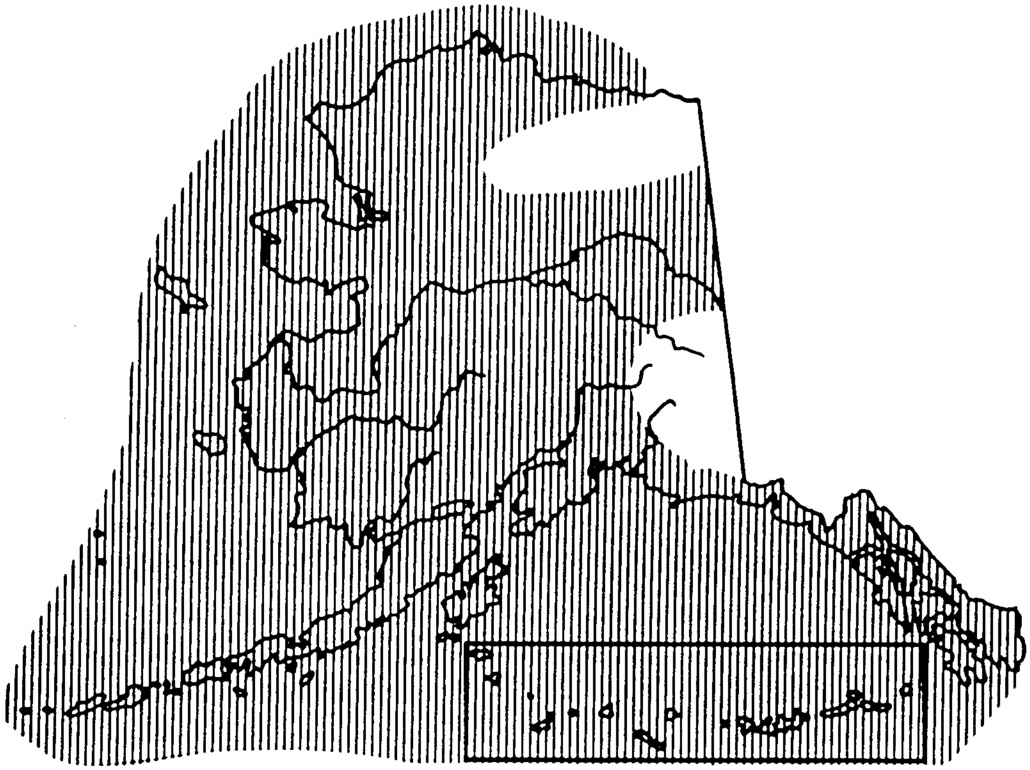
Chum Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



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

I. NAME
   A. Common Names: Chum salmon, dog salmon, keta salmon
   B. Scientific Name: <u>Oncorhynchus keta</u>
   C. Native Names: See appendix A.

II. RANGE
   A. Worldwide

Chum salmon have the widest distribution of any of the Pacific salmon. In North America, the chum salmon ranges from the Sacramento River in California (and as far south as Del Mar, about 50 km north of the Mexican border) north to the arctic and east at least as far as the Mackenzie and Anderson rivers in northern Canada. In Asia, they range from the Lena River on the arctic coast of Siberia east and south along the coast to near Pusan, Korea, and Honshu Island, Japan. They are also found in the Aleutian, Commander, and Kurilei islands (Morrow 1980, McPhail and Lindsey 1970, Hart 1973).

B. Statewide

Chum salmon generally occur throughout Alaska, except for certain streams in the Copper River drainage upstream of Miles Lake (Roberson, pers. comm.) and in the eastern Brooks Range (Hale 1981). Relatively few streams north of the Kotzebue Sound drainage support runs of chum salmon (ibid.).

C. Regional Distribution Maps

To supplement the distribution information presented in the text, a series of blue-lined reference maps has been prepared for each region. In this series, chum salmon distribution information is included on the 1:250,000-scale maps titled Distribution of Anadromous Fish. 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.

D. Regional Distribution Summary

1. Southwest. In the Kodiak area, very little escapement information for chum salmon is available. They utilize many of the same streams as pink salmon for spawning (ADF&G 1977b), but the majority of the important chum salmon-producing systems are located on the south shore of the Alaska Peninsula between Cape Douglas and Kaflia Bay and on the east side of Kodiak Island (Pedersen, pers. comm.).

   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, Togiak, and Naknek-Kvichak districts are the major producers of chum salmon (Middleton 1983). Other important runs are also found in the Egegik and Ugashik systems (Russell, pers. comm.) and at Izembek-Moffet lagoons, Bechevin Bay, the Sapsuk River (Nelson Lagoon), Herendeen Bay, Moller Bay, Frank's Lagoon, Port Heiden, and Cinder River (Shaul, pers. comm.).

