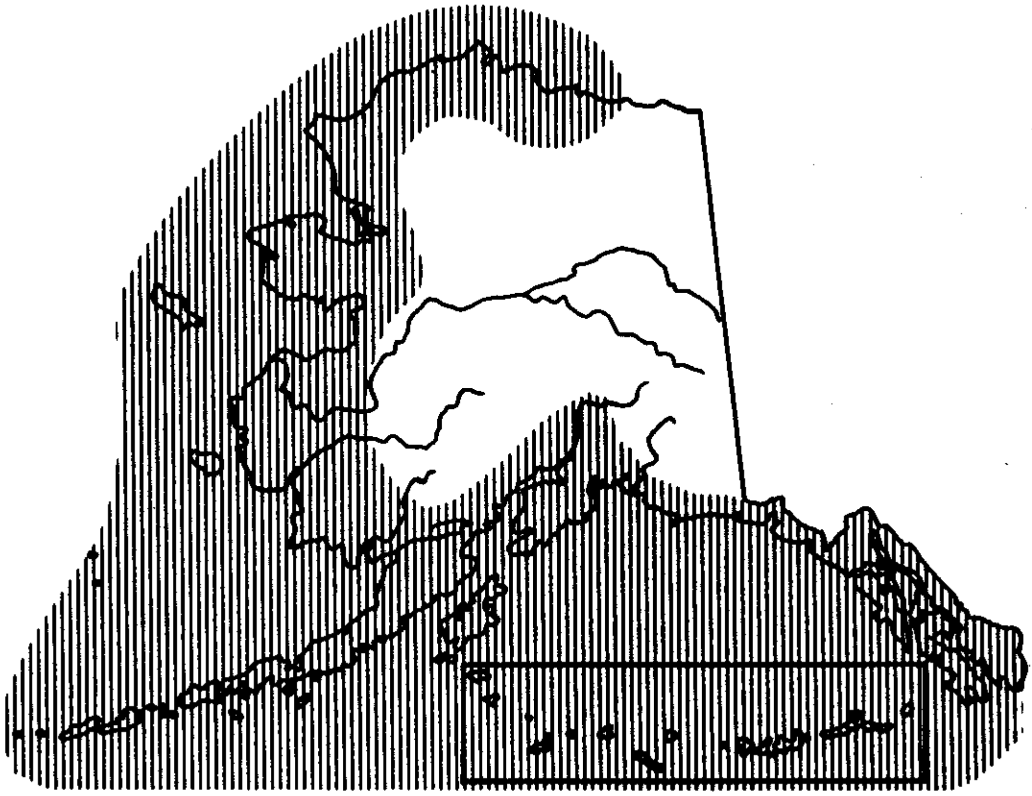
— Pink Salmon —

Oncorhynchus gorbuscha

The following pages are excerpted from the *Alaska Habitat Management Guide, Southcentral Region, Volume 1: Life Histories and Habitat Requirements of Fish and Wildlife*, produced by the State of Alaska Department of Fish and Game, Division of Habitat, Juneau, Alaska, 1985.

Pink Salmon Life History and Habitat Requirements
Southwest and Southcentral Alaska



Map 1. Range of pink salmon (ADF&G 1978, Morrow 1980)

I. NAME
   A. Common Names: Pink salmon, pinks, humpback salmon, humpy
   B. Scientific Name: <u>Oncorhynchus gorbuscha</u>

II. RANGE
   A. Worldwide

Pink salmon are the most abundant of the Pacific salmon (Krueger 1981). In North America, pink salmon range from the Russian River, California, north through the Bering Strait, and east to the Mackenzie River in the Northwest Territories, Canada. In Asia, pink salmon occur from the Tumen and North Nandai rivers of North Korea and the island of Hokkaido, Japan, north to the Lena River, Siberia. They also occur in the Kurile, Commander, and Aleutian islands (Neave 1967).

