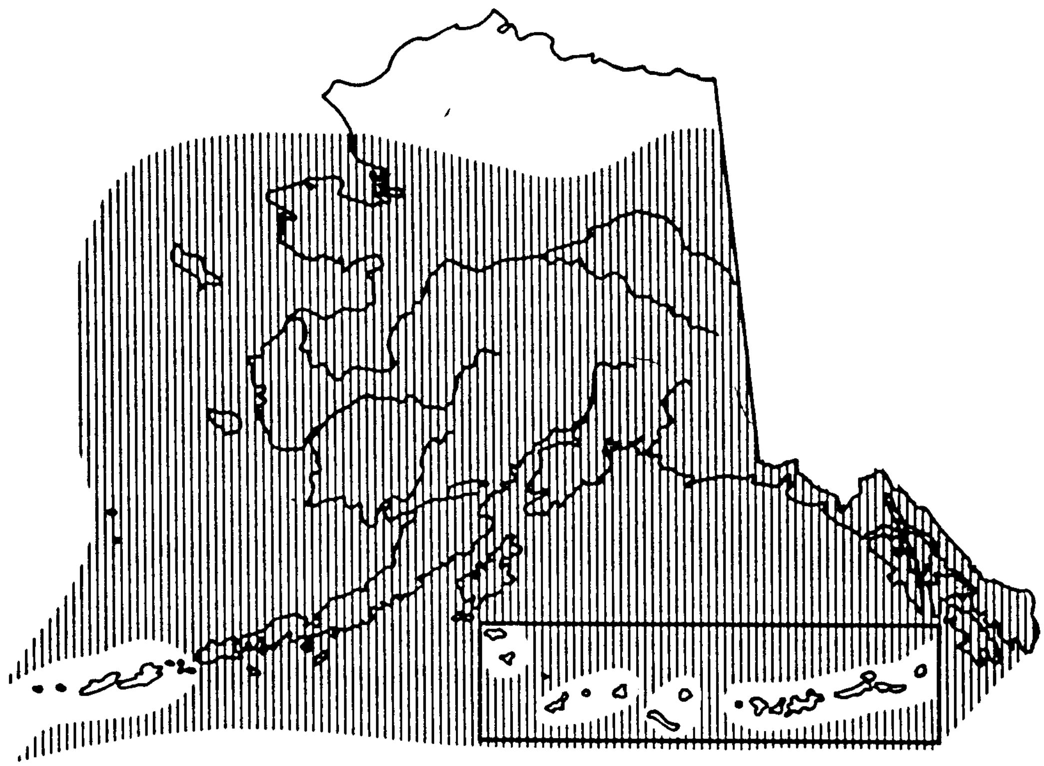
Chinook Salmon Life History and Habitat Requirements
Southwest, Southcentral, Arctic, Western, and Interior Regions



Map 1. Range of chinook salmon (ADF&G 1978, Holmes 1982)

I. NAME:
   A. Common Names: Chinook salmon, king salmon, spring salmon, tyee, tule, quinnat, blackmouth
   B. Scientific Name: *Oncorhynchus tshawytscha*
   C. Native Names: See appendix A.

II. RANGE
   A. Worldwide

Chinook salmon are native to the Pacific coasts of Asia and North America, and, except for areas immediately adjacent to the coast, it is possible that they do not occur on the high seas south of about 40°N (Major et al. 1978). In North America, spawning populations range from the Ventura River, California, northward to the Wulik River, Kotzebue Sound, Alaska. Along the Asian coast, they are found from the Anadyr River, Siberia, south to the Amur River, and they occur in the Komandorskie Islands, USSR, and at Hokkaido Island, Japan (Hart 1973, Major et al. 1978).

B. Statewide

Chinook salmon are found in major river drainages from Southeast Alaska to the Wulik River, Kotzebue Sound, Alaska (Major et al. 1978). During an Aleutian Islands salmon study, Holmes (1982) found that there were no systems in the Aleutian Islands (from Unimak Pass to Attu Island) that would provide for spawning and rearing of chinook salmon.