   In south-side Alaska Peninsula streams, chum salmon are found at Canoe Bay and in every other major bay east of False Pass (ADF&G 1977a). Unga Island in South Peninsula waters produces moderate numbers of chum salmon compared to other south-side areas (Shaul, pers. comm.). In the Chignik area, the Chignik Lagoon, Amber Bay, Ivanof Bay, Kuikukta Bay, Ivan River, Kujulik Bay, Chiginagak Bay, Agripina Bay, Aniakchak River, Hook Bay, and Nakalilok River support runs averaging several thousand fish each (ibid.). Small runs of chum salmon occur sporadically throughout the Aleutian Islands chain, but few of these would ever be expected to be of commercial importance (Holmes 1984). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Upper Cook Inlet (UCI) area, chum salmon survey and escapement data are limited. Production areas for chum have been identified as Chinitna Bay, west-shore river systems of UCI, and the Susitna River (ADF&G 1982). In Lower Cook Inlet (LCI), chum salmon production areas include Port Graham, Tutka Bay, Dogfish (Koyuktolik) Bay, Island Creek (in Port Dick), Tonsina and Clear creeks in Resurrection Bay, and Port Chatham (ADF&G 1981a). In addition, all streams in the Kamishak Bay District are chum salmon producers. They include the McNeil, Douglas, Big Kamishak, Little Kamishak, Bruin, and Iuiskin rivers and Cottonwood, Sunday, and Ursus Lagoon creeks (Schroeder, pers. comm.).

   In the Prince William Sound area, chum salmon stocks exhibit an early, middle, and late run pattern that is linked to geographic distribution and related to stream temperature regimes. Early run (early and mid July) stocks spawn in major, non-lake-fed mainland streams of all districts. Middle-run (late July-mid August) stocks spawn in lake-fed streams of the mainland and most chum salmon streams of the outer island complex. Included is these stocks are the Coghill and Duck river (in Galena Bay) runs, which are the two largest stocks of the middle run. The late-run (mid August-late September) stocks spawn almost exclusively in small spring-fed creeks at the upper ends of Port Fidalgo and Valdez Arm (ADF&G 1978a).

   A more detailed narrative regarding chum salmon distribution and abundance in the Southcentral Region is included in volume 2 of the Alaska Habitat Management Guide for the Southcentral Region. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. Major chum salmon-producing systems in the Norton Sound District include the Unalakleet and Fish river drainages and the Shaktoolik, Egavik, Inglutalik, Ungalik, Koyuk, Tubutulik, Kwiniuk, Kachavik, Bonanza, Eldorado, Flambeau, Nome, Snake, and Sinuk rivers (Schwarz, pers. comm.).

   Within the Port Clarence District, chum salmon have been documented in the Bluestone, Cobblestone, Agiapuk, and Kuzitrin river systems (ADF&G 1984).

   Major chum salmon-producing systems in the Kotzebue District are the Kobuk and Noatak rivers (ADF&G 1977). Important spawning areas in the Kobuk River system are found in the Squirrel, Salmon, and Tutuksuk rivers and the headwaters of the main Kobuk River (ADF&G 1983a). Important spawning areas in the Noatak River system are found in the Eli and Kelly rivers, Eli Lake, and in the main Noatak River (ibid.).

The Northern District of the Arctic Region represents the most northern range of chum salmon in North America. Populations in the area are existing at the outer limits of their environmental tolerances, and their numbers are extremely limited (ADF&G 1977c). First-order streams (those with mouths at salt water) in which chum salmon have been documented include the Pitmegea, Kukpowruk, Kokolik, Utukok, Kuk, Meade, Fish, Colville, Sagavanirktok, and Canning (ADF&G 1984). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Arctic Region.)

4. Western. Both the Kuskokwim and Yukon rivers traverse the Western Region and serve as migration corridors for chum salmon. Important Western Region chum salmon-producing waters of the Kuskokwim River system (i.e., those tributaries located downstream and including the Holitna River drainage) include the Eek, Kwethluk, Kisaralik, Kasigluk, Aniak, Salmon (Aniak River tributary), Kipchuk, Tuluksak, Chukowan, Kogrukluk, Holitna, Holokuk, George, and Oskawalik river systems (ADF&G 1983b, 1983c). The Yukon River supports a distinct summer and a distinct fall run of chum salmon (ADF&G 1978b). Summer chum salmon spawn primarily in runoff tributaries of the lower 500 mi of the drainage and in the Tanana River system, whereas fall chum salmon migrate farther upstream and spawn in spring-fed tributaries that usually remain ice-free during the winter (ADF&G 1983d). Within that portion of the Yukon River found in the Western Region (i.e., tributaries downstream of the village of Paimuit), chum salmon are found in many of the sloughs, passes, and branches of the river in the delta area and in such tributaries as the Archuelinguk, Andreafsky, and Chuilnak rivers and Kako Creek (ADF&G 1985). Chum salmon are also documented between the Yukon and Kuskokwim rivers on the delta in such systems as the Anerkockik, Azun, Manokinak, Kashunuk, Keoklevik, Ningikfak, Kun, and Kolavinarak rivers (ibid.). South of the Kuskokwim River mouth, chum salmon are known to utilize most of the Kanektok River, the lower portion of the Arolik River, Jacksmith Creek, Cripple Creek, and the Indian and Goodnews rivers for spawning (ADF&G 1977c; Francisco, pers. comm.). On Nunivak Island, the ADF&G (1985) documents 32 streams in which chum salmon have been found. (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

