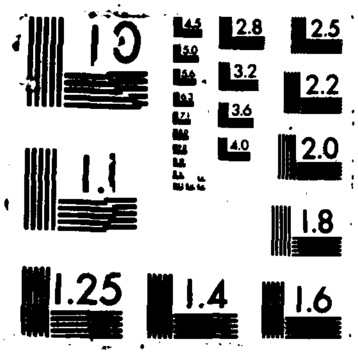
AD-A147 263 SPECIES PROFILES: LIFE HISORIES AND ENVIRONMENTAL 1/1
REQUIREMENTS OF COASTA (U) WASHINGTON COOPERATIVE
FISHERY RESEARCH UNIT SEATTLE D A BEAUCHAMP ET AL

UNCLASSIFIED OCT 83 FWS/OBS-82/11 6 F/G 6/3 NL

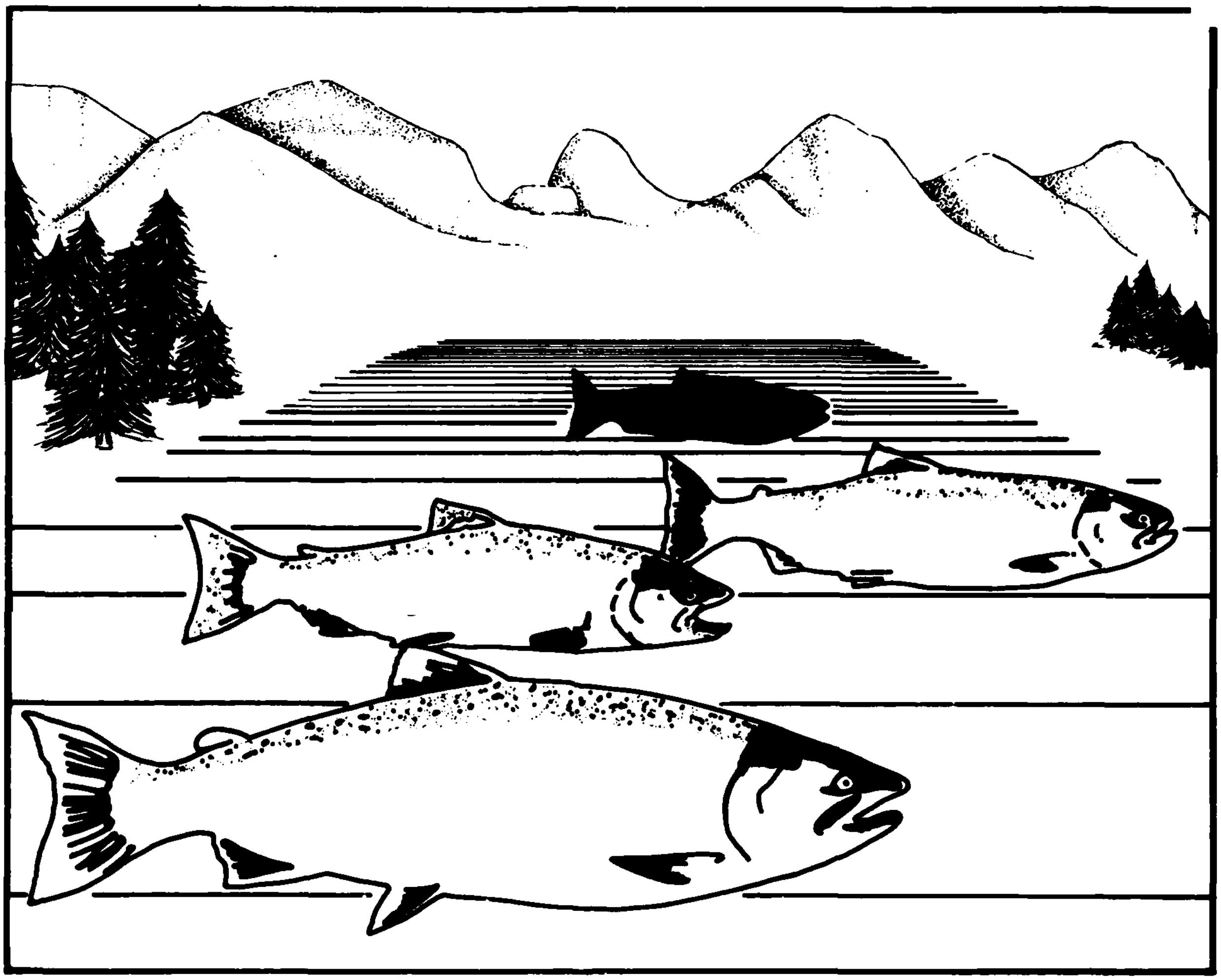

1.0
4.5
5.0
5.6
6.3
7.1
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

FWS/OBS-82/11.6
October 1983

TR EL-82-4

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

CHINOOK SALMON



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

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

FWS/OBS-82/11.6
TR EL-82-4
October 1983

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

CHINOOK SALMON

by

David A. Beauchamp, Michael F. Shepard
and Gilbert B. Pauley
Washington Cooperative Fishery Research Unit
School of Fisheries
University of Washington
Seattle, WA 98195

Project Manager
Larry Shanks
Project Officer
Norman Benson
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

This study was conducted
in cooperation with
Coastal Ecology Group
U.S. Army Corps of Engineers
Waterways Experiment Station

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

CONVERSION FACTORS

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (gm)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (mt)	2205.0	pounds
metric tons (mt)	1.102	short tons
kilocalories (kcal)	3.968	BTU
Celsius degrees	1.8(C°) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
BTU	0.2520	kilocalories
Fahrenheit degrees	0.5556(F° - 32)	Celsius degrees

CONTENTS

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to:

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

or

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

This series should be referenced as follows:

U.S. Fish and Wildlife Service. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11. U.S. Army Corps of Engineers, TR EL-82-4.

This profile should be cited as follows:

Beauchamp, D.A., M.F. Shepard, and G.B. Pauley. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) -- chinook salmon. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.6. U.S. Army Corps of Engineers, TR EL-82-4. 15 pp.

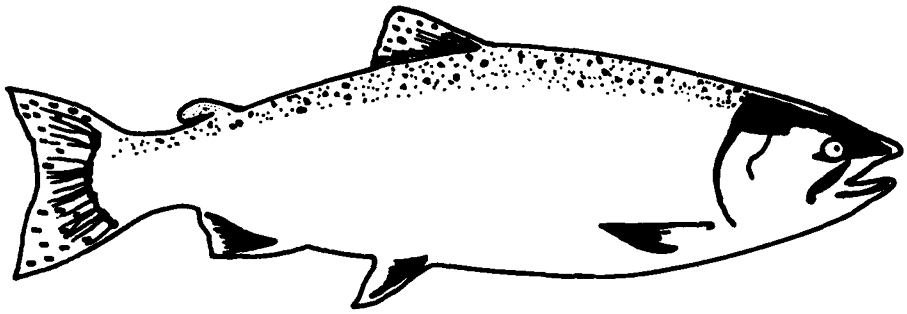


Figure 1. Chinook salmon.

CHINOOK SALMON

NOMENCLATURE/TAXONOMY/RANGE

Scientific name...Oncorhynchus tshawytscha (Walbaum) (Figure 1)
Preferred common name...Chinook salmon
Other common names........King salmon, tyee, spring, blackmouth (Haw and Buckley 1973)
Class......................Osteichthyes
Order.....................Salmoniformes
Family......................Salmonidae

Geographic range: Anadromous in larger rivers from San Francisco Bay north to Arctic waters of Alaska, Canada, and the Soviet Union. Populations occur in Asia as far south as the islands of Japan. Freshwater populations have been introduced into the Great Lakes. Major rivers supporting chinook salmon runs in the Northwest Pacific biogeographical region are shown in Figure 2. Migration patterns are shown in Figure 3.