B. Statewide

Pink salmon are widely distributed along coastal Alaska, with only a few in the Copper River delta and none in the upper Copper River drainage (ADF&G 1978; Roberson, pers. comm.). They typically ascend streams only short distances (65 km or less), and some spawn in the intertidal areas of short coastal streams (Bailey 1969, Scott and Crossman 1973). In larger river systems such as the Kuskokwim and Yukon some may go as much as 160 km (Morrow 1980). They are known to move great distances in the Nushagak River drainage. Measuring from Picnic Point at the Wood River confluence with the Nushagak River, pink salmon have been documented about 230 km upstream in the Nuyakuk River and approximately 410 km upstream in the Mulchatna River (ADF&G 1984). Recent studies on the Susitna River in Southcentral Alaska have found spawning pink salmon at least 223 km upstream (ADF&G 1981).

C. Regional Distribution Summary

To supplement the distribution information presented in the text, a series of bluelined reference maps has been prepared for each region. Most of the maps in this series are at 1:250,000 scale, but some are at 1:1,000,000 scale. These maps are available for review in ADF&G offices of the region or may be purchased from the contract vendor responsible for their reproduction. In addition, a set of colored 1:1,000,000-scale index maps of selected fish and wildlife species has been prepared and may be found in the Atlas that accompanies each regional guide.

1. Southwest. In the Kodiak area, there are approximately 300 streams that produce pink salmon, although 60 to 85% of the total escapement is usually contained in 35 major river systems during odd-numbered years and in 47 of the major river systems during even-numbered years (Prokopowich, pers. comm.). These systems comprise the Kodiak area's index streams.

   In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula streams south to Cape Sarichef), the Nushagak District is the major pink salmon producer. Within the district, pink salmon spawn almost entirely in the Nuyakuk River, with smaller populations also found in the Wood, Igushik, Nushagak, and Mulchatna rivers. Occasionally, strong runs occur in the Kvichak, Alagnak (Branch), and Naknek rivers (Middleton 1983). Bechevin Bay streams occasionally produce strong pink salmon runs during even-numbered years (Shaul, pers. comm.).

   In south-side Alaska Peninsula streams and the Aleutian Islands, pink salmon are abundant and are found in many drainages. In the Chignik area, there are approximately 75 salmon streams. In the south peninsula area, Mino Creek, Settlement Point, and Southern Creek on Deer Island occasionally produce one-half the total pink salmon run to the area. Two other streams (Apollo Creek and Middle Creek) have the combined potential of producing another 500,000 to

2 million pink salmon in a good year, if waterfalls on these streams could be bypassed with fish-passage structures (ibid.). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Northern and Central districts of the Upper Cook Inlet area the majority of the pink salmon are produced in the Lake Creek, Deshka, Talachulitna, Kenai, and Kasilof river drainages (ADF&G 1977b). In the Southern, Outer, and Kamishak districts of the Lower Cook Inlet area, the majority of the pink salmon are produced in the following locations: Humpy Creek, Tutka Lagoon, Seldovia Creek, Port Graham River, Windy Left River, Windy Right River, Rocky River, Port Dick Creek, Bruin Bay River, Big Kamishak River, Little Kamishak River, Amekedori Creek, Sunday Creek, and Brown's Peak Creek (ADF&G 1981a).

   In Prince William Sound (PWS), the genetically unrelated odd-year and even-year pink salmon stocks have adapted differently to the use of the same spawning streams. The odd-year stocks use primarily upstream spawning sites, with 43 to 65% (average of 25.6%) selecting spawning sites above the high tide line, while even-year stocks are more oriented toward intertidal spawning areas, with only 23 to 28% (average of 25.6%) selecting spawning sites above high tide. With regard to spawning areas, PWS pink salmon may be generally catagorized as early, middle, and late spawning stocks, which are distributed by geographic zones associated with different temperature regimes. Early runs (about July 20 to August 5) are found in relatively few streams, primarily in the major fiords of the northern main land, Port Wells, Valdez Arm, Port Fidalgo, Port Gravina, and Sheep Bay. Middle runs (about August 6 to August 20) utilized most of the larger, cold, clear streams of the mainland districts and a few cold mountain streams of Knight and LaTouche islands. Late runs (about August 21 to September 10)occupy the majority of the streams used and include nearly all the island streams, mainland lake-fed streams, and mainland streams in which only intertidal zones are accessible to migrants (ADF&G 1978).