5. Interior. The Kuskokwim and Yukon rivers serve as pathways for chum salmon bound for spawning areas in the Interior Region. Important chum salmon-producing waters of the Kuskokwim River system in the Interior Region (i.e., those tributaries upstream of the Holitna River drainage) extend to the North, East, and South Forks of the Kuskokwim River and include the Pitka Fork of the Middle Fork Kuskokwim,

Tatlawiksuk, and Cheeneetnuk rivers and Can Creek, a tributary of the Stony River (ADF&G 1983b). The Yukon River supports distinct runs of summer and fall chum salmon. Summer chum salmon spawn primarily in runoff tributaries of the lower 500 mi of the drainage and in the Tanana River system, whereas fall chum salmon migrate farther upstream and spawn in spring-fed tributaries that usually remain ice-free during the winter (ADF&G 1983d). Within the Yukon River drainage of the Interior Region (i.e., those tributaries upstream of the village of Paimuit), important summer chum salmon-producing systems include the Anvik, Nulato, Koyukuk, Melozitna, and Tanana drainages (ibid.). The Porcupine and Tanana river drainages are the two most important systems for fall chum salmon production (Buklis and Barton 1984). Major known spawning areas include the Sheenjek, Chandalar, Toklat, and Delta rivers and the Tanana River near the town of Big Delta (ibid.). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Western and Interior regions.)

III. PHYSICAL HABITAT REQUIREMENTS

A. Aquatic

1. Water quality:

a. Temperature. Egg hatching and alevin development have occurred in Alaska at temperatures ranging from 0.2 to 6.7°C during the winter months (Hale 1981). Optimal incubation temperatures, however, appear to range between 4.4 and 13.3°C (Bell 1973). Vining et al. (1985), during chum salmon incubation studies in tributary, slough, main stem, and side channel habitats of the middle reach of the Susitna River, Alaska, found that the pattern of accumulation of thermal units for developing salmon embryos varies between spawning habitat types. A general thermal regime describing the incubation period for each type was described as follows (ibid.):

- Tributary habitats typically have intragravel water temperatures that are strongly influenced by surface water temperatures. This results in relatively high intragravel water temperatures during the fall and spring months, with near-freezing water temperatures during the intervening winter months.
- Slough habitats generally have relatively high and more stable intragravel water temperatures during most of the incubation period because of the influence of suitable upwelling sources.
- Main stem habitats are similar to tributary habitats, having winter intragravel water temperature that are strongly influenced by surface water

temperatures. They differ, however, from tributary habitats by having colder water temperatures during fall and spring periods.

- In general, winter intragravel water temperatures in side channel habitats are quite variable and may reflect any of the patterns exhibited by the other habitat types, depending upon the relative influences of and relationships between upwelling and surface water sources.

Emergence from the gravel and downstream migration to the sea have occurred at temperatures between 3.0 and 5.5°C for Delta River fall chum salmon (Raymond 1981); peak movements, however, derived from several stocks, occur at warmer temperatures (i.e., 5.0 to 14°C) (Hale 1981). During laboratory experiments, Brett (1952) found the upper lethal temperature limit of British Columbia chum salmon juveniles to be 23.8°C. Brett and Alderdice (1958), in later experiments, showed the ultimate lower lethal temperatures of juveniles from British Columbia to be 0.1°C.

In Alaska, adult chum salmon have migrated upstream in temperatures ranging from 4.4 to 19.4°C (Hale 1981), with peaks of migration occurring between 8.9 to 14.4°C. Bell (1973) suggests water temperature criteria for successful upstream migration of from 8.3 to 15.6°C, with an optimum of 10°C.

Spawning has occurred in Alaskan waters at temperatures from 6.9 to 12.8°C, with preferred temperature ranges of 7.2 to 12.8°(Hale 1981).

b. <u>The pH factor</u>. There is no optimum pH value for fish in general; in waters where good fish fauna occur, however, 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. <u>Dissolved oxygen (D.O.)</u>. Laboratory experiments show that the supply of dissolved oxygen to eggs and alevins is of critical importance because a low (less than 1 ppm) supply leads to increased mortality or delay in hatching and/or decreased fitness (Alderdice et al. 1958). These same tests tend to indicate a slow but steady increase in the incipient low oxygen lethal level through development. Early stages exhibit a plasticity in which development may decelerate virtually to zero under extreme hypoxial conditions. In later stages, this plasticity is lost, and oxygen levels that would produce no more than a cessation of development at earlier stages become rapidly lethal. The rate of supply to the embryos and alevins is influenced primarily by the D.O. concentration of the source water and the rate of flow through the gravel substrate. Dissolved oxygen levels as low as about 2 mg/l can meet the oxygen requirements of eggs and alevins if the rate of flow of intragravel water is sufficient (Kogl 1965, Levanidov 1954). Intragravel D.O. concentrations in the Chena River during incubation of chum salmon eggs ranged from 0.6 to 6.5 mg/l and resulted in low survival rates at the lower concentrations and high survival rates at the higher concentrations (Kogl 1965).

