res. Board Can. 22(1): 172-190.

McDonald, J. 1960. The behavior of Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. J. Fish. Res. Board Can. 17(5): 655-676.

McMahon, T.E. 1983. Habitat suitability index models: Coho salmon. U.S. Fish Wildl. Serv. FWS/OBS-82/10.49. 29 pp.

Milne, D. 1950. The difference in the growth of coho salmon on the east and west coasts of Vancouver Island in 1950. Fish. Res. Board Can. Pac. Prog. Rep. 85:80-92.

Mundie, J.H. 1969. Ecological implications of the diet of juvenile coho in streams. Pages 135-162 in T.G. Northcote, ed. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver, Canada.

Pearson, L.S., K.R. Conover, and R.E. Sams. 1970. Factors affecting the natural rearing of coho salmon during the summer low flow season. Fish. Comm. Oreg., Portland (unpublished; cited in Reiser and Bjornn 1979).

Phillips, R.W., and H.J. Campbell. 1961. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. Pac. Mar. Fish. Comm. Annu. Rep. 14:60-73.

Platts, W.S. 1981. Effects of live stock grazing. Pages 1-25 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-124. Pacific Northwest Forest and Range Experiment Station, Portland, Oreq.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. Pages 1-54 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-96. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Roos, J.F. 1960. Predation of young coho salmon on sockeye salmon fry at Chignik, Alaska. Trans. Am. Fish. Soc 89(4): 377-379.

Salo, E.O. 1974. Anadromous fishes. Pages 12-21 in A.R. Grove, ed. Salmonid management. Trout 15(1): winter supplement.

Salo, E.O., and W.H. Bayliff. 1958. Artificial and natural reproduction of silver salmon, Oncorhynchuskisutch, at Minter Creek, Washington Wash. Dep. Fish. Res. Bull: 4. 75 pp.

Schmiege, D.C. 1980. Processing mills and camps. Paaes 1-17 in W.R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-113. Pacific Northwest Forest and Range Experiment Station, Portland, Qreg.

Scott, Y.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 pp.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri and silver salmon (Oncorhvnchus kisutch) with special reference ki Waddell Creek, California, and recommendation regarding their management. Calif. Dep. Fish. Game Fish. Bull. 98. 375 pp.

Shumway, D.L., C.E. Warren, and P. Duodoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Trans. Am. Fish. Soc. 93(4): 342-356.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Trans. Am. Fish. Soc. 113(2): 142-150.

Silliman, R.P. 1941. Fluctuations in diet of the chinook and silver salmons (Oncorhynchus tshawytscha and O. kisutch) off Washington, as related to the troll catch of salmon. Copeia 1941(1): 80-87.

Smoker, W.A. 1953. Stream flow and silver salmon production in western Washington. Wash. Dep. Fish. Res. Pap. 1(1): 5-12.

Stein, R.A., P.E. Reimers, and J.D. Hall. 1972. Social interactions between juvenile cii (Oncorh nchus kisutch) and fall chinook l+iiz (O. tshawytscha) in Sixes River, Oregon. J fish. Res. Board Can. 29(12): 1737-1748.

Stober, Q.J., B.D. Ross, C.L. Melby, P.A. Dinnel, T.H. Jagielo, and E.O. Salo. 1981. Effects of suspended volcanic sediment on coho and chinook salmon in the Toutle and Cowlitz Rivers. Univ. Wash. Fish. Res. Inst., Seattle. Tech. Compl. Rep. FRI-UW 8124. 161 pp.

Tagart, J.V. 1976. The survival from egg deposition to emergence of coho salmon in the Clearwater River, Jefferson County, Washington. M.S. Thesis. University of Washington, Seattle. 101 pp.

Tanner, H. 1974. Salmonids in lakes. Pages 22-31 in A.R. Grove, ed. Salmonid Management. Trout 15(1): Winter Supplement.

U.S. Department of Commerce, National Marine Fisheries Service. 1982. Fisheries of the United States, 1981. U.S. Natl. Mar. Fish. Serv. Curr. Fish. Stat. No. 8200. 131 pp.