MORPHOLOGY/IDENTIFICATION AIDS[1]

Morphology: Dorsal fin (10-14 rays), adipose stout and fleshy, anal (13-19), pelvic (10), abdominal with a free-tipped fleshy appendage above its insertion. Cycloid scales. Gill rakers (18-30) rough and widely spaced on first gill arch. Body elongate, moderate, lateral compression.

Identification aids: Tail moderately forked with stiff outer rays. Moderately large irregular black spots on back, upper sides, dorsal, adipose, and both lobes of the caudal fin. Black lower gumline. Juveniles: Parr marks appear as long vertical dark bars extending equally above and below the lateral line. Parr marks are wider than or equal to the width of spaces between marks.

---

[1]Extracted from Hart (1973).

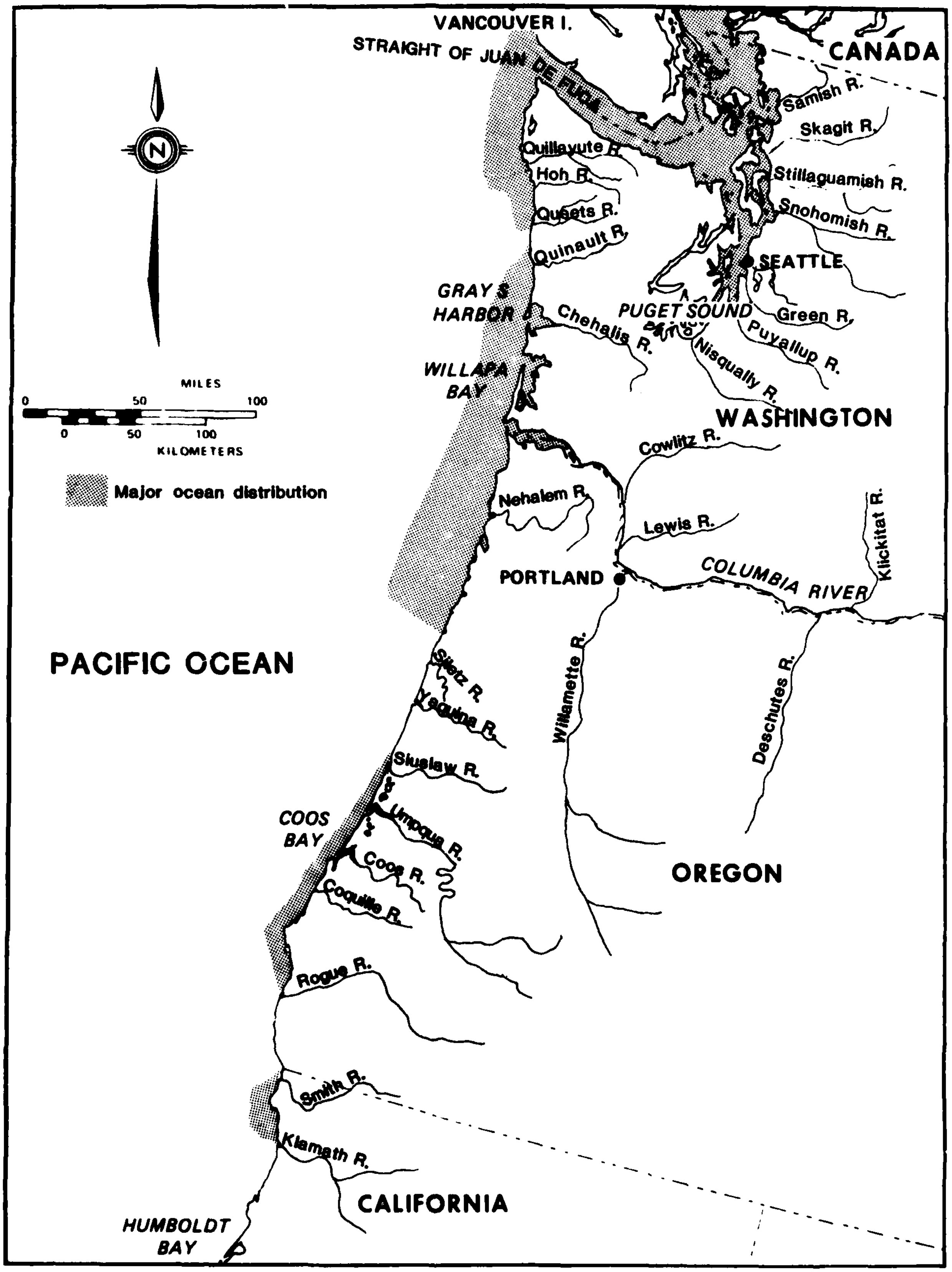


Figure 2. Major rivers and coastal areas supporting chinook salmon in the Pacific Northwest.