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, chinook 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, major chinook salmon spawning and rearing drainages include the Karluk and Red river systems (ADF&G 1977b).

   In the Bristol Bay area (for waters from Cape Newenham to Cape Menshikof and north-side Alaska Peninsula streams south to Cape Sarichef), major chinook-producing drainages include the Togiak, Wood, Nushagak, Mulchatna, Alagnak (Branch), and Naknek rivers. Other Bristol Bay drainages supporting lesser runs of chinook salmon include the Egegik, Ugashik, Meshik, Cinder, and Sapsuk rivers (ADF&G 1977a).

   Streams on the Alaska Peninsula (south and west of Moffet Bay) and the Aleutian Islands appear to be unsuitable for supporting chinook salmon (ADF&G 1977a, Holmes 1982). Chinook salmon are found in one drainage on the south side of the Alaska Peninsula: the Chignik River system (ADF&G 1977a). (For more detailed narrative information, see volume 1 of the Alaska Habitat Management Guide for the Southwest Region.)

2. Southcentral. In the Cook Inlet area, major chinook spawning and rearing drainages include the Susitna, Kenai, and Kasilof river drainages. In the Prince Williams Sound area, the Copper River drainage accounts for most of the chinook salmon production (ADF&G 1977b, 1978a). (For more detailed narrative information, see volume 2 of the Alaska Habitat Management Guide for the Southcentral Region.)

3. Arctic. The presence of chinook salmon has been documented in 13 first-order streams (those with mouths at salt water) within the Norton Sound District (ADF&G 1984). Although other important chinook salmon-producing systems exist in the

area, the Unalakleet River drainage and the Shaktoolik River are considered the major chinook salmon producers in the district (Schwarz, pers. comm.).

Within the Port Clarence District, chinook salmon have been documented in the Kuzitrin River system (ADF&G 1984).

In the Kotzebue District, chinook salmon have been documented in the Buckland, Kobuk, Noatak, Wulik, and Kivalina rivers (ibid.).

Within the Northern District, chinook salmon have been documented in the Kuk and Colville rivers; however, in these systems they are considered strays (Hablett 1979, Bendock and Burr 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 chinook salmon. Important Western Region chinook salmon-producing waters of the Kuskokwim River system (i.e., those tributaries located downstream of and including the Holitna River drainage) include the Kwethluk, Kisaralik, Aniak, Salmon (Aniak River tributary), Kipchuk, Tuluksak, Chukowan, Kogrukluk, Holitna, Hoholitna, Kasigluk, Eek, George, Oskawalik, Holokuk, and Cheeneetnuk rivers (ADF&G 1977c, 1978b, 1983). Within the Yukon River system, the Andreafsky River is a major chinook salmon producer of the Western Region (i.e., of those tributaries located downstream of the village of Paimuit) (ADF&G 1977c, Barton 1984). Other known chinook salmon spawning systems of the Western Region include the Kanektok, Arolik, and Goodnews rivers (ADF&G 1977c, 1983). They are located south of the mouth of the Kuskokwim River. (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 chinook salmon bound for spawning areas in the Interior Region. Important chinook-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 Salmon (tributary of Pitka Fork of Middle Fork Kuskokwim River), Tatlawiksuk, Gagaryah, Big Salmon Fork (tributary of South Fork Kuskokwim River), and Nixon Fork (tributary of Tokotna River) rivers, and Bear Creek (a tributary of the Salmon River that flows into the Pitka Fork of the Middle Fork Kuskokwim River) (ADF&G 1983). Chinook salmon are present in nearly all of the major Yukon River tributaries of the Interior Region (i.e., those upstream of the village of Paimuit) (ADF&G 1977c). A few of these systems include the Anvik, Innoko, Nulato, Rodo, Tozitna, Gisasa, Hogatza, Alatna, Koyukuk, Chandalar, Sheenjek, Porcupine, Black,