   (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. Temperature. Pink salmon in Southeast Alaska have been observed to spawn in water temperatures ranging from 7.4 to 18.3°C (Sheridan 1962). The preferred range appears to be 7.2 to 12.8°C (Krueger 1981).

Egg hatching rates are influenced by water temperature; abnormally warm or cold water can accelerate or depress developmental rates and cause premature or delayed fry emergence. Laboratory tests have shown that eggs require at least 4.5°C water temperatures from the time the egg is deposited in the redd through the gastrula stage of development (Bailey and Evans 1971). Thereafter, the embryos can tolerate water temperatures to 0°C if the water does not freeze. The upper lethal temperature limit for pink salmon juveniles was experimentally determined to be 23.9°C (Brett 1952), but lower lethal limits were not determined. Brett found, however, that juveniles preferred 12 to 14°C temperatures.

b. The pH factor. There is no optimum pH value for fish in general; however, in waters where good fish fauna occur, the pH usually ranges between 6.7 and 8.3 (Bell 1973). State of Alaska water quality criteria for freshwater growth and propagation of fish call for pH values of not less than 6.5 or greater than 9.0, with variances of no more than 0.5 pH unit from natural conditions (ADEC 1979).

c. Dissolved oxygen (D.O.). From laboratory experiments, Bailey et al. (1980) recommend that for successful development of pink salmon eggs and alevins the D.O. level should exceed 6.0 mg/l. Dissolved oxygen levels below 6.0 mg/l apparently cause premature emergence, decreased size, and low survival (ibid.).
State of Alaska water quality criteria for growth and propagation of fish state that "D.O. shall be greater than 7 mg/l in waters used by anadromous and resident fish. Further, in no case shall D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning . . . . In no case shall D.O. above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection" (ibid.).

d. Turbidity. Sedimentation causes high mortality to eggs and alevin by reducing water interchange in the redd. If 15 to 20% of the intragravel spaces become filled with sediment, salmonoid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles, which can result in fungal and pathogenic bacterial infection. Excess turbidity from organic materials in the process of oxidation may reduce oxygen below safe levels, and sedimentation may smother food organisms and reduce primary productivity (ibid.). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to the adult's upstream spawning migration (Reiser and Bjornn 1979).

2. Water quantity:

   a. Instream flow. Sufficient water velocity and depth are needed to allow proper intragravel water movement (apparent velocity) so that dissolved oxygen is transported to eggs and alevin, and in turn metabolic wastes are removed (ibid.).

      Adults returning to spawning grounds may be blocked if current velocities exceed 2.1 m/sec (Krueger 1981). Low flows and shallow water depths can also block upstream migration. Thompson (1972) suggests that adult pink salmon need a minimum of about 0.18 m water depth for upstream passage. These values will vary with the size and condition of adult pink salmon and the length of stream reach with shallow water (Krueger 1981). Pink salmon have been observed passing over shallow riffles less than 0.09 m deep in the Kizhuyak and Terror rivers on Kodiak Island (Baldridge, pers. comm. cited in Krueger 1981).

      Water velocity at spawning locations has ranged from 0.1 to 1.32 m/sec, and the preferred range appears to be about 0.35 to 0.75 m/sec (Krueger 1981). Depth at redds has ranged from 0.1 to 1.32 m, with preferred depths ranging from 0.39 to 0.70 m (ibid.). Use of waters outside the preferred ranges may in large part be due to crowding on the spawning grounds.

3. Substrate. Pink salmon spawn over a variety of substrates ranging widely in size and composition. Adults generally select areas with a relatively low gradient combined with beds of small-to-medium-size gravel (1.3 to 10 cm diameter) (Neave 1966, Scott and Crossman 1973, Krueger 1981).