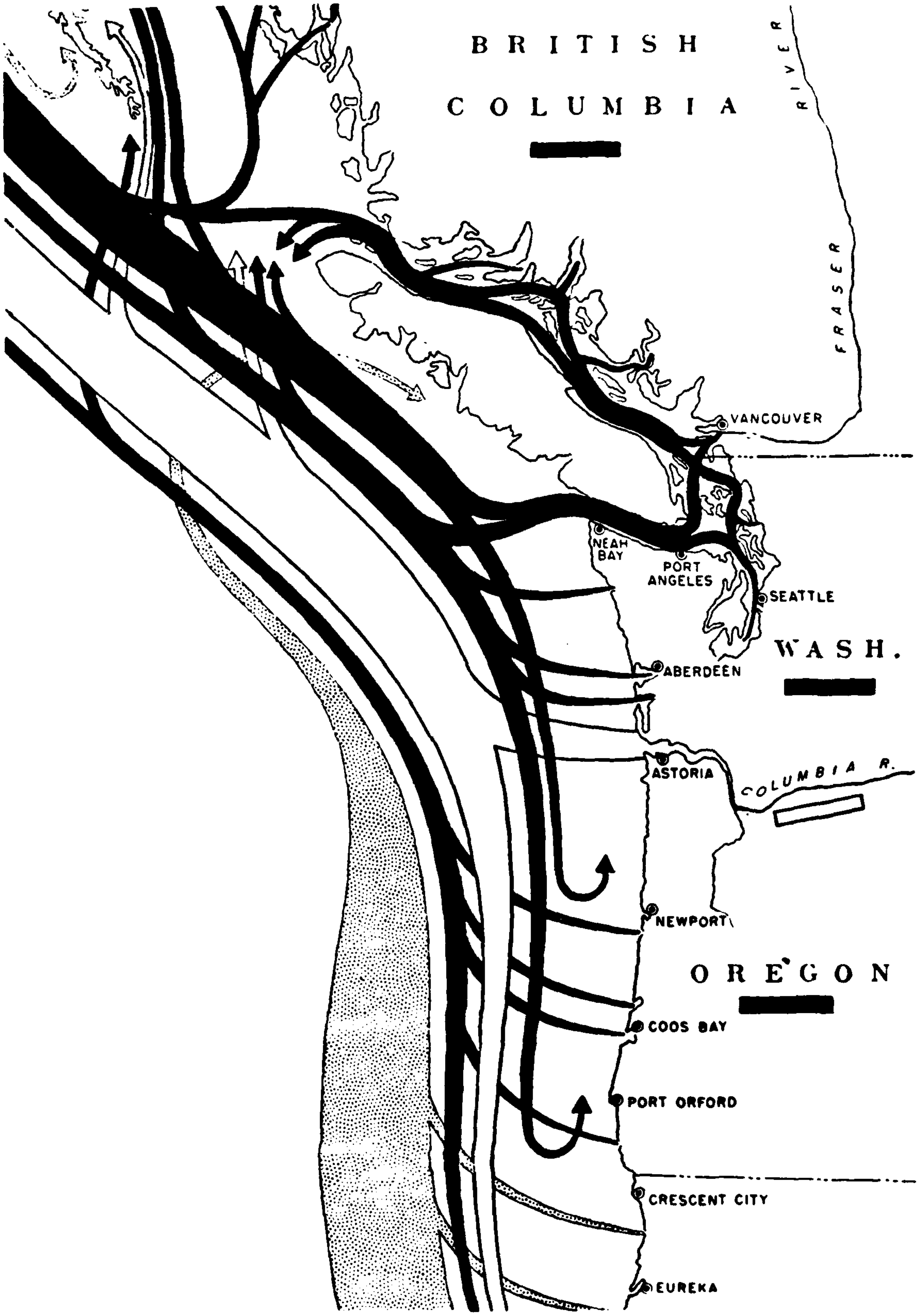


Figure 3. Migration patterns of chinook salmon from southern British Columbia to northern California (from Washington State Department of Fisheries 1959).

LIFE HISTORY

Spawning

Chinook salmon (Oncorhynchus tshawytscha) exhibit at least three distinct life history patterns. Spring chinook salmon populations occur in large river systems where enough flow is available over the summer to hold these fish. Spring-run fish may enter freshwater as early as February or March, but they usually spawn between August and November. These fish travel upstream slowly and remain for protracted periods in pools near the spawning grounds (Hodges and Gharrett 1949; Briggs 1953) and typically spawn in the upper reaches of rivers. Summer chinook salmon enter the rivers from late spring through midsummer and hold in the river until they spawn in the fall. Fall-run chinook salmon enter both large rivers and small coastal streams in autumn. They generally move rapidly during high water periods to the spawning areas and commence spawning activities (Briggs 1953). Complete spawning normally occurs within 7 days after the initial breeding activity. Males are attracted by females digging and testing the gravel. When the female is satisfied with her excavation site, spawning proceeds. The female deposits a portion of her ova in the gravel depression while one primary male and possibly several subdominant males move alongside simultaneously to fertilize the eggs. Following each of these spawning acts, the female moves directly upstream to dig a new depression, which also covers the eggs fertilized in the preceding act. Briggs (1953) reported that the average depth of productive redds was 203 mm (8 inches) to 356 mm (14 inches) beneath the surface of the stream bed. Columbia River chinook constructed redds from 1.2 m (4 ft) to 10.7 m (35 ft) in diameter (Chapman 1943). Nest building commences earliest in the uppermost reaches of the river and progresses sequentially downstream as river temperatures drop to the levels encountered by the upstream spawners (Mattson 1948; Cramer and Hammack 1952). When females have expended their ova, the males desert them and apparently search for additional matings until they are spawned out or die. Chinook slamon live 2 to 4 weeks after spawning. During this time, females will defend their redds and an area as wide as 6.1 m (20 ft) beyond the margin of the redd against other females, but they will normally ignore male chinook salmon (Briggs 1953).

Fecundity, Eggs, and Alevins

Female chinook salmon produce 3,000 to 6,000 eggs. Fecundity is size related, and higher in southern populations. Chinook salmon eggs are the largest of the Salmonidae (Rounsefell 1957). The eggs require an average of 882 to 991 temperature units for hatching (1 temperature unit = 1 degree Fahrenheit above freezing for a period of 24 hours), with fewer temperature units required for eggs incubated at lower temperatures (McKee 1950). During the incubation period, substantial mortality may be incurred by redd disturbances from overspawning, fluctuating flows, dewatering, freezing, isolation, suffocation, and microbial infestation. Depending upon the temperature regime of the natal stream, eggs hatch in the late fall or early winter. The alevins remain in the gravel for 4 to 6 weeks until the yolk sac is absorbed (Mottley 1929; Dill 1968). The alevins are initially negatively phototactic and migrate downward into the gravel. High CO_2 levels may elicit a dispersal response within the gravel. When the yolk sac is nearly absorbed, the alevins begin to express positive rheotaxis (Dill 1968). After yolk absorption, young chinook salmon generally emerge after dark as free-swimming fry.

Fry and Smolts

Fry spend 1 to 18 months in freshwater. Some fry migrate seaward immediately after emergence while others live in the stream for about a year before migrating downstream (Mottley 1929). Ninety percent of the juvenile chinook from the Sacramento River migrate downstream from the middle of January to the middle of March, and most enter saltwater by June of their first year (6 to 10 months following spawning) at an average length of 41 mm (1.6 inches). Downstream fall migrants, including both fall- and spring-run juveniles, reach saltwater at an average length of 100 mm (3.9 inches) according to Mottley (1929). In British Columbia, 78% of the chinook salmon migrate to sea as fry while the remaining 22% enter saltwater as yearlings (Pritchard 1940). Some chinook populations, particularly from coastal streams, leisurely feed and migrate downstream rather than living in distinct reaches of the river for extended periods of time. Spring chinook salmon from the upper reaches of large rivers, such as the Columbia, exhibit the more familiar year-long freshwater rearing stage. Chapman and Bjornn (1968) reported that in warmer months, young chinook are associated with velocities and depths in proportion to body size, shifting to faster, deeper waters as they grow. Chinook are primarily drift and benthic feeders. During the day the fish remain in a small home area. At night they settle to the bottom, usually after moving inshore. In early autumn, juvenile chinook salmon emigrate downstream from the tributaries to overwinter in larger streams, often living in the substrate. Stream temperatures of 4.4°C (39.9°F) to 5.5°C (41.9°F) function as cues for this hiding behavior in the substrate. Winter cover, especially large rocks, is important in holding overwintering fish. Juvenile chinook salmon prefer deeper water with smaller substrate particles than do steelhead (Chapman and Bjornn 1968).

Chinook salmon migrations into estuaries are correlated with periods of high discharge and turbidity, and migration is normally heaviest at night (Reimers 1968; Davis 1981). These migrations occur primarily during spring and early summer, but continue at lower levels through fall. Fish entering the estuary range from 35 mm (1.4 inches) to 160 mm (6.3 inches) according to several authors (Rich 1920; Gharrett and Hodges 1950; Mains and Smith 1964; Barraclough 1967; Davis 1981). The larger juveniles tend to migrate earlier and growth increases in brackish estuarine waters (Rich 1920). Spatial distribution of juvenile chinook within an estuary may be size dependent, while schooling in an estuary may be influenced by fright elicited in the fish due to tidal cycles and wave action (Reimers 1968).

Estuarine residence times may be influenced by the occurrence of fall freshets, population abundance, and various estuarine characteristics; duration and timing of estuarine residence vary geographically with seasonal differences (Miller et al. 1967; Reimers 1968; Sims 1970; Sibert 1975). Chinook salmon in the Skagit River Estuary occupied the inner estuarine salt marshes for 2 to 3 days before emigrating farther out in the estuary. The larger smolts, greater than 46 mm (1.8 inches), spent approximately a day less in the salt marsh than did the smaller fish. Smolts congregated in tidal streams at low tide, with the majority of fish observed in deep, slow water over soft substrates. The highest chinook salmon densities occurred in tidal streams without any freshwater influence (Shepard 1981).

