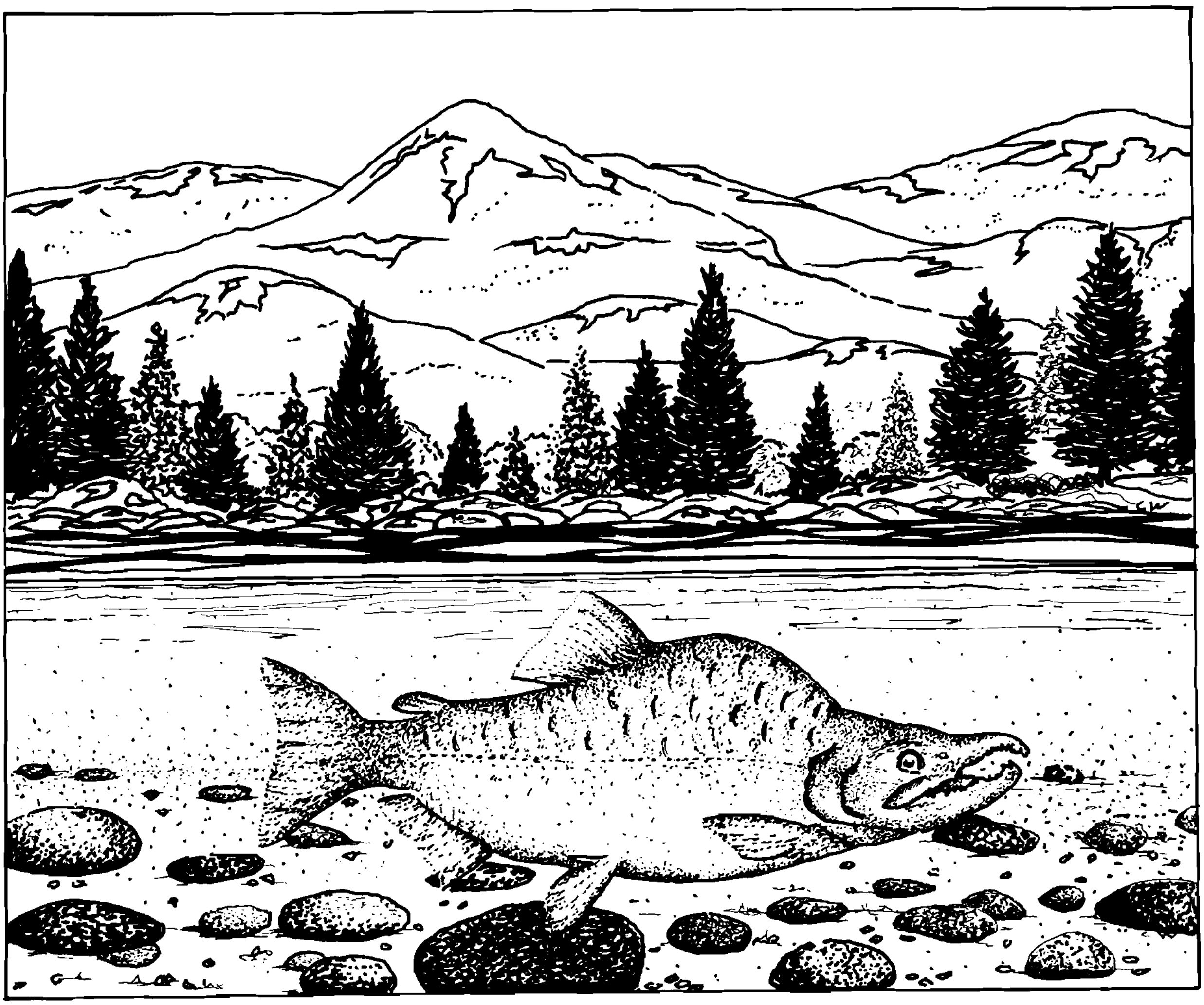
Biological Report 82(11.88)
January 1989

TR EL-82-4

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

PINK SALMON



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

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

Biological Report 82(11.88)
TR EL-82-4
January 1989

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

PINK SALMON

by

Scott A. Bonar, Gilbert B. Pauley, and G.L. Thomas
Washington Cooperative Fishery Research Unit
School of Fisheries
University of Washington
Seattle, WA 98195

Project Officer
David Moran
U.S. Fish and Wildlife Service
National Wetlands Research Center
1010 Gause Boulevard
Slidell, LA 70458

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

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
National Wetlands Research Center
Washington, DC 20240

This series may 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.

This profile may be cited as follows:

Bonar, S.A., G.B. Pauley, and G.L. Thomas. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--pink salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.88). 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 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.

Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slidell 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
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical 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 (m^3)	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 (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	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
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

We gratefully acknowledge reviews by Robert F. Donnelly and Steven S. Parker, both of the Fisheries Research Institute, University of Washington, Seattle.

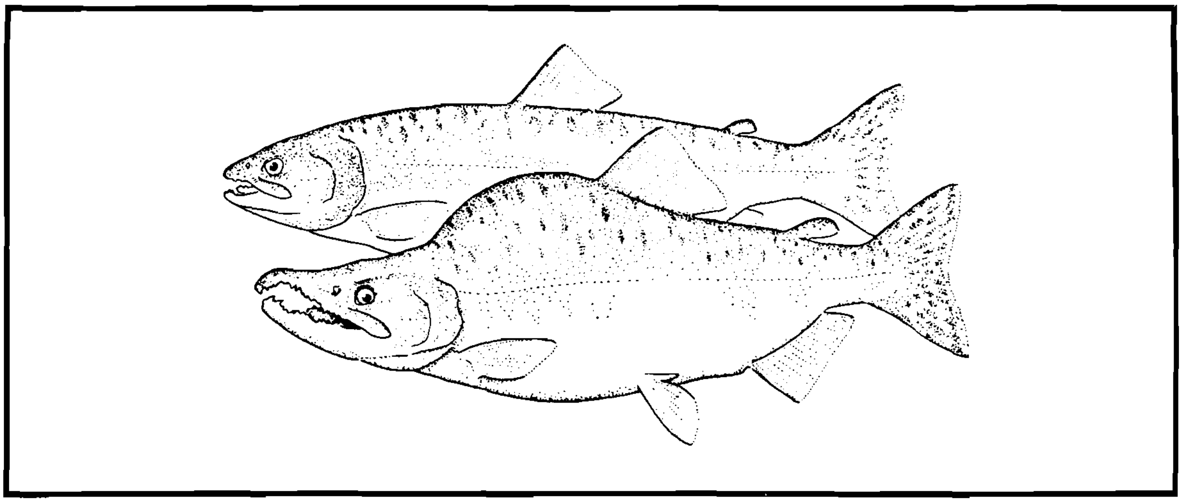


Figure 1. The pink salmon, showing extreme sexual dimorphism of the male (lower fish). Reprinted with permission of Scott and Crossman (1973).

PINK SALMON

NOMENCLATURE/TAXONOMY/RANGE

Scientific name...........*Oncorhynchus gorbuscha* (Walbaum) (Figure 1)
Preferred common name.....Pink salmon
Other common names....humpback, humpback salmon, humpy (Scott and Crossman 1973)
Class.....................Osteichthyes
Order....................Salmoniformes
Family.....................Salmonidae

Geographic range: Anadromous in rivers and small streams from northern California north to the arctic waters of Alaska, Canada, and the Soviet Union. Washington State appears to be at the southern end of the range for streams that support consistently exploitable spawning runs of pink salmon. Populations in Asia occur as far south as Hondo Island in Japan. Pink salmon have been introduced into the Great Lakes. Major rivers supporting pink salmon runs in the Pacific Northwest are shown in Figure 2. South of British Columbia, only a few rivers in the State of Washington that empty into Puget Sound support major pink salmon runs. Migration patterns of fish entering British Columbia and Washington waters are shown in Figure 3. Tagging studies have indicated that the majority of adult pink salmon destined for Puget Sound rivers migrate through the Strait of Juan de Fuca at the southern end of Vancouver Island, while those fish returning to southern British Columbia migrate primarily through the Strait of Georgia on the eastern side of Vancouver Island, with some returning through the Strait of Juan de Fuca (Figure 3).