Tanana, Kantishna, Toklat, Chatanika, Salcha, Chena, Delta, and Goodpaster rivers (ibid.). Of these, the Anvik, Nulato, Salcha, and Chena rivers are major chinook salmon spawning streams (Barton 1984). (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. Water temperature requirements play an important role in the chinook salmon life cycle and encompass an extremely wide range of temperatures, 0 to 25°C. The ability to survive within this temperature range and specific requirements, however, vary by life stage (i.e., egg, alevin, juvenile, and adult), the temperature to which the fish have been acclimated, and adaptations that specific stocks have made over the course of their evolutionary history. The results of several field and laboratory studies are provided in the following paragraphs.

Egg hatching and alevin development have occurred under a variety of temperature regimes in hatchery and laboratory conditions. Combs and Burrows (1957) found that 100% mortality of eggs from Entiat River and Skagit River Washington stocks occurred when water temperatures in laboratory tests remained constantly at 1.7°C; and they established a temperature range of 5.8 to 14.2°C for normal development if the temperatures remained constant throughout incubation, a situation not likely to occur under natural conditions. In later experiments, Combs (1965) found that Entiat River chinook salmon eggs that had developed to the 128-cell, or early blastula, stage in 5.8°C water could tolerate 1.7°C water for the remainder of the incubation period, with only normal losses. The 128-cell stage was attained after eggs had been incubated for 144 hours in 5.8°C water.

Alderdice and Velson (1978) assembled data from the literature and analyzed the relations between incubation temperature and rate of development from fertilization to 50% hatch of the eggs. They found that early imposition of low (below 6 to 7°C), constant (having a range around a mean not greater than 2°C) temperatures appears to slow egg development below those rates occurring at ambient (average daily temperatures with ranges around a mean greater than 2°C) temperatures having the same mean values. Information in these analyses included constant temperature values ranging from 1.6 to 18.1°C and ambient temperature values ranging from 2.3 to 16.4°C (ibid.).

The juvenile (including fry, fingerling, and parr stages of development) upper lethal limit was found to be 25.1°C under laboratory conditions (Brett 1952). During the same experiment, he found that young chinook salmon were very sensitive to low temperatures. The lower lethal temperature, however, could not be precisely defined because it appears to be conditioned by the size of the juvenile, the temperature to which the juvenile has been acclimated, the length of time it is exposed to low temperatures, and the osmotic balance. For young chinook salmon from Dungeness, Washington, hatchery stocks acclimated to 23°C, the lower lethal temperature was 7.4°C.

Chinook salmon eggs were hatched at the ADF&G Crooked Creek Hatchery near Soldotna, Alaska, in waters with gradually decreasing, fluctuating mean daily temperatures ranging from 11.1 to 4.4°C (in 1981) and 11.7 to 6.7°C (in 1982). Within five weeks after hatching, the water temperature dropped to 0°C. The alevin were successfully incubated at this temperature and within 4.5 months had absorbed their yolk sacs. The fry were then transferred to rearing ponds that contained 0°C waters, and feeding was begun. During both years, the pond water temperatures remained at 0°C for at least 70 days following the introduction of the fry. During this time, the young fish fed and grew (Och, pers. comm.).

Adult spawning studies in the Columbia River watershed revealed that temperatures at redd sites ranged from 8.3 to 11.7°C, 4.4 to 16.7°C, and 5.6 to 16.1°C for the spring, summer, and fall runs, respectively (Burner 1951). Burrows (1960) indicates that Columbia River female chinook salmon in holding ponds apparently lost all inclination to spawn naturally when the water temperature dropped abruptly below 4.4°C.