Preference for soft, packed substrate was also documented by Miyamoto et al. (1980). These authors suggested that the abundance of the epibenthic prey fauna in that type of habitat attracted juvenile chinook. In the Nanaimo River Estuary, Healey (1980) found chinook salmon in water a few centimeters to over a meter deep over gravel, sand, and mud substrates. Where an extensive estuarine environment exists, juvenile chinook will reside there for up to 2 months (Salo 1969; Sims 1970; Healey 1980). Within estuaries and bays, juvenile chinook salmon utilize shoreline areas extensively. Meyer et al. (1980) presented data suggesting that smaller fish utilize the inshore areas while larger ones occupy deeper waters. Juvenile chinook salmon in Similk Bay primarily occupy the surface waters (93.8%) while a few (1.8%) extend down to 18.3 m (60.0 ft) according to Stober et al. (1973). In river systems with high flushing rates relative to the amount of existing estuarine habitat, juveniles may move quickly through the mouth of the river and into the receiving marine waters. From work on the Snohomish River, Tyler (1963) hypothesized that fish carried in midstream have little chance to contact the shoreline and are carried offshore by strong river and tidal currents during ebb tide. Miller et al. (1967) observed juvenile chinook salmon in several nearshore habitats, inshore from the 20-m (65.6-ft) depth level, between mid-May and September in Puget Sound.

During estuarine rearing, chinook salmon exhibit significant growth. Salo (1969) calcualted a minimum growth estimate of 2.6 mm (0.1 inch) per week for juveniles in the Duwamish River Estuary. Shepard (1981) indicated minimum growth estimates of 1.5% of fork length per day for juvenile chinook salmon in the Skagit River Estuary. This spurt of growth before entering the marine environment may be vital to the subsequent early marine survival of juvenile chinook salmon. For a more extensive review of estuarine requirements and utilization by juvenile chinook salmon, refer to Shepard (1981).

Marine Stages

Upon leaving the rivers of Oregon, Washington, and British Columbia, juvenile chinook salmon move up the coast in a northwesterly direction (Pritchard 1940). This migration is a relatively slow feeding and dispersal movement with distance from the natal stream increasing with age. Sacramento River chinook are caught off the Washington and Oregon coast while Columbia River chinook are collected as far north as Alaska and as far south as San Francisco, California (Hallock et al. 1952; Washington State Department of Fisheries 1959). For chinook salmon migration patterns between British Columbia and California, see Figure 3. Pritchard (1940) found that Columbia River fish dominate the catch along the west coast of the Queen Charlotte Islands, and that the Fraser River fish replace the Columbia River stocks north of the Queen Charlotte Islands. They remain in the marine environment between 1 and 6 years with the average being 3 or 4 years. Pritchard (1940) obtained age and distribution data from various coastal waters from the mouth of the Columbia River to the Queen Charlotte Islands. Certain races of chinook salmon, such as the Puget Sound blackmouth, tend to remain in local marine areas (Junge and Bayliff 1955). Two- to five-year-old chinook salmon comprised the bulk of the troll catch in the nearshore areas, while the offshore catches were dominated by 5- and 6-year-old fish. [illegible]ne (1957) reported that chinook [illegible]mon captured in the outer waters of [illegible]itish Columbia were on long spawnir[illegible]igrations, traveling southeast along [illegible] Continental Shelf. Pritchard (1940, [illegible]ated that the return migration was fairly rapid in comparison to the feeding or dispersal migration.

One- and two-year-old chinook salmon in the Straits of Georgia were caught from the surface down to 30 m (98 ft) with the majority occupying the deeper water (Mottley 1929). In southeast Alaska, chinook salmon reside in marine waters throughout the year, feeding at relatively shallow depths in the spring and summer and occupying deeper waters 60-80 m (197 - 262 ft) in the winter (Cobb 1910).

Salmon spawning migrations are elicited by environmental cues, such as temperature or salinity, olfaction, celestial navigation, and magnetic orientation (Brannon, in press). The timing of this migration is innate, while the location or destination of the migration is learned through imprinting. The numerous theories which have been advanced to explain salmonid homing are discussed in detail in Brannon (in press).

Growth Characteristics

Chinook fry emerge from the gravel during the winter, and some will migrate to sea after the first month when about 30 mm (1.2 inches) long. Some spring chinook populations enter saltwater as yearlings at lengths exceeding 100 mm (3.9 inches). O'Connor (1977) obtained growth data from numerous authors and presented the data in a table of lengths and weights for ages 1 through 5 (Table 1).

The Fishery

Chinook salmon represent an extremely important component of both the commercial and sport fisheries of the Pacific Northwest. Charter boat fisheries exist along the Pacific coast from San Francisco to Alaska. Chinook and coho salmon support extensive troll fisheries over the same latitudes, but trollers additionally fish well out into the Fishery Conservation Zone (3-200 mi offshore). Nearshore and terminal area fisheries are conducted with purse seines and gill nets, and inriver set net fisheries are allowed by treaty-Indian fishermen in most river drainages.

For river fisheries, Chapman (1940) offered this evaluation of the various races of Columbia River chinook salmon: spring fish entered the river in April and May with a small average size but with high quality flesh; summer fish were large and high quality fish that entered the river in June and July; and fall fish were large, poor quality fish that entered the system between August and October. From 1876 to 1886, the Columbia River April-July fishery produced an average of 3.1 million kilograms (6.8 million pounds) of salmon per year (Chapman 1940), but since then has continually declined to where only treaty-Indian fishermen currently harvest fish in the river.

Total United States commercial catches of chinook salmon from 1930 to 1980 have been summarized by total annual catch and total catch value (Table 2). These catch statistics clearly indicate a decline in the commercial catch of chinook salmon over time. Despite this decline, inflation more than tripled the value of the catch between 1970 and 1980. Although chinook salmon represent only 9% to 13% of the total commercial salmon catch, they are the most important in terms of market value and preference. Troll-caught fresh or fresh-frozen chinook salmon in the 11-18 lb (4.9-8.2 kg) size range are the most highly preferred salmon by market buyers. Among the Pacific States and Provinces, British Columbia contributed the largest percentage (27%) of the chinook commercial and sport catch for the years 1953-1957 (Figure 4).

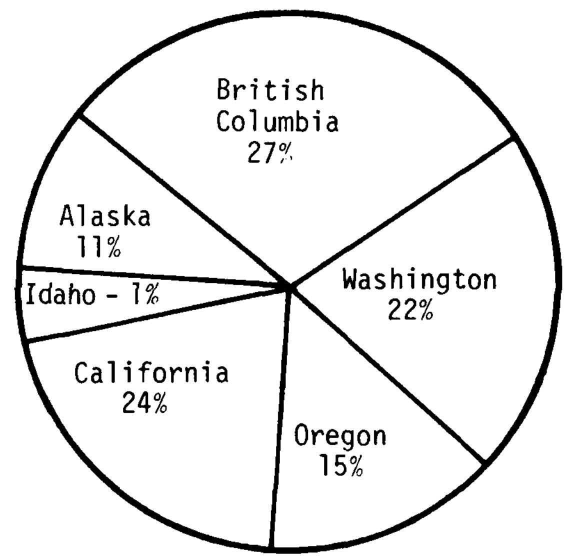


Figure 4. Percentage contribution of each Pacific Coast State and British Columbia to the chinook salmon fishery for all types of commercial and sport gear combined, 1953-1957 (Washington State Department of Fisheries 1959).