MORPHOLOGY/IDENTIFICATION AIDS

Morphology and identification aids are from Hart (1973) and Scott and Crossman (1973). Dorsal fin 10-15 rays; adipose small, slender, fleshy; anal 13-17 rays; pelvics 10 rays, abdominal, with a free-tipped

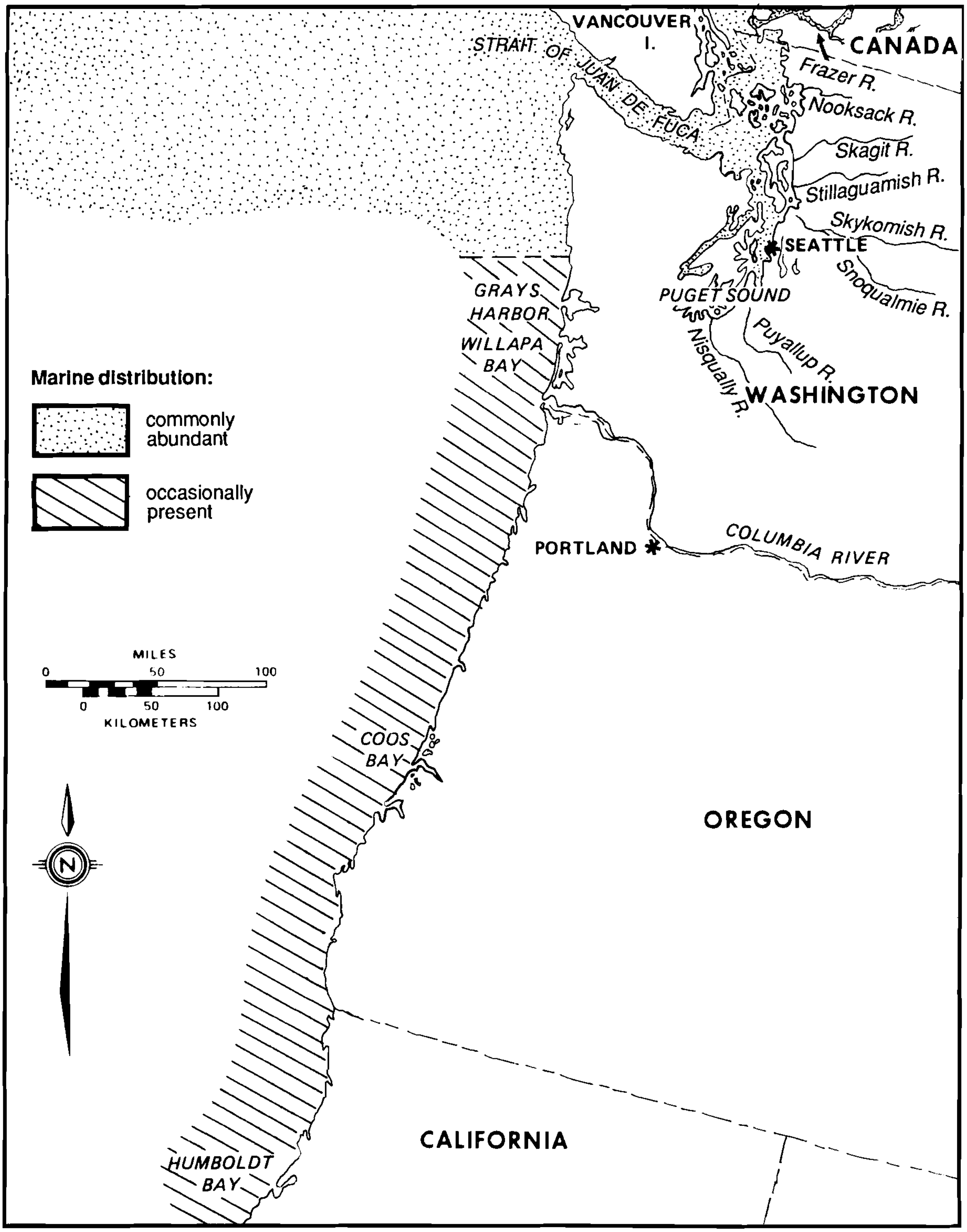


Figure 2. Major rivers in the Pacific Northwest supporting pink salmon runs.

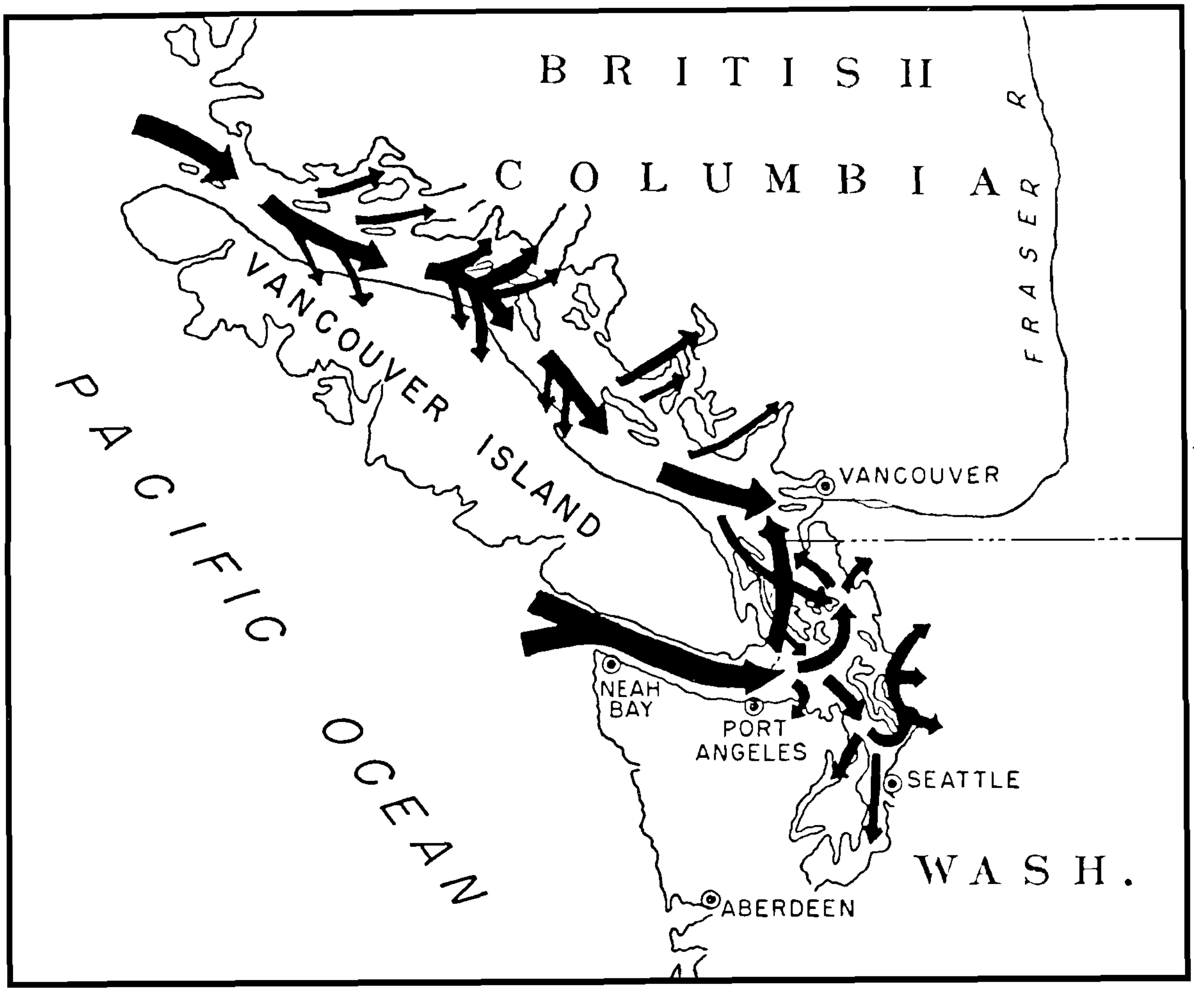


Figure 3. Principal migration routes (arrows) of pink salmon entering Puget Sound and British Columbia waters (from Washington State Department of Fisheries 1959).