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 specify 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). Silver et al. (1963), during laboratory studies, found that low (1.6 ppm) dissolved oxygen concentrations caused total mortality of chinook embryos in 11°C waters flowing at rates of 82,570 and 1,310 cm/hr. They also found that oxygen concentrations of 2.5 ppm and more (3.5, 5.6, and 8.0 ppm) resulted in low prehatching mortalities similar to controls reared at 11.7 ppm. Further, embryos reared to hatching at low and intermediate (2.5 to 8.0 ppm) concentrations produced smaller sacfry than did embryos reared at high (11.7 ppm) concentrations.

Whitmore et al. (1960) noted that juvenile chinook salmon showed marked avoidance of mean oxygen concentrations near 1.5, 3.0, and 4.5 ppm in laboratory experiments when summer water temperatures were high (means of 18.4 to 22.8°C). They also noted that juvenile chinook salmon showed little avoidance of concentrations near 4.5 ppm in the fall when water temperatures were low (means of 8.1 to 13.2°C) and that no avoidance of concentrations near 6.0 ppm occurred regardless of the temperature range.

Adult swimming performance is adversely affected by reduction of D.O. concentrations below air saturation level. Bell (1973) states that it is desirable that D.O. concentrations be at or near saturation and that it is especially important in spawning areas where D.O. levels must not be below 7 ppm at any time. 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."

d. Turbidity. Sedimentation causes high mortality in 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. 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 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.). Juveniles are closely associated with low (3.0-60.0 cm/sec, depending on fish size) velocities and are typically found in pools along the margins of riffles or current eddies (Burger et al. 1983: Kenai River). Kissner (1976), during studies on the meandering Nahlin River (in the Taku River drainage of Southeast Alaska), found that the highest densities of juvenile chinook salmon were located on the steep sides of S-curves below riffles. Measured depths of juvenile rearing areas range from 0.15 to 0.30 m in Idaho (Everest and Chapman 1972), with water velocities of less than .5 m/sec. Burger et al. (1983) indicate that juvenile chinook salmon utilize depths up to 3 m when water velocities are not limiting and avoid depths less than 6.0 cm during their free-swimming stage.

Velocity is also important to juveniles because it is the most important parameter in determining the distribution of aquatic invertebrates (food sources) in streams (Reiser and Bjornn 1979).

Excessive velocities and shallow water may impede migrating fish. Thompson (1972) indicates that Pacific Northwest chinook salmon require a minimum depth of .24 m, with velocities less than 2.44 m/sec for migration. No measurement of Alaskan waters for adult migration criteria is available.

Velocity is also important in redd construction because the water carries dislodged substrate materials from the nesting site. Measured flow rates at 0.12 m above the streambed include 0.186 to 0.805 m/sec in Oregon and 0.305 to 1.144 m/sec in the Columbia River tributaries (Smith 1973). Minimum water depths at the spawning sites ranged from 0.183 to 0.305 m in Oregon and 0.381 to 1.983 m in Columbia River tributaries (ibid.). Burger et al. (1983), in a Kenai River tributary stream, found redds at depths from 61.0 to 70.2 cm. Their velocity measurements at 0.6 of total depth had mean values of 39.6 to 94.5 cm/sec pit velocity and 70.2 to 115.9 cm/sec tailspill velocity. Burger et al. (1983) also suggest that mainstream spawning might occur in depths from 1.0 to 2.8 m, with velocities near the bottom (0.2 total depth) ranging from 0.3 to 1.4 m/sec. Vincent-Lang et al. (1983) determined from studies of four Susitna River tributary streams that suitable chinook salmon spawning depths ranged from 0.15 to 1.22 m, with depths of 0.3 to 0.48 being most often used in the study areas. Suitable mean water column velocities as measured at the upstream end of each redd ranged from 0.09 to 1.37 m/sec, with velocities of 0.5 to 0.7 m/sec being most often used. Water velocities in these studies were measured at 0.6 of the total depth (from the surface of the water) if the total depth was less than 0.76 m. If total depths exceeded 0.76 m, measurements were made at 0.2 and 0.8 of the total depth (from the surface) and then averaged. Mean velocities less than 0.09 m/sec were not utilized for spawning, and those greater than 1.37 m/sec were considered unsuitable for spawning (ibid.).