Chinook salmon are highly prized sportfish due to their trophy size, tremendous fighting qualities, and excellent table fare. Various attempts at quantifying the value of a recreationally caught fish often include cost of transportation, lodging, other work or recreational opportunities foregone, and equipment. Persons purchasing a charterboat reservation may

Table 1. Size (with maturity) for various fall chinook salmon stocks from California to Alaska at the end of each growing season (from O'Connor 1977).

Author	Fork length[a] (cm) at end of year					Maturity
	1	2	3	4	5	
Fraser (1920)	27.3	42.2	60.4	77.0	93.0	Years 2-5
Snyder (1923)	----	32.0	55.0	73.0	----	All
Parker and Kirkness (1956)	25.4	48.3	68.6	87.6	104.1	Mixed
Parker and Larkin (1959)	18.1	52.8	70.4	84.6	95.5	Years 2-5
Junge and Phinney (1963)	----	49.5	80.0	95.2	----	All
Van Hyning (1973)	30.5	53.3	71.1	83.8	----	Unknown
Parks (1975)	25.4	53.3	72.4	88.9	99.1	Unknown
	Round weight (kg) at end of year					
Newton (1972)	----	4.54	5.90	9.07	12.24	Unknown
Van Hyning (1973)	0.54	2.27	5.22	8.44	-----	Unknown
Parks (1975)	0.18	2.04	5.53	10.79	15.33	Unknown

[a]Frazer (1920) used total length, by scale method.

Table 2. Catches and values of the United States commercial chinook salmon fishery, 1930-1980. (Based on National Marine Fisheries Service 1977, 1981).

Year	Annual catch[a]	Annual value[b]
1930	55.4	
1935	50.4	
1939	39.5	
1945	48.2	$7.4
1950	36.6	$8.3
1955	42.8	$11.6
1960	24.0	$9.3
1965	33.3	$12.9
1970	31.5	$14.8
1975	31.3	$28.6
1980	28.5	$47.5

[a]Catch in millions of pounds.
[b]Value in millions of dollars.

spend $40-$60 in expectation of landing a fish. Most biologists and economists agree that sport-caught salmon represent a much higher value per pound than do commercially landed fish.

Salmon fisheries management is an extremely complex problem due to user-group allocations and mixed-stock and mixed-age fisheries. Optimum yield is the desired management goal for this fishery. Wright (1981) offers an excellent overview of current Pacific salmon fisheries management approaches. Ocean fisheries are managed by a catch quota, while terminal area fisheries are managed by subtracting escapement goals from pre-season run forecasts, which are updated throughout the season. This yields the total allowable harvest, which must be allocated among the user groups involved. Individual chinook salmon stocks can be identified by studying the fine structure of the scales (Rogers and Myers 1981a). Stocks are artificially identified by extensive coded wire tagging programs. Chinook salmon of Canadian and United States origin often are intercepted on the high seas by Japanese motherships. These fish are primarily taken as immature fish in the western Pacific Ocean and Bering Sea. Estimated incidental catch of chinook salmon by foreign trawl vessels was about 113,000 fish in 1981 (Rogers and Myers 1981b).

ECOLOGICAL ROLE

Juvenile chinook are characterized as opportunistic drift and benthic feeders, primarily eating insects in the stream-rearing phase of life. During this time, chinook salmon are most closely associated with juvenile steelhead and resident trout. Chapman and Bjornn (1968) indicated that interaction for space between species is minimized by differing spawning and emergence times. Distribution close to high-velocity water is largely food related. Age 0 chinook salmon distribute themselves both vertically and horizontally to adjust to food supply. Density within suitable habitat is socially controlled, with the greatest distributional role of social behavior being played among fish of near-equal size. During the day the fish remain in a small home area, and at night settle to the bottom, usually after moving inshore. The juveniles apparently subordinate minimal space requirements to exploit periods of short-term food abundance. Juvenile chinook salmon prefer deeper water with smaller substrate particles than do steelhead.

Upon entering the estuary, chinook utilize a wide range of invertebrate prey while retaining their insectivorous feeding habits. Gammarid amphipods, insects, mysids, isopods, copepods, and fish larvae comprise the bulk of the estuarine juvenile chinook salmon diet (Dunford 1975; Lipovsky 1977; Meyer et al. 1980). According to Lipovsky (1977), prey preference may be related to size, time of year, temperature, salinity, and location in the river.

As the young chinook salmon grow and move farther into the marine environment, their diet includes crab zoea, Pacific sand lance (<u>Ammodytes hexapterus</u>), eulachon (<u>Thaleichthys pacificus</u>), copepods, euphausids, cephalopods, isopods, and amphipods (Barraclough 1967; Robinson et al. 1968). In late winter and early spring off San Francisco, chinook salmon feed on herring, rockfish, other fish, crab megalops, and squid. Euphausids and squid, and later, herring, crab megalops, and rockfish comprise the spring diet. In late spring through summer, rockfish dominate the diet, distantly followed by other fishes and some invertebrates. Anchovies are the dominant diet item for the remainder of the year. Merkel (1957) summarized this by saying chinook salmon primarily eat fish, except during the spring when invertebrates (especially euphausids) are extremely abundant. Chinook salmon frequent the waters of southeast Alaska throughout the year and feed heavily on herring, smelt, and eulachon. During the winter they move deeper and feed on halibut, rockfish, cod, and octopi (Cobb 1910).

Predators of juvenile chinook salmon include osprey (Pardion haliaetus), kingfishers (Megaceryle alcyon), mergansers (Mergus sp.), terns (Sterna sp.), squawfish (Ptychocheilus oregonensis), larger salmon, trout, char, walleye (Stizostedion vitreum), largemouth bass (Micropterus salmoides), and smallmouth bass (Micropterus dolomieui). Estuarine and marine predators include fish-eating birds, pelagic fishes, killer whales (Orcinus orca), seals (Phoca sp. and Callorhinus sp.), sea lions (Zalophus californianus and Eumatopius jubata), and humans. Adult chinook salmon returning to their streams of origin encounter bears, seals, and other large carnivorous mammals and birds which prey on them to some degree. Predation on young salmon by fish in freshwater has been reviewed (Bennett 1979; Brown and Moyle 1981; Pauley 1982).

Ames (1981) has observed a number of negative correlations of abundance shifts among the five species of salmon in Puget Sound and concluded that the bulk of this interaction occurred in the early marine stages.

ENVIRONMENTAL REQUIREMENTS

Temperature

According to Reiser and Bjornn (1979), the recommended temperatures for spawning of chinook salmon ranges between 5.6°C (42.1°F) and 13.9°C (57.0°F). Chinook salmon eggs can incubate successfully at temperatures from just above freezing to 10.0°C (50.0°F) without significant mortality (Olson and Foster 1955). The recommended incubation temperatures range between 5.0°C (41.0°F) and 14.4°C (57.9°F), according to Reiser and Bjornn (1979). Seymour (1956) concluded that the optimum temperature for chinook eggs and fry is 11.0°C (51.8°F) and for fingerlings 17.0°C (62.6°F). Brett (1957) determined that small chinook salmon were more vulnerable to high temperatures than large fish. Adult spring chinook can survive in deep pools in the summer with the surface temperature 23.0°C (73.4°F), but cannot spawn above 22.0°C (71.6°F) (Mattson 1948; Hodges and Gharrett 1949). Brett (1957) indicated that the upper lethal temperature for chinook salmon was 25.1°C (77.2°F).

Salinity

Juvenile chinook salmon encounter a wide range in salinity when moving from freshwater through an estuary and into the marine environment. Estuaries normally maintain a freshwater lens above the area of saltwater intrusion that smolts tend to occupy during the initial stages of their estuarine and marine residence. Robinson et al. (1968) found chinook salmon associated with salinities from 6.75 to 25.73 ppt in the Straits of Georgia off the Fraser River plume.