fleshy appendage above insertion; pectorals 15 rays. Cycloid scales small, 150 to 205 on lateral line, which easily distinguishes pink salmon from other species of salmon. Gill rakers 26 to 34 on first gill arch. Body elongate and somewhat laterally compressed.

Identification aids: Tail (caudal fin) moderately forked. Numerous large, black, oval spots on upper sides and back and all of caudal fin. Upper jaw reaches beyond posterior margin of orbit. Males on spawning migration develop a prominent high hump immediately behind the head (Figure 1). Juveniles have no parr marks, are blue to greenish along back and silvery on sides. Distinguishable from other salmon by small scales.

REASON FOR INCLUSION IN SERIES

Pink salmon are the most abundant of the species of Pacific salmon. They spawn in North American and Asian streams bordering the Pacific and Arctic Oceans. Their range in North America is extensive; they are the most numerous salmon in the commercial salmon fisheries with a very high rate of exploitation by Canadian, Japanese, Russian, and United States commercial fishermen (Alexandersdottir and Mathisen 1983).

LIFE HISTORY

Spawning

Pink salmon have a 2-year life cycle, which is so invariable that fish running in odd-numbered calendar years are effectively isolated from even-year fish so that no gene flow occurs between them (Larkin and Ricker 1964; Hart 1973; Donnelly 1983). It is the simplest and least varied life history of any salmon. Because of this simplicity, the life cycle may be diagrammed as a circle with very little overlap of the various stages (Figure 4). Usual age at maturity is 2 years; however, 3-year-old specimens have been discovered on occasion (Anas 1959; Turner and Bilton 1968; Alexandersdottir and Mathisen 1983).

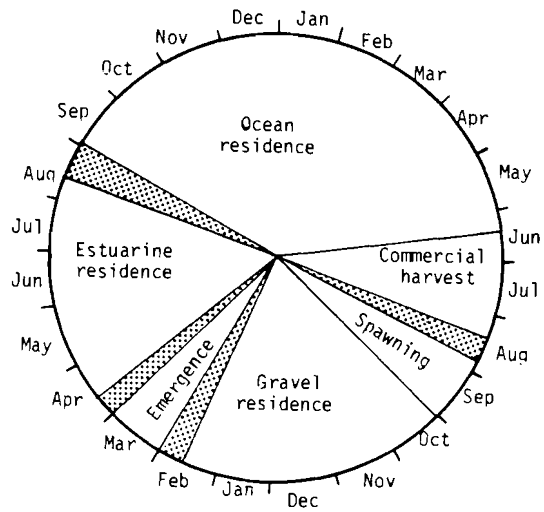


Figure 4. Two-year life cycle of pink salmon from Kodiak Archipelago. Dates may vary in different areas along the Pacific coast. Shaded areas show overlaps in time (after Donnelly 1983).

The salmon return to their stream of origin to spawn in the fall when the water temperature ranges from 8 to 14 °C (Pritchard 1939; Hunter 1959), and usually enter the river on high water freshets (Pritchard 1939). Some pink salmon spawn several miles upstream from saltwater in a few river systems (Scott and Crossman 1973), but spawning generally takes place either in freshwater close to the sea or in the intertidal zones. Pink salmon are considered the most specialized of the salmon in the genus Oncorhynchus because they are the least dependent on freshwater, regularly spawning in the intertidal areas (Miller and Brannon 1982; Alexandersdottir and Mathisen 1983).

Males are larger than females. In general, larger fish, predominantly males, enter the streams first (Hart 1973). Runs may be alternately large and small in consecutive years (Merrell 1962). Spawning usually occurs in late August through early October in much of the range (Sheridan 1962). The female digs a depression in the gravel on the stream bottom in an area averaging 0.6 to 0.9 m in width (Wells and McNeil 1970), and in water with an average depth of 0.15-0.53 m and velocity of 21-100 cm/s (Collings 1972). The tail is used to force water down on the gravel to remove fine sediments (Wickett 1959a). A dominant male guards the female during the digging process, attacking competitors or intruders.

Once the nest (redd) is dug, the female drops into the middle of the deepest part with a dominant male (Chebanov 1982), and the deposition of eggs and milt occurs. Up to six males have been recorded spawning with a single female (Wickett 1959a).

Chebanov (1980) observed that, compared to larger males, smaller males showed less spawning activity and performed more movements within the spawning ground. After a brief milling, the spawning procedure is repeated upstream from the nest, and the new diggings cover the eggs in the previously dug redd. The female stays in the area, protecting her redds from other digging females (Chebanov 1980). When densities of spawners are high, nests are sometimes superimposed upon one another and the total number of eggs surviving is reduced (McNeil 1967).

Fecundity, Eggs, Alevins, and Fry

Mature female pink salmon contain between 1,500 and 1,900 eggs (Pritchard 1937; Hart 1973). Fecundity is related positively to size (Foerster and Pritchard 1941). The eggs are large (about 6 mm in diameter) and orange-red. Both extragravel and intragravel chemical and physical (including hydraulic) factors control the success of egg survival. Water percolating through the gravel provides oxygen. During the incubation period, substantial mortality in redds may result from freezing, flow fluctuations, dewatering, oxygen reduction, predation, and microbial infestation. In some instances, the total egg mortality may be as high as 75% to 90% (Krueger 1981).

The length of the incubation period is dependent on water temperature (Carl et al. 1959). Under natural conditions in British Columbia, eggs hatch from late December to late February (Neave 1966). Once hatched, the alevins remain in the gravel for several weeks while the yolk sac is absorbed and incorporated into the body. Swimming fry emerge from the gravel in British Columbia streams as early as late February, but peak emergence in most localities occurs during April or May (Neave 1966).

Pink salmon migrate to the sea soon after emerging from the gravel and spend most of their lives in saltwater. Fry were abundant in marsh area tidal channels of the Fraser River Estuary from March to June, with peak numbers occurring in April and early May (Levy and Northcote 1982). Unlike chinook and chum salmon fry which reside temporarily in the marsh before migrating into the Pacific Ocean, pink salmon fry appear to be only transient residents of the estuarine marsh area as they make their rapid and active migrations downstream (Levy and Northcote 1982). The fry swim at the surface, creating ripples during their downstream migration when cruising speeds of 0.6 ft/s are reached at temperatures of 6 to 7 °C (Wickett 1959b).

Downstream migrations usually begin at night. Brett and Alderice (1958) reported that migrations rarely commenced before the incident light intensity had fallen below 0.1 foot candle at about 8:30 to 8:45 p.m., with a peak migration between 9:00 and 10:30 p.m., and nearly no movement by 12:30 a.m. A strong light avoidance reaction is shown initially by individual fry, but schooling fry acclimate to the light in about 15 min and no longer avoid it (Hoar 1956).