3. Substrate. Egg incubation and alevin development occur in substrates ranging widely in size and composition. Successful growth and emergence has been recorded in areas with the following bottom materials:
   - 1.9 to 10.2 cm diameter materials (Bell 1973)
   - 5% mud/silt/sand, 80% 15.2 cm in diameter to heavy sand, 15% larger than 15.2 cm diameter (averages of Burner 1951: Columbia River tributaries)
   - 11.3% less than 0.8 cm, 28.7% 0.8 to 1.6 cm, 45% 6.4 to 1.6 cm, 15% 12.7 to 6.4 cm (mean values of Burger et al. 1983: Kenai River tributary)
   - 15.5% less than 0.8 cm, 17.9% 1.6 to 0.8 cm, 46.4% 6.4 to 1.6 cm, 20.2% 12.7 to 6.4 cm (mean values of Burger et al. 1983: Kenai River mainstream)

   Generally, sediments less than .64 cm diameter should comprise less than 20 to 25% of the incubation substrate (Reiser and Bjornn 1979).

   Substrate composition regulates production of invertebrates, which are food sources for juveniles. Highest production is from gravel and rubble-size materials associated with riffle areas (ibid.). Substrate is important to juveniles during winter months when temperatures fall and the streambed becomes partially dewatered. During this period, many juvenile chinook salmon burrow into the substrate (Bjornn 1971, Edmundson et al. 1968: in Idaho) and do not begin growing again until the following spring (Everest and Chapman 1972). Studies on the Kenai River from late fall to early spring found juvenile chinook salmon throughout reaches with large cobble substrate and water velocities under 30 cm/sec. In river sections without large substrate materials, chinook salmon were observed to school in pool-riffle interfaces and remained close to cover such as log debris and/or surface ice, if these were present (Burger et al. 1983).

B. Terrestrial

1. Conditions providing security from predators or other disturbances. Overhanging vegetation along shorelines and undercut banks serves as cover for juveniles and adults during spring and summer high-flow conditions. At other times, many (49 to 52%) of the juveniles were found within one swimming burst of cover provided by overhanging banks, tree stumps and branches, and large boulders (ibid.).

2. Protection from natural elements. Bank irregularities provide small pools and current eddies, with little or no

velocities, for rearing juveniles (ibid.). Kissner (1977) found that juvenile chinook salmon were closely associated with log jams and cover in the main channels of the Taku River and in places where the river braided and the water was shallow.

IV. NUTRITIONAL REQUIREMENTS

A. Food Species Used

Upon hatching, young alevin remain in the gravel for two to three weeks until the yolk sac has been absorbed. Following emergence from the redd and while still in fresh water, juveniles feed on plankton, aquatic insect larvae, terrestrial insects, salmon eggs, and spiders (Scott and Crossman 1973, McLean et al. 1977). They are characterized as opportunistic drift and benthic feeders (Beauchamp et al. 1983). Juvenile chinook salmon food habitat studies during August and September in sloughs and clearwater tributaries of the middle reach of the Susitna River suggest that the range and diversity of invertebrates in their diet indicate an ability to adopt to variable conditions (ADF&G 1982). Specimens collected during the study had consumed both terrestrial and aquatic invertebrates. Midges (Diptera: Chironomidae) were the numerically dominant taxa and were consumed as larvae, pupae, and adults. Chironomid adults and terrestrial invertebrates caught on the water surface, as opposed to immature insects drifting in the water column, were often an important food item for juvenile chinook salmon (ibid.). Upon migration to the sea, young chinook salmon eat crab larvae, amphipods, copepods, euphasiids, cladocerans, barnacles, and a variety of small fish, such as sand lance, eulachon, herring, rockfish, and smooth tongue (Hart 1973). Adults eat fish, squid, euphasiids, shrimps, and crab larvae (Major 1978). Fishes make up the bulk (97%) of the food of marine adults, with herring and sand lance being the most frequently eaten (Scott and Crossman 1973). Crustaceans (composed dominantly of euphasiids but including young crabs, crab megalops, and other miscellaneous forms) are eaten in considerable numbers in the spring months (May and June), as documented by Prakash (1962) in studies off the coast of British Columbia. Merkel (1957) made a similar finding for chinook salmon in the marine waters near San Francisco, California, where euphasiids dominated the diet during April and May. Major (1978) suggests that the diet of adult chinook salmon at sea is related to the types and abundance of food items available.