   Egg and alevin development is influenced by substrate composition because increased amounts of small material (fines) can reduce intragravel water flow. McNeil and Ahnell (1964), from studies in Southeast Alaska, concluded that productive pink salmon streams generally contained fines (0.833 mm diameter) contributing less than 5% of the volume of the substrate. They also found that less productive streams were characterized by 15% or more fines in the substrate.

B. Terrestrial

1. Conditions providing security from other predators or disturbances. The gravel over fertilized eggs reduces the disturbance caused by ice and floods. It also protects the eggs from sunlight and predation by other fish and aquatic insects.

2. Conditions providing protection from natural elements. Because pink salmon remain in fresh water for a very short

time after emergence from the substrate, no data are available concerning protection from natural elements for free-swimming juveniles.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for several weeks until the yolk sac has been absorbed. Immediately upon emerging from the gravel, juveniles begin migrating downstream (Scott and Crossman 1973). Migrating juveniles generally do not feed; if the distance to the sea is great, however, they may feed on nymphal and larval insects (ibid.). Studies in Lake Aleknagik and Tikchik Lake in the Bristol Bay area, however, indicate differences in the early life history of pink salmon that spawn in a lake system from those that spawn in coastal rivers. Rogers and Burgner (1967) state that "in coastal rivers, the fry migrate to salt water upon emergence from the gravel. They area then about 30 mm long. The young fry obtain little food from the freshwater environment and subsist largely on the yolk. In the Wood River lakes and Tikchik Lake, the fry must travel some distance to reach the outlet rivers (96 km in the case of Agulukpak River fry); and it is quite apparent that they feed actively during the course of their travel." In addition, it was found that some of the juvenile pink salmon remained in Lake Aleknagik long after emergence, were caught in tow net samples as late as September 10, and had grown to mean lengths of 89 mm (ibid.). An examination of stomach contents taken from Lake Aleknagik fry during July 1-8, 1967, revealed that zooplankton (i.e., Bosmina, Daphnia, Holopedium, Cyclopoida, and Calanoida) made up the bulk of the food (ibid.). In nearshore salt water, the juveniles consume small crustaceans (e.g., copepods, euphasiids, amphipods, ostracods), larvae of decapods, cirripedes and tunicates, and dipterous insects (Neave 1966). As they grow, the diet consists of larger items until, during their final summer in the high seas, the diet consists of many organisms, the most important being euphasiids, amphipods, fish, squid, copepods, and pteropods (ibid.).

B. Types of Feeding Areas Used

Because pink salmon spend such a short time in natal waters following emergence from the gravel, little data are available on freshwater feeding locations. Samples of pink salmon fry in Lake Aleknagik indicate that although they were caught in the lake littoral zone (inshore), their stomach contents indicated that they had foraged mainly in the pelagic zone of the lake (Rogers and Burgner 1967). Juvenile pink salmon school in estuarine waters and frequent the water's edge along mainland and inland shores (Neave 1966). They remain in nearshore areas for about a month, and when they have attained a length of 6 to 8 cm they begin a gradual, irregular movement to offshore waters. On the high seas, pink salmon vertical distribution has been found to range from 10 to 23 m (Takagi et al. 1981), although a few have been caught at depths from 24 to 36 m (Neave 1966).

C. Factors Limiting Availability of Food

Because pink salmon feed very little if at all in fresh water, the major factors limiting food availability would be those found in the estuarine environment. Variations in weather patterns and ocean currents, which affect dispersal of planktonic organisms, could influence food sources for juvenile pink salmon.

D. Feeding Behavior

Pink salmon select their food by sight and swallow it whole (Bailey 1969). In offshore marine waters, pink salmon appear to have a vertical feeding pattern, with light intensity the major factor. Studies by Shimazaki and Mishima (1969) show that feeding indices of pink salmon near surface waters began to increase before sunset, attained a maximum two to three hours after sunset, and thereafter decreased to a minimum before sunrise. The feeding indices again became large in daytime. Whereas the dominant organisms of the stomach contents before sunset were large prey animals such as squids and fish larvae, the percentage of amphipods (whose numbers increased in surface waters with darkness), as well as feeding indices, increased after sunset, when amphipods became the main item of diet. Shimazaki and Mishima (ibid.) concluded that darkness prevented pink salmon from seeing and feeding on amphipods.