Studies concerning juvenile chum salmon dissolved oxygen requirements summarized by Hale (1981) indicate lower thresholds of 1.5 mg/l at water temperatures of 10°C. Dissolved oxygen levels of 8 to 9 mg/l at 8 to 10°C seem most favorable.

Adult swimming performance can be reduced by levels of D.O. below air saturation (Rieser and Bjornn 1979).

State of Alaska water quality criteria for the 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" (ADEC 1979).

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, salmonid eggs have suffered significant (upwards of 85%) mortality (Bell 1973). Prolonged exposure to turbid water causes gill irritation in juveniles that can result in fungal and pathogenic bacterial infection. High suspended sediment loads could be inhibiting to adults attempting an upstream migration (Hale 1981). Exposure can lead to tail rot and reduction of gas exchange across gills by physical damage, coating, or accumulation of mucous (Smith 1978). Turbid water will absorb more solar radiation than clear water and may thus indirectly raise thermal barriers to adult upstream spawning migration (Reiser and Bjorrn 1979).

2. Water quantity:

a. Instream flow. Hale (1981) states, "The flow of water in the stream channel is important to incubating embryos in promoting an adequate intragravel flow and in protecting the substrate from freezing temperatures. Heavy mortality of embryos can occur during periods when there is a relatively high or a relatively small discharge. Flooding can cause high mortality by eroding eggs from the redds or by depositing fine sediments on the surface of the redds which can reduce permeability or entrap emerging fry. Low discharge periods can lead to dessication of eggs, low oxygen levels, high temperatures, or, during cold weather, freezing."

During laboratory tests in British Columbia, juveniles 25 to 45 mm long when presented with a choice between two 8-cm-wide, 4-cm-deep channels with "laminar" flows preferred 350, 500, 600, and 700 ml/min flows to a flow of 200 ml/min, and the greatest response (i.e., positive rheotaxis) was toward the 500 ml/min flow (Mackinnon and Hoar 1953). In another experiment with "turbulent" water flow, they found that fry seemed to prefer flows of about 5,000 to 12,000 ml/min over either lesser or greater flows. Levanidov (1954) stated that optimum stream velocities to support the feeding of fry in the Amur River, USSR, are less than 20 cm/sec.

There is little information available on the maximum sustained swimming velocity of which adult chum salmon are capable. Chum salmon have less ability than other salmon to surmount obstacles (Scott and Crossman 1973) and in general show less tendency to migrate upstream beyond rapids and waterfalls (Neave 1966). In a study of the migration of adult chum salmon in the middle reach of the Susitna River, Alaska, Blakely et al. (1985) found that the upstream passage criteria were primarily determined by depth of water, were slightly affected by the length of the reach, and were not significantly influenced by channel configuration or substrate size. A brief summary of the water depth thresholds for successful, difficult, and unsuccessful upstream migration is provided in table 1.

During spawning, chum salmon in the Chena River of Alaska make redds in water depths ranging from 5 to 120 cm (Kogl 1965). Those in the side channels and sloughs of the middle reach of the Susitna River seemed to prefer depths of 9.6 to 70.1 cm for spawning, although it was determined that depth alone, if greater than 70.1 cm, would not likely affect chum salmon spawning within the ranges of conditions encountered in the study sites (Vincent-Lang et al. 1984). Water velocity at spawning sites has ranged from 0 to 118.9 cm/sec (Hale 1981). Spawning chum salmon in sloughs and side channels of the middle reach of the Susitna River exhibited a general preference for velocities between 0 and 39.6 cm/sec (Vincent-Lang et al. 1984). The ADF&G (1977) states that optimum stream velocity is 10 to 100 cm/sec (presumably for spawning and incubation).

Table 1. Adult Chum Salmon Passage Criteria Thresholds for Reaches up to 200 ft Long Within Slough and Side Channel Habitats in the Middle Portion of the Susistna River, Alaska

Upstream Movement	Threshold Depths (in Feet)	
	Thalweg[a]	Passage[b]
Successful[c]	0.35 and greater	0.26 and greater
Difficult[d]	0.28 to 0.34	0.20 to 0.25
Unsuccessful[e]	0.12 to 0.26	0.09 to 0.19

Source: Blakely et al. 1985.

a Thalweg depth is the maximum depth in a stream cross-sectional profile.

b Passage depth was defined as an average of the mean depth and the thalweg depth of a passage reach transect and was considered to be a more accurate indicator of the water depth affecting salmon passage. Passage depth values were calculated using the equation, $d_p = 0.75d_t^{1.02}$, where d_p = passage depth, and d_t = thalweg depth.

c Fish passage into and/or within a spawning area was uninhibited.

d Fish passage into and/or within a spawning area was accomplished, but with stress and exposure to predation.

e Fish passage into and/or within a spawning area may be accomplished by a limited number of fish, which, because of excessive exposure, are susceptible to increased stress and predation.