Fry migrating to saltwater usually do not feed, but if the distance is great, they may feed on larval insects (McDonald 1960). Both the distance traveled by the fish and the constancy of direction are greater for large schools than for small ones (Hoar 1958). The behavior of fry in large schools appears to be more orderly and precise than in small schools (Hoar 1958).

Early hatchery fry migrate downstream about 35 days ahead of late hatchery fry and about 55 days ahead of wild fry in British Columbia (Taylor 1980). Later migrating fry have considerably higher marine survival than early migrating fry, possibly because low water temperatures encountered by early migrating fry may slow their growth in the estuary and make them more vulnerable to predators (Taylor 1980).

After leaving freshwater, the young tend to remain close inshore during their first summer (Manzer 1956). In the intertidal regions, the young salmon prefer feeding in water of relatively low salinity. Preferred food includes various invertebrate eggs, amphipods, and copepods in Puget Sound (Gerke and Kaczynski 1972; Kaczynski et al. 1973), although other planktonic organisms are eaten elsewhere (Cooney et al. 1981). Adult pink salmon feed primarily on amphipods, euphausiids, and fish (LeBrasseur 1966). Godin (1981a) conducted laboratory tests which showed that 68% of the juvenile fish were most active during the day. Stomach analyses from fry showed that most feeding occurs during daylight hours in the littoral zone (Godin 1981b).

Migration in the sea is saltatory, with short periods of active migration interspersed with longer periods when the fry do not migrate (Healey 1967). Theories for the control of marine migration include movement toward higher salinities (Baggerman 1960; McInerney 1964; Leggett 1977) and the use of tidal flow and food gradients (Hurley and Woodall 1968; Leggett 1977). The fish begin moving offshore in late summer (Manzer 1956), in a manner that appears to be gradual or irregular, and leave the young-of-the-year at a distance of 6-12 mi from the nearest land in the fall (Neave 1966).

Marine Stages

At the beginning of their ocean migrations, pink salmon from Washington, Oregon, and Southern British Columbia move northward from their streams of origin in a narrow belt along the coast (Hart 1973). Substantial numbers of fish from British Columbia stocks move up to 500 mi offshore, migrating rapidly to attain that distance (Hart 1973). Tidal currents may strongly influence the direction of movement, as well as other orientation cues (Leggett 1977). Stocks from southern locations tend to enter the ocean first, followed by stocks from more northern and western locations as the season progresses. In winter and early spring, the distribution of stocks is more southerly in the western North Pacific than in the eastern North Pacific. This may reflect the influence of colder waters in the western subarctic gyre (Royce et al. 1968; Burgner 1980). Ocean migrations of pink salmon vary greatly between populations from different geographical areas; the migration of stocks of the eastern North Pacific is much more restricted than that of other stocks (Burgner 1980).

The vertical distribution of pink salmon in the ocean is not well known. Gillnet and longline catches on which knowledge of horizontal distribution is based are usually made within 6 to 7 m of the surface. In the Gulf of Alaska, some fish have been caught at depths of 24 to 36 m (Manzer and LeBrasseur 1959; Neave 1953, 1966).

After spending about 18 months at sea, adults return to the spawning streams in predictable and highly segregated even-numbered-year and odd-numbered-year runs. Salmon spawning migrations are thought to be guided by environmental cues such as olfaction, currents, temperature, and salinity, as well as by celestial navigation or magnetic orientation (Royce et al. 1968; Leggett 1977; Brannon 1982), but the exact cause of the migrations is not known. The timing of the migrations is variable. The rate of straying is much higher in pink salmon than in other species of salmon. This straying could constitute a survival strategy that pink salmon have evolved either to recolonize streams which have lost a year class due to environmental catastrophe or to ensure that all fish headed for an uninhabitable stream are not eradicated. This straying mechanism could have evolved with the normal tendency of pink salmon to spawn in small, environmentally unstable streams. Leggett (1977) and Brannon (1982) discussed in detail the numerous theories that have been advanced to explain salmonid homing.

GROWTH CHARACTERISTICS

The use of scale annulus formation to determine age in pink salmon has been discussed by Pearson (1966). When the fry hatch and leave the substrate, they range from 3.2 to 3.8 cm in total length from the tip of the snout to the fork of the tail and weigh approximately 0.3 g (Pritchard 1944). The fry feed relatively little, if at all, during their downstream migration and thus leave the streams at about this same size (Pritchard 1944).

During the first 30-day period at sea (beginning in August or September), the fry increase in weight by a factor of 6 (LeBrasseur and Parker 1964). During their first 40 days at sea, pink salmon grow to about 8 cm and by the following March reach a length of about 33 cm (Parker 1968). During the last spring and summer in the sea, growth is rapid from about 0.5 kg up to an average weight of between 2 and 4 kg (LeBrasseur and Parker 1964).

THE FISHERY

The pink salmon is less desirable than other Pacific salmon in commercial and sport catches, because of its small size, pale flesh, and flaccid texture. However, its status as a food item and sport fish is increasing. The history of the pink salmon's importance in the early Pacific Northwest fishery was given in an overview by Cobb (1911). Early salmon canneries, established in the Seattle area in the 1870's, occasionally packed pink salmon.

Hoar (1951) summarized the pink salmon fishery for 1917 to 1947. The pink and the chum salmon, referred to as autumn salmon, were considered less desirable species on the market than coho, chinook, and sockeye salmon because their flesh was soft and pale. At the beginning of World War I, a substantial increase occurred in the fishery because of wartime food requirements and the temporary decrease in the Fraser River catch of other salmon due to the rock slide at Hell's Gate in British Columbia that blocked the Fraser River. Since that time, the pink salmon has been increasing in importance. The fish are usually taken by purse seines or gill nets, but troll fishing for pink salmon has been increasing in importance since 1950 (Di Donato 1968). The primary reason for the increased troll catch is an expanded market for pinks in the fresh- and frozen-fish markets, in which fish caught by trolling are preferred over those taken in nets (Di Donato 1968). From 1935 to 1963, the average commercial catch of pink salmon in Washington State generally increased (Di Donato 1968). Washington commercial pink salmon landings in number of fish by gear type (Table 1) indicate the predominance of the strong odd-year runs in Washington State.

Di Donato (1968) indicated that the Puget Sound region was the southern geographic limit of streams supporting major pink salmon runs in the eastern North Pacific. Significant pink salmon runs are present only in odd-numbered years in Puget Sound rivers and in the Fraser River, which is the major pink salmon producing river in southern British Columbia (Di Donato 1968). In contrast, the more northerly streams of British Columbia and Alaska have strong annual runs of pink

Table 1. Commercial Landings of number of pink salmon in Washington State by gear type (data from Washington State Department of Fisheries 1983).

Year	Troll	Gill net	Purse seine	Reef net	Other gears	Total fish
1968	4,804	117	163	9	--	5,093
1969	59,360	92,440	782,774	37,278	29,688	1,001,540
1970	6,689	1,050	662	22	83	8,506
1971	20,573	333,192	1,903,322	119,050	122,913	2,499,050
1972	3,532	65	54	--	16	3,667
1973	55,381	346,478	1,798,023	102,742	116,107	2,418,731
1974	1,259	126	23	3	18	1,426
1975	76,325	193,833	973,301	58,823	105,226	1,407,508
1976	1,512	92	11	--	18	1,633
1977	288,335	186,293	1,642,420	30,581	174,707	2,322,336
1978	3,476	216	54	--	--	3,746
1979	560,728	620,476	3,445,174	42,815	38,495	4,707,688
1980	1,677	315	119	5	--	2,116
1981	237,278	466,493	3,332,571	82,069	17,501	4,135,912
1982	295	40	6	--	7	348

salmon in both odd- and even-numbered years (Manzer et al. 1965; Donnelly 1983), while Bristol Bay, Alaska, has essentially just even-numbered year runs (R. Donnelly, 1986, Fish. Res. Inst., Seattle; pers. comm.). The cyclical nature of the dominant odd-year pink salmon runs in Washington State can be observed in the commercial catches for those years (Figure 5).