B. Types of Feeding Areas Used

Juveniles feed in low-velocity areas of streams and rivers, such as riverbank pools formed by bank irregularities (Burger et al. 1983) and in the pools below riffles, where drifting invertebrate material provides a ready food supply. During the first year at sea, the young fish stay near shore. During the second and subsequent years, chinook salmon are far-ranging, undertake extensive migrations, and are found over a wide range of depths, from surface waters to depths exceeding 100 m. It is not unusual to encounter them at depths ranging from 20 to 110 m (Major 1978).

C. Factors Limiting Availability of Food

Sedimentation is one of the major factors that affects freshwater food availability. Excessive sedimentation may inhibit production of aquatic plants and invertebrate fauna (Hall and McKay 1983). Bell (1973) states that primary food production is lowered above levels of 25 JTU (Jackson Turbidity Unit) and visual references lost above levels of 30 JTU.

D. Feeding Behavior

Chinook salmon are opportunistic feeders. Food consumption is related directly to the types and abundance of items available (Major 1978), although juvenile chinook salmon in fresh water do not seem to utilize fish as food (Scott and Crossman 1973, Morrow 1980). Upon returning to fresh water, adult salmon no longer feed but live off the fat stored up in the ocean (Netboy 1974).

V. REPRODUCTIVE CHARACTERISTICS

A. Breeding Habitat

The general nature of the spawning ground, which may be located from just above tidal limits to great distances upstream (over 3,200 km in the Yukon River), varies considerably (Mayor 1978). Main channels and tributaries of larger rivers serve as the major chinook spawning areas (Scott and Crossman 1973). Normally, the spawning grounds are characterized by stream underflow (downwelling currents or intragravel flow) created by the depth and velocity of the water, rather than being associated with the emergence of groundwater (Vronskiy 1972, Burner 1951). Vronskiy found that 95% of the redds in the Kamchatka River, USSR, were situated precisely at the transition between a pool and a riffle. Burger (1983) found that many chinook salmon redds were located near the upstream tips of vegetated islands in the Kenai River where loose, clean gravels aggraded and where predominant substrates ranged from 1.6 to 6.4 cm diameter materials. Areas just below log jams, where flow through the gravel is increased as a consequence of reduced surface flow, are also favorite spawning sites (Major 1978).

Exceptions to what may be considered normal breeding habitat and behavior have been documented. During late October and early November 1965, approximately 50 chinook salmon from University of Washington hatchery stocks spawned in groundwater seepage areas of gravel and sand beaches in Lake Washington (Roberson 1967). This behavior is believed to have resulted from crowding and high water temperatures, both unfavorable conditions, at the hatchery homing pond. Although the returns were similar in 1964, 1965, and 1966, the biomass in 1965 was 1.81 and 1.82 times that in 1964 and 1966, respectively. A decline in the rate of entry was noted in 1965, when water temperatures rose to about 14.4°C during peak entry. In 1965 and 1966, the water temperature dropped from about 14.4 to 11.1°C during the entry period. Also, during the 1965 return, the water temperatures remained .6 to 1.4°C warmer for the remainder of the run than during the same time frames in 1964 and 1966. A sample of several redds, approximately two weeks after spawning had occurred, revealed that, of all eggs recovered, most had been fertilized, but all were dead (ibid.).