3. Substrate. Egg incubation and alevin development occur in substrates ranging widely in size and composition. Hale (1981) summarizes redd sites by stating that, "in general, chum salmon excavate redds in gravel beds with a particle size of 2 to 4 cm diameter, but they will also construct redds in substrates with particles of a greater size and will even use bedrock covered with small boulders (Morrow 1980, Scott and Crossman 1973). Vincent-Lang et al. (1984) found that spawning chum salmon in sloughs and side channels of the middle reach of the Susitna River seem to prefer substrates of larger gravel and rubble ranging in size from 2.5 cm to 22.8 cm in diameter for spawning. Generally, substrates with a percentage of fine particles (less than 0.833 mm in diameter) greater than 13% are of poor quality because of reduced permeability (Thorsteinson 1965). Chum salmon, however, often spawn in areas of upwelling ground water and may therefore be able to tolerate higher percentages of fines than would seem desirable if some of the fines are kept in suspension by the upwelling water." Studies of slough and side channel habitat within the middle reach of the Susitna River note that spawning chum salmon appear to key on upwelling areas (Vincent-Lang et al. 1984). The ADF&G (1977) observed that spawning usually occurs in riffle areas and that chum salmon generally avoid areas where there is poor circulation of water through the stream bed.

B. Terrestrial

1. Conditions providing security from predators or other disturbances. Upon emergence from the gravel of short streams, chum salmon juveniles migrate mainly at night and seek cover in the substrate during the daytime if the journey is not completed in one night (Neave 1955). Hoar (1956) found that chum salmon fry, after schooling has occurred during downstream migration, use the protection of schools during daylight and no longer seek protection in the substrate.

2. Conditions providing protection from natural elements. A gravel substrate was found to prevent yolk sac malformations of alevins reared at 12°C and water velocities of 100cm/hr (Emadi 1973). Alevins reared on a smooth substrate with identical temperature and water velocities were susceptible to yolk sac malformation. Since alevins prefer to maintain an upright position, which is difficult on a flat surface, the swimming activity to right themselves results in continual rubbing on the flat surface, which is thought to injure the yolk and cause malformation (ibid.).

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for 30 to 50 days until their yolk sacs are absorbed (Bakkala 1970). Bailey et al.

(1975) found that about 63% of the preemergent juveniles excavated from redds in the Traitors River of Southeast Alaska contained items such as sand or detritus in the digestive tract. Of the total sample, however, only 13% contained food organisms that included chironomid larvae and pupae, plecopteran nymphs, ephemeropteran nymphs, and an arachnid. Most chum salmon juveniles begin their downstream migration to the sea soon after emergence. Young chum salmon with only a short distance to travel probably do not feed until they reach the ocean (Morrow 1980). Bailey et al. (1975), however, sampled 40 downstream-migrating chum salmon in the short, coastal Traitors River and found that 22.5% contained substantial numbers of chironomid pupae and plecopteran nymphs. Those that must spend several days to weeks on their journey, however, feed actively on chironomid larvae, cladocerans (water fleas), copepods, nematodes, and a variety of mature and immature insects (Morrow 1980, Scott and Crossman 1973). Stomach contents of chum salmon fry caught in the main stem of the Noatak River, its tributaries, and its backwaters, during the period May through early August 1980 reveal that the fry had fed mainly on the larvae, pupae, and adult forms of insects. Only 4% of the stomach contents were of other types of organisms, and, of these, most were zooplanktors (Merritt and Raymond 1983). The primary insect prey species were of the order Diptera and the order Plecoptera. Other types of insects were represented and included specimens from the orders Ephemeroptera (mayflies), Homoptera, and Hymenoptera. Zooplanktors included specimens from the order Cladocera. Cyclopoid and Harpacticoid forms of the subclass Copepoda were also represented. Some chum salmon fry had also consumed roundworms (Nematoda) (ibid.).
During their early sea life they feed on a wide variety of organisms, such as diatoms, many small crustaceans (e.g., ostracods, cirripeds, mysids, cumaceans, isopods, amphipods, decapods), dipterous insects, chaetognaths, and fish larvae (Morrow 1980, Scott and Crossman 1973). Bailey et al. (1975) found that chum salmon fry in Traitors Cove consumed food items that were mostly from 0.3 to 3.0 mm long. They also tended to feed on larger and harder items than did pink salmon, as evidenced by the greater incidence of harpacticoid copepods, collembolans (intertidal spring tails), cumaceans, and chironomids in chum salmon. Benthic and intertidal forms of mysids, cumaceans, isopods, amphipods, and insects were rare in plankton samples, and their presence in some of the stomachs shows that chum salmon did on occasion feed in these ecological niches (ibid.). The food of chum salmon fry caught in the brackish water areas in Kotzebue Sound during June and early July 1980 consisted largely of insects (58%). Zooplankton, which made up most of the remainder, were mostly copepods. During early August of 1981, chum salmon fry caught near Cape Blossom in Kotzebue Sound in more saline water than the 1980 samples were found to be feeding primarily on cladocerans (Chydorinea) and copepods (Merritt and Raymond 1983).