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Pink salmon spawning takes place in a variety of locations. Neave (1966) states: "In some instances spawning takes place in stream mouth areas where water levels change with the tides and where varying degrees of salinity are experienced. In small coastal streams the upstream limit is usually defined by a waterfall situated within a few miles of the sea. In larger rivers without major obstructions, the end-point may be less definite. The grounds that are intensively occupied by pink salmon tend to have a relatively low gradient."

B. Reproductive Seasonality

In Alaska, pink salmon ascend freshwater streams from June to late September, depending largely on location. Spawning takes place in mid July in the lower Yukon but generally not until late August to October in areas to the south (Morrow 1980).

C. Reproductive Behavior

As with other salmon, adult pink salmon return from the sea and move into their natal freshwater streams to spawn. There is, however, a degree of wandering. Adults have been taken in spawning streams as much as 643 km from their original stream. The female selects the spawning site and digs the redd (nest) by turning on her side and thrashing her tail up and down. The current washes loosened substrate material downstream, and a depression up to 45.7 cm deep is formed in the river bottom (ibid.). Eggs and sperm (milt) are released simultaneously and deposited in the redd. After egg deposition, the female moves to the upstream margin of the redd and repeats the digging process. Dislodged substrate is washed over the eggs. In this manner the eggs are covered and prevented from washing away. The process is repeated many times, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 0.9 m in length (Morrow 1980). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970). Males may also spawn with several females (Neave 1966).

D. Age at Sexual Maturity

Unlike the other Pacific salmon, the pink salmon matures in two years. Though rare three-year-old fish have been found, it is probable that they are sterile (Morrow 1980).

E. Fecundity

The number of eggs carried by pink salmon entering the spawning area varies with the size of the female, the area, and the year (Scott and Crossman 1973). Each female may produce as few as 800 or as many as 2,000 eggs (Morrow 1980), with the average estimated at 1,500 to 1,900 (Scott and Crossman 1973). In general, larger fish have more eggs, but fish from small runs are said to be more fecund than those of the same size from large populations (Nikolskii 1952).

F. Frequency of Breeding

As with all Pacific salmon, the spawning cycle is terminal. Both male and female die after spawning.

G. Incubation Period/Emergence

The amount of time required for eggs to hatch is dependent upon many interrelated factors, including 1) dissolved oxygen, 2) water temperature, 3) apparent velocity in gravel, 4) biological oxygen demand, 5) substrate size (limited by percentage of small fine material), 6) channel gradient, 7) channel configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Hart 1973). Generally speaking, factors 4 through 12 influence/regulate the key factors 1, 2, and 3.

Egg development requires from 61 to about 130 days, depending largely on temperature (Morrow 1980). The young hatch from late December through February and remain in the gravel until April or May.

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Size of Use Areas

From studies of Columbia River tributaries, Burner (1951) suggests that a conservative figure for the number of pairs of salmon that can satisfactorily utilize a given area of spawning gravel may be obtained by dividing the area by four times the average size of the redds. The redd area can be computed by measuring the total length of the redd (upper edge of pit to lower edge of tailspill) and the average of several equidistant widths (Reiser and Bjornn

1979). No documented information on the average size of pink salmon redds in Alaska was found in the preparation of this report.

B. Timing of Movements and Use of Areas

Pink salmon fry emerge from the gravel at night and begin their downstream migration to the sea (Bailey 1969). During July of 1967, small schools of pink salmon fry were observed migrating upstream along shore through the narrows between Tikchik Lake and Nuyakuk Lake in company with larger sockeye fry and yearlings. This behavior is unusual for pink salmon (Rogers and Burgner 1967). When the distance to the sea is short, they reach the estuary of the stream before dawn (Bailey 1969). On longer journeys that cannot be made in one night, the fry hide in the gravel during the day and resume their downstream movement the next night (Neave 1955). Fry that must migrate for several days sometimes become daylight-adapted, in which case they school and no longer hide during the day (Hoar 1956).