B. Breeding Seasonality

In Alaska, mature chinook salmon ascend the rivers from May through July. Generally, fish that appear at the river mouth earliest migrate farthest (Scott and Crossman 1973). Peak spawning occurs from July through September (Morrow 1980).

C. Breeding Behavior

As with other salmon, adult chinook salmon return from the sea and normally 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 loosened substrate material downstream, and a depression 35 to 60 cm deep is formed in the river bottom (Burner 1951, Morrow 1980, Major 1978). 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 1.3 to 5.6 m in length and 1.5 to 3.3 m wide (Morrow 1980, Burger et al. 1983). A female may dig several redds and spawn with more than one male (McPhail and Lindsey 1970). Males may also spawn with several females (ADF&G 1977, Morrow 1980).

D. Age at Sexual Maturity

The age at which chinook salmon reach sexual maturity ranges from two to eight years (generally zero to two years in fresh water and one to seven years at sea), although the vast majority of the fish mature in their third to sixth year. Age at maturity, like freshwater age and ocean age, tends to be greater in the north than in the south because more northern populations spend a longer time at sea (Major 1978, Scott and Crossman 1973). From California northward to Cook Inlet, Alaska, for example, three, four, and five-year-old fish prevail (there are significant numbers of six-year-olds in some areas, but few if any seven-or eight-year-olds). Five-and six-year-olds dominate runs from Bristol Bay northward, but seven- and eight-year-olds are not uncommon (Major 1978).

E. Fecundity

Chinook salmon fecundity varies by stock and the size of the female; however, northern stocks generally produce more eggs. In Alaska, the number of eggs ranges from 4,242 to 17,255 per female (Morrow 1980, Burger et al. 1983).

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 and 7) configuration, 8) water depth, 9) surface water discharge and velocity, 10) permeability, 11) porosity, and 12) light (Reiser and Bjorhn 1979, Hart 1973). Generally speaking, factors 4 through 12 influence/regulate the key factors 1, 2, and 3.

Eggs require about 900 temperature units (TU) to hatch and become alevins and an additional 200 to 800 TUs to absorb their yolk sac (Burger et al. 1983). The TUs for one day = mean 24-hour water temperature in degrees Farenheit - 32°F + 1°F if the mean temperature is 32°F. Incubation of the eggs takes place with both ascending and descending water temperatures (Scott and Crossman 1973). Depending on the time of spawning and the water temperature, the eggs usually hatch in late winter or early spring (Gusey 1979). The newly hatched fish, or alevins, remain in the gravel until the attached yolk sac has been absorbed, normally two to three weeks after hatching. The juveniles then work their way up through the gravel to become free-swimming, feeding fry (Morrow 1980).

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). Burger et al. (1983) list mean measurements for a Kenai River tributary stream, indicating that chinook salmon redds are about 4.37 m^2 in size. Mean values for mainstream Kenai River chinook salmon redds, however, are 6.38 m^2. Vining et al. (1985), from chum salmon incubation studies of main stem, tributary, side channel, and slough habitats within the middle reach of the Susitna River, Alaska, caution that because of the effects of dewatering and freezing, the amount of available habitat at the time when adult 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

Young-of-the-year juveniles move downstream in the fall to overwinter in areas of the stream with larger substrate (possibly because it provides better cover) (Bjornn 1971, Burger et al. 1983). Out-migrating smolt bound for the sea depart fresh water in the springtime. Major and Mighell (1969), during studies on the Yakima River, Washington, noted that smolt out-migrations tended to be nocturnal. Where known, Alaska specific timing information is contained in the salmon Distribution and Abundance narratives found in this report series.

Adults return to fresh water during the period of May through July. Studies on the Kenai River (Burger et al. 1983) indicate that of all radio-tagged adults returning to the spawning grounds, most moved between 1400 and 2200 hours. Neave (1943), during studies of the Cowichan River, Vancouver Island, British Columbia, found that adult chinook salmon moved upstream mainly in the daytime.