Copepods, tunicates, and euphausiids dominate the diet at sea (Morrow 1980, Scott and Crossman 1973). Other items eaten at sea include other fishes, pteropods, squid, and mollusks.

B. Types of Feeding Areas Used

Because chum salmon spend such a short time in natal water following emergence from the gravel, no data are available on freshwater feeding locations. At sea, the fish are found from close to the surface down to at least 61 m. There is some indication of vertical movement according to the time of day, with the fish tending to go toward the surface at night and deeper during the day (Manzer 1964). This is probably a response to movements of food organisms (Morrow 1980).

C. Factors Limiting Availability of Food

Chum salmon juveniles that feed while in fresh water eat benthic organisms. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983) and thereby decrease available food.

D. Feeding Behavior

Juvenile daily food intake while in fresh water increases as water temperatures increase. Levanidov (1955), using aquaria, found that at 4 to 10°C the weight of food eaten daily was 5 to 10% of the body weight; at 12 to 20°C it was 10 to 19% of the body weight.

Bailey et al. (1975), during studies of estuarine feeding habits at Traitors Cove in Southeast Alaska, found that many more food items were contained in the stomachs of juvenile chum salmon collected in daytime than in those collected at night - an average of 124 items versus 4. They also found that the fry fed selectively. Relatively more cladocerans, decapod zoeae, and larvaceans were eaten than appeared in the samples of available planktonic food items. Visual observations of individual chum salmon fry in shore-oriented schools indicate that their feeding varied with the speed of the water current. Bailey et al. (1975) found that "at velocities of 0 to 10.7 cm/s, a fry would typically swim a darting course as much as three times its body length to capture a food item. At higher velocities, 10.8 to 19.8 cm/s, schools of fry sometimes held position relative to the shore or bottom while facing the current, and an individual would typically deviate up, down, or to the sides no more than one-third of its body length to capture oncoming food. At still higher velocities, 19.9 to 24.4 cm/s, fry in schools often held a constant position relative to shore or bottom but did not feed. Fry that appeared to be in visual contact with the shore or bottom avoided currents above 24.4 cm/s unless frightened."

Adult feeding seems to be opportunistic and is based on the availability of, rather than a preference for, certain kinds of food (Le Brasseur 1966). Upon returning to fresh water to spawn, adults cease feeding and obtain energy from body fat and protein (Morrow 1980, Bakkala 1980).

V. REPRODUCTIVE CHARACTERISTICS

A. Reproductive Habitat

Chum salmon spawn in waters ranging from short coastal streams, where the adults may spawn within the tidal zone, to large river systems, such as the Yukon River, where they are known to migrate upstream over 2,500 km. Most, however, spawn above the reaches of salt water and within 200 km of the sea (Bakkala 1970). Spawning grounds must provide suitable substrate as well as suitable stream conditions. Many stocks of chum salmon (particularly fall chum) select areas with springwater or groundwater emergence. These areas tend to maintain water flows and temperatures warm enough to keep from freezing during the winter months (Morrow 1980, Hale 1981), as in the lower Delta River southeast of Fairbanks, Alaska, where spawning occurs in several small spring-fed channels whose fall and winter flows are composed entirely of clear upwelling groundwater (Bulklis and Barton 1984). Vining et al. (1985), from studies of artificial chum salmon redds in slough, side channel, tributary, and main stem habitats of the middle reach of the Susitna River, determined that dewatering and freezing of salmon redds were the most important factors contributing to the high levels of embryo mortality found in the habitats used for incubation. In general, they found that these factors were most pronounced in slough habitats that were protected from cold surface water overtopping and where upwelling groundwater was more prevalent. Upwelling is the most significant physical variable affecting the development and survival of chum salmon embryos incubating in the slough and side channel habitats because 1) it eliminates or reduces the likelihood of dewatering or freezing of the substrate environment; 2) it provides a relatively stable intragravel incubation environment, buffering it from variations in local surface water and climatic conditions; and 3) it increases the rate of exchange of intragravel water over the embryos, which enhances the replenishment of dissolved oxygen and the removal of metabolic wastes (ibid.).

B. Reproductive Seasonality

The chum salmon is typically a fall spawner. In Alaska, they ascend the rivers from June to September, the peak spawning for most of the northern populations occuring from July to early September and for southern populations in October or November (Morrow 1980, Hale 1981). Within the Yukon River drainage, summer chum salmon spawn from July through early to mid August, whereas fall chum salmon spawn from September through early November (Barton 1984). On the Alaska Peninsula, spawning occurs from August to early September (Shaul, pers. comm.).