After entering the estuary, the juveniles begin feeding and move with surface currents (Bailey 1969). After about a month, the young fish attain a length of 4 cm, then follow the salinity gradient within the estuary, generally staying fairly close to the shore. When they reach a length of 6 to 8 cm they move to offshore waters (Morrow 1980). After about 18 months at sea, the adult pink salmon return to fresh water to spawn (Scott and Crossman 1973).

C. Migration Routes

Freshwater streams and rivers serve as downstream migration corridors for ocean-bound juveniles and as upstream migration pathways for spawning adults.

Following is a summary of ocean migration patterns taken from Takagi et al. (1981). From marine distribution data, it is evident that pink salmon are present across the entire North Pacific Ocean from Asia to North America, north of about 42°N. Tagging studies have shown that each stock has a characteristic distribution that is similar in odd-and even-year cycles. When combined, these studies have shown that the mass of maturing pink salmon in the North Pacific is composed of a number of stocks, each of which has a rather well-defined distribution that may overlap with one or more distributions of adjacent stocks.

1. Southeastern, Southcentral, and Southwestern (south-side of Alaska Peninsula) stocks. The oceanic migrations of stocks of pink salmon originating in Southeast, Southcentral, and Southwest Alaska (south-side Alaska Peninsula) are similar enough to be treated as one. Generally speaking, these stocks are found in the North Pacific and Gulf of Alaska in an area bounded on the west by about longititude 165°W, on the south by latitude 42°N, and on the east and north by the North American continent. Juveniles from Southeast Alaska in their first marine summer and fall move generally northwestward but likely do not move far offshore. Juveniles from

Southcentral and Southwest Alaska (south of the Alaska Peninsula) in their first marine summer and fall move southwestward along the Alaska Peninsula. Some juveniles from Southeast Alaska may move west and join the Southcentral and Southwestern stocks in this area.

Juvenile pink salmon are distributed farther offshore in the north Gulf of Alaska than they are off Southeast Alaska, which may indicate that offshore dispersion begins in the north-central Gulf of Alaska. No adequate measurements of offshore dispersion have been made south of the Alaska Peninsula.

Assumed migrations during the late fall and winter of their first year at sea indicate that the young pink salmon are further offshore and have begun a general southeastward movement that probably occurs on a broad front within the spring-summer distribution. During their second spring and summer, the maturing fish begin a generally northward movement from the high seas enroute to their natal streams.

2. Southwestern (north-side Alaska Peninsula). Very little information is available concerning pink salmon marine migrations from stocks in Western and Southwestern Alaska (north of the Alaska Peninsula). No data are available on seaward migrations of the juveniles during their first summer. From small numbers of tag returns of maturing adults it is supposed that these stocks are found in an area bounded on the west by 180° in the Bering Sea. They may also be found south of the eastern and central Aleutian Islands south to about latitude 50°N and thence southeasterly to about longitude 140°W at latitude 48°N. They probably do not extend beyond 54°N in the North Pacific.

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The greatest natural mortality of pink salmon occurs during the early life stages. Bailey (1969) states that, in streams, less than 25% of the eggs survive from the time of spawning to the time of emergence from the gravel; he lists the principle causes of death of the eggs as 1) digging in the redds by other females, 2) low oxygen supply because of low stream flows or impairment of water circulation within the streambed, 3) dislodgement of eggs by floods, 4) freezing of eggs during periods of severe and prolonged cold, and 5) predation by other fish.

Juveniles are preyed upon by a variety of fishes (e.g., cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, squawfish, and sculpins), kingfisher, mergansers, and other predaceous birds and mammals. Morrow (1980) states that mortality during early sea life (first 40 days) is fairly high at 2 to 4% per day, where predation by birds, fishes, and various invertebrates may be an important factor in mortality at this time. Adults at sea are preyed upon by man, marine mammals, Pacific and arctic lamprey, and to a lesser extent by large fish (Scott and Crossman 1973). Sea survival rates are highly variable and have been computed at about 2 to 22% and probably average 5% (Morrow 1980).