Washington Department of Fisheries. In press. Coho Salmon Workshop, Reston, Washington, October 13-14, 1983. Proceedings.

Washington Department of Fisheries, U.S. Fish and Wildlife Service, and Washington Department of Game. 1973. Joint statement regardinq the biology, status, management, and harvest of the salmon and steelhead resources of the Puqet Sound and Olympic Peninsula drainaqe in western Washington. 140 pp.

Wedemeyer, G.A., R.L. Saunders, and W.C. Clarke. 1980. Environmental factors affecting smoltification and early marine survival of anadromous salmonids. Mar. Fish. Rev. 42(1): 1-14.

Wright, S.G. 1968. Origin and migration of Washington's chinook and coho salmon. Wash. Dep. Fish. Inf. Booklet 1. 25 pp.

Wright, S.G. 1981. Contemporary Pacific salmon fisheries management. N. Am. J. Fish. Manage. 1(1):29-40.

Yee, C.S., and T.D. Roelofs. 1980. Planning forest roads to protect Salmonid habitat. Paqes l-26 in W.R. Meehan, ed. Influence of forest and ranaeland management on anadromous fish habitat in western North America. U.S. For. Serv. Gen. Tech. Rep. PNW-109. Pacific Northwest Forest and Ranqe Experiment Station, Portland, Oreg.

Zillges, G. 1977. Methodology for determining Puget Sound coho escapement goals, escapement estimates, 1977 pre-season run size prediction and in-season run assessment. Wash. Dep. Fish. Tech. Rep. No. 28. 65 pp.

Ic::? 'c:

REPORT DOCUMENTATION PAGE

1. REPORT NO. Biol. Rep. 82(11.48)*

2.

3. Recipient's Accession No

4. Title and Subtitle

Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--Coho Salmon

5. Report Date

April 1986

6.

7. Author(s)

Jeffrey C. Laufle, Gilbert B. Pauley, and Michael F. Shepard

8. Performing Organization Rept. No

9. Performing Organization Name and Address

Washington Cooperative Fishery Research Unit
College of Ocean and Fishery Sciences
University of Washington
Seattle, WA 98195

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12 Sponsoring Organization Name and Address

National Coastal Ecosystems Team
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

13. Type of Report & Period Covered

14.

15. Supplementary Notes

*U.S. Army Corps of Engineers Report No. TR EL-82-4

16. Abstract (Limit: 200 words)

This Species Profile of the coho salmon (Oncorhynchus kisutch) is designed to give background material on virtually all aspects of the fish's life history. The coho is anadromous, swimming upstream from the ocean in fall to spawn. The fry hatch in the spring and outmigrate 1 to 2 years later. They usually spend two growing seasons at sea. They require clear, cold, well-oxygenated (<4 mg/l) stream water- (1 m/sec) for spawning and rearing, with a gravel substrate, adequate cover, and a food supply of insects, crustaceans, and fishes for the young. All populations of coho salmon are limited by the amount of suitable rearing area available. They are sought after in both sport and commercial fisheries, and are very sensitive, especially the early life stages in streams, to such human-made impacts as siltation, pollution, removal of cover, and barriers to migration.

Current management objectives of the State of Washington are toward MSH (maximum sustained harvest), with the treaty Indian tribes under the Boldt Decision (United States vs. State of Washington) having a legal right to 50% of the catchable allocation.

17. Document Analysis a. Descriptors

Salmon
Fisheries
Feeding habits
Animal migrations
Life cycles
Growth

b. Identifiers/Open-Ended Terms

Coho salmon
Oncorhynchus kisutch
Environmental requirements

c. COSATI Field/Group

18. Availability Statement

Release unlimited

19. Security Class (This Report)

Unclassified

20. Security Class (This Page)

Unclassified

21. No. of Pages

18

22. Price

FORM 272 (4-77)

U.S.G.P.O. 1986/661-638