Dissolved Oxygen

Chinook eggs require dissolved oxygen (DO) concentrations of 5.0 mg/l (Leitritz and Lewis 1980). Whitmore et al. (1960) described a marked avoidance of oxygen concentrations at or below 4.5 mg/l by juvenile chinook salmon in the summer at 20.0°C (68.0°F). Decreased avoidance occurred in the fall as temperatures declined or as DO concentrations rose above 4.5 mg/l, with no avoidance noted at 6.0 mg/l. Although migrating adult chinook salmon encountered DO levels of 3.0 to 4.0 ppm in the Duwamish River Estuary, it could not be demonstrated that this impeded the spawning migration of chinook salmon (Fujioka 1970). Katy et al. (1959) found that chinook salmon could survive when resting with DO levels as low as 2.0 mg/l and could swim against an 0.8 ft/s current for a day when DO concentrations were 3.0 mg/l.

Substrate

Adult chinook salmon spawn in gravel ranging from 6 cm (2.4 inches) to 14 cm (5.5 inches) in diameter (Briggs 1953). Reiser and Bjornn (1979) list gravel substrates from 1.3 cm (0.5 inches) to 10.2 cm (4.0 inches) in diameter as acceptable for spawning.

Spring chinook juveniles that overwinter in freshwater require large boulder habitat for winter refuge areas (Chapman and Bjornn 1968). However, they prefer different habitats than do steelhead. In the estuaries, juvenile chinook salmon show a wide range of substrate associations including mud, sand, gravel, and eelgrass (Healey 1980). No substrate preference has been documented for adults in the marine environment.

Depth

Chinook salmon will spawn in rivers with depths of 0.10 m (0.3 ft) to 10 m (32.8 ft) (Chapman 1943; Briggs 1953). The preferred depth for spawning is >0.24 m (>0.79 ft) for spring and fall chinook salmon and >0.30 m (>0.98 ft) for summer chinook (Reiser and Bjornn 1979). Juvenile chinook salmon prefer deeper water (>0.5 m or >1.6 ft) than steelhead in the same streams, according to Chapman and Bjornn (1968). Juvenile chinook salmon occupy the water near the surface during their initial marine stages and then utilize water down to 60 m (197 ft), according to several authors (Merkel 1957; Barraclough 1967; Robinson et al. 1968). Upstream migrations are generally triggered by rains, which raise the river levels and change the water temperature.

Water Movement

Chinook salmon require enough current on the spawning beds to ventilate the eggs during incubation. Juvenile chinook can detect and orient in water velocities of 0.005 m/s (0.016 ft/s) (Gregory 1962). A 70-mm (2.8-inch) chinook can maintain a home station facing velocities of 0.23 m/s (0.76 ft/s) but lie under a layer of 0.45 m/s (1.48 ft/s) water and be surrounded by velocities of 0.6 m/s (1.97 ft/s) (Chapman and Bjornn 1968).

Turbidity

According to Reiser and Bjornn (1979), salmonid fishes will cease movement or migration in streams with high silt loads (>4000 mg/l). Study has shown that exposure to low levels of volcanic ash in a Y-test chamber caused chinook salmon to exhibit significant avoidance reactions (Whitman et al. 1982). Because turbid water absorbs more radiation than clear water, a thermal barrier to movement and migration may also develop (Reiser and Bjornn 1979).

Problems may result if turbidity is great enough to cause the deposition of excessive amounts of sand and silt in the gravel, such as after a landslide. Fry emergence from the gravel may be hindered by excessive amounts of sand and silt (Reiser and Bjornn 1979). Those conditions also may limit production of benthic invertebrates necessary for optimum rearing of juvenile fish (Reiser and Bjornn 1979). Chinook salmon smolts may be quite tolerant of high concentrations of volcanic ash and mudflow sediments according to Ross (1982), who determined 96-hr LC_{50} values for these fish to be 11,000 mg/l. Sublethal sediment concentrations did not produce consistent effects on swimming performance or fatigue velocity. Chinook smolts were much less tolerant of seawater after exposure to high concentrations of volcanic ash and mudflow sediments, but low level exposure did not affect them. Gill tissues revealed only minor effects even at the highest exposure concentrations, but death at high concentrations of these materials was caused by hypoxia (Ross 1982). Wallen (1951) observed that behavioral reactions to high suspended solid concentrations were identical to responses to low DO: the fish stayed near the surface.

LITERATURE CITED

Ames, J. 1981. Competition and predation among Puget Sound salmon stocks and some implications for enhancement programs. Wash. Dep. Fish., Harvest Manage. Div., Draft. 51 pp.

Barraclough, W. E. 1967. Number, size and food of larval and juvenile fish caugh with an Isaacs-Kidd trawl in the surface waters of the Strait of Georgia. April 25-29, 1966. Fish. Res. Board Can. Rep. Ser. No. 926. 79 pp.

Bennett, D. H. 1979. Probable walleye (Stizostedion vitreum) habitation in the Snake River and tributaries of Idaho. Idaho Water Resource Res. Inst., University of Idaho, Moscow. 44 pp.

Brannon, E. L. (In press). Proceedings from the symposium on trout and salmon migratory behavior. School of Fisheries, University of Washington, Seattle.

Brett, J. R. 1957. Temperature tolerance in young Pacific salmon genus Oncorhynchus. J. Fish. Res. Board Can. 9(6):265-323.

Briggs, J. C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif. Dep. Fish Game Fish Bull. No. 94. 62 pp.

Brown, L. R., and P. B. Moyle. 1981. The impact of squawfish on salmonid populations: a review. N. Am. J. Fish. Manage. 1(1):104-111.

Chapman, D. W., and T. C. Bjornn. 1968. Distributions of salmonids in streams with special reference to food and feeding. Pages 153-176 in T. G. Northcote, ed. Salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Chapman, W. M. 1940. The average weight of food fish taken by the commercial fishery in the Columbia River. Biol. Rep. Dep. Fish., State of Washington. 39A:31 pp.

Chapman, W. M. 1943. The spawning of chinook salmon in the main Columbia River. Copeia 1943(3):168-170.

Cobb, J. N. 1910. The king salmon of Alaska. Trans. Am. Fish. Soc. 39:124-128.

Cramer, F. K., and D. F. Hammack. 1952. Salmon research at Deer Creek, California. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 67. 16 pp.

Davis, S. K. 1981. Determination of body composition, condition, and migration timing of juvenile chum and chinook salmon in lower Skagit River, Washington. M.S. Thesis. University of Washington, Seattle. 97 pp.

Dill, L. M. 1968. The subgravel behavior of Pacific salmon larvae. Pages 89-100 in T. G. Northcote, ed. Salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Dunford, W. D. 1975. Space and food utilization by salmonids in marsh habitats of Fraser River Estuary. M.S. Thesis. University of British Columbia, Vancouver. 81 pp.

Fraser, C. M. 1920. Further studies on the growth rate in Pacific salmon. Contrib. Can. Biol. Fish. 1918-20: 7-27.

Fujioka, J. F. 1970. Possible effects of low dissolved oxygen content in the Duwamish River Estuary on migrating adult chinook salmon. M.S.

Thesis. University of Washington, Seattle. 77 pp.

Gharrett, J. F., and J. I. Hodges. 1950. Salmon fisheries of the coastal rivers of Oregon south of the Columbia. Oreg. Fish. Comm. Contrib. No. 13. 3 pp.

Gregory, R. W. 1962. Lower velocity thresholds for juvenile silver and chinook salmon. M.S. Thesis. University of Washington, Seattle. 59 pp.