B. Human-related

A summary of possible impacts from human-related activities includes the following:

- Alteration of preferred water temperature, pH, dissolved oxygen, and chemical composition
- Alteration of preferred water velocity and depth
- Alteration of preferred stream morphology
- Increase in suspended organic or mineral material
- Increase in sedimentation and reduction in permeability of substrate
- Reduction in food supply
- Reduction in protective cover (e.g., overhanging stream banks or vegetation)
- Shock waves in aquatic environment
- Human harvest

(For additional impacts information, see the Impacts of Land and Water Use volume of this series.)

VIII. LEGAL STATUS

A. Managerial Authority

The Alaska Department of Fish and Game manages fresh waters of the state and marine waters to the 3-mi limit.

The North Pacific Fishery Management Council is composed of 15 members, 11 voting and 4 nonvoting members. The 11 are divided as follows: 5 from Alaska, 3 from Washington, and 3 from state fishery agencies (Alaska, Washington, Oregon). The four nonvoting members include the director of the Pacific Marine Fisheries Commission, the director of the U.S. Fish and Wildlife Service, the commander of the 17th Coast Guard District, and a representative from the U.S. Department of State.

The council prepares fishery management plans, which become federal law and apply to marine areas between the 3-mi limit and the 200-mi limit. With regard to salmon, the only plan prepared to date is the Salmon Power Troll Fishery Management Plan.

The International North Pacific Fisheries Commission (INPFC) a convention comprised of Canada, Japan, and the United States, has been established to provide for scientific studies and for coordinating the collection, exchange, and analysis of scientific data regarding anadromous species.

With regard to salmon, the INPFC has also prepared conservation measures that limit the location, time, and number of fishing days that designated high seas areas (beyond the 200-mi limit) may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

Limited life history and habitat information concerning Alaskan pink salmon has been collected/published. Most of the available information has been documented from Pacific Northwest and Canadian field laboratory studies.

X. SPECIAL CONSIDERATIONS

Neave (1966) states: "Schools of adult pink salmon often frequent bays and estuaries for days and even weeks before entering the streams. Fish tagged at this stage still show movements away from, as well as towards, the nearest spawning grounds. It appears, therefore, that spawning populations are not necessarily well segregated until actual entrance into the spawning streams."

Because of the two-year life cycle, returns of spawning adults are predictable by highly segregated even-numbered year and odd-numbered year runs. Both types of runs, or races, may use the same stream, or one or the other may predominate in a particular river (Scott and Crossman 1973). Some streams with a dominant run of one type have a very much smaller off-year run of the other race; they often utilize different tributaries as spawning grounds. There may be a significant difference in the date of return and in the length and weight of individuals of the two races or of the same race in different spawning rivers (ibid.).

In addition, caution must be used when extending information from one stock of pink salmon to another stock. Environmental conditions for one area must not be treated as absolute; the stocks (races) have acclimated/evolved over time and space to habitat conditions that can vary greatly.

The distribution and abundance narrative for the salmon species, presented by ADF&G commercial fisheries management areas, follows the aggregated salmon life histories.

REFERENCES

ADEC. 1979. Water quality standards. Juneau. 34 pp.

ADF&G, comp. 1977a. A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands, and Bristol Bay areas. Vol. 2: Fisheries. [Juneau.] 557 pp.

________. 1977b. A fish and wildlife inventory of the Cook Inlet-Kodiak areas. Vol. 2: Fisheries. [Juneau.] 443 pp.

________. 1978. A fish and wildlife resource inventory of the Prince Willam Sound area. Vol. 2: Fisheries. [Juneau.] 241 pp.

ADF&G. 1981. Juvenile anadromous fish study on the lower Susitna River. ADF&G Susitna Hydro Aquatic Studies. Phase 1: Final draft rept. Anchorage, AK.

________. 1981a. Lower Cook Inlet annual management report. Div. Commer. Fish. 99 pp.

________. 1984. An atlas to the catalog of waters important for spawning, rearing, and migration of anandromous fishes, Southwestern Resource Management Region III. Div. Habitat, Anchorage. 5 pp. + maps.