Not until the late 1950's was it realized that pink salmon would take artificial bait. Since then, their popularity as sport fish has increased. From 1957 to 1961, the estimated annual sport catch in British Columbia varied from 1,000 to 37,000 fish (Scott and Crossman 1973). The sport fishery for pink salmon in Puget Sound, Washington, has been extremely productive in recent years, perhaps stimulated by extremely liberal catch limits set by the Washington Department of Fisheries.

Pink salmon fisheries management is made complex by user-group allocations

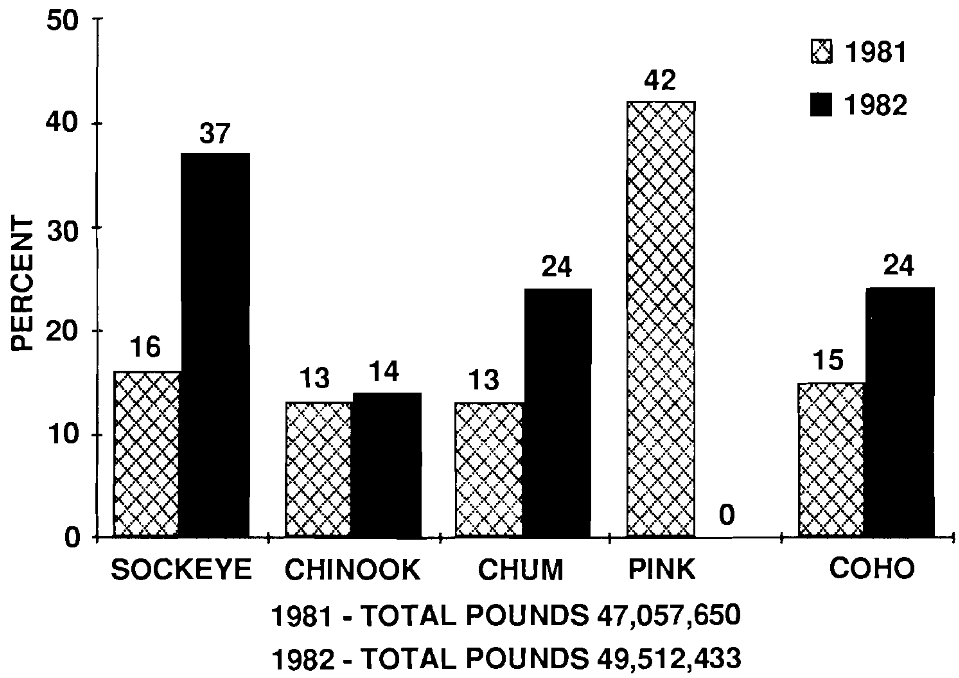


Figure 5. Cyclical nature of the commercial pink salmon catch relative to other salmon in Washington State is shown for odd- and even-numbered years that yielded 42% and 0% pink salmon, respectively (modified from Washington State Department of Fisheries 1983).

and mixed-stock fisheries. Optimum yield is the desired goal. Successful management requires effective data systems, advance planning, well-established spawning escapement objectives, dependable predictions of population size, and recognition of practical differences between recreational and commercial fisheries (Wright 1981).

Ocean fisheries are managed by a catch quota system, while fisheries in terminal areas are managed by subtracting escapement goals from preseason run forecasts and inseason run updates. After subtraction of the ocean catches and escapement goals, the estimated number remaining gives the total allowable harvest, which is allocated among user groups. The Washington Department of Fisheries and the various tribal entities have worked much more closely toward a unified salmon management plan due to the Boldt Decision in 1974 (Clark 1985).

ECOLOGICAL ROLE

When juvenile pink salmon enter the estuarine environment, they feed near the surface, primarily during daylight hours (Godin 1981a). Stomach analyses of pink salmon in British Columbia showed that maximum mean prey biomass occurred near or at dusk (Godin 1981a). Apparently, once a fish's stomach is full, spontaneous feeding resumes after only 15% of the stomach contents have been evacuated (Godin 1981b). Juvenile pink salmon quickly adapt to feeding on pelagic copepods and other epibenthic and planktonic organisms (Gerke and

Kaczynski 1972; Bailey et al. 1975; Cooney et al. 1981). Food of juveniles in protected waters such as Chatham Sound, Alaska, and Puget Sound, Washington, includes harpacticoid copepods, copepod nauplii, invertebrate eggs, tunicates, and barnacle larvae (Manzer 1969; Gerke and Kaczynski 1972; Kaczynski et al. 1973; Simenstad et al. 1980; Godin 1981b). Pink salmon co-occurring with juvenile chum salmon of approximately the same size in Hood Canal had an overlap in dietary items that approached 75% (Simenstad et al. 1980). The estuarine residence time of juvenile pink salmon varies from 4 to 18 weeks (Simenstad et al. 1982). Allen and Aron (1958) found the preferred food of pink salmon in the ocean to be amphipods, supplemented by fish, euphausiids, squid, and crustacean larvae. However, differences were noted in the diets of fish close to shore versus those of fish far from shore: for fish from inshore waters, amphipods were the most important and crustacean larvae ranked second in importance; for fish from offshore waters, copepods and euphausiids were the dominant food items. Pink salmon appeared to select larger food items as they moved further offshore (Allen and Aron 1958). It has been hypothesized that appreciable differences in average size of individual pink salmon in different years are probably due, in part, to differences in feeding conditions (Davidson and Vaughan 1941; Neave 1953).

Competition and predation can have significant effects on the pink salmon populations. Young pink salmon fry are preyed upon by a variety of stream fishes, including Dolly Varden (Salvelinus malma), cutthroat trout (Salmo clarki), rainbow trout (Salmo gairdneri), young coho salmon (Oncorhynchus kisutch), northern squawfish (Ptychocheilus oregonensis), and sculpins (Cottus spp.) (Hunter 1959; Hart 1973; Scott and Crossman 1973; Hargreaves and LeBrasseur 1985). Kingfishers, mergansers, other predaceous birds, and mammals also probably account for some amount of predation (Hart 1973; Scott and Crossman 1973; Simenstad et al. 1982). Infestations of leeches on eggs and fry can also significantly increase mortality (Earp and Schwab 1954). Predation by and competition with juvenile coho salmon was considered the main contributor to early sea mortality in pink salmon according to Parker (1971). Yearling Coho apparently prey selectively on young pink salmon, even in the presence of chum salmon that are both significantly smaller and more abundant than the pink salmon (Hargreaves and LeBrasseur 1985). Early sea mortality can also be associated with predation by certain species such as herring (Thorsteinson 1962). Adults at sea are preyed upon by humans, marine mammals, and, to a lesser extent, large fishes. Upon returning to the rivers, pink salmon are preyed on by bears and humans.

ENVIRONMENTAL REQUIREMENTS

Water Temperature

According to Reiser and Bjornn (1979), the optimum water temperatures for pink salmon spawning range from 7.2 to 12.8 °C. Pink salmon eggs tolerate long periods of low temperature, provided the initial temperature was above 6.0 °C when embryogenesis began and initial development of the embryo progressed to a stage that was tolerant of colder water (Combs and Burrows 1957; Combs 1965; Reiser and Bjornn 1979). Incubation temperatures for successful development range from 4.4 to 13.3 °C (Reiser and Bjornn 1979). Extremely cold water and low air temperatures cause mortality among incubating eggs and fry when ice formation reduces water interchange (Neave 1953; McNeil 1966; Reiser and Bjornn 1979).