C. Reproductive Behavior

As with other salmon, adult chum salmon return from the sea and move into their natal freshwater streams to spawn. 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 loose redd substrate material downstream, and a depression 8 to

43 cm deep is formed in the river bottom (Burner 1951, Bakkala 1970). 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, and the redd appears to move upstream (Burner 1951). As a result of the continued digging, the redd may grow to become 1.6 to 3.2 m long and 1.1 to 2.1 m wide (Bakkala 1970). A female may spawn with several males, and a male may mate with more than one female (Morrow 1980).

D. Age at Sexual Maturity

The age at which chum salmon mature sexually ranges from two to seven years, although most mature in their third to fifth year. In general, fish from the southern part of the range return to streams during their third and fourth years, whereas those from the Yukon (and probably other far north rivers) return mostly in their fourth and fifth years (Bakkala 1970, Morrow 1980). In Alaska Peninsula waters, fourth-year chum salmon are normally predominant, followed by significant numbers of third- and fifth-year fish (Shaul, pers. comm.). Fish in their fourth year are usually most common in Southeast Alaska. Fifth-year fish predominate from Prince William Sound northward, with fourth-and sixth-year fish being next in abundance. Seventh-and eighth-year fish are rare (Hale 1981).

E. Fecundity

Fecundity varies by stock and the size of the female and ranges from 1,000 to 8,000 eggs. In Alaska, 2,000 to 3,000 are most common (ibid.). Samples taken from the lower Noatak River north of Kotzebue on September 1, 1981, ranged from 1,860 to 4,190 eggs and averaged 3,120 eggs, which is larger than fecundities reported for other Alaskan chum salmon (Merritt and Raymond 1983).

F. Frequency of Breeding

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

G. Incubation Period/Emergence

The 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 and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjornn 1979, Hale 1981). Generally speaking, factors 4 through 12 influence or regulate the key factors 1, 2, and 3.

The time from fertilization to hatching can range from 1.5 to 4.5 months, depending primarily on water temperature. In Alaska, hatching of eggs occurs from December to February in the southerly parts of the range. The time of hatching in northern Alaska is not definitely known, although studies of spawning grounds in the

Noatak River in northwestern Alaska suggest that egg hatching occurs from late December through January (Merritt and Raymond 1983). Results of three years of study in the Delta River of Interior Alaska reveal that hatching began in early February and was completed by mid March (Buklis and Barton 1984). Vining et al. (1985), during studies of incubation in different habitat types within the middle reach of the Susitna River, found that embryos fertilized on August 26, 1983, and placed in slough, side channel, and main stem habitats reached 100% hatch at approximately late January, late December, and mid April, respectively. Embryos in slough and side channel habitats were influenced by warmer upwelling water, whereas embryos in the main stem were not. The alevins remain in the gravel until the yolk sac is absorbed, 60 to 90 days after hatching, then make their way through the gravel and begin migration to the sea (Morrow 1980). Although rare, chum salmon that have spent at least a year in freshwater lakes and grown to lengths of 160 to 170 mm have been captured at Lake Aleknagik in the Wood River system of Bristol Bay (Roberson, pers. comm.).

VI. MOVEMENTS ASSOCIATED WITH LIFE FUNCTIONS

A. Sizes 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. 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 Bjorrn 1979).

The average size of the redd area has been reported to range from 1.0 m^2 to 4.5 m^2 (Hale 1981). The ADF&G (1977) states that the optimum size is considered to be 3 m^2. Schroder (1973) found that the optimum density at which maximum egg deposition occurred ranged from 1.7 to 2.4 m^2 per female chum salmon. Vining et al. (1985) caution that, because of the effects of dewatering and freezing, the amount of available habitat at the time when adult chum salmon are spawning is a poor indicator of the amount of actual habitat that is available as potential incubation habitat. Estimates of available incubation habitat must take into account the differential effects of dewatering and freezing in various habitat types.

B. Timing of Movements and Use of Areas

Soon after emerging from the gravel, juvenile chum salmon begin moving to the sea. Where known, Alaska specific timing informa tion is contained in the salmon distribution and abundance narratives found in this report series. In studies of Hooknose Creek, British Columbia, Hunter (1959) found that downstream migration in this relatively shallow (13 inches deep), coastal stream is usually at night near the surface of the water and in the center of the stream, where the currents are strongest. Barton (1978), however, found that out-migrating juvenile chum salmon were captured in similar numbers at all stations sampled across the Yukon River. The sampling location was near the Anuk River, approximately 101 km upstream of Flat Island at the mouth of the Yukon River.

In summarizing several studies conducted in different locations of the Yukon River system, Buklis and Barton (1984) suggest that chum salmon fry out-migrations tend to be correlated with increased or peak water flows following spring breakup.

In their first year at sea, chum salmon migrate to offshore waters of the North Pacific Ocean and Bering Sea.