C. Migration Routes

Large rivers serve as corridors for smolt out-migration. Barriers to adult upstream movement include excess turbidity, high temperatures (20.0°C or more), sustained high-water velocities, and blockage of streams (log jams, waterfalls) (Reiser and Bjornn 1979). While in the marine environment, first-year ocean fish are confined primarily to coastal areas and are much less abundant in the open ocean (Major 1978). During the second and subsequent years of ocean life, they are found widely distributed in the North Pacific Ocean and Bering Sea. Morrow (1980) states that chinook salmon from Alaskan streams enter the Gulf of Alaska gyre and move extensively across the North Pacific. In the spring, they seem to be scattered across the northern Pacific and in the Bering Sea, and during the summer their numbers increase in the area of the Aleutian Islands and in the western Gulf of Alaska. Many of the inshore fish of Southeast Alaska, however, appear to be of local origin (Morrow 1980).

Major (1978) suggests that except for areas immediately adjacent to the coast it is possible that chinook salmon do not occur in the high seas south of 40°N. The central Bering Sea is a feeding ground and migration path for immature chinook salmon in Western Alaska (defined as the area from and including Bristol Bay northward to Point Hope). Tag recoveries are known to occur in the Bering Sea as far west as 172°12'E (at 59°03'N), whereas scale-pattern and maturity studies, combined with seasonal distribution and Japanese mothership and research vessels information, push the range further west, to probably at least 160° to 165°E (Major 1978). These same stocks have been found as matures in the North Pacific Ocean just south of Adak at 176°18'W (at 51°36'N). Scale-pattern analysis shows tentatively that they may extend from 160°-170°E to at least 175° W; but their distribution to the south over this range, at least beyond 50° N, is even more uncertain (ibid.).

Other North American chinook salmon (including stocks from central Alaska [Cook Inlet] southward) are known to occur as immatures in the North Pacific Ocean as far west as 176°34'W (at 51°29'W) (ibid.). Recent coded-wire tag recoveries of chinook salmon marked in Oregon, Southeast Alaska (Stikine River and Little Port Walter), and Southcentral Alaska (Crooked Creek, a tributary of the Kasilof River on the Kenai Peninsula) indicate that these stocks occur in the southeastern Bering Sea north of the Alaska Peninsula (Meyers et al. 1984). Tag recoveries occurred during the months of November, February, April, and May in an area from 54°21' to 55°26'N and 165°21' to 167°58'W (ibid.). The tag recovery of the Crooked Creek fish at 55°26'N, 167°58'W was a definite range extension of Southcentral Alaska chinook salmon stocks into the Bering Sea (Wertheimer and Dahlberg 1983).

VII. FACTORS INFLUENCING POPULATIONS

A. Natural

Juvenile chinook salmon are preyed on by other fish (e.g., rainbow, cutthroat, Dolly Varden, coho salmon smolts, and sculpins) and birds (e.g., mergansers, king fishers, terns, osprey, other diving birds). Estuarine and marine predators include fish-eating birds, pelagic fishes, killer whales, seals, sea lions, and possibly the Pacific lamprey (Scott and Crossman 1973, Beuchamp et al. 1983).

The greatest natural mortality occurs in fresh water during the early life stages and is greatly influenced by the environment (Straty 1981); therefore, deleterious changes in freshwater quality, quantity, or substrate are most detrimental.

Flooding can either wash away or bury eggs. Natural sedimentation can smother eggs.

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, vegetation, or large rocks)
- Obstruction of migration routes
- 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 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, 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, 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.

3. 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, exchanges, 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. SPECIAL CONSIDERATIONS

Caution must be used when extending information from one stock of chinook salmon to another stock. Environmental conditions for 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.

X. LIMITATIONS OF INFORMATION

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

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