Adult pink salmon are cold-water fish with a preferred temperature range of 5.6 to 14.6 °C, an optimal temperature of 10.1 °C, and an upper lethal temperature of 25.8 °C (Reiser and Bjornn 1979). The relatively high stream temperatures (17 °C) and low dissolved oxygen levels associated with drought conditions have apparently killed many mature adult pink salmon in Alaskan streams (Krueger 1981).

Salinity

Juvenile pink salmon encounter a wide range of salinities in their migrations. Salinity gradients are thought to play a part in salmon migrations (Baggerman 1960; McInerney 1964). Noerenburg (1963) estimated that over 50% of the pink salmon spawning activity in Prince William Sound, Alaska, occurs in intertidal areas. Bailey (1969) showed that developing pink salmon eggs and alevins can be adversely affected when exposed to some high intertidal salinities.

Dissolved Oxygen

Dissolved oxygen (DO) is supplied to developing eggs and alevins within the redd by intragravel flow. Dissolved oxygen level within the redd is influenced by the dissolved oxygen in the stream, the rate of intragravel water flow, and the biological demand for oxygen in the immediate area. For incubation of salmonid eggs, concentrations at or near saturation with temporary reductions to levels no lower than 5.0 mg/l are optimal (Reiser and Bjornn 1979). However, DO levels exceeding 6.0 mg/l are required for successful development of pink salmon eggs and alevins (Bailey et al. 1980). Oxygen consumption generally increases as embryo development progresses, and DO generally decreases in an area supporting large numbers of eggs or alevins (Bailey et al. 1980). Low DO concentrations may result in a variety of fry abnormalities (Silver et al. 1963; Shumway et al. 1964; Reiser and Bjornn 1979). During the latter part of incubation, reduced DO can cause premature hatching (Alderdice et al. 1958; Bailey et al. 1980). Growth rate, food consumption, and efficiency of food utilization by juvenile salmon all declined at lowered DO (Reiser and Bjornn 1979). Reduced DO concentrations can significantly hamper the swimming performance of migrating adult salmonids (Jones 1971; Reiser and Bjornn 1979). In addition, mortalities may occur in adults when low DO is combined synergistically with high temperatures (Krueger 1981).

Substrate

The diameter of gravel that composes the substrate for spawning pink salmon ranges from 1.3 to 10.2 cm (Lucas 1959; Collings 1974). Pink salmon spawn over a variety of substrate materials. The size, shape, density, and embeddedness of the material, current velocity, water depth, and densities of fish can influence substrate selection. Successful fry emergence is physically hindered by excessive amounts of sand and silt in the gravel, which also limit the percolation of water with its DO content (Reiser and Bjornn 1979). Hourston and MacKinnon (1957) suggested that very small gravels made ideal pink salmon spawning areas. No differences in size or time of return of adults could be traced to the nature of the gravel environment from which they came (Bailey et al. 1976).

Eggs and developing alevins are influenced by the substrate. Productive pink salmon streams generally contained less than 5.0% by volume of fine sediments (<0.8 mm), whereas less productive streams had 15.0% or more fines in the substrate (Krueger 1981).

Water Depth

Water depth selected by pink salmon is determined by current velocity and substrate type. Preferred water depths for spawning pink salmon in selected Washington State streams ranged from 0.2 to 0.5 m (Collings 1974). Hourston and MacKinnon (1957) studied water depth preferences in a spawning channel and found that the first fish that entered the channel chose sites with mean depths of 0.4 m and subsequent fish occupied progressively shallower mean depths. It appears that in nature these shallower depths are used even though they are less than optimal situations (Krueger 1981; Wilson et al. 1981).

Water Velocity

Although several current velocities are suitable for pink salmon spawning, the preferred velocities range from 21 to 101 cm/s (Collings 1974). Pink salmon in the Terror River, Alaska, spawned in areas with current velocities ranging from 0.19 to 0.66 m/s, but the preferred spawning velocities ranged from 0.35 to 0.47 m/s (Wilson et al. 1981). Flow regimes can affect developing pink salmon eggs and alevins through either mechanical damage, temperature changes, or reduced intragravel dissolved oxygen levels (McNeil 1966; Reiser and Bjornn 1979; Krueger 1981).

The high current velocities associated with high stream discharges sometimes exceed the swimming capabilities of pink salmon and prevent upstream migration. However, pink salmon can negotiate current velocities up to about 2.1 m/s (Krueger 1981). Upstream migrations of adults can be hampered by either too little or too much stream flow (Wickett 1958; Reiser and Bjornn 1979; Krueger 1981).

Turbidity

According to Reiser and Bjornn (1979), migrating salmon avoid or cease to migrate in waters with very high silt loads (4,000 mg/l). Turbid water absorbs more radiation than clear water, thus possibly resulting in temperature barriers to upstream migration. Increased turbidity also may cause osmoregulatory problems in young fish by interfering with gill function. This results in delayed entry into seawater and increased predation on the estuarine population (Kehoe 1982). Eggs may be suffocated by the increased deposition of fine sediment and adults may suffer from impaired oxygen transport, decline in nutritional intake, and physical damage to the gill filaments by abrasion (Rivier and Seguier 1985).

LITERATURE CITED

Alderdice, D.W., W.P. Wickett, and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. J. Fish. Res. Board Can. 15(2):229-250.

Alexandersdottir, M., and O.A. Mathisen. 1983. Life history of pink salmon (Oncorhynchus gorbuscha) and implications for management. Univ. Washington, Fish. Res. Inst., Rep. No. FRI-UW-8313. 72 pp.

Allen, G.H., and W. Aron. 1958. Food of salmonid fishes of the western north Pacific Ocean. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 237. 11 pp.

Anas, R.E. 1959. Three-year-old pink salmon. J. Fish. Res. Board Can. 16(1):91-92.

Baggerman, B. 1960. Salinity preference, thyroid activity, and the seaward migration of four species of Pacific salmon (Oncorhynchus). J. Fish. Res. Board Can. 17(2):295-322.

Bailey, J.E. 1969. Effects of salinity on intertidal pink salmon survival. Alaska Dep. Fish Game Inf. Leafl. No. 87:12-15.

Bailey, J.E. B.L. Wing, and C.R. Mattson. 1975. Zooplankton abundance and feeding habits of fry of pink salmon, Oncorhynchus gorbuscha, and chum salmon, Oncorhynchus keta, in Traitors Cove, Alaska, with speculation on the carrying capacity of the area. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 73(4):846-861.

Bailey, J.E., J.J. Pella, and S.G. Taylor. 1976. Production of fry and adults of the 1972 brood of pink salmon, Oncorhynchus gorbuscha, from gravel incubators and natural spawning at Auke Creek, Alaska. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 74(4):961-971.

Bailey, J.E., S. Rice, J. Pella and S. Taylor. 1980. Effects of seeding density of pink salmon, Oncorhynchus gorbuscha, eggs on water chemistry, fry characteristics and fry survival in gravel incubators. U.S. Natl. Mar. Fish. Serv. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 78(3): 649-658.

Brannon, E.L. 1982. Orientation mechanisms of homing salmonids. Pages 219-227 in E.L. Brannon and E.O. Salo, eds. Proceedings of the salmon and trout migratory behavior symposium. School of Fisheries, University of Washington, Seattle.

Brett, J.R., and D.F. Alderdice. 1958. Research on guiding young salmon at two British Columbia field stations. Bull. Fish. Res. Board. Can. No. 117. 75 pp.

Burgner, R.L. 1980. Some features of ocean migrations and timing of Pacific salmon. Pages 153-164 in Symposium on salmonid ecosystems of the north Pacific Ocean, Otter Crest, Oregon, May 1978.