Hallock, R. J., G. H. Warner, and D. H. Fry, Jr. 1952. California's part in a three-state salmon fingerling marking program. Calif. Fish Game 38(3):301-332.

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

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

Healey, M. C. 1980. Utilization of Nanaimo River Estuary by juvenile chinook salmon (Oncorhynchus tshawytscha). U.S. Natl. Mar. Fish. Serv. Fish. Bull. 77(3):653-668.

Hodges, J. I., and J. F. Gharrett. 1949. Tillamook Bay spring chinook. Oreg. Fish Comm. Res. Briefs 2(2):11-16.

Junge, C. O., and W. H. Bayliff. 1955. Estimating the contribution of a salmon production area by marked fish experiments. Wash. Dep. Fish. Fish. Res. Pap. 1(3):51-58.

Junge, C. O., and L. A. Phinney. 1963. Factors influencing the return of fall chinook salmon (Oncorhynchus tshawytscha) to Spring Creek hatchery. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 445. 32 pp.

Katy, M., A. Pritchard, and C. E. Warren. 1959. The ability of some salmonids and a centrarchid to swim in water of reduced oxygen content. Trans. Am. Fish. Soc. 88(2):88-95.

Leitritz, E., and R. C. Lewis. 1980. Trout and salmon culture. Calif. Dep. Fish Game Fish Bull. No. 164. 197 pp.

Lipovsky, S. J. 1977. Food habits of juvenile salmon in the Columbia River. Pages 14-21 in Juvenile salmonids in the estuary, a workshop. Am. Inst. Fish. Res. Biol., Oregon-S.W. Wash. Dist. 38 pp.

Mains, E. M., and J. M. Smith. 1964. The distribution, size, time, and current preferences of seaward migrant chinook salmon in the Columbia and Snake Rivers. Wash. Dep. Fish. Fish. Res. Pap. 2(3): 5-43.

Mattson, C. 1948. Spawning ground studies of Willamette River spring chinook salmon. Oreg. Fish Comm. Res. Briefs 1(2): 21-32.

McKee, F. B. 1950. Study of the water supply at the New Marion Forks hatchery on the North Santiam River. Oreg. Fish Comm. Res. Briefs 3(1):22-32.

Merkel, T. J. 1957. Food habits of the king salmon (O. tshawytscha) in the vicinity of San Francisco, California. Calif. Fish Game 43 (4): 249-270.

Meyer, J. H., T. A. Pierce, and S. B. Pathan. 1980. Distribution and food habits of juvenile salmonids in the Duwamish Estuary, Washington. FAO Rep. U.S. Fish Wildl. Serv., Olympia. 41 pp.

Miller, D. M., J. A. Wetherall, S. Zebold, W. H. Lenary, G. D. Stauffer, J. Fujioka, M. Halstead, E. O. Salo, and T. S. English. 1967. Estuarine ecology studies. Pages 24-31 in 1966 Research in fisheries. Annu. Rep., Contrib. No. 280, School of Fisheries, University of Washington, Seattle.

Milne, D. J. 1957. Recent British Columbia spring and coho salmon tagging experiments, and a comparison with those conducted in 1926 and 1927 off the coast of Vancouver Island. Bull. Fish. Res. Board Can. No. 113. 56 pp.

Miyamoto, J., T. Deming, and D. Thayer. 1980. Estuarine residency and habitat utilization by juvenile anadromous salmonids within Commencement Bay, Tacoma, Washington. Puyallup Tribal Fish. Div., Fish. Manage. Div., Tech. Rep. No. 80-1 (Draft).

Mottley, C. M. C. 1929. Pacific salmon migration: report on the study of the scales of spring salmon (O. tshawytscha) tagged in 1926 and 1927 off the west coast of Vancouver Island. Contrib. Can. Biol. Fish., N.S. 4(30):473-493.

National Marine Fisheries Service. 1977. Fisheries of the United States. Current fishery statistics. No. 7200. U.S. Govt. Print. Office. 96 pp.

National Marine Fisheries Service. 1981. Fisheries of the United States. Current fishery statistics. No. 8100. U.S. Govt. Print. Office. 132 pp.

Newton, J. D. 1972. The Washington State salmon fisheries: a simulation study. Ph.D. Dissertation. University of Washington, Seattle. 201 pp.

O'Connor, R. J. 1977. Ocean growth, mortality and maturity of Columbia River fall salmon. M.S. Thesis. University of Washington, Seattle. 71 pp.

Olsen, P. A., and R. F. Foster. 1955. Temperature tolerance of eggs and young of Columbia River chinook salmon. Trans. Am. Fish. Soc. 85: 203-207.

Parker, R. R., and W. Kirkness. 1956. King salmon and the ocean troll fishery of southeastern Alaska. Alaska Dep. Fish. Res. Rep. No. 1. 64 pp.

Parker, R. R., and P. A. Larkin. 1959. A concept of growth in fishes. J. Fish. Res. Board Can.16(5):721-745.

Parks, W. W. 1975. A Pacific salmon fisheries model for the study of gear regulation: an application to the Washington troll fishery. Ph.D. Dissertation. University of Washington, Seattle. 159 pp.

Pauley, G. B. 1982. Effects of recreational fishing on anadromous salmonids. Wash. Coop. Fish. Res. Unit, University of Washington, Seattle. Tech. Rep. No. 7-82. .05 pp.

Pritchard, A. L. 1940. Studies on the age of the coho salmon (Oncorhynchus kisutch) and the spring salmon (Oncorhynchus tshawytscha) in British Columbia. Trans. R. Soc. Can., Ser. 3, Sect. 5, 34:99-120.

Reimers, P. E. 1968. Social behavior among juvenile fall chinook salmon. J. Fish. Res. Board Can. 25(9): 2005-2008.

Reiser, D. W., and T. J. Bjornn. 1979. Habitat requirements of anadromous salmonids. Pages 1-54 in W. R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in the Western United States and Canada. U.S. For. Serv. Gen. Tech. Rep. PNW-96.

Rich, W. H. 1920. Early life history and seaward migration of chinook salmon in the Columbia and Sacramento Rivers. Bull. U.S. Bur. Fish. Vol. 37. 74 pp.

Robinson, D. G., W. E. Barraclough, and J. D. Fulton. 1968. Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia, May 1-4, 1967. Fish. Res. Board Can. Rep. Ser. No. 964. 105 pp.

Rogers, D. E., and K. W. Myers. 1981a. Origins of chinook salmon in the

Japanese mothership salmon fishery. Page 11 in 1980 Research in fisheries. Annu. Rep. Contrib. No. 575, School of Fisheries, University of Washington, Seattle.

Rogers, D. E., and K. W. Myers. 1981b. Origins of chinook salmon in foreign trawls. Page 11 in 1980 Research in fisheries. Annu. Rep. Contrib. No. 575, School of Fisheries, University of Washington, Seattle.

Ross, B. D. 1982. Effects of suspended volcanic sediment on coho (O. kisutch) and fall chinook (O. tshawytscha) salmon smolts in artificial streams. M.S. Thesis. University of Washington, Seattle. 128 pp.

Rounsefell, G. A. 1957. Fecundity of North American Salmonidae. U.S. Fish and Wildl. Serv. Fish. Bull. 57(122):451-468.

Salo, E. O. 1969. Estuarine ecology research project. Final Rep. School of Fisheries, University of Washington, Seattle. 80 pp.

Seymour, A. H. 1956. Effects of temperature upon young chinook salmon. Ph.D. Dissertation. University of Washington, Seattle. 127 pp.