Adults return to fresh water during the period from June through September. Rates of movement during upstream migration vary greatly. Bakalla (1970) gives the following examples: "Yukon River chum salmon migrated at 80 km per day for the first 1,300 km and 56 km per day for the next 1,100 km. In the Amur River, USSR, the average rate of migration was 115 km per day. In some rivers of Japan where spawning grounds are much closer to the sea, the average rate of travel was 1.9 to 4.2 km per day." Bulklis and Barton (1984), in summarizing several fall chum salmon studies at different locations of the Yukon River system, showed estimates of average upstream migration rates to range from 28 to 39 km per day. They suggested that 37 km per day was the best average migration rate for Yukon River fall chum salmon.

C. Migration Routes

Rivers serve as corridors for smolt out-migration. Adult upstream migration may be hindered or prevented by excess turbidity, high temperatures (20.0°C or more), sustained high water velocities (greater than 2.44m/sec), and blockage of streams (e.g., log jams, beaver dams, and waterfalls) (Reiser and Bjornn 1979).

Once in the sea, the young chum salmon remain close to shore (within 37 to 55 km of the shoreline) during July, August, and September before dispersing into the open ocean (Morrow 1980, Neave et al. 1976). During this time, stocks found along the northern coast of the Gulf of Alaska and south of the Alaska Peninsula probably migrate westward. Stocks found north of the Alaska Peninsula probably move to the southwest (Neave et al. 1976).

From tagging studies, Neave et al. (1976) summarize maturing Alaskan chum salmon movements as follows: "Maturing chums of western Alaskan origin occupy the entire Gulf of Alaska in spring and were found westward along the Aleutians to 179°E. There was no tagging evidence of the presence of Alaskan chums in the Bering Sea before June. The recovery in the Yukon River of a maturing fish tagged in July at 60°N, 174°E, not far from the U.S.S.R. coast, constitutes the westernmost record of a north American chum salmon, as revealed by tagging. Other chums, tagged in the Gulf of Alaska, were found to travel as far north as the Arctic Ocean. The direction of movement in the Gulf of Alaska is westward in

April-June. In the latter month most of the fish pass through the eastern part of the Aleutian Chain and migrate rapidly northward in the Bering Sea. No significant penetration of the Bering Sea by immature fish (from the Gulf of Alaska) was disclosed.
Maturing chum salmon originating in central and southeastern Alaska occupy a large part of the Gulf of Alaska in spring but were rarely found west of 155°W. From May to July the fish tend to shift northward into waters from which western Alaska chums have largely withdrawn. Some immature fish move westward along the Aleutians to at least 177°W. No significant penetration of the Bering Sea by immature or maturing fish was indicated."

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

The period the eggs and alevin spend in the gravel is a time of heavy mortality. The survival rate from eggs to fry in natural streams averages less than 10% (Hale 1981).

Scott and Crossman (1973) state that "young chum salmon on the spawning grounds and during downstream migration are preyed upon by cutthroat and rainbow trout, Dolly Varden, coho salmon smolts, and sculpins. . . . kingfisher, merganser, other predaceous birds, and mammals are also responsible for a small loss. Even stonefly larvae and possibly other predaceous insects many prey on eggs and alevins. Water temperature, floods, droughts, other fluctuations in water level, spawning competition, and poor returns of adults, control number of young to a far greater extent." Barton (pers. comm.) states that there is often heavy predation on eggs of spawning fall chum salmon by arctic grayling and mallard ducks in such Yukon River drainage systems as the Delta, Sheenjek, and Toklat rivers.

Murphy (1985) documents the die-off of prespawn adult chum salmon in Porcupine Creek on Etolin Island in Southeast Alaska. The fishes' migration route to spawning areas was blocked at the intertidal stream reach by low stream flow and neap tides. Within four days, about 3,000 pink and chum samlon had collected in a large pool in the intertidal reach of the stream. The crowded fish lowered the dissolved oxygen level to less than 2 mg/l, and some salmon began to die in the center of the pool.

At sea, chum salmon are preyed upon by marine mammals, lampreys, and, in the early sea life, possibly by large fishes. Upon returning to fresh water to spawn, adults fall prey to bears, eagles, osprey, and other mammals (Scott and Crossman 1973).

B. Human-related

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

- Alteration of preferred water temperatures, 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

1. The Alaska Board of Fisheries develops regulations governing the commercial, sport, and subsistence harvest of salmon in Alaska. The Alaska Department of Fish and Game manages salmon populations in the fresh waters of the state and in the marine waters to the 3-mi limit.
2. 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 managment plans that 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.
3. The International North Pacific Fisheries Commission is a convention comprised of Canada, Japan, and the United States 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 (beyond the 200-mi limit) areas may be fished by Japanese nationals and fishing vessels.

IX. LIMITATIONS OF INFORMATION

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

X. SPECIAL CONSIDERATIONS

Caution must be used when extending information from one stock of chum salmon to another stock. Environmental conditions from one area must not be treated as absolute; the stocks (races) have acclimated or evolved over time and space to habitat conditions that can vary greatly.

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