Carl, G.C., W.A. Clemens, and C.C. Lindsey. 1959. The freshwater fishes of British Columbia. British Columbia Prov. Mus. Handb. No. 5. 192 pp.

Chebanov, N.A. 1980. Osebennosti povedeniya gorbushi (Oncorhynchus gorbuscha Walb.) prinereste. [Pecularities of the spawning behavior of the pink salmon (Oncorhynchus gorbuscha Walb.)] Vopr. Ikhtiol. 20(6):844-854.

Chebanov, N.A. 1982. Onerestovom povedenii gorbushi (Oncorhynchus gorbuscha Walbaum) apri raznom sootnoshenii polovna nerestilishche (On the reproductive behavior of pink salmon (Oncorhynchus gorbuscha Walbaum) present on spawning grounds in different sex ratios). Ekologiya 1:57-66.

Clark, W.G. 1985. Fishing in a sea of court orders: Puget Sound salmon management 10 years after the Boldt Decision. North Am. J. Fish. Manage. 5(3B):417-434.

Cobb, J.N. 1911. The salmon fisheries of the Pacific Coast. U.S. Bur. Comm. Fish. Government Printing Office. 179 pp.

Collings, M.R. 1974. A methodology for determining instream flow requirements for fish. Pages 72-86 in Proceedings, Instream flow methodology workshop. Washington State Water Program, Olympia.

Combs, B.D. 1965. Effect of temperature on the development of salmon eggs. Prog. Fish-Cult. 27(3): 134-137.

Combs, B.D., and R.E. Burrows. 1957. Threshold temperatures for the normal development of chinook salmon eggs. Prog. Fish-Cult. 19(1):33-36.

Cooney, R.T., D. Urquhart, and D. Bernard. 1981. The behavior, feeding biology, and growth of hatchery released pink and chum salmon fry in Prince William Sound, Alaska. Alaska University Publication, Alaska Sea Grant College Program, Fairbanks, 121 pp.

Davidson, F.A., and E. Vaughan. 1941. Relation of population size to marine growth and time of spawning migration in the pink salmon (Oncorhynchus gorbuscha) of southeastern Alaska. J. Mar. Res. 4(3): 231-295.

Di Donato, G. 1968. The Washington troll pink salmon (Oncorhynchus gorbuscha) fishery through 1965. Wash. Dep. Fish., Fish. Res. Papers 3(1):37-46.

Donnelly, R.F. 1983. Factors affect ing the abundance of Kodiac Archipelago pink salmon (Oncorhynchus gorbuscha Walbaum). Ph.D. Dissertation. University of Washington, Seattle. 157 pp.

Earp, B.J., and R.L. Schwab. 1954. An infestation of leeches on salmon fry and eggs. Prog. Fish-Cult. 16(3):122-124.

Foerster, R.E., and A.L. Pritchard. 1941. Observations on the relation of egg content to total length and weight in the sockeye salmon (Oncorhynchus nerka) and the pink salmon (O. gorbuscha). Trans. R. Soc. Can. 35(B):451-460.

Gerke, R.J., and V.W. Kaczynski. 1972. Food of juvenile pink and chum salmon in Puget Sound, Washington. Wash. Dep. Fish. Tech. Rep. No. 10. 27 pp.

Godin, J.G.J. 1981a. Circadian rhythm of swimming activity in juvenile pink salmon (Oncorhynchus gorbuscha). Mar. Biol. (N.Y.) 64(3):341-349.

Godin, J.G.J. 1981b. Effect of hunger on the daily pattern of feeding rates in juvenile pink salmon, Oncorhynchus gorbuscha Walbaum. J. Fish Biol. 19(1):63-71.

Hargreaves, N.B., and R.J. LeBrasseur. 1985. Species selective predation on juvenile pink (Oncorhynchus gorbuscha) and chum salmon (O. keta) by coho salmon (O. kisutch). Can. J. Fish. Aquat. Sci. 42(4):659-668.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can. Bull. No. 180. 740 pp.

Healey, M.C. 1967. Orientation of pink salmon (Oncorhynchus gorbuscha) during early marine migration from Bella Coola River System . J. Fish. Res. Board Can. 24(10):2321-2338.

Hoar, W.S. 1951. The chum and pink salmon fisheries of British Columbia, 1917-1947. Fish. Res. Board Can. Bull. No. 90. 46 pp.

Hoar, W.S. 1956. The behavior of migrating pink and chum salmon fry. J. Fish. Res. Board Can. 13(3):309-325.

Hoar, W.S. 1958. The evolution of migratory behavior among juvenile salmon of the genus Oncorhynchus. J. Fish. Res. Board Can. 15(3): 391-428.

Hourston, W.R., and D. MacKinnon. 1957. Use of an artificial spawning channel by salmon. Trans. Am. Fish. Soc. 86:220-230.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Board Can. 16(6):835-886.

Hurley, D.A., and W.L. Woodall. 1968. Responses of young pink salmon to vertical temperature and salinity gradients. Int. Pac. Salmon Fish. Comm., Progr. Rep. 19. 80 pp.

Jones, D.E. 1971. The effect of hypoxia and anemia on the swimming performance of rainbow trout (Salmo gairdneri). J. Exp. Biol. 55:541-551.

Kaczynski, V.W., R.J. Feller, J. Clayton, and R.G. Gerke. 1973. Trophic analysis of juvenile pink and chum salmon in Puget Sound. J. Fish. Res. Board Can. 30(7):1003-1008.

Kehoe, D.M. 1982. The effects of Grays Harbor Estuary sediment on the osmoregulatory ability of coho salmon smolts, Oncorhynchus kisutch. Army Corps of Engineers Report (Seattle District). 27 pp.

Krueger, S.W. 1981. Freshwater habitat relationships--pink salmon (Oncorhynchus gorbuscha). Alaska Department of Fish and Game Project Rep. Contract No. 14-16-0009-79-119. Anchorage. 40 pp.

Larkin, P.A., and W.E. Ricker. 1964. Further information on sustained yields from fluctuating environments. J. Fish. Res. Board Can. 21(1):1-7.

LeBrasseur, R.J. 1966. Stomach contents of salmon and steelhead trout in the northeastern Pacific Ocean. J. Fish. Res. Board Can. 23(1): 85-100.

LeBrasseur, R.J., and P.R. Parker. 1964. Growth rates of central British Columbia pink salmon (Oncorhynchus gorbuscha). J. Fish. Res. Board Can. 21(5):1101-1128.

Leggett, W.C. 1977. The ecology of fish migrations. Annu. Rev. Ecol. Syst. 8:285-308.

Levy, D.A., and T.G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Frazer River Estuary. Can. J. Fish. Aquat. Sci. 39(2): 270-276.

Lucas, K.C. 1959. The Robertson Creek spawning channel. Can. Fish. Cult. 25:4-23.

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

McInerney, J.E. 1964. Salinity preference, an orientation mechanism in salmon migration. J. Fish. Res. Board Can. 21(5):995-1018.

McNeil, W.J. 1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. U.S. Fish Wildl. Serv. Fish. Bull. 65:495-523.

McNeil, W.J. 1967. Randomness in distribution of pink salmon redds. J. Fish. Res. Board Can. 24(7): 1629-1632.

Manzer, J.I. 1956. Distribution and movement of young Pacific salmon during early ocean residence. Fish. Res. Board Can. Pacific Progr. Rep. 106:24-28.

Manzer, J.I. 1969. Stomach contents of juvenile Pacific salmon in Chatham Sound and adjacent waters. J. Fish. Res. Board Can. 26(8): 2219-2223.