Shepard, M. F. 1981. Status and review of the knowledge pertaining to the estuarine habitat requirements and life history of chum and chinook salmon juveniles in Puget Sound. Final Rep. Wash. Coop. Fish. Res. Unit, University of Washington, Seattle. 113 pp.

Sibert, J. 1975. Residence of juvenile salmonids in the Nanaimo River Estuary. Fish. Mar. Ser. Res. Dev. Tech. Rep. No. 537. 23 pp.

Sims, C. W. 1970. Juvenile salmon and steelhead in the Columbia River Estuary. Pages 80-86 in Proceedings of Northwest Estuarine and Coastal Zone Symposium. Bureau of Sport Fisheries and Wildlife, Portland, Oregon.

Snyder, J. O. 1923. A second report on the return of king salmon marked in 1919, in the Klamath River. Calif. Fish Game 9:1-9.

Stober, Q. J., S. J. Walden, and D. T. Griggs. 1973. Juvenile salmon migration through Skagit Bay. Pages 35-70 in Q. J. Stober and E. O. Salo, eds. Ecological studies of the proposed Kiket Island nuclear power site. Final Rep. FRI-UW-7304, University of Washington, Seattle.

Tyler, R. W. 1963. Distribution and migration of young salmon in Everett Harbor, 1982. Final Rep. Everett Bay Studies. Fish. Res. Inst., University of Washington, Seattle. 26 pp.

Van Hyning, J. M. 1973. Factors affecting the abundance of fall chinook salmon in the Columbia River. Oreg. Fish. Comm. Res. Rep. 4:1-87.

Wallen, I. E. 1951. The direct effect of turbidity on fishes. Ph.D. Dissertation. University of Michigan, Ann Arbor. 57 pp.

Washington State Department of Fisheries. 1959. Fisheries: Volume 2. Contributions of Western States, Alaska, and British Columbia to salmon fisheries of the North American Pacific Ocean. 83 pp.

Whitman, R. P., T. P. Quinn, and E. L. Brannon. 1982. Influence of suspended volcanic ash on homing behavior of adult chinook salmon. Trans. Am. Fish. Soc. 111(1):63-69.

Whitmore, C. M., C. E. Warren, and P. Doudoroff. 1960. Avoidance reactions of salmonid and centrarchid fishes to low oxygen concentrations. Trans. Am. Fish. Soc. 89(1):17-26.

Wright, S. 1981. Contemporary Pacific salmon fisheries management. N. Am. J. Fish. Manage. 1(2):29-40.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-82/11.6*	2.	3. Recipient's Accession No. AD-A147262

4. Title and Subtitle Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) -- Chinook Salmon	5. Report Date October 1983 6.
7. Author(s) David A. Beauchamp, Michael F. Shepard, Gilbert B. Pauley	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Washington Cooperative Fishery Research Unit School of Fisheries University of Washington Seattle, WA 98195	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address National Coastal Ecosystems Team, Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC 20240 U.S. Army Corps of Engineers, Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180	13. Type of Report & Period Covered 14.

15. Supplementary Notes

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

16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in environmental impact assessment. The chinook salmon (*Oncorhynchus tshawytscha*), which make up 9% to 13% of the commercial salmon catch, are the most highly prized and represent the most dollar value of the Pacific salmon. They are also a highly prized sportfish, reaching weights of 8.2 to 9.1 kg (18 to 20 lb) or more during their fourth year. They are anadromous fish that spend 1 year to 18 months in freshwater and then migrate to saltwater. They remain in the marine environment 1 to 6 years, averaging 3 to 4 years before returning to their river of origin to spawn. Three major races of chinook salmon exist (spring, summer, fall) and have different spawning cycles. All chinook salmon die after they spawn.

17. Document Analysis a. Descriptors

Fishes
Estuaries
Anadromous
Catch
Migration

b. Identifiers/Open-Ended Terms

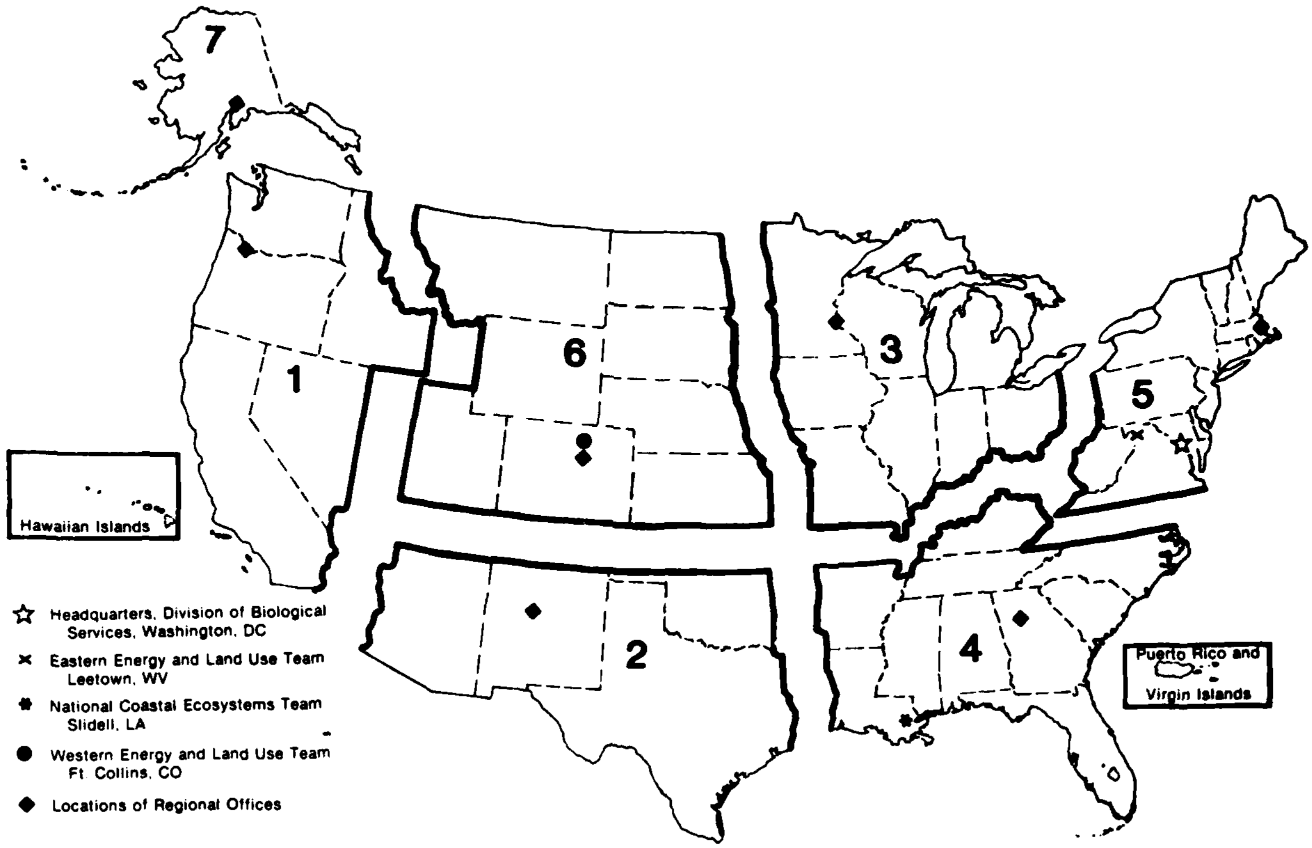
Salinity requirements
Temperature requirements
Chinook salmon
Oncorhynchus tshawytscha
Life history
Spawning

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	15
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18)

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



REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

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

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

END

7-87

DTIC