Bailey, J.E. 1969. Alaska's fishery resources - the pink salmon. USFWS, Bureau Commer. Fish., Fishery Leaflet No. 619. 8 pp.

Bailey, J.E., and D.R. Evans. 1971. The low temperature threshold for pink salmon eggs in relation to a proposed hydroelectric installation. USFWS, Fish. Bull. 69(3):487-593. Cited in Krueger 1981.

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. USFWS, Fish. Bull. 78:649-658. Cited in Krueger 1981.

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries Engineering Research Program, Corps of Engineers, North Pacific Div., Portland, OR. Approx. 500 pp.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus Oncorhynchus. J. Fish. Res. Bd. Can. 9(6):265-322.

Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. USFWS, Fish. Bull. 61(52):97-110.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Can. Bull. 180. Ottawa, Can. 739 pp.

Hoar, W.S. 1956. The behavior of migrating pink and chum salmon fry. J. Fish. Res. Bd. Can. 13(3):309-325. Cited in Morrow 1980.

Krueger, S.W. 1981. Freshwater habitat relationships pink salmon (Oncorhynchus gorbuscha). ADF&G, Div. Habitat, Resource Assessment Branch. Anchorage. 45 pp.

McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173. Ontario, Can. 381 pp.

Middleton, K.R. 1983. Bristol Bay salmon and herring fisheries status report through 1982. Informational Leaflet No. 211. ADF&G, Div. Commer. Fish. 81 pp.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Anchorage, AK: Alaska Northwest Publishing Company. 248 pp.

Neave, F. 1955. Notes on the seaward migration of pink and chum salmonfry. J. Fish. Res. Bd. Can. 12(3):369-374. Cited in Morrow 1980.

_______. 1966. Chum salmon in British Columbia. INPFC Bull. 18. Vancouver, Can. 86 pp.

Nikolskii, G.V. 1952. O tipe dinauriki stada i kharaktere neresta gorbushi o.g. (walb.): keti o.k. (walb) v Amure. Doklady Adad. Nauk USSR 86(4). Israel Prog. Sci. Transl. 538 pp. Cited in Morrow 1980.

Prokopowich, D. 1983. Personal communication. Kodiak Area Asst. Fisheries Mgt. Biologist, ADF&G.

Reiser, D.W., and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America - habitat requirements of anadromous salmonids. USDA, Forest Service Gen. Tech. Rept. PNW-6, Pacific Northwest Forest and Range Experiment Station. Portland, OR. 54 pp.

Rogers, D.E., and R.L. Burgner. 1967. Nushagak district salmon studies. Pages 12-14 in J.R. Matches and F.B. Taub, eds. Research in fisheries - 1967. Contribution No. 280. College of Fisheries, Fisheries Research Institute, Univ. Wash., Seattle, WA. 82 pp.

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

Shaul, A. 1984. Personal communication. Alaska Peninsula-Aleutian Island Area Fisheries Mgt. Biologist, ADF&G, Kodiak.

Sheridan, W.L. 1962. Relation of stream temperatures to timing of pink salmon escapements in Southeast Alaska. Pages 87-102 in N.J. Wilimovsky, ed. H.R. MacMillian lectures in fisheries: symposium on pink salmon. 1962. Institute of Fisheries, Univ. Brit. Col., Vancouver. 226 pp.

Shimazaki, K., and S. Mishima. 1969. On the diurnal change of the feeding activity of sockeye salmon in the Okhotsk Sea. Hokkaido Univ., Facul. Fish., Bull. 20(2):82-93. (In Japanese, English summary.) Cited in Takagi et al. 1981.

Takagi, K., K.V. Aro, A.C. Hartt, and M.B. Dell. 1981. Distribution and origin of pink salmon (Oncorhynchus gorbuscha) in offshore waters of the North Pacific Ocean. INPFC. Bull. 40. Vancouver, Can. 195 pp.

Thompson, K. 1972. Determining stream flows for fish life. Pages 31-50 in Proceedings, instream flow requirement workshop. Pac. NW River Basin Comm. Vancouver, WA.