Manzer, J.I., and R.J. LeBrasseur. 1959. Further observations on the vertical distribution of salmon in the northeast Pacific. Fish. Res. Board Can. Manuscr. Rep. Ser. (Biol.) No. 689. 9 pp.

Manzer, J.I., T. Ishida, A.E. Peter son, and M.G. Hanavan. 1965. Salmon of the North Pacific Ocean - Part V. Offshore distribution of salmon. Int. North Pac. Fish. Comm. Bull. No. 15. 452 pp.

Merrell, T.R. 1962. Freshwater survival of pink salmon at Sashin Creek, Alaska. Pages 59-72 in N.J. Wilinovsky, ed. Symposium on pink salmon, H.R. MacMillan Lectures in Fisheries. Univ. British Columbia, Vancouver.

Miller, R.J., and E.L. Brannon. 1982. The origin and development of life history patterns in Pacific salmonids. Pages 296-309 in E.L. Brannon and E.O. Salo, eds. Proceedings of the Salmon and Trout Migratory Behavior Symposium. University of Washington Press, Seattle.

Neave, F. 1953. Principles affecting the size of pink and chum salmon populations in British Columbia. J. Fish. Res. Board Can. 9 (4):450-491.

Neave, F. 1966. Pink salmon in British Columbia. A review of the life history of north Pacific salmon. Int. Pac. Salmon Fish. Comm. Bull. 18:70-79.

Noerenburg, W.A. 1963. Salmon forecast studies on 1963 runs in Prince William Sound. Alaska Dep. Fish Game. Inf. Leafl. No. 21. 28 pp.

Parker, R.R. 1968. Marine mortality schedules of pink salmon of the Bella Coola River, Central British Columbia. J. Fish. Res. Board Can. 25(4):757-794.

Parker, R.R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. J. Fish. Res. Board Can. 28(10): 1503-1510.

Pearson, R.E. 1966. Number of circuli and time of annulus formation on scales of pink salmon (Oncorhynchus gorbuscha). J. Fish. Res. Board Can. 23(4):747-756.

Pritchard, A.L. 1936. Factors in fluencing the upstream migration of the pink salmon (Oncorhynchus gorbuscha Walbaum). J. Biol. Board Can. 2:383-389.

Pritchard, A.L. 1937. Variation in the time of run, sex proportions, size and egg content of adult pink salmon (Oncorhynchus gorbuscha) at

McClinton Creek, Masset Inlet, B.C. J. Biol. Board Can. 3:403-416.

Pritchard, A.L. 1939. A study of the natural propagation of the pink salmon, Oncorhynchus gorbuscha, in British Columbia. Trans. Am. Fish. Soc. 69:237-239.

Pritchard, A.L. 1944. Physical characteristics and behavior of pink salmon fry at McClinton Creek, B.C. J. Fish. Res. Board Can. 6(3):217-227.

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 the Western United States and Canada. U.S. For. Serv. Gen. Tech. Rep. PNW-96. Portland, Oregon.

Rivier, B., and J. Seguier. 1985. Physical and biological effects of gravel extraction in river beds. Pages 131-146 in J.S. Alabaster, ed. Habitat modification and freshwater fisheries. Butterworth and Co., London.

Royce, W.F., L.S. Smith, and A.C. Hartt. 1968. Models of ocean migrations of Pacific salmon and comments on guidance mechanisms. U.S. Fish Wildl. Serv. Fish. Bull. 66(2):441-462.

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

Sheridan, W.L. 1962. Relationship of stream temperature to timing of pink salmon escapement in southeast Alaska. Pages 87-101 in N.J. Wilimovsky, ed. Symposium on pink salmon, H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver.

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.

Silver, S.T., C.E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Trans. Am. Fish. Soc. 92(4):327-343.

Simenstad, C.A., W.J. Kinney, S.S. Parker, E.O. Salo, J.R. Cordell, and H. Buechner. 1980. Prey community structure and trophic ecology of outmigrating juvenile chum and pink salmon in Hood Canal, Washington. Univ. Wash. Fish. Res. Inst., Rep. No. FRI-UW-80 26. 113 pp.

Simenstad, C.A., K.L. Fresh, and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. Pages 343-364 in V.S. Kennedy, ed. Estuarine comparisons. Academic Press, New York.

Taylor, S.G. 1980. Marine survival of pink salmon fry from early and late spawners. Trans. Am. Fish. Soc. 109(1): 79-82.

Thorsteinson, F. 1962. Herring predation on pink salmon fry in a southeastern Alaska estuary. Trans. Am. Fish. Soc. 91(3):321-323.

Turner, C.E., and H.T. Bilton. 1968. Another pink salmon (Oncorhynchus gorbuscha) in its third year. J. Fish. Res. Board Can. 25(9):1993-1996.

Washington State Department of Fisheries. 1959. Pink salmon. Pages 37-39 in Fisheries, Vol. 2: Contributions of western states, Alaska, and British Columbia to salmon fisheries of the North American Pacific Ocean. Olympia, Wash.

Washington State Department of Fisheries. 1983. 1982 fisheries statistical report. Olympia, Wash. 77 pp.

Wells, R.A., and W.J. McNeil. 1970. Effect of quality of spawning bed on growth and development of pink salmon embryos and alevins. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 616. 116 pp.

Wickett, W.P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Board Can. 15(5):1103-1126.

Wickett, W.P. 1959a. Observations on adult pink salmon behaviour. Fish. Res. Board Can. Prog. Rep. Pac. Coast Stn. No. 113:6-7.

Wickett, W.P. 1959b. Notes on the behavior of pink salmon fry. Fish. Res. Board Can. Prog. Rep. Pac. Coast Stn. No. 113:8-9.

Wilson, W., W. Trihey, J. Baldridge, C. Evans, J. Thiele, and D. Trudgen. 1981. An assessment of environmental effects of construction and operation of the proposed Terror Lake Hydroelectric Facility, Kodiak, Alaska. Arctic Environmental Information and Data Center, Anchorage, Alaska. 429 pp.

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

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(11.88)*	2.	3. Recipient's Accession No.
4. Title and Subtitle Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)--Pink Salmon			5. Report Date January 1989 6.
7. Author(s) Scott A. Bonar, Gilbert B. Pauley, and G.L. Thomas			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Washington Cooperative Fishery Research Unit 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 U.S. Dep. of the Interior Fish and Wildlife Service National Wetlands Research Center 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)

Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are designed to assist in environmental impact assessment. The pink salmon, often called humpback salmon or humpy, is easily identified by its extremely small scales (150 to 205) on the lateral line. They are the most abundant of the Pacific salmon species and spawn in North American and Asian streams bordering the Pacific and Arctic Oceans. They have a very simple two-year life cycle, which is so invariable that fish running in odd-numbered years are isolated from fish running in even-numbered years so that no gene flow occurs between them. Adults spawn in the fall and the young fry emerge in the spring. The pink salmon is less desirable in commercial and sport catches than most other salmon because of its small size and its soft pale flesh. The Puget Sound region of Washington State is the southern geographic limit of streams supporting major pink salmon runs in the eastern North Pacific. Pink salmon runs are presently only in odd-numbered years in this region. Optimum water temperatures for spawning range from 7.2 to 12.8 °C. Productive pink salmon streams have less than 5.0% by volume of fine sediments ($\leq$0.8 mm).

17. Document Analysis a. Descriptors

Estuaries	Temperature	Life cycle
Fisheries	Sediments	Growth
Salmon	Suspended sediments	Oxygen competition
Salinity	Feeding habits	Animal migrations

b. Identifiers/Open-Ended Terms

Pink salmon	Life history	Predators
Humpback salmon	Spawning	Competitors
Oncorhynchus gorbuscha	Temperature requirements	
	Salinity requirements	

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	18
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

TAKE PRIDE *in